CAVE FORMATION BY ROCK DISINTEGRATION

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The processes generally cited in theories of cavern formation are corrasion† and solution. Neither of these processes adequately explains the presence of cave fill in many caves. A new concept in cavern formation involves a possible disintegration process due to release of former high pressure on sediments that were being elevated from depths in which they were formed. This process can account for the relationship of cavern plans to joint systems, the generally horizontal development of caves, and other characteristics besides accounting for the formation of cave fill in place. This avoids the problem of explaining how cave fill can be transported into caves from outside. Application of the theory of disintegration to problems of origin of dome pits in caves is discussed, and the possibility of this explanation of the formation of caves in non-carbonate rocks is suggested.

Some Theories of the Formation of Caves

Much discussion about the origin of caves involves the notion of a zone of ground water saturation, called the water table. Some writers, such as Davis[1] and Bretz[2] believed caves were originally formed by solution below the water table. These conditions are described as "phreatic".

Davis and Bretz suggested that some caves have been formed in conditions that were phreatic, and that there has since been a change to the present vadose state in which these caves are found today. The term "vadose" refers to "water that is in the zone of aeration, and therefore on its way down from the land surface to the zone of saturation".

According to these writers, the water table in many cavernous regions has dropped from a former higher level. However this idea has not proved acceptable to some speleologists. Where caves occur in rugged mountain regions, the idea of a former high water table is difficult to entertain. Caves in mountainous areas occur in the Rocky Mountains, and also in various parts of Europe. How could the former water tables in these mountainous rocks have remained high long enough for solution to erode out the cavities in them?

Early speleologists attributed the major role in cavern formation to corrasional activity. Streams in caverns can often be found enlarging their channels, and it was supposed that cave systems had been formed by this process. Yet it is difficult to see how corrasion would be possible if an initial passage were not already present in the rock. The question remains, how could the cavity have been initiated?

The history of speleology involves a conflict between these two kinds of explanation of cavern formation. Each view appears deficient in certain respects. The shortcomings of each view were stated by Davis:

> No account of caverns that I have read explains, in case the author favors solutional excavation, how it can proceed when galleries grow so large that only thin, discontinuous films of water trickle down their walls, films from which evaporation should discourage solution and provoke deposition instead; or in case the author favors corrasional excavation, how that process can produce galleries of the network pattern which prevails in large caverns.[3]

Davis recognized that dripstones have begun to form in caves only after their excavation was completed. The present conditions, he pointed out, were not those in which cave systems originally formed. The history of many caverns involved two cycles of events, first a phreatic cycle, in which caverns were formed by solution, and secondly a vadose cycle, following a drop in the water table. In this second cycle the dripstones have begun to form.

The Presence of Fill in Caves

Caves rarely enlarge very much in vadose conditions, Davis believed. To his idea of two cycles in cavern formation, Bretz introduced the concept of an epoch of deposition in the history of many caves. He suggested that after the initial development of caverns a period of clay filling of the passages and chambers occurred, before the lowering of the water table. He showed that many caves are completely filled up with cave-fill, usually consisting of red clay, and that this fill is now being eroded by streams. Caverns with little fill often contain fragmentary remnants of formerly extensive fills, in the form of deposits high on the walls and in pockets and branching passages.[4]

The presence of cave fills seems anomalous to present ideas about the formation of caves. It is sometimes mentioned in the literature that the fills do not usually come from the detrius left by the process of excavation of caves, but must have been somehow brought into the caverns from outside. The fill could not have been present in caverns while they were being excavated, because solution and corrasion could not occur below a protecting layer of cave-fill.

No problem in speleology is quite so ticklish as the question of the origin of cave-fill. Present theories about cavern formation attempt to account for an empty space in a rock, by processes of solution and corrasion, and the means by which such extensive fills could have been deposited are not readily apparent from theories of cave formation.

Discussing the origin of fill in Breathing Cave, Va., George H. Deike III wrote:

> I haven't satisfied myself that I understand how some of the fill material was deposited. The fills consist of lenses of silt and sand, with a great deal of coarse conglomerate in many places. The deposits look like free surface stream channel deposits . . .[5]

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†"Corrasion" means erosion by the abrasive action of running water containing sand, pebbles, and other debris. This is in contrast to "corrosion" which means a chemical action such as formation of a rust, or the "eating away" of a substance as nitric acid corrodes copper.

It is particularly difficult to imagine how coarse gravels, containing pebbles and boulders up to cobble size, could have been brought into the caves. These could not have been transported except by rapid currents. The gravel occurs throughout many caverns, even within blocked passages where former rapid stream currents are difficult to conceive. Postulating a period of phreatic submergence does not resolve this difficulty. Commenting on this problem, Sweeting wrote: "In some caves cobble deposits are found in passages where it is difficult under present conditions to see both where they came from and how they got there."[6]

Jennings believed that the extent of former cave fills may have been exaggerated by many speleologists. He wrote:

> As well as active channel deposits, abandoned stream deposits are frequently found in caves, e.g. as terraces. Some caves may be practically filled with gravel like Baldocks Cave, Mole Creek, Tasmania, where the fill is probably of Pleistocene glacifluvial origin. However, too frequently inference of thick or complete fill has been made from small patches of deposit in high positions in cave walls.[7]

Cave fills may consist of clay, sand, or gravel, and also of conglomerates or cemented gravels. These materials are all considered to have been formed by deposition in streams flowing through the caves after original excavation of the cavities.

