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Speleology in Hungary

FRANK HOLLY

Abstract – Although a small country, Hungary is rich in karst areas and caves. Many of the latter were known from antiquity but since World War II, numerous new ones have been discovered. Notable among them is the Béke barlang, smaller than its famous neighbor, Baradla, but probably more beautiful. Great impetus to speleology in Hungary has been given by many spelunking groups formed of youngsters, students, and tourists. These groups have recently been coordinated by the formation of the Hungarian Speleological Society (HSS, 1959). Since there is a great demand for exact cave discovering methods, the development and use of physical and chemical methods has started.

Hungary is a rather small country, its area being 90,000 square kilometers. However, it is quite rich in karst areas. By taking a glance at the map of Hungary (fig. 1), one can see that the limestone mountains are located mainly in the northern part of the country, and around Budapest.

Let us start from Budapest. In the Capital and its immediate neighborhood, there are six large cave systems (longer than 500 m), five of medium size (between 50-500 m) and forty smaller caves and rock shelters (shorter than 50 m). It is understandable therefore, that people sometimes call Budapest the "city of caverns." Approximately in the heart of the city, in the depths of the Castle Hill (on which the Royal Palace is built), there extends a large and complicated labyrinth of cellar caves. It is made up of three cellar systems located one above the other. Among them the lowest level is a natural network of cavities developed in limestone tufa. The second level was used as a hiding place and escape route during the Turkish occupation of the 16th and 17th centuries. The first level forms the cellars of the houses, which are also connected with each other. This complicated network of cavities has been extended through the whole of Castle Hill. At the present time, only a small portion of it is known, the other parts having been destroyed or forgotten. These tunnels and caves contain many historical relics (skulls, weapons etc.), especially of the Turkish occupation. Many of them were used as prisons and torture chambers. One small part of these caves has been open to the public and, as a little underground museum, has attracted a large number of visitors from year to year.

Not far from the Danube River, among the cottages of Buda, one can find four large cave systems in close proximity.. The *Pálvölgyi barlang** has been known since the beginning of this century. It is commercialized and electrified. The other three have been known for only a couple of decades. It is characteristic of these caves that they were formed by thermal water bursting up along big crevices and meeting the cold karstwater moving horizontally. Their structure is labyrinthine. They are not very rich in stalagmites and stalactites, but some of them are richly covered by grape-like cave corals. The *Szemlőhegyi barlang* is like a petrified flower garden, the beauty of which is enhanced by microcrystal gypsum like freshly fallen snow. The longest among these four is the *Mátyás barlang,* with a length of 1800 meters. The lowest part of this cave is under water, the level of which fluctuates slowly. According to some speleologists, this water level indicates the local water table. Its constant temperature (13°C) agrees with this hypothesis. Cave diving attempts have not been successful in this "lake". *Ferenchegyi barlang* is nearly 1 kilometer in length. Some parts of it are very much like the Szemlőhegyi barlang. To visit these caves, except the commercial-

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* barlang means cave in Hungarian.

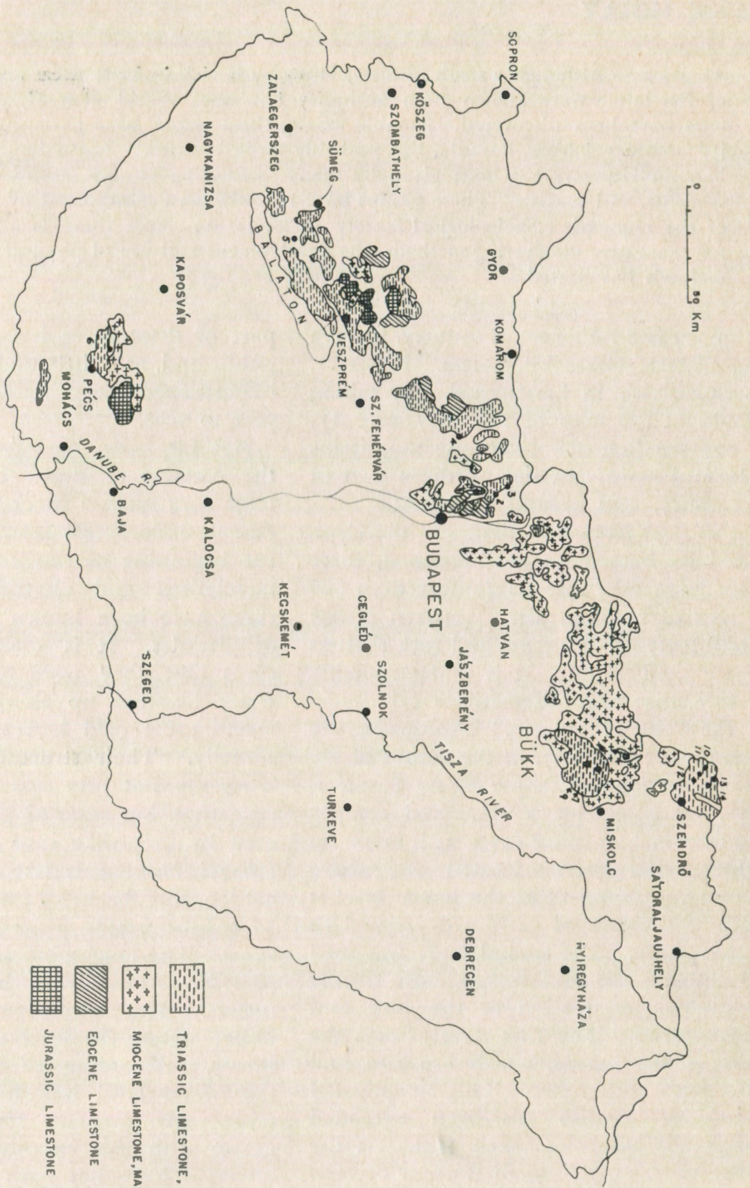

Figure 1

Karst areas of Hungary. 1. Solymári Ördöglyuk, 2. Kissomlyói barlang, 3. Sátorkőpusztai barlang, 4. Szelim barlang, 5. Tapolcai tauas barlang, 6. Abaligeti barlang, 7. Kiskőháti zsoulody, 8. Istállóskői barlang, 9. Pénzpataki barlang, 10. Baradla, 11. Béke barlang, 12. Szabadság barlang, 13. Vass Imre barlang, 14. Kossuth barlang.

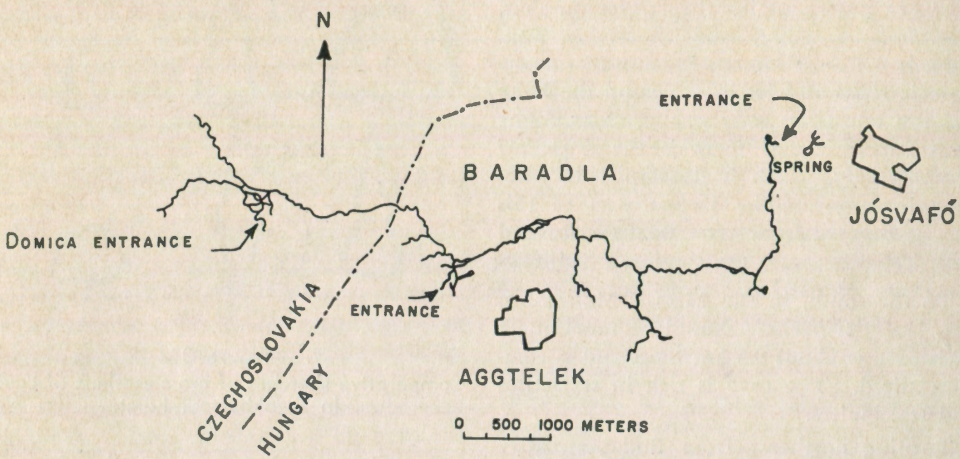

Figure 2
Cave system of Baradla and Domica.

ized one, requires good rock climbing technique.

Near these large thermal cave systems, almost on the shore of the Danube, one finds the small but rather interesting *Malomtavi forrásbarlang* (spring cave). This cave is a huge cleft, half filled with water, parallel to the Danube. The depth of the water is more than 8 meters, and its temperature is 28°C. Swimming along the walls of the cleft, it is noticeable that the temperature of the water drops. It is assumed that the thermal waters bursting up along crevices are mixed with the cold karst water in different ratios at different places. It is of interest to note that there are two thermal baths in the neighborhood of this cave. As a matter of fact, along the shore of the Danube, there are many thermal springs, due to the large fault whose eastern side has shifted down 2,000 meters. This slip has defined the bed of the Danube in this region. This tectonic event also caused lively activities of different thermal springs. Each of the caves mentioned above has been developed in nummulitic Eocene limestone.

In the hills of Buda, there is a smaller but rather interesting cave, the *Báthory barlang.* Its ceiling is sandstone while the cave itself has been developed in limestone. László Báthory, a Pauline Monk, translated the Bible in this cave in the fifteenth century. The first hall at the entrance served as a chapel for him. The relics of his altar can be seen today.

A few miles from Budapest we find a rather large thermal cave, the so-called *Solymári Ördöglyuk* (Devil's Hole), which has been developed in Triassic limestone. Although this cave is not rich in formations, its snow-white walls and nicely corroded rocks make up for it. This cave has been open since the time of the Ice Age. The clay deposits contain a large number of bones and teeth, usually of bears (*Ursus speleus*). Presumably thermal water rising under pressure played an important role in the development of this cave, although there are no stone flowers or cave corals, except in a few of the smaller passages. Some of its halls once contained large amounts of guano; most of it was exploited at the end of the last century.

In the bend of the Danube, several caves are known. Among those, the *Sátorkőpusztai barlang* and the *Kissomlyói barlang* are famous because of their wonderful "aragonite" needles and cave flowers. Both of these caves — as were most of the thermal caves — were discovered during limestone quarrying.

In the Magyar Középhegység (southwest of Budapest) caves are also found. The northern part contains the largest number. The *Szelim barlang,* near the city of Bánhida, is the most famous because of its prehistoric relics and fossils. Around the Lake Balaton one finds only smaller caves. The most interesting of them is the *Tapolcai Tavasbarlang,* which is developed in Miocene limestone. The largest part of this cave is covered by water. Boat service and electric lights assure the comfort of visitors.

To the south, in the Mecsek Mountains, the *Abaligeti barlang* should be mentioned. This cave is about 0.5 km long, and is commercialized. The cave is rich in stalactites and stalagmites.

Turning northeast from Budapest, after a hundred miles we arrive in the Bükk Mountains, which are rich with caves. The mountains themselves are very much favored by tourists for their indescribable beauty. The limestone plateau of Bükk is almost 1,000 m high on the average; most of the known caves are developed vertically. Here is found the *Kiskőháti zsomboly** the deepest pothole in Hungary, with a depth of more than 140 m. The *Istállóskői barlang* is barely 50 m long, but it is very famous because of prehistoric relics found in its clay fills. In past years several stream cave systems have been discovered by excavating sinkholes (notably the caves of Pénzpataki and Bolhási sinkholes). The entrance to the *Pénzpataki barlang* is at 503 m above sea level and the local water table is assumed to be at 230 m. Therefore, the passages are mostly vertical; and here one of the highest underground waterfalls of the world can be found, the famous *Nagy Fal* (64 m). Around the elegant health resort of Lillafüred, there are several smaller caves which are more or less commercialized. In the *Szent Anna barlang,* there are wonderful tufa formations that preserve plants and animals.

Continuing north from here, we arrive at Hungary's biggest cave center (the *Északborsodi Karszt*) which is the southern part of the *Gömör-tornai* karst area, partly located in Czechoslovakia. For a long time people knew only one cave, the *Baradla.* Its entrance near the village of Aggtelek has been open since prehistoric times. Therefore, as we may expect, many relics of early man were found there. In 1932, its connection with Domica cave was discovered, and so Baradla became the longest cave in Europe (at that time) with a lengh of 22 km (fig. 2). Fifteen kilometers of the cave are in Hungary, where an artificial entrance has been made at the Jósva spring. The Baradla is in Triassic limestone throughout its length and is extremely rich in structures, such as stalactites, stalagmites, and columns. The stalagmite called Csillagvizsgáló (Observatory) is 28 m. tall. The width of the passages is about 10 m on the average and the height is 8-10 m but in the "Hall of Giants" the cave is up to 60 m wide, and at some places it is over 50 m high. There is no permanent stream in it but occasionally flood waters penetrate the cave. Most of it is commercialized; the passages in the neighborhood of the entrances are lighted by electricity.

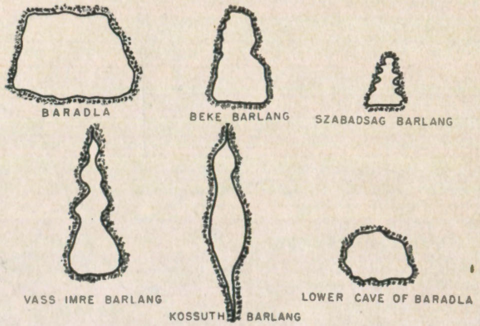

Figure 3
Comparative sketches of cross sections of caves in Északborsodi karst.