Some of the cave fill exhibits the pattern of cross stratification. Davies showed that the fill material in Salts Cave, Dismal Valley, Kentucky is cross stratified sand and gravel. He supposed that the fill in caves is deposited after the development of the cavity. He wrote:

> Cave fills of clastic materials are deposited towards the end and after the integration and mature development of cavern passages. The clastic material with included clay and fine silt suggests deposition in alternately submerged and open passages, a condition to be expected as the time of stability draws to a close.[8]

Davies also noted that many caves contained fills that were packed tightly to their ceilings. In a discussion following the previously quoted article, he stated: "I would like to point out that in the Appalachian caves most clastic fill is topped either by clay or fine silt. This material is generally packed tightly to the ceiling and reflects deposition in pools in blocked passages . . ."[9]

It seems difficult to conceive how fill could penetrate water filled caves, and pack them so completely in stratified layers. It seems that there would have to be some space near the top of such a deposit for water to exit after depositing the sediment.

Depositional Origin Seems Improbable

A depositional origin of cave-fill appears particularly improbable when considering the presence of large pebbles and cobbles. The gravel could hardly have been transported upwards, to levels higher than the cave exit, by streams flowing into the cave. Yet it is consistently claimed that cave-fill has been brought into the caves from outside.

A proper idea of the extent of cave-fills is often difficult to obtain, since the floors of caves, when consisting of fill, conceal the true dimensions of the chambers. Since the theories of cave formation do not easily account for the presence of all this material, many speleologists tend to underestimate its extent.

There is a tendency, in scientific observations, to notice only the evidence that seems to fit in well with what accepted suppositions and patterns of interpretation of natural phenomena would lead one to expect. Facts that do not fit into current patterns of interpretation often escape close scrutiny. For this reason, it seems, the extent of many cave fills may not have been fully recognized and reported.

An exception to defects of this nature in the writings of speleologists is the work of J. H. Bretz. Bretz comprehended the extent of former and present cave fills more completely than many speleologists either before or since publication of his reports.

Bretz was able to show, because of a number of mining excavations in the fills inside some cave formations in the Galena dolomite of Illinois, Iowa, and Minnesota, the profiles of caves that were almost completely filled up. One passage was excavated, in the course of mining operations, to a depth of 40 feet without any sign of rock bottom. The fill material was described as "soft dolomitic sand". The excavation was conducted in part of Crystal Lake Cave near Dubuque, Iowa.

In this cave, fill was quite extensive, and occupied most of the volume of the passages, and some passages completely. These filled passages and chambers were sometimes discovered only as a result of excavation. In his description of the caves, Bretz stated:

> The ceilings are low throughout the system, and head room for visitors in the opened part of the cave is secured by excavating trenches for footpaths, as much as three feet deep, in the fill. This excavation has revealed the tops or ceilings of several north south and quartering routes that are entirely filled. How the bottoms of the different members are related would be very interesting to know.[10]

All of the passages, Bretz reported, contained fill, and the cave does not seem to have ever contained a vadose stream. The head room in passages off the visitor's route Bretz attributed entirely to compaction of the cave-fill.[11]

Where streams occur in these filled caverns, they are in the process of eroding channels in the unconsolidated fill material. Some caves are completely filled above the point of entrance of a stream, and also beyond the point of its exit. Bretz described an example of this in Meramec Cave in Missouri:

> The stream in Meramec Cave has left terraces on the sides of its valley in the fill, the tops reaching almost to the ceiling. Farther downstream, the terraces are so wide and so close under the ceiling that a narrow trench in the clay is the only open space. By a good inference, Meramec is still completely clay-filled beyond the place of escape of the stream.[12]

Cave investigators sometimes find themselves crawling through passages with low ceilings, that are extensive in the horizontal plane. The floors of these passages may be damp and dirty, but few would suspect they may be crawling along on top of a thick layer of unconsolidated material, that mostly fills up a chamber of much larger proportions than the constricted passage through which they are trying to inch their way.

In some cases the floors in caverns containing fill are sloped parallel to the ceiling. Bretz cited an example in Craigshead Cavern, Tennessee, and interpreted its significance. The fill, he suggested, had been compacted, and formerly filled the cavern entirely. He wrote:

> Craigshead Cavern, Tennessee, has some chambers with dip-determined ceilings in which the clay fill beneath, untouched by the numerous slump pits, is sloped accordingly. There is a clearance of only a very few feet. This can record only compaction of a fill once tight against the ceiling slope.[13]

These reports would lead one to wonder why the fill in caverns so frequently fills up the passages and chambers entirely. A cave is usually throught of as an empty or rather air-filled space within a rock. But it is natural to think of caves in this way, for those who explore caverns are occupied with problems of getting through them, and squeezing through narrow holes and cracks. Yet inquirers into the question of the mode of origin of the caverns may find it advantageous to picture caves from a different point of view.

A Different Viewpoint: Caves as Filled Cavities

Instead of thinking of a cavern as an air filled space in rocks, why not consider them as filled cavities? The caves, according to Bretz, were often filled up with unconsolidated material prior to the initiation of present conditions. The erosional activities of streams, and the deposition of calcite on dripstones are presently occurring in vadose conditions. The dripstones began to form only after the formation of the caves, and this process is one of deposition rather than one of excavation.

Considering the problem of the formation of filled cavities, rather than trying to explain how an empty space might be formed within a rock, would lead one to consider the possibility that a change in the consolidated rock at depth may have resulted in large chambers and passages being formed, by an alteration of part of the host formation. Portions of the rock changing from the *consolidated* to the *unconsolidated* condition would result in filled caverns within the rock.

Formation by Rock Disintegration

A process of rock disintegration that may have an important application in the theory of formation of caves is a possible effect