The main sinkhole of the Baradla system is the oldest entrance of the Domica cave. This is a sinkhole that recieves surface drainage only during rains; there is a permanent stream in Domica fed by seepage. The stream coming from Domica (the Czechoslovakian part of this huge cave system) does not flow in the cave all the way, but is swallowed by different cave sinkholes developed in the underground bed of the stream (called "Styx"). The water reaches the spring on a lower level, where a new cave (the so-called "lower cave") is developing. Recently a 200 m long part of this lower cave has been discovered. It carries a large amount of water, the average rate of flow of Jósva spring being 17,000 liters per minute.

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* zsomboly means vertical pothole in Hungarian

At the beginning of the fifties, another large stream cave system, the so-called *Béke barlang* was discovered near Baradla by water tracing methods. Although this is a bit smaller in size than the Baradla, its abundant, untouched, beautiful structures and the permanently running stream make up for it. Parts of this cave close to the entrance are open to the public. It is of interest to note that research has been going on in this cave on medicinal effects of caves. It was found that cavers having a cold or flu—after spending several hours in the cave—have been completely cured; no one has caught cold there, although some of the cavers spent 20 to 40 hours in the ice cold water of the cave—having only their bathing suits on. The cavers noted that pieces of wood and other materials of organic origin quickly mold in the cave. Since penicillin and streptomycin, well known medicines, are forms of molds, it is not hard to understand that the cold curing effect of the Béke barlang can be traced back to the cave air, containing the spores of different molds. After the Béke barlang was discovered, the location of several new caves in this region soon followed. The *Szabadság barlang* (1954), *Vass Imre barlang* (1955), and the *Kossuth barlang* (1956) are the newly discovered stream cave systems of different karst springs.

Discussing the caves of this karst-area, one should note the geological structure of the region. This karst-area is divided into two regions by the valley of Jósva extending from west to east. The non-permeable layers are made of Werfen clay slates (of lower Triassic age), which form anticlines under the karst mountains and constitute the base of the water-table. The Jósva valley has been developed in a syncline. In the southern regions the limestone layers have been left essentially undisturbed, and moreover, in the watershed of the sinkholes, there is much quartz-gravel. The quartz, which is much harder than limestone, is an excellent tool of erosion when carried by underground streams. These have helped the development of large cave systems (Béke, Baradla). The effects of mechanical erosion may be seen in the shapes of the cross sections of these cave passages (fig. 3). On the other hand, in the northern part no quartz-gravel can be found in the soil layers of the water-sheds. Therefore, erosion played little part in developing these caves, which were largely formed by corrasion. This is shown in the cross sections of Vass Imre and Kossuth caves (fig. 3). Also, the layers of the northern region have been very much disturbed by intensive tectonic activities and the streams have changed their paths inside the karst several times. Hence, in the case of Vass Imre cave, there has developed a cave system on five different levels.

The Kossuth barlang is the most recently discovered Hungarian cave. The rate of flow of its spring nearly equals that of Baradla, although the cave is considerably smaller. This smallness reflects the lack of mechanical erosion in the development of this cave. The lower passages carry the water to the spring. The water is 30-50 feet deep at some places; therefore, it is passable only by boat. An inactive higher level is known, which frequently intersects the lower passage.

Let us now take a brief glance at the history of speleology in Hungary. There have always been some people interested in caves since the 15th century, as we can see from the literature, but that could not be called speleology. The first famous Hungarian speleologist, who really explored caves, was Imre Vass, who discovered a large part of Baradla as early as 1825. Until the second World War, the most important part of speleological research was archeology and complete exploration of caves. Following the two World Wars, but especially after World War II, interest in speleology increased rapidly and many spelunking groups have been organized, largely youngsters, tourists, and students. To coordinate the work of different groups, the Karst and Cave Exploring Committee was formed in 1955. One of the main goals of this organization was to organize a speleological society. They achieved this early in 1959, when the Hungarian Speleological Society (HSS) was formed.

As a result of the boom in spelunking, all the known holes and cave entrances have been well explored and most of them surveyed. Today, there is a great need for methods by which the existence of completely unknown underground networks of cavities can be discovered. The geologist László Jakucs has tried to draw conclusions from data obtained by water tracing. Dr. Hubert Kessler, sectional director in the Research Institute of Hydrology, has been studying the rainfall-absorption on the surface of limestone regions and has obtained very useful results. The search for new methods has tended toward the physical and chemical examination of the water of karst springs. It is thought that by examining the properties of karst spring water, one can draw conclusions about the karst water system belonging to the spring. This work has not been completed, but it appears that good results may be obtained.

Recently, the cave exploration group of Budapest Technical University has started to make exact measurements in the Vass Imre cave during one hydrological year in order to obtain data concerning the "life" of the cave at the present time. This project includes temperature, humidity and draft measurements at several points in the cave, measuring the hardness and volume of water dripping from stalactites, measuring the calcium-magnesium ion-ratio in the stream water. All these quantities are measured as a function of both time and place. Much is expected from the results of this work.

Finally, let us see who is who in speleology in Hungary:

Dr. Endre Dudich, professor in biology. He is the president of HSS at present. His specialty is cave biology. He has worked out the biology of Baradla, determining 262 different animal species, among them some entirely new ones (i.e., *Niphargus aggtelekiensis* Dudich). He is the head of the Underground Biological Laboratory located in Baradla (Budapest V. Szemere u. 9, Hungary).

Dr. Hubert Kessler, karsthydrologist, geologist-engineer, famous pothole explorer. Vice-president of HSS. He discovered the connection between Baradla and Domica, and is the discoverer of Szemlőhegyi, Ferenchegyi, and Kossuth caves. He introduced very useful new concepts into karsthydrology, such as "oozing percentage", indices of reliability of a karst spring, etc.; he typifies the expert in practical cave exploring and in the science of speleology (Budapest XI. Ménesi ut 19, Hungary)

László Jakucs, geologist, the present director of Baradla cave. Pénzpataki, Sátorkőpusztai, Béke caves were discovered by him. He worked out a new theory of the origin of thermal caves. He emphasized the value of water-tracing in cave exploration. (Jósvafő, Tengerszem Szálló, Hungary).

László Maucha, geologist, discoverer of Vass Imre cave. He is the present leader of the cave exploring group of Budapest Technical University. He has introduced physical methods and new concepts in speleology (Budapest I. Ostrom U. 29, Hungary).

Frank Holly Ph.D. candidate in physical chemistry at Cornell University. Before he came to Cornell, he was one of the founders and later the leader of the cave exploration group of Budapest Technical University. Discoverer of Kissomlyói, Pénzpataki, and Vass Imre caves. He has introduced chemical methods in speleology (Chemistry Department, Cornell University, Ithaca, New York).

Other scientists working in fields connected with speleology:

Dr. Sándor Láng, Dr. Sándor Leél-Őssy, Denise Radó in the field of karst-morphology (Geographical Institute. Budapest VIII. Muzeum krt 9, Hungary).

Sándor Jaskó, István Venkovits in the field of karsthydrology, (MÁFI, Budapest X. Vorosilov ut 14, Hungary).

László Vértes in archeology (National Museum, Budapest. VIII. Muzeum krt 2-4, Hungary).

Dr. Károly Bertalan, László Schönviszky in bibliography (MÁFI. Budapest X. Vorosilov ut 14, Hungary).

Sándor Holly, MS in E.E. (82 Hazelton Circle, Briarcliff Manor, N. Y.), *László Markó* in cave photography. *József Tóth* in Speleometry (Budapest XIX. Áram u. 44, Hungary).

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Meteorological Observations in Martens Cave, West Virginia*

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Abstract — Measurements of flow and temperature of air and water in Martens Cave near Lobelia, West Virginia were made from 1948 to 1960. The main passage of Martens Cave, 800 feet long, extends through a low hill. Air temperature in this part of the cave reflects seasonal variation in surface temperature with a slight time lag. The highest temperature in the main passage is 53°F. which is the same as the mean annual surface temperature; the coldest is 27°F. In other parts of the cave temperatures are 49° to 53°F. throughout the year. The stream flowing through the main passage loses heat at a rate of 2°F. per hundred feet in the cave in summer to a stable temperature of 53°F. In winter it gains very little heat except from a small side stream which joins it 500 feet inside the cave causing a temperature rise of 2°F. In the rocks enclosing the cave there is a net yearly heat gain of about 7,000,000 BTU.

Martens Cave has two distinct features; (1) it is a relatively simple cave of uniform size extending through a hill, and (2) as a result, has strong, persistent air currents seldom observed in other caves. The cave is in Pocahantas County, West Virgina, 1 mile east of the town of Lobelia (Lobelia Quadrangle).

The cave offers the unique opportunity to study the meteorological regime of a subterranean, non-static, atmosphereic system. The two entrances, uniform size of cave passage, simple plan, and ease of access make it possible to obtain significant data on air movement and heat exchange in relation to surface temperature.

Studies on the meteorology of Martens Cave were started in the summer of 1948. Since then the cave has been visited periodically to obtain meteorological data. After the first few years the visits were spaced so that the measurements were made near the end of the months of February, May, August and November. In addition other visits were made as often as time permitted.

The cave was originally surveyed in 1948; a revised and more detailed survey was made in 1959. Based on these surveys, stations were established along the main passage at intervals of 100 feet. Measurements of both air and water were made at these stations. In addition 8 other stations in side passages and rooms were established to augment the readings obtained in the main passage.

At all stations air temperature, humidity, and air movement were observed. Where streams occured the temperature and discharge of the streams were measured. At selected stations rock-wall temperatures were measured, using soil thermometers inserted into holes or cracks in the rock.

The data collected over the past 11 years have not been continuous, as regular daily observations were not possible because of lack of time and finances. Use of self-recording instruments maintained by local residents was not successful because of failure to rewind the clock-recording mechanisms, failure to change recording cards, and errors in dating records. The lack of regularity in data is compensated for by the number of observations made over the 11-year period. Without exception these data were consistant with the cumulative average and it is believed that the mean of the observations are close to that which would have been obtained had daily observations been possible.

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* Publication authorized by the Director, U. S. Geological Survey

Martens Cave is in the top part of the Greenbrier limestone (Late Mississippian age). The limestone is thick bedded, and gray in color. At the cave the dip is 5° to the west.

The valley into which the cave opens is a large sink valley trending northeast-southwest. The sink valley is 2 miles long and a half mile wide. Martens Cave is near the head of a large tributary valley that extends a mile east of the north end of the sink valley (fig 1). The south entrance to Martens Cave is in a large uvala (fig. 2). The uvala consists of two large sinks, the east one into which the cave opens is 1,500 feet wide and about a mile long; it is 50 to 100 feet deep. The floor of the sinkhole is narrow and trends east-west. A small stream flows across the sink into the cave. The vegetation in the sinkhole is grass; wooded areas are along the lip of the sinkhole.

The south entrance to Martens Cave is in a cliff 50 feet high. The entrance is 40 feet wide and on the east is partly filled with soil and leaves. The north entrance is in a cliff about 25 feet high. This entrance is 60 feet wide and is floored by fallen rock which forms a low ridge across the floor. In front of the north entrance the slope is steep for 40 feet down over fallen rock to the valley floor.

The main passage of Martens Cave is 800 feet long; width is 30 to 60 feet with most of the passage about 40 feet wide (fig. 3). The ceiling is about 10 feet high through the passage except at station 5 where it reaches 30 feet. Most of the main passage is floored by large slabs of breakdown which are piled almost to the ceiling between stations 3 and 4 (fig. 4). From station 3 to near station 1 the floor is of silt and gravel.

A large side passage (Back Room) leads south from the main passage near station 6. It is 150 feet long, 25 feet wide, 6 to 10 feet high and ends in clay-covered breakdown. Another side passage extends east from near station 6. It is 200 feet long and consists of crawlways as much as 30 feet wide. In some of the crawlways the floor is limestone into which have been cut a system of solution crevices that are a foot or two wide and are grooved by lapiez and other solution features (Lapiez Room). Several complicated crawlways connect this side passage and the main cave. These connecting passages trend north parallel to the main passage.

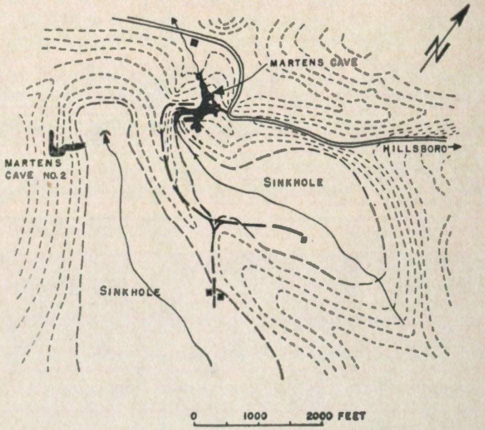

Figure 1
Topographic sketch of Martens Cave and vicinity; relief by form lines.

Between stations 3 and 4 a large room (Side Room) is to the east of the main passage. Actually this room is a part of the main passage but breakdown has formed a partition between them. The room is floored with breakdown which slopes up to the ceiling on the east.

Figure 2
South entrance to Martens Cave

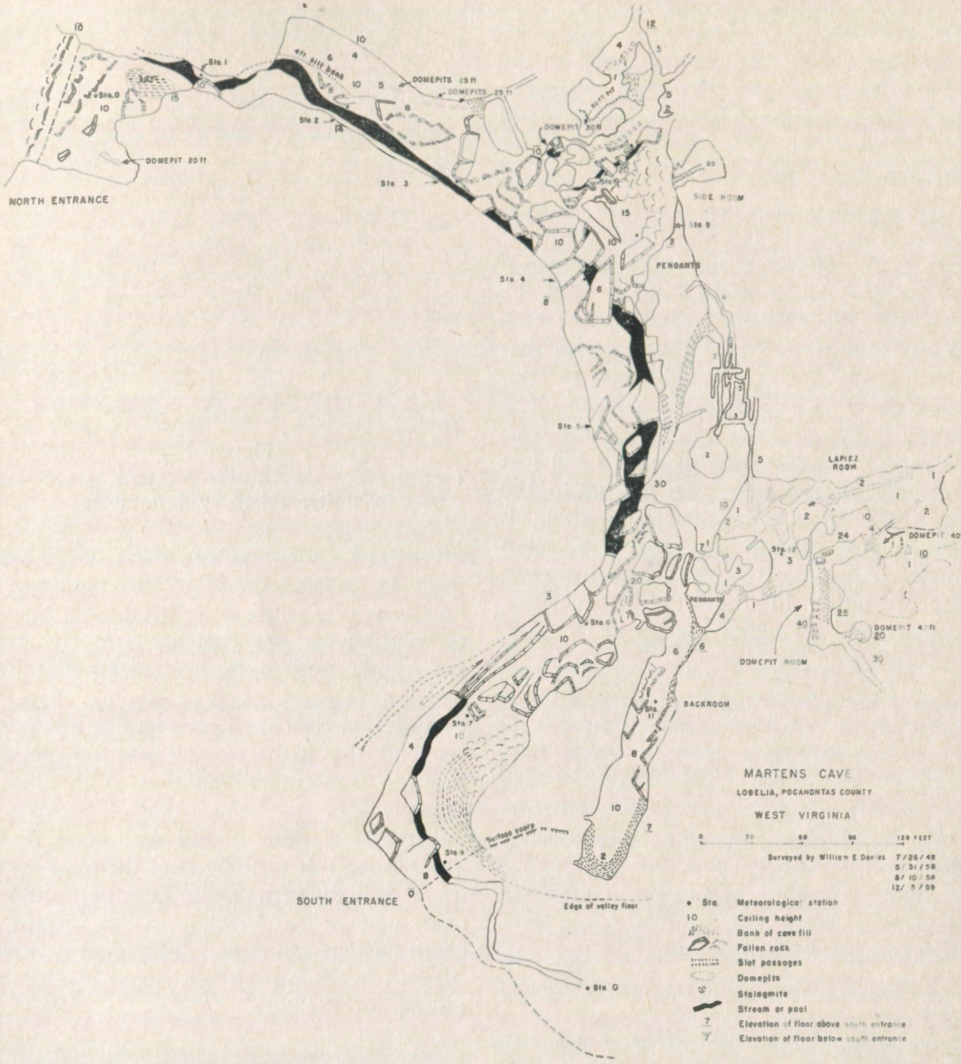

Figure 3. Map of Martens Cave

Domepits are developed at several points in the cave. On the east side of the passage between station 2 and 3 there are 5, each about 2 feet in diameter and 30 feet high. All are active and grooved. Several large domepits, about 10 feet in diameter and 30 feet high are on the north side of the Side Room opposite stations 3 and 4. Several large domepits are on side passages leading south and east from the Lapiez Room. One of them, at the edge of the Lapiez Room, 10 feet in diameter, 40 feet high, has cut a pit 5 feet deep into gravel fill at its base. West from this domepit is a passage formed by the coalescing of 3 similar pits (Domepit Passage). Several other domepits are in this area and are cutting pits into the gravel fill.

Pendants are well developed on the east side of the main passage at the entrances to the Back Room and the Lapiez Room and on a high shelf along the east side of the main passage between stations 4 and 5. Cave fill is common in the Back Room, the Lapiez Room and on the shelf between stations 4 and 5. The stratigraphy of the fill is:

Top

Dark red brown clay	4 in.	(10 cms.)
Dark red brown gravel	22 in.	(60 cms.)
Dark brown sand	55 in.	(140 cms.)
	81 in.	210 cms.

TABLE I

Average Monthly Temperature (°F)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Cranberry Glades	27.9	30.9	36.8	46.6	55.1	61.4	64.7	63.3	58.4	48.4	37.0	28.4	46.6
Lewisburg	32.4	33.3	42.1	50.5	60.1	67.2	71.0	69.4	65.7	53.2	41.9	33.2	51.6

Source—U. S. Weather Bureau, Climatological data, annual summary, West Virginia, 1902-58

METEOROLOGY

Martens Cave lies along the eastern edge of the Alleghany Plateau. Regular weather observations are made at Cranberry Glades 4 miles north of the cave. This station is 800 feet higher in altitude than the cave, and the temperature is lower and precipitation greater than that in the area of the cave. Regular observations are also made at Lewisburg, West Virginia, 27 miles south. Weather conditions are milder here than at the cave. It is probable that the conditions around the cave are about a mean of the records for Cranberry Glades and Lewisburg (Table I).

Temperatures in the cave are in two distinct groups—those along the main passage which are affected by conditions outside the cave and those in the side room which show little or no variation throughout the year. As temperature readings are not continuous and were taken at various dates throughout the year they have been grouped into four sets based on the mean positions on graphs.

Figure 4
Main passage, view south at station 3.

The area between stations 4 and 5 has been taken as the "average" condition of the cave. Observations indicate that this region is the least affected by outside temperature changes of short duration. Long-range seasonal changes in surface temperatures, however, are reflected in the temperature in the area of stations 4 and 5. In this area the relation between the mean surface temperature and the mean cave temperature is consistent (fig. 5). The temperature curves are sinuous. The surface

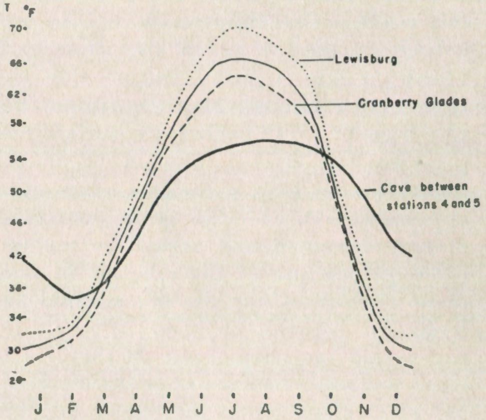

Figure 5
Mean of cave and surface temperatures. Light solid line is approximate mean surface temperature at cave based on mean of Cranberry Glades and Lewisburg. (Surface records from U. S. Weather Bureau, Climatological data, annual summary, West Virginia, 1902-58.)

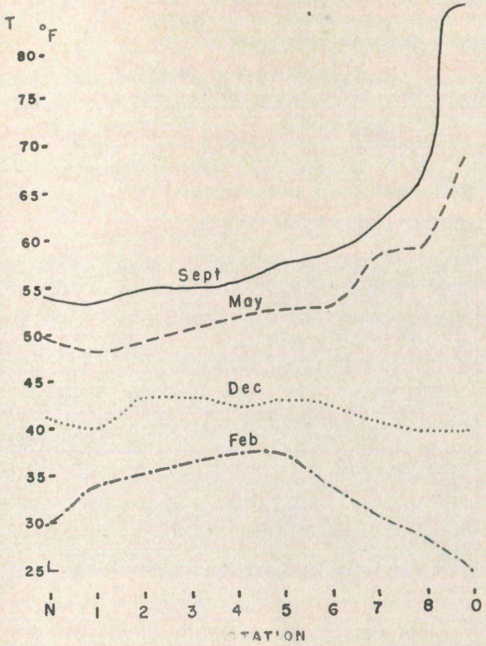

Figure 6
Mean air temperatures in Martens Cave. Solid line, late September; dashed line, late May; dotted line, late December; dotted and dashed line, late February. N is north entrance; O is 40 feet SE of south entrance.

temperature curve reaches a maximum in late July and drops away on either side of this point. The temperature in the area between stations 4 and 5 rises from early March to late August. During this rise, from March through May the temperature lags from 0° to 4° behind the surface temperature (all temperatures in °F in this paper). After May, as the cave temperature approaches 53°, which is the annual mean of surface temperature as well as the uniform temperature of the cave air in areas of no circulation, the rise is less rapid and levels off between 53° and 57°. During this period the temperature in the area of stations 4 and 5 remains at or slightly above 53° which characterizes the rest of the cave. The drop in temperature at stations 4 and 5 begins in late September and is much less rapid than the decline of surface temperatures. In late December the lag of the cave temperature behind surface temperature reaches a maximum of 6°.

The temperature distribution along the main passage varies throughout the year (fig. 6). From late spring through late fall the temperature decreases uniformly from the south to north entrances. From late fall to early spring the gradient is very different and the temperatures rise slightly from both entrances towards stations 4 and 5.

In the side rooms leading from the main passage the temperature varies slightly throughout the year. In the Back Room, 200 feet from the south entrance to the cave, the summer temperature is 58° to 60°, whereas the winter temperature drops to 43°. This range in temperature reflects small openings that connect to the surface at the end of the room. At its south end the room is 10 feet from the surface on the side of the sinkhole and is blocked by breakdown and clay.

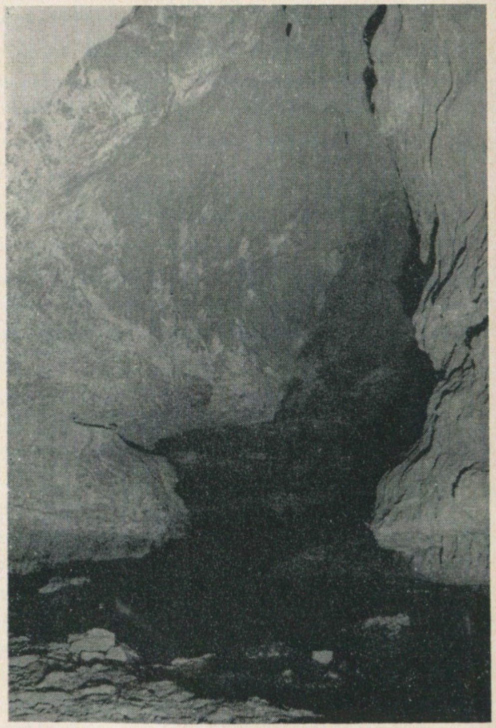

Figure 7
Constriction in main passage at station 1: view north.

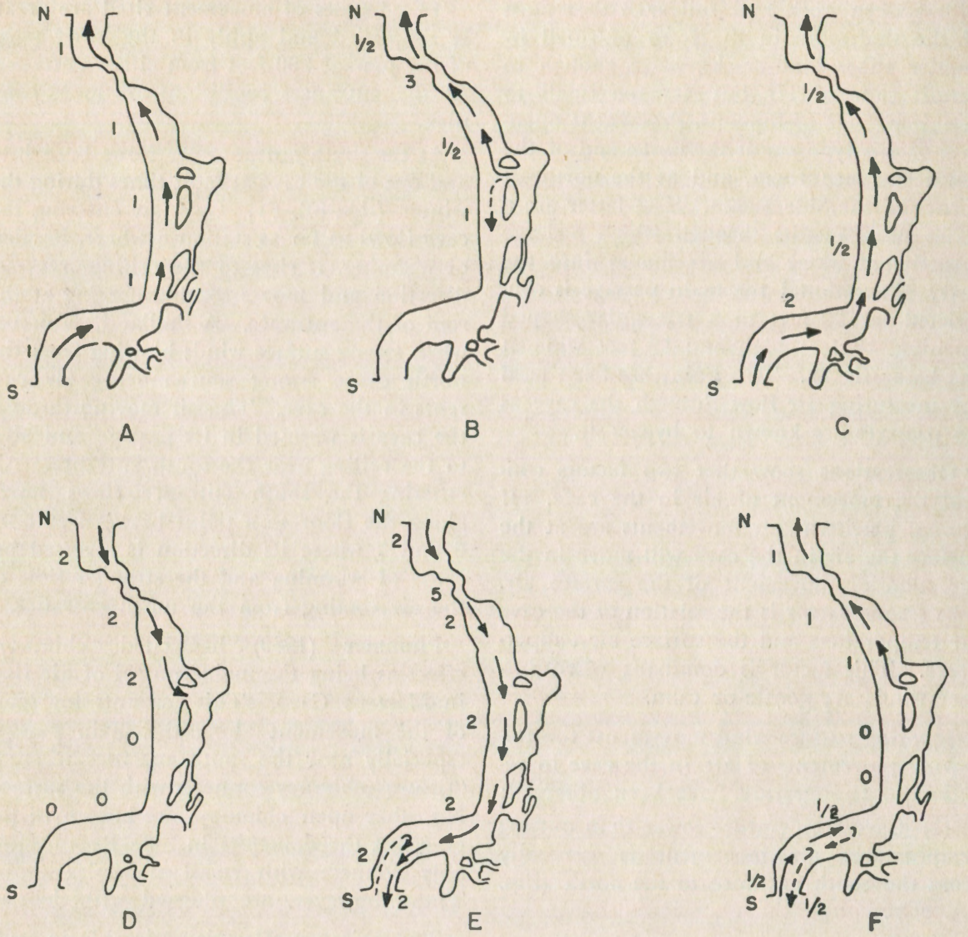

Figure 8
Diagrams of air movement. A. — Surface temperature 65°F., cave temperature 52°F. in late spring; B. — Surface 85°F., cave 57°F. in late summer; C. — Surface 48°F., cave 43°F. in early fall; D. — Surface 41°F., cave 43°F. in late fall; E. — Surface 24°F., cave 34°F., in late winter (strong surface wind from north); F. — Surface 27°F., cave 37°F in late winter. Surface winds calm unless noted. Figures along left side of diagrams are velocity of air (ft./sec.). Dash arrows are weak air movements.

In the Side Room opposite stations 3 and 4 the temperature ranges from 34° in winter to 53° in late summer. This room is connected to the main passage by two wide openings and the effect of the air flow of the main passage on the Side Room is great. In small pockets at the top and on the side of the room the temperature is 53° in the summer and 49.5° in winter. Similar variation occurs in the domepits on the north side of the Side Room where the summer temperature is 53° and the winter low is 46°. The temperature variation in the Lapiez Room and Domepit Passage has the same pattern as the domepits of the Side Room.

The circulation of the air in the main passage is complicated. In addition to the openings to the surface at each end of the passage several small, irregular openings reach the surface as domepits and fissures. These openings to the surface are choked with broken rock and soil, such that most of the shafts are in the form of small irregular tubes and cracks, large enough to permit flow of air but far too small to permit passage of humans. Prominent openings of this type are at the north end of the south entrance room, and at the northeast corner of the Side Room. The latter are a series of domepits through which a large quantity of water and air moves into the cave. At station 1 the main passage is constricted for 20 feet to a triangular shaped opening 10 feet high and 10 feet wide at the base (fig 7). This point has been used for measuring air flow through the cave as no passages are known to bypass it.

Observations show that two factors control the movement of air in the cave. If strong, persistent air movements are at the surface the air in the cave will move in the direction of movement of the surface air. The second factor is the relation of the cave air temperature and the surface air temperature. This factor is dominant when surface winds are gentle or calm.

Ignoring surface wind movements the following movements of air in the cave in relation to temperature have been observed:

(1) Cave temperature lower than outside temperature: air movement is generally from the south entrance to the north (figs. 8A, 8C).

(2) Cave temperature a few degrees higher than outside temperature: air movement is generally from north entrance to Side Room, no movement between Side Room and south entrance (fig. 8D).

(3) Cave temperature 10° or more higher than outside temperature: air movement is from Side Room to north entrance, no movement between Side Room and south entrance (fig. 8F).

(4) Cave temperature much lower than outside temperature (20° to 40° difference): movement is primarily from Side Room to north entrance (fig. 8B).

The air movement is confined to the main passage and the north part of the Side Room. The other parts of the cave show no measurable movement.

The 4 types of movement cited are greatly simplified and apply in the inner parts of the passage 200 feet from either entrance. At the entrances conditions are more complex.

At the south entrance air flows both into and out of the cave at most times during the winter (figs. 8E, F). Cold air entering the cave flows as far as station 6 where, because of warming, it rises to the ceiling, reverses direction and moves south emerging at the roof of the entrance. A similar flow occurs when strong surface winds blowing from the north cause strong south-moving air currents in the cave. The air moving through the cave is warmed in its passage and rises to the ceiling near the south entrance. Air entering the south entrance flows north along the floor to a point between stations 6 and 7 where its direction is reversed because of warming and the stronger flow of the air coming from the north entrance.

Plummer (1960) has cited "chimney" effect as being the main control of air flow in Martens Cave. This accounts for some of the movement along the main passage especially near the south entrance where a "fissure" chimney connects with the surface. No other open chimneys are known in the cave but the domepits in Side Room probably connect with small sinkholes above. These, however, are plugged with debris.

The chimney effect is noticeable in some parts of the cave when the surface wind is not strong and differences between surface and air temperature are small. At other times the chimney effect is obscured by the mass movement of air through the cave. Even under the latter condition the chimney effect is significant in the north part of the Side Room and the temperature in the adjacent main passage between stations 3 and 4 is modified by the resulting air movements.

HYDROLOGY

Several streams flow in the cave. The largest is a surface stream that drains the sinkhole to the south. This stream enters the cave at the south entrance and flows along the main passage to the north entrance. A small stream flows from the Side Room to join the main stream at station 3. Other streams, generally mere trickles, enter the main passage from the west at station 4 and from the east midway between stations 5 and 6.

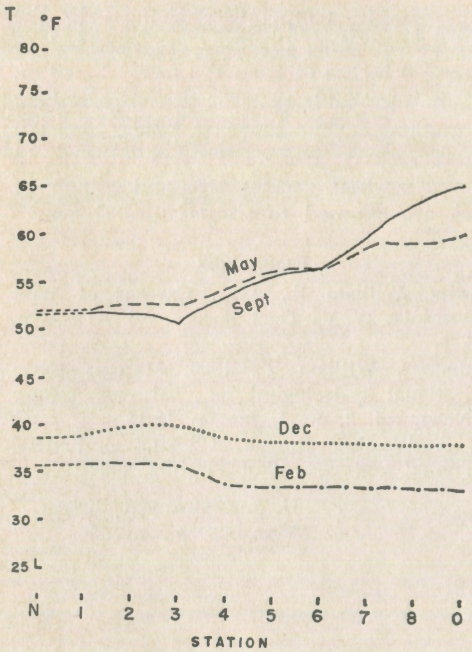

Figure 9

Mean stream temperatures in Martens Cave. Solid line, late September; dashed line, late May; dotted line, late December; dotted and dashed line, late February. N is north entrance; O is 40 feet SE of south entrance.

The main stream averages 4 feet wide and 4 inches deep. Discharge is about 4 cubic feet per second at station 1. During heavy rains the discharge is as much as 12 cubic feet per second, for periods of a day or two. The stream from the Side Room has a year round flow of ¼ cubic foot per second; it is a foot wide and about an inch deep.

In addition to the streams, significant quantities of water enter the cave from domepits. Small trickles of water flow from the pools at the base of the domepits and join the main stream.

Temperatures along the main stream show much less variation than does the air (fig. 9). During spring and summer, when the temperature of the surface water is above 53°, the stream loses heat at a uniform rate after entering the cave. From stations 8 to 3 this is about 1½° per 100 feet. At station 3 the stream from the Side Room enters the main stream and causes an abrupt lowering of temperature in the summer and an abrupt rise in the winter. The temperature of the stream in the Side Room (station 10) varies little during the year. In spring, summer and fall it is 49° or 50°; minimum in winter is 48°.

In late fall and winter, when the surface temperatures are below those of the cave, the water in the main stream is warmed very little in the cave until it reaches station 3, where the stream from the Side Room causes a rise of 1° or 2°.

Drip water from domepits is nearly constant throughout the year, at temperatures of 49° to 53° depending on the location in the cave.

CONCLUSIONS

Observations in Martens Cave indicate that the temperature of cave air changes seasonally if the cave has a large flow of air between two entrances. In addition, the observations show that the temperature remains relatively constant throughout the year in passages that have only a slow, uniform movement of air.

The exchange of heat between the walls and ceiling of the cave and the cave air is very large. Continuous measurements of temperatures would be necessary to calculate the heat exchange but an order of magnitude can be developed based on the data available.

In spring and summer the rocks around the cave absorb heat from the air. Based on temperature differences and air flow this amounts to about 20,000,000 BTU. In fall and winter the heat loss is somewhat less than the gain in spring and summer; it is estimated as 13,047,840 BTU. The difference in the heat balance probably results from heat reaching the surface by way of distribution through the bedrock adjacent to the cave. The heat changes are so large that it is probable that the winter and summer changes involve considerable quantities of air in pores, fissures, and small passages adjacent to the cave. The air movement between the Side Room and the main passage is indicative of this.

Chimney effect is probably of secondary importance in air movement as shown by conditions in the Lapiez Room and the east side of the Side Room, where several domepits lead to the surface. These parts of the cave are partially closed off from the rest of the cave. Because of this, air movement is greatly reduced and the temperature is fairly stable throughout the year. Therefore, it is concluded that the chimney effect on air movement is significant only where the chimneys connect with a passage that opens to the surface.

Noticeable temperature changes in the rock surrounding the cave are confined to a zone 6 inches in from the face. Based on this it is probable that the exchange of heat is greatest in the air that moves through pores, fissures, and small tubes adjacent to the cave where greater area and volume of rock are exposed to temperature changes.

REFERENCES

Davies, William E., 1958, Caverns of West Virginia: W. Va. Geol. Survey, vol. XIX-A, p. 275.

Plummer, William T., 1960, Martens Cave: National Speleological Soc., Baltimore Grotto News, vol. 3, no. 1, Jan., p. 13-15.

U. S. Weather Bureau, Climatological data, annual summary, West Virginia, 1902-1958.

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Additional Notes on Vertical Shafts in Limestone Caves

GLEN K. MERRILL

Abstract — The life cycles of domepits illustrate characteristic relationships to the stratigraphy and physiography of the area and to each other. They originate from the action of meteoric waters and their general form is a result of the highly uniform characteristics of the limestone bedrock and a zone of concentrated water seepage either in a sinkhole or along ridge margins. Usually they are formed where ravines intersect the ridge. The domepits frequently occur in series, developing along with headward valley erosion. The shafts are normally smaller in both depth and diameter in their relation headward along valleys. Both seeping (solution) and dripping (solution and abrasion) water help to excavate the walls and floor of the domepit.

Local resistant strata can restrict or entirely stop domepit formation, frequently resulting in the forming of shafts beneath the original ones.

Probably the single outstanding feature of the caves in "The Central Cave Region" of Kentucky is the presence of deep vertical shafts. These shafts are typical of this area although not confined to it. Many of these shafts are nearly perfect cylinders; frequently decorated by vertical flutings, a single fluting sometimes extends from top to bottom. These shafts are usually referred to as "pits" if one views them from near the top; and "domes", if the observer is nearer the bottom. Some confusion exists regarding a general term for these shafts, having been variously referred to as pits, domes, wells, pit and dome, pit-dome, dome pits, dome-pits, and domepits among others. The author has adopted the term *domepit* as used by Barr (1955, p. 271), largely because of its compactness and brevity. Although the occurrence of these features is well documented in the literature and various brief and often misleading explanations have been proposed for them, it remained for E. R. Pohl (1955, p. 1-24) to describe them adequately and to explain their speleogenesis in general.*

Pohl proposed the following as general characteristics of domepits:

1. Vadose origin
2. Recent, and generally continuing development
3. An intimate relationship to surface features, plateau and ridge edges and sinkholes
4. Formation by seepage of surface water through the caprock
5. Nearly total lack of relationship to horizontal passages
6. Frequent development along joints and cross-joints
7. Frequent serial development

The basic statements listed above are not in contention; the author intends to elaborate on these findings and to describe a type of development of domepits that has received no attention.

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SURFACE FEATURES

The area of the author's work has been confined to the southern portion of the Central Cave Region, outside the boundaries of the Mammoth Cave National Park, and primarily in James and Coach (formerly Hundred Domes) Caves. These two caves have the distinction of possessing the two deepest, and in many respects, some of the most typically developed domepits in the region. Although this southern area was not included in Pohl's discussion and has received little attention elsewhere, its genesis is clearly related to that of the remainder of Mammoth Cave Plateau and has produced an environment as favorable for the production of vertical shafts as the area farther north. Both of these caves are situated on a ridge mass extending southward from the main portion of the plateau, a little over one mile WNW of Park City. This area is shown on the United States Geological Survey 7½ Minute Park City Quadrangle.

For convenience the Central Cave Region can be subdivided into 3 physiographic units:

1. The Pennyrile Plateau (also Sink Hole Plain, Mississippian Plateau and Pennyroyal Plateau) exhibits a fairly wide range in elevations despite its gently rolling character. "The Knobs", outliers of the Mammoth Cave Plateau, represent circumdenudated remnants of this Plateau. As would be expected these knobs contain domepits, some of them of considerable depth. The Pennyrile Plateau itself contains many caves, some of considerable extent although domepits are lacking. This plateau surface is developed on the St. Louis and basal Ste. Genevieve limestones and occupies the southern and southeastern part of the area.

2. The Mammoth Cave Plateau, a high level dissected plateau, is separated from the lower Pennyrile Plateau by the Dripping Springs Escarpment. This escarpment is a clearly marked division in the area. The Pennyrile Plateau averages between 550 and 650 feet altitude, while the Mammoth Cave Plateau averages between 700 and 850 feet, giving a local relief along the escarpment of as much as 250 feet. The base of the escarpment must not be construed as base level however, for caves in both plateaus penetrate strata lower than the escarpment base. Local base level is that of the Green River (elevation about 430 feet) which drains most, if not all, of the higher plateau and possibly a portion of the lower one as well by subsurface channels. It is the extensive and famous caves of The Mammoth Cave Plateau that contain the domepits under discussion. For our purposes this plateau is bordered as follows: east and south by the Dripping Springs Escarpment; north by the Green River; and west by a line generally coinciding to the outcrop of basal Pennsylvanian sediments. This western boundary is established generally by a thickening of strata over limestones. This is one of America's finest areas of karst topography.

3. The area north of the Green River contains caves in a relatively narrow strip bordering the river. However, solution effects are not extensive because the regional northwest dip results in an increased overburden of non-carbonate rock. This area is not discussed in this paper.

Pohl has demonstrated that domepits are located near the edges of the escarpment proper, or along the edges of ridges within the dissected plateau. Commonly these shafts are located beneath sinkholes or valleys dissecting the ridge mass. Where no surface valley is present, the shaft is usually located near the margin of the capping sandstone at the head of the slope. Two criteria for domepit formation that are therefore suggested are a suitable volume of water and a method of penetrating the caprock. This location of shafts presages a form of runoff diversion or subsurface piracy. It must not be concluded, however, that surface streams are diverted underground *in toto* with a resulting deluge, but rather that a portion of the water running into or along a surface depression seeps downward where conditions are favorable.

As headward erosion of these small, intermittent valleys progresses, destroying the caprock and attacking the limestone, a series of domepits is commonly formed. These shafts will normally be smaller both in diameter and depth headward. Observation indicates that this is usually but not universally the case. Local stratigraphy and other factors exert an influence in this matter. As new domepits are formed headward, older ones are being destroyed down valley. As Pohl suggests (1955, pp. 13, 22) the former locations of domepits are frequently marked by sinkholes in the solution valleys. The Park City and Mammoth Cave quadrangles show several fine examples of these life cycles. Gorin's Dome, Side Saddle Pit, Bottomless Pit and the sinks in Bluebell Hollow illustrate such a series.

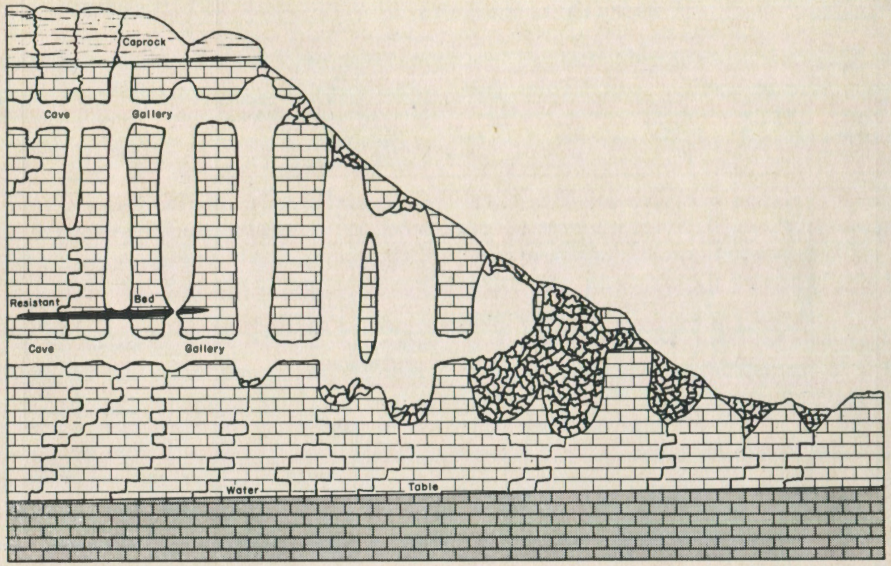

Figure 1

Profile of an idealized domepit series showing stages from origin to destruction (not to scale).

On the basis of the preceding it is probable that domepits are both a cause and effect of surface topography.

STRATIGRAPHY

The important elements of the regional stratigraphy are well known. They consist of a resistant caprock, the Cypress (Big Clifty) sandstone, and a thick sequence of carbonate rocks, including the following limestones in descending order: Paint Creek, Renault, Ste. Genevieve and St. Louis. Clastic members, developed to the west, are absent or nearly so, giving a limestone sequence several hundred feet thick in the region. In the immediate vicinity of Mammoth Cave the St. Louis limestone is below drainage, but farther to the south on the Pennyrile Plateau this limestone is exposed and cavernous.

Despite the well known general rock units, details regarding local contacts and elevations are frequently lacking. The limestones are generally poor in fossils; many of the species present are long-ranged or inadequately defined or both. Recent studies of the microfossils in the region may shed light on these problems.

The deepest surveyed domepits and passages in the southern high plateau region do not reach the water table nor the St. Louis limestone which should occur just above drainage. Nevertheless they are below the level of the adjacent Pennyrile Plateau. The possible resurgences of the northward

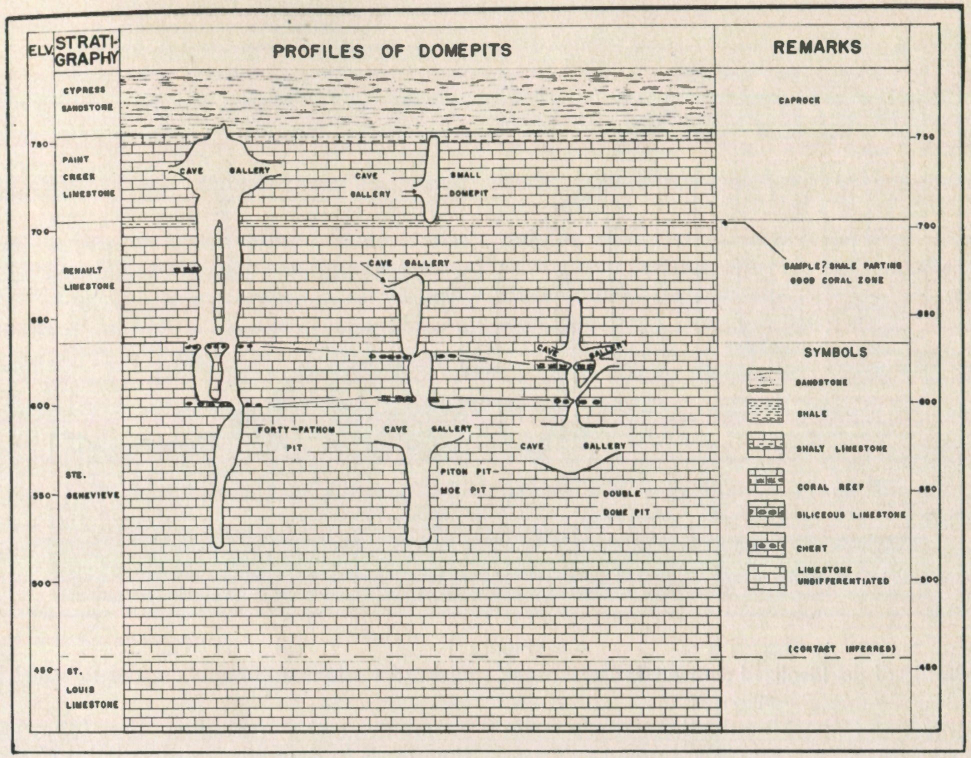

Figure 2

Stratigraphy and domepits in James Cave. No vertical exaggeration, distance between domepits not to scale.

flowing, sinking streams which disappear south of the escarpment are thus of considerable interest (Barr, 1955, p. 267).

The inferred stratigraphic relationships are illustrated in Figure 2.

General Features of Domepits

Domepits take the form of vertical cylinders. With few exceptions they are quite regular in plan and section. No definite relations can be established between the diameter and height of these shafts. In plan view many of these shafts vary only slightly from perfect circles. Much of their regularity can be attributed to horizontal seepage from a central, nearly point source, the downward percolating water spreading laterally in all directions. The dependence upon relatively uniform solubility of the limestone for such regularity has been pointed out by Pohl (1955, p. 22). The vertical fluting mentioned previously is a conspicuous feature of these shafts and will be dealt with more fully under the heading of speleogenesis.

The walls of many of the shafts show differential solution along bedding planes. Where both this differential solution and vertical flutings are present, the vertical flutings appear dominant, some trace of them remaining despite secondary sculpturing along bedding planes. This would indicate that flutings are of primary origin (contemporaneous to the formation of the domepit), while lateral solution is a penecontemporaneous modification of existing shafts by recurrent and continuing seepage.

The ceilings of these domepits vary considerably. Cavities, some of them minor shafts themselves, frequently extend upward from the general level of the ceiling. Such a ceiling cavity will tend to channel water into the center, open portion of the shaft, resulting in more rapid downward solution. Floors of the shafts are usually hemispherical. In most cases they contain small, transient pools of water, or are wet, bare rock. Breakdown occurs on the floors and frequently testifies to an intimate relationship to the surface. Rounded blocks of both limestone and sandstone are common. The presence of sand and gravel is not conclusive since their derivation could have been reworked spelean deposits. Most of this material was derived from the top of the shaft however, by collapse or direct introduction from above. An interesting occurrence has been observed where a small domepit has developed in a large breakdown block. As this indicates, not all domepits are of impressive size; small, very minor and incompletely developed examples abound in the area.

Normally these shafts are well drained via joints and other small openings. Rarely does a horizontal passage carry off this water. Where this does occur it must be considered a fortuitous example. The same holds true of the occurrence of waterfalls in domepits. Such waterfalls occur strictly by chance, the domepit being antecedent to the subsequently diverted stream.

Speleogenesis

The speleogenesis of the entire region is complex and incompletely understood. As pointed out by Smith (1957, p. 6), the classic two-cycle theory of cavern development is inadequate to explain features encountered in this region. The problems of overall speleogenesis need not concern us too greatly here, however, as the domepits are the product of the most recent stage, that of course being the present vadose conditions.

The water which excavates these vertical shafts is derived from the surface by seepage through the porous caprock, and after that is breached, continues in increasing amounts along joints in the limestone. Once the caprock has been breached, however, the rapid solution and collapse cause the destruction of the shaft, the process of formation also being the one of destruction (fig. 1). Initially the downward percolation of the acid-bearing waters, usually along a joint or joints, causes the first beginnings of a shaft. This embryonic domepit is irregular, frequently rather linear, and has walls showing irregular pitting. The flow, or more accurately trickle, of the water at this time is still rather turbulent. Many shafts do not develop beyond this stage, others can be observed in all phases of formation. Some of these are also small and irregular, but actively enlarging. For a true domepit to be formed a rather permanent water source must be present. Where this occurs, as beneath small valleys and sinkholes, the pit continues to enlarge both in depth and diameter. As the size increases so does the regularity caused by the flow of seepage eroding the walls peripherally. Finally a stage is reached where the water originating from a rather small areal source does not reach the walls of the shaft in large volume, but collects on the ceiling and drips into the shaft. This additional force, the abrasive impact of dripping water, tends to increase the depth of the domepit in relation to its diameter. Not only do these droplets have the same solution potential as the smaller volume flowing down the walls, but they impart quite an impact at the floor as anyone who has looked up these domepits in wet weather can testify. This conclusion is further supported by the concave nature of the domepit floors, which bear a striking resemblance to the plunge pools found beneath waterfalls. Dripping water is probably the principal erosive agent in the deepening of most domepits. It might also be noted that although delicate fossils frequently weather out of the domepit walls they are seldom, if ever, found *in situ* in the floors of these shafts. This combination of forces permits shafts with quite small diameter-depth ratios to develop. One extreme example of a ratio of 1:20 has been observed.

The absence of flowstone in these domepits can well be explained by three factors

Figure 3
Forty-Fathom Pit, view down for 90 feet showing subcircular outline, vertical flutings, and a small ledge (lower right corner) formed by resistant stratum.

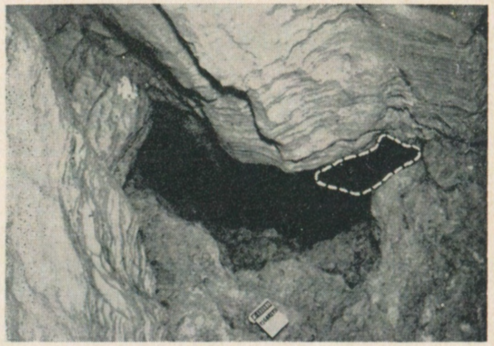

Figure 4
Entrance to Moe Pit. Dashed white line indicates original size of opening.

which, taken together, control this lack of deposition. First, the short travel distance of the water through limestone permits minimal loss in acidity and hence, minimal calcium bicarbonate in solution. Second, the volume of the water is relatively great. This, coupled with its velocity, not only is not conductive to travertine deposition but has a slight abrasive action. Finally, because of the large volume of water, the lack of evaporation permits most of the material in solution to be carried to the water table.

As new domepits are formed by the process of headward erosion, they begin to entrap an increasing amount of runoff from the surface. The valleyward domepits still receive their share however, and even the oldest ones of the series continue to enlarge. As additional limestone overburden is removed, ceilings collapse and the domepit is destroyed, yielding a sinkhole in the valley.

As the diameters of closely related shafts in a series increase, it is inevitable that this peripheral erosion causes the individual domepits to join on their edges, leaving roughly triangular projections representing the former partition. All stages of this junction can be observed, from a few small, ragged holes in a wall, to thin, irregular arches and projections as remnants. It would be expected therefore, that a great many domepits await discovery, separated from known shafts by a thin shell of rock. Where several of these join, a large, canyon-like passage may result. These are easily distinguished from generally similar high, narrow passages of other origin by the presence of flutings, projections marking the position of former walls, and other similar criteria.

The wallrock remnants resemble the vertical flutings in general form, which might lead one to the conclusion that all such flutings are the remnants of former partitions between small, parallel shafts that have joined to form the main shaft. This concept, while quite attractive, is not supported by field evidence. Some large flutings apparently have been formed in this manner, however.

Stratigraphic Control of Domepits

The progressive nature of a domepit series normally dictates the relative floor levels of that series as well as the relative diameters. In a limestone sequence of uniform lithology, when all other considerations are satisfactory, this would be the case. Despite the remarkable uniformity of the cavernous limestone, small but significant differences in the local lithology play an important role in domepit formation.

The domepits as observed today seldom reach the level of the water table, which is the ultimate limiting factor of their formation. A rough concordance of floor elevations of several very deep domepits as well as certain passages, is suggestive of a former base level of rather recent date. All observed solution below this general level consists of small cavities and small streams of high gradient which appear to be actively downcutting. Whether or not this is truly indicative of a geologically recent downward adjustment of base level remains to be determined. Evidence farther north in Flint and Mammoth Cave Ridges appears to contradict this (Pohl, 1955, p. 16).

Although the ultimate arresting factor of the depth of domepits must be the ground water table, locally strata of relatively greater resistance may impede, constrict or completely arrest downcutting. Examples of such strata are: more siliceous or sandy limestones. lenses of chert, and local reefs of silicified corals (*Lithostrotion* etc.). It can be observed however, that little or no pondage of water occurs where downcutting is thus arrested. The well jointed and porous limestones, fractured cherts, etc., carry off the water. The resistant stratum acts as a caprock, resists solution and abrasion for a time at least, and channels the water downward, principally along joints, into the more soluble limestones below. The joints, cracks and crevices are subsequently enlarged by this water, causing the same general conditions as applied initially beneath the sandstone caprock, with the same result—a second shaft is formed beneath the first. The resistant beds when followed laterally grade into less resistant strata. Nevertheless there seems to be a definite correlation in the elevations of constrictions of widely separated domepits (fig. 2). The secondary domepits are usually smaller in depth and similar in diameter to the shaft above. Since any constriction must be a transient structure, constantly being destroyed, all degrees of closure can be expected among these shafts. In some of them only small ledges of resistant material remain, but a great many have definite floors with holes of various sizes leading into the subpit below. Holes far too small to permit the passage of a man have been opened and several remain to be enlarged. Undoubtedly many subpits exist which have not been detected due to the lack of any visible opening. All domepits with bases at relatively high levels need to be rechecked. The author refers to such "pit-beneath-domepit" shafts as "hourglass domepits".

Description of Individual Domepits

The following domepits are located in James Cave and illustrate the principle of "hour-glass domepits" (fig. 2). Each example is separated from the next by considerable horizontal distance. These by no means exhaust the number of examples which could be selected, but well illustrate the principles involved.

Forty-Fathom Pit—This is the deepest known domepit in central Kentucky, with a total depth of nearly 240 feet (fig. 3). This domepit can be considered as a type example for "hourglass domepits". It is divided horizontally into two shafts. Each shaft is further divided vertically, so that the deep shaft is 120 feet deep (from passage intersection, not ceiling) with a subpit beneath it 85 feet deep. The opening into this subpit is in a narrow fissure where one wall meets the floor. Water exits from the shaft through a narrow fissure at the bottom. The shallower shaft is 90 feet deep with a subpit 30 feet deep reaching the same level as the first drop of the deeper shaft. A small bedding plane enlargement connects them at this level but is not passable. No shaft is known to occur beneath this 30 foot pit. Entrance to this subpit is gained by an 18 inch hole in the center of the floor. Other domepits occur nearby but they can be reached only by roundabout routes and apparently do not form a series with Forty-Fathom Pit which is located beneath a double sinkhole.

Piton Pit—Moe Pit Complex—The total number of domepits known to occur in this small area now stands at seven, of which all but three are omitted for clarity. They represent an excellent series, well demonstrating headward erosion and stratigraphically controlled floor levels. Piton Pit is an irregular domepit with a drop of 41 feet to the floor. The base connects with several other shafts up to 70 feet high. The floors of the domepits are siliceous limestone. During exploration a small hole, developed along a joint at the junction of the floor and one wall was discovered. This hole, originally 4 by 10 inches, was enlarged to permit entry into the shaft below. Beneath is Moe Pit, 106 feet deep (fig. 4). In this example there is a slight offset of the two domepits. A small domepit intersects a higher level passage 40 feet directly above but has no known connection (fig 2).

Double Domepit—This is also located in an area of highly developed vertical solution. The term "double" in this case is a misnomer. It is actually a triple domepit.

The uppermost domepit is about 40 feet high and intersects a horizontal passage. A small opening connects to a shaft 20 feet deep directly below, which can also be reached by a chute. At the base of this shaft is another impassable hole. Below this is another shaft with a depth of 40 feet intersecting a large passage near its base.

REFERENCES

The papers listed below cover the aspects of geology and speleology of the cavernous area of central Kentucky; some have not been cited in the text.

Barr, T. C., Jr. *in* Lawrence, Joe, Jr., and Brucker, R. W., 1955, The caves beyond: Funk and Wagnalls Co., New York, 283 p.

Livesay, A., 1955, Geology of the Mammoth Cave National Park area: Kentucky Geol. Survey, series IX, Spec, Pub. no. 2, 40 p.

Lobeck, A. K., 1928, The geology and physiography of the Mammoth Cave National Park: Kentucky Geol. Survey, series VI, pam. 21, 69 p.

McGrain, P. and Walker, F. H., 1954, Geology of the Mammoth Cave region, Barren, Edmonson and Hart Counties, Kentucky: Geological Society of Kentucky, a guide to the field trip, April 1954, 32 p. (available from Kentucky Geol. Survey, Lexington).

Pohl, E. R., 1955, Vertical shafts in limestone caves; National Speleological Society, Occasional Paper no. 2, 24 p.

Smith, P. M., 1957, Discovery in Flint Ridge, 1954-1957: National Speleological Society Bull. 19, p. 1-10.

Weller, J. M., 1927, Geology of Edmonson County, Kentucky: Kentucky Geological Survey, series VI, v. 28, 246 p.

Pseudokarst in The United States

WILLIAM R. HALLIDAY

Abstract — Features analogous to those characteristic of karstic areas are distributed widely in the western United States, but have received little study. The most obvious of these are found in basalt flows but they also occur in littoral zones, glaciers, and certain poorly consolidated sediments. These features must be considered in defining terms applied to geomorphic forms which occur in either karst or pseudokarst.

About 25 years ago, European geologists began to discuss features of non-solutional origin which are analogous to those of areas of karstic geomorphology. These they termed pseudokarst. As in so many new concepts, it is difficult to determine the exact origin of the term. William E. Davies (pers. comm.) reports that the Russian geologist, F. P. Savarenskij, published a paper in 1935 in which he referred to "suffosional karst". Hans Peter Kosack, noted German geomorphologist, believes that the term *pseudokarst* was first employed in print in an Italian publication in 1941 (Florida, 1941). However, as Dr. Kosack has pointed out (pers. comm.), the late karst geologist H. Cramer employed the term in an unpublished study of the karst of the British Isles which was prepared in 1936, and believes that the term was in use in Europe as early as 1930.

Until very recently, these phenomena have been overlooked by American geologists and speleologists. As mentioned in a preliminary report (Halliday, 1954), the only specific published mention of pseudokarst in America which I have been able to find is a single sentence in German to the effect that: "In northern California, Oregon and Idaho, there are widespread manifestations of pseudokarst in porous lava" (Kosack, 1952).

Areas showing pseudokarstic features are distributed quite widely throughout the Western United States, and local inhabitants and some speleologists have spontaneously applied karst nomenclature to them.

In the west, I have observed examples of pseudokarst in four major non-calcareous realms: basalt flows, glaciers, littoral cliffs and certain poorly consolidated deposits. In addition, William E. Davies (pers. comm.) reports its occurence also in the form of sinks and ponors in sands and silts of the Coastal Plain of Mississippi, Alabama and Florida; as sinks in a gravel mantle of the High Plateau of the Chuska Mountains of northwestern New Mexico; as sinks in the Ogallala formation of the High Plains of the Texas panhandle and adjacent states; as long, narrow, steep collapse features in the Navajo and adjacent formations of the Four Corners region; and "depressions from giant gas bubbles" in a California rhyolite flow. Palmer has described lapies-like features on basalt cliffs in Hawaii (Palmer, 1927), but these appear to be basically of solutional origin. Kosack (1952) mentions the occurrence of pseudokarst in tuff and granite, but with one possible exception described below, the writer has not observed its occurence in these rocks.

Pseudokarst reaches its greatest morphological development and speleological significance in basalt flows. In the western United States, Quaternary flows of pahoehoe lava contain numerous sizeable lava tubes in widely scattered locations (Halliday, 1959). These caves very greatly in size and pattern (fig. 1). They reach lengths of many thousand feet, and some possess both horizontal and vertical complexity due to intermingling of successive flows. Entrance to these tubes is usually gained through a sink formed through collapse of a portion of the tube (fig. 2).

In most of these youthful regions, few surface streams exist. Small creeks some-

Figure 1
Entrance to Arnold Ice Cave, a lava sinkhole.

Figure 2
Lava sink resulting from collapse of a segment of a tube.

Figure 3
Looking seaward from littoral cave at Ocean Beach, California. Part of sinkhole atop cliff is visible at upper right.

times flow on the surface of the lava, but soon disappear into a contraction fissure, often appearing in a canyon wall many miles away. Such fissures, which are analogous to ponors, may be enlarged by corrasion and perhaps by a certain degree of solution, but almost never assume cavernous proportions. Large streams rarely have any relation to lava tubes. Sometimes, small fissures in lava flows are so oriented that they conduct seasonal runoff, or small brooks, into a cave. Usually, this occurs through the ceiling, and leads to locally increased breakdown which may eventually develop into a collapse sink. In Lake Cave, Wash., two stream channels, beneath the flow, lateral to the tube, join just outside the tube and enter it through a large opening about 6 feet above the floor of the tube. These stream channels are dendritic and corrasional. They are beneath a lava flow and have been incised into the partially compacted soil onto which the lava flowed. Within the tube itself, no solutional or corrasional speleogens are present, and the streams in this and nearby caves have modified the tubes only by aggradation. Perhaps this is because of their extreme youth, and the vulnerability of lava features to rainfall and stream action. I have been able to find only one very short length of lava tube overlain by subsequent sedimentary deposits (Black Mesa Cave, New Mexico), and have come to the conclusion that the lava tubes of the more humid sections of the west (if not all of the west) are of very late Pleistocene or Recent origin. A preliminary radiocarbon age of about 2,000 years for carbonized roots exposed in the stream channels adjacent to the tube of Lake Cave has been obtained through the courtesy of Dr. Arthur Fairhall of the University of Washington.

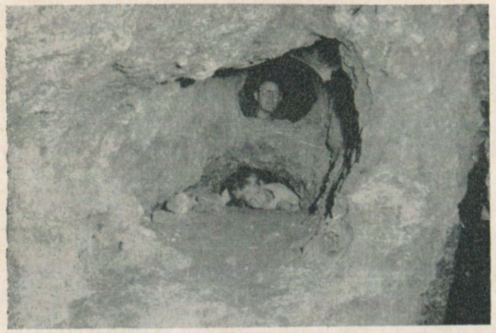

Figure 4
Largest tube in Clay Cave, California.

Figure 5
Mudflow Cave near Panoche Pass, California

In many basalt flows, the only collections of water are at the bottom of lava tubes, in collapse sinks with unfissured floors, or where the fissures are obliterated with stream debris. In the latter case, the pools are homologous to lokven, the sink pools of limestone terrains. Pools are not common in lava tubes, but are present in Malheur Cave, Oregon, Lake Cave, Washington, and in several caves in Craters of the Moon National Monument, Idaho.

Segmental collapse is a characteristic of lava tubes. Where collapse of adjoining tubes has caused coalescence of sinks, the situation is similar to uvala formation from coalescence of limestone sinks. Parenthetically, coalescence of sinks from multiple collapse along a single tube lacks the analogy as this results in trough formation, which is rare in limestone terrain. Lava tube sinks vary from tiny depressions in the center of a tube to giant collapse sinks a hundred feet wide and hundreds of feet long.

In many cases, lava sink formation is due to collapse of an overloaded, excessively thin roof, a feature often found at intervals in pahoehoe flow. Quite commonly, collapse occurs at junctions or bifurcations of passages or levels. While this phenomenon is one of the many features of lava tubes of which the origin is obscure, the situation is morphologically analogous to certain joint-controlled breakdown domes in limestone caverns. While other features, such as cupolas and fissures, may also predispose to collapse, they seem to be of lesser importance. Other sink-like openings in lava tubes, however, which show evidence of origin through explosion of gases within the tube, lack this analogy.

The lava beds north of Capulin Mountain, New Mexico, demonstrate an unusual example of pseudokarst. The flow is in a much later stage of erosion than most tube-containing pahoehoe flows. One large section is characterized by irregularity scalloped lava ridges 4 to 10 feet high. These low ridges enclose small, smooth, arcuate meadows, partially separated from one another by low barricades of disintegrating lava talus which disrupt what would otherwise be serpentine-shaped meadows.

By crawling through lava talus at the foot of these small ridges, a semilunar remnant of a lava tube can often be entered. Their smooth, glazed surface is in striking contrast to the rubble in which they are found. Black Jack Cave is entered in this way. It extends for about 300 feet along the length of one of the intervening ridges which is not much larger than the cave itself. This area consists of pseudokarst in its final stages. The low boundary ridges are analogous to *buttes temoines* or *hums*, the final remnant of the boundary ridges of coalesced limestone uvalas.

Glacier Pseudokarst

In mentioning glacier pseudokarst, it is not my purpose to present all of the analogies of glacial pseudokarst to karst. Cotton (1945, p. 291) has previously mentioned some of these analogies. Glaciers possess ponors in the form of crevasses and moulins, hypogean streams and other pseudokarstic features. Glacier sinks can be formed through collapse of glacier caves (Halliday, 1954) as well as through moulin development. Any definition of the term *sink* or *doline* must take this fact into consideration.

Littoral Pseudokarst

Another type of collapse sink is present at Mendocino, California (Goodman, 1960), and Ocean Beach, California. About 20 feet from the edge of the marine cliff at Ocean Beach there is a funnel-shaped sinkhole 25 feet in diameter on the flat, mantled surface between Sunset Cliffs Boulevard and the conglomerate cliff. It opens into the ceiling of a broad, spacious littoral cave about 30 feet below (fig. 3). Several small bays in this same area appear to have been formed by the collapse of the entire roof of such a sea cave. During and after heavy rains, rivulets disappear into tiny ponors atop this same cliff. This runoff undoubtedly enter joints widened by littoral speleogenetic processes.

Pseudokarst in Poorly Compacted Sediments

Reports of large caves encountered by drilling in sand or earth must be questioned in view of present knowledge. Certain other phenomena occuring in unconsolidated or poorly consolidated deposits, however, must be mentioned in a discussion of pseudokarst. In some of these, such as the so-called "soil caves" of Equador (Funkhowser, 1951), solution probably plays an important part, rendering them karstic rather than pseudokarstic. This may also be true in the case of Clay Cave, Napa Co., California which has developed largely through vadose solution and corrasion. The walls and ceiling of the lower part of its entrance room, however, contain small, partially interconnected tubes and pockets (fig. 4). Both the main entrance and a small "swallet" entrance are located in collapse sinks near the upper end of its course of several hundred feet. This cave is in the Sonoma volcanics, which consist of rhyolite and tuff. A somewhat similar situation, although apparently without speleogenesis, has been reported in the form of minor phenomena in diorite in North Carolina (LeGrand, 1952).

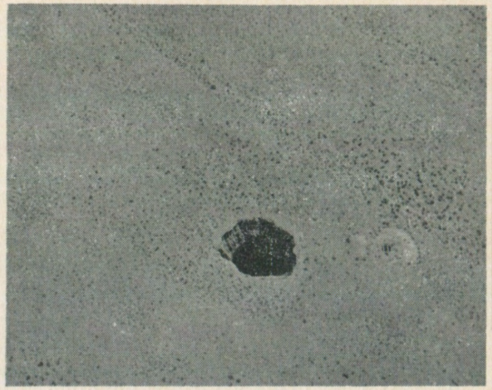

Figure 6
Mystery Hole, Utah. Aerial photo courtesy Delta (Utah) Chronicle.

Clearly pseudokarstic is the small-scale occurrence of ponors, caves and tubes in mudflows in the hills north of the eastern approach to Panoche Pass, California (fig. 5), and probably quite commonly elsewhere in the deserts of the Southwest. "Mystery Hole", Millard Co., Utah, may also be pseudokarstic in nature (fig. 6). Judging from aerial photographs and reports from the few persons who have visited this isolated spot, the Hole is a natural pit about 70 feet deep and nearly as wide, located in thick alluvium. It is said to end abruptly, and its slightly funneled mouth lacks any raised collar. Its origin is locally believed to be meteoritic, but a mining venture failed to reveal any metallic fragments. Like sinks in areas of essentially insoluble rocks, its origin can only be said to be undetermined at present, and may conceivably be due to the presence of deeply buried karst.

If the explanation by Malott (1938) of the "numerous small sinkholes (on) many of the slightly rounded and nearly level spur surfaces between steep-sided ravines" in Triassic shales in Petrified Forest National Park is correct, this occurrence also should be listed as pseudokarstic rather than karstic as suggested by that writer. However, it is conceivable that solution has been more important in their development than initially believed.

Summary

In summation, it can be said that pseudokarstic topography possesses morphological analogies to all stages of karst. In both the ponor-doline-uvala-hum cycle is demonstrable. On the other hand, almost none of the features of the two systems are truly homologous, and their relationships to speleogenesis are quite different.

Superficial pseudokarstic features are generally superimposed on the landscape and its features are largely superficial. Even lava tubes are usually very shallow features. In contrast, many features of karst are developed by solution at depth within the rocks. Karst develops in the absence of significant speleogenesis. While lava, glacier and littoral pseudokarst can develop in the absence of significant caves, these forms of pseudokarst are more intimately associated with speleogenesis since their most prominent forms are due to the collapse of pre-existing caves.

References Cited

Cotton, C. A., 1945, Geomorphology: Whitcomb and Tombs, Ltd., Christchurch, N.Z., 4th Ed.

Florida, G. B., 1941, Un particolare fenomeno pseudokarstico manifestato de un algune argile: Boll. della Soc. di Sci. Nat. ed Econ. di Palermo, v. 23.

Funkhowser, J. W., 1951, "Soil caves" in tropical Ecuador: Nat. Speleo. Soc. News, v. 9, no. 5, May, p.4.

Goodman, Lou, 1960, More on California sea caves: Calif. Caver 2nd ser, v. 3, no. 3, Sept., p. 18.

Halliday, William R., 1954, Pseudokarst: Nat. Speleo. Soc., Salt Lake Grotto, Tech. Note 25, Nov.

——— 1959, Adventure is underground: Harper and Bros., New York, p. 187.

Kosack, H. P., 1952, Die Verbreitung der Karst —und Pseudokarsterscheinungen uber die Erde: Petermans Geog. Mitt., 96 Jahr, 1st Quart., p. 16-22.

Kunsky, Josef, 1957, Types of pseudokarst phenomena in Czechoslovakia: Czechoslovensky Kras, vol. 10, no. 3, p. 111-125.

LeGrand, H. E., 1952, Solution depressions in diorite in North Carolina: Amer. Jour. Sci., v. 250, no. 8, p. 566-585.

Malott, C. A., 1938, Karst features in the badlands shale areas of Petrified Forest National Park, Arizona: Ind. Acad. Sci., Pr., v. 48, p. 114-115.

Palmer, Harold S., 1927, Lapies in Hawaiian basalts: Geog. Rev., v. 19, Oct., p. 627.

Western Speleological Survey
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SHORTER CONTRIBUTIONS

Caves in Northern Greenland *

WILLIAM E. DAVIES AND DANIEL B. KRINSLEY

Several unsuspected solution features in the limestone plateau of northeastern Greenland were discovered during the summer of 1960. The most interesting of these discoveries are several large solution caves.

The area of caves is along a south tributary of a large valley (fig. 1), provisionally named Grottedalen, about 15 miles due north of Centrum Sø (80°24′ N; 22°22′W on current American maps). Grottedalen trends southeastward from the central part of Kronprins Christian land and empties into Vandredalen which in turn connects with Hekla Sund via Saefaxi Elv. Grottedalen is about 3,000 feet wide, 1,500 to 2,000 feet deep near the caves, and is floored with morainal deposits. The valley walls are steep. The lower 500 feet are formed of glacial moraine and talus; the upper part is limetsone forming stepped, vertical cliffs along the face of the plateau, the summit of which is at an altitude of 2,100 to 2,400 feet (fig. 4). The Centrum limestone (Ordovician-Silurian) is the bedrock along most of Grottedalen. In the vicinity of the caves it dips gently westward, but 6 miles to the east it is folded and faulted. The Centrum limestone is gray to black, with beds of chert and dolomitic limestone intercalated. In the cavern zone it is massive and weathers dark brown. The Centrum is about 7,500 feet thick (Adams and Cowie, 1953).

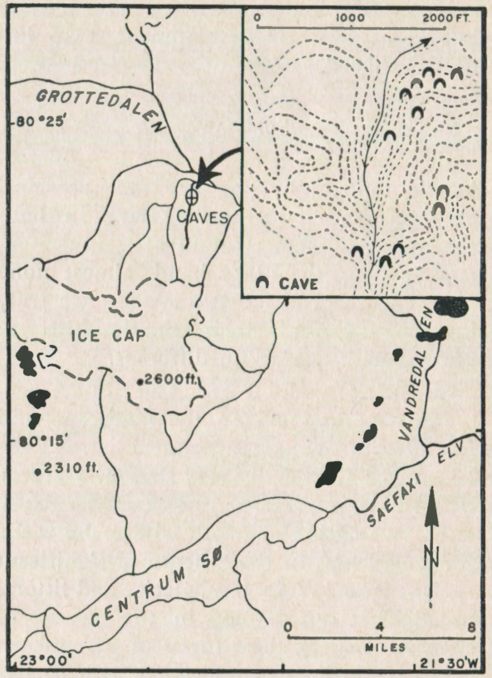

Figure 1
Map of area around Grottedalen showing location of caves. Solid black areas are lakes; dashed lines on inset are form lines.

The caves are along both sides of a small north-south valley tributary to Grottedalen. This valley extends 3,000 feet to the south. Near its mouth it is 200 to 500 feet wide and 1,500 feet deep; at its head it is a canyon about 100 feet wide and 300 feet deep. There are 11 caves along the east wall of the valley and one on the west wall (fig. 1). The caves are at 3 levels, 1,600-1,700 feet, 2,000-2,050 feet, and 2,200 feet altitudes. The passages are 15 to 40 feet in diameter and extend 30 to 200 feet from the valley wall. The largest cave is on the east side of the valley at the north end of the canyon (elevation, 2,000 feet). In plan it is U-shaped with 2 openings on the valley wall (fig. 2). The lower caves (1,600-1,700 feet elevation) are partly filled with glacial moraine. The higher caves contain no morainal deposits and thus the upper surface of the most recent ice advance down the valley appears to be below 2,000 feet. At their ends the caves are blocked by cave fill and ice crystals. The fill is well exposed in the cave on the west wall of the valley (fig. 3). This cave is at an elevation of 2,050 feet and contains a fill of orange yellow silt 7 feet thick. Near the base of the fill is a layer of red silt about half a foot thick. The fill is capped by a flowstone deposit 4 inches thick formed of coarsely crystalline calcite. On top of this are stubs of stalagmites about an inch in diameter and ½ to 1 inch high. The fill is frozen hard and both the fill and flowstone are covered by a coating of hoar frost and ice crystals up to 4 inches thick. The walls in the front part of the cave contain horizontal solution grooves; the floor is level and is formed of bedrock covered by stubs of stalagmites similar to those on the fill. No morainal deposits were seen in the cave. At the front of the cave is a small chimney 50 feet high.

Figure 2
Caves on southeast side of valley. The two entrances are connected by a passage 40 feet high and 40 feet wide.

Figure 3
Interior of cave on west side of valley showing fill and solution grooves.

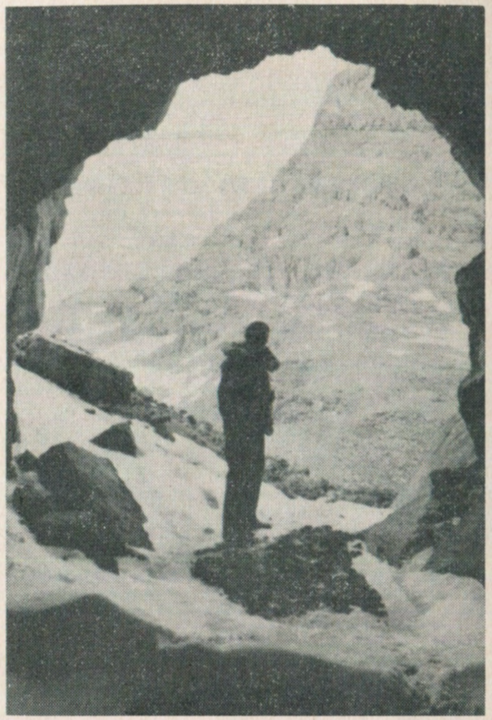

Figure 4
View northeast from cave on west side of valley.

At the time the caves were visited (June 29, 1960) the outside temperature ranged from 39° to 45° F. The temperature in the caves was 32° to 39°F.

These caves show that extensive limestone solution has occured in the north polar areas. The color and composition of the cave fill indicate that is was laid down under warmer climatic conditions, probably similar to those now existing in the Mammoth Cave area of Kentucky. The thick flowstone cap on the fill was probably deposited from ground water, a feature that is now absent because of the presence of permanently frozen ground. This, too, indicates that a milder climate existed during

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*Publication authorized by the Director, U. S. Geological Survey the deposition of the fill and its flowstone cap. The caves are older than the last ice advance down Grottedalen (probably Wisconsin) since the lower ones contain morainal material deposited during this advance. Because the caves above 1,700 feet contain no morainal material it is probable that the cliff face was ice-free during this advance.

The caves in Grottedalen are the only solution caves that have been explored in Greenland. Other solution caves are known to exist but have not been visited. Several caves open along the north side of Saefaxi Elv 2 or 3 miles west of Centrum Sø. A large solution cave is near the top of the valley wall on the southwest side of the east lake in Wulff Land (81°59′N; 47°55″ W) in northwest Greenland.

REFERENCE

Adams, P. J. and J. W. Cowie, 1953, A geological reconnaissance of the region around the inner part of Danmarks Fjord, Northeast Greenland: Meddelelser om Grønland, Bd. III, No. 7, pp. 12-13.

U. S. GEOLOGICAL SURVEY
WASHINGTON 25, D. C.

Use of Ethyl Mercaptan for Detection of Airflow Between Caves

ROBERT S. FETROW

It has long been suspected that Sinnit (38°31′08″N; 79°22′08″W, Circleville Quadrangle, West Virginia) and Thorn Mountain Caves (38°31′08″ N; 73°22′17″ W, same quadrangle) are connected. The former is located on the south side of Whitethorn Creek while the latter is located on a spur of Thorn Mountain, 800 feet west of Sinnit (Davies, 1958). Two reasons for suspecting that these two caves comprise a single system are: a) air flows into Thorn Mountain Cave and out of Sinnit Cave; and b) the two cave entrances are 800 feet apart, on opposite sides of the spur of Thorn Mountain.

An attempt to prove the existance of this suspected connection was made in September, 1959, by introducing an odorous gas into one entrance and trying to detect it somewhere in the other cave. For this purpose, my father, Clare Fetrow, supplied transportation to Franklin, W. Va. for Bill Jahn, Rodger Stewart, Paul Gerhard, Clare Fetrow, Jr. and me. We carried a thermos bottle containing ice (to condense vapors before opening the vial) and a glass vial of ethyl mercaptan (C_2H_5SH) in addition to our regular caving gear. Ethyl mercaptan is a very volatile compound with an extremely notable, nauseating odor. Butyl mercaptan ($C_2H_5(CH_2)_2SH$) is the skunk's claim to fame.

Having found no evidence of other cavers in either cave, Rodger Stewart and I went up to Thorn Mountain Cave and cooled the vial of E. mercaptan in the ice. In the meantime, Clare Fetrow, Jr., Bill Jahn and Paul Gerhard waited at the entrance to Sinnit. They were told nothing about the odor of the chemical being used in order to prevent imaginative detection.

At 11:00 A.M., I broke the vial of E. mercaptan and poured half of the contents on a rag; the remainder was poured into a bottle and sealed with wax. At this moment we fully realized the extreme effects of the chemical. We lowered the rag about seven feet into the cave entrance, then fixed a cable ladder in place. This hopeful gesture was planned to eliminate the need for retracing our steps through Sinnit should we succeed in demonstrating a passable connection.

After returning the remaining E. mercaptan to the car, Roger and I joined the rest of the party and proceeded into the cave. There was no noticeable odor in the "waterfall" passage or at the falls; then we went to the Big Room. There the odor was stronger in some places than others but with no noticeable pattern. About 23 minutes after lowering the rag the odor was detected at Sinnit Cave for 3 minutes, then reappeared 15 minutes later for 2 minutes.

When we returned to the car, we found that fumes of the E. mercaptan had somehow escaped from the bottle. The car was nearly unbearable. I was firmly requested to hold the bottle out the window on the drive back to Franklin.

Next morning, we returned to burn the rag and recover the ladder. We then went to Trout Cave (38°36′14″ N; 79°22′10″ W., Circleville Quad.)

At Trout, there is a small fissure which lies 200 feet west of the main entrance and 25 feet above the base of the cliff. This fissure becomes a narrow crawlway heading northeast for 50 feet, then east toward Trout Cave, too small to negotiate.

I put the remainder of the E. mercaptan into the entrance of this fissure. The odor was detected in the entrance room of Trout. The fumes came through the first passage on the left as you enter the cave, on the north side. This passage turns northeast for about 80 feet, then becomes too small for passage.

Ethyl mercaptan was decided upon for these experiments after considering radioactive dust, smoke and other expensive or difficult to obtain tracing compounds. We did not know where or how to obtain radioactive dust and we did not want to contaminate the cave permanently anyway. Smoke dissolves in water and it probably would have required many smoke bombs to be detected at any distance. We used ethyl mercaptan because it is highly volatile and fairly cheap.

References Cited

Davies, William E., 1958, The Caverns of West Virginia: W. Va. Geol. Surv., vol. XIX-A, p. 241, 249.

Some Challenges of Free Diving Prospecting and Collecting

STANLEY J. OLSEN

I recall resting in the scanty midday shade of a cut bank in the middle of the Big Horn Basin in Wyoming a few years ago. It was a particularly stifling July day and it set me to wondering why I had not taken up the study of fresh water trout rather than that of vertebrate paleontology. It would at least have kept me in the immediate vicinity of shade-covered, clear, cool streams without need of the half-canteen of lukewarm water at my side, the only liquid within many miles.

Since that time development of self-contained diving apparatus has made it possible to prospect for and collect vertebrate fossils in the clear water dreamworld of yesterday's musings. It is, of course, apparent that one must go to those areas where the water covers the vertebrate remains and this eliminates a good many places. However, Florida is one of the unique states that meets these requirements. Here semitropic forests are cut and dotted with many clear deep streams and large spring-heads, the depths of which are strewn with the remains of vertebrate fossils. Many of the more accessible spots have been cleared of these treasures but many more await the adventurous, hardy skindiver and underwater speleologist.

This vast accumulation of bones in the sinkhole ponds, springs and rivers is readily understood when the structure of these natural traps is taken into consideration. The average spring, sinkhole or river in Florida has no shallow area beginning at the bank and gradually increasing in depth. Instead, these watery collecting spots exhibit vertically or nearly vertical sides, and in the case of sinkholes or springs, are merely wells or shafts which penetrate the Eocene limestone in a more or less vertical direction. Many of these shafts are from 80 to 100 feet in depth and not a few angle off to unplumbed distances, shutting out daylight after the first change in direction in these water filled caves. Many of the rivers, although crystal clear, are merely bankless channels which wind through swampy woodland and can be reached only by water travel after putting in at one of the few landings along their courses.

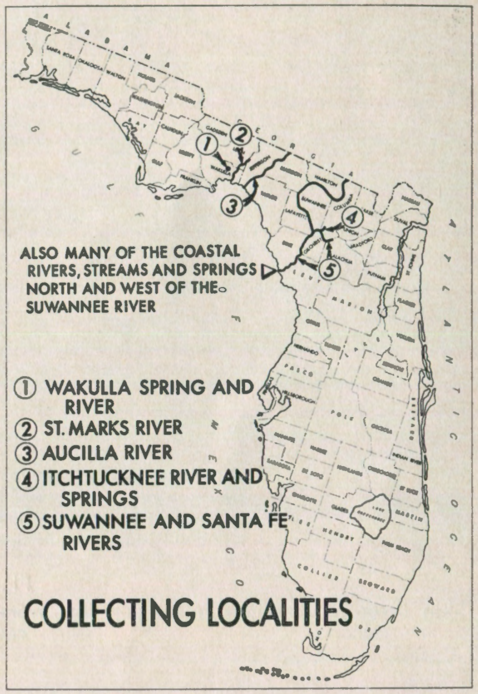

Figure 1
Outline map of Florida showing locations of some of the better underwater collecting areas.

In a few instances, these natural snares have yielded entire skeletons of animals which were previously known from surface finds only as isolated scraps or incomplete skeletons. Among these rarer finds are those of the Pleistocene camel and tapir.

Figure 2
Skin diver recovering a mastodon jaw from the depths of one of Florida's larger spring caverns.

In the past, too much emphasis has been placed on the larger, more spectacular finds of mastodon or mammoth while the smaller mammals (rodents and carnivores) have usually been overlooked or passed by. It is far more important to search for and recover these smaller forms whose remains may aid in filling in the missing gaps of our understanding of the ecology of Pleistocene and sub-recent times, rather than to bring up a 70-pound limb bone of an already well-known mastodon, which can add little to our knowledge.

Pleistocene man and the sabertooth tiger are known in Florida from fragmentary bones only. This may be due to the ability of both these animals to extricate themselves from a dry sinkhole or fissure after a fall (discounting broken limbs or injuries incurred in such a fall), which would not be the case if these same animals were to fall into a partially filled sinkhole and drown. Not only would the skeletons lie undisturbed from serious damage by predators and weathering in such a crypt, but flood-borne silts would soon cover their remains until such a time as some fortunate free diver might discover them. It would not be foolhardy to suggest that some of the most important gaps in our knowledge of Pleistocene man and his contemporaries may be bridged by students using self-contained diving equipment.

In the field of history several papers have appeared recently which hint at finds still to be uncovered. Very little actual material has been recovered in this country which can be traced back to the Spanish explorers of the seventeenth and eighteenth centuries. The following quotation from Diego Pena's journal of 1716, as translated by Dr. Mark Boyd (1949), will suffice as an example; "The 2nd day I left the said spot and went to the Rio DeAsile (Aucilla River). I found it so swollen that the beasts were obliged to swim the flood. It was very laborious to open a road here. In this river my horse was drowned, and I narrowly escaped, because in leading it into the river by the halter, the current caught us and forced us down on a tree, toppled by the weather, which had fallen in midstream in the branches of which I could not avoid entanglement." This country today is nearly as wild as it was in Pena's time and the banks of the rivers are just as inaccessible. The Aucilla stream bed, for a good distance, is of limestone which is pockmarked with eroded holes, some of which are many feet in diameter and depth. These depressions are natural catch-basins for anything which is carried by the current toward the Gulf of Mexico. I have taken a complete pre-Columbian pot from one of these pits and have found many partial vessels or sherds. It is entirely possible, and not improbable, that in one of these holes, a horse bit, stirrup, or piece of chain mail of Spanish manufacture may turn up. Many similar rivers in Florida were crossed by the Spaniards and with the same hazards as encountered by Diego Pena.

It is essential to stress that in recent years several deaths have been recorded among unfortunate prospectors who had grown careless after repeated dives in the same areas. One casualty was due to faulty home-made equipment but none were due to faulty professional gear. Instead, they were due to the careless use of good equipment or disregard for accepted safety practices. That this last statement is not an idle assumption is illustrated by the record of the six-man diving team from the Florida State University which made over 100 dives in Wakulla Springs to depths beyond the 200-foot level without a minor mishap (Oslen, 1958). Survival under water is dependent on "going by the book." Narrow escapes are generally indicative of poor planning.

REFERENCES CITED

Boyd, M. F., 1949, Diego Pena's expedition to Apalachee and Apalachicola in 1716: Fla., Historical Quarterly, v. 28, no. 1, p. 1-27.

Olsen, S. J., 1958, The Wakulla Cave: Nat. Hist. Mag., v. 67, no. 7, Aug.-Sept., p. 396-403.

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ORIGIN OF LIMESTONE CAVES

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Errata

Bulletin, vol. 21, pt. 2 Takahasi and Kawano, Speleology in Japan

Fig. 2, p. 47: read Terayama for Teratama

Fig. 4, p. 49: read 100, 200, 300 m for 10, 20, 30 m in scale.

Page 53, right column, line 30: read *Megaceras* for *Megaloceras*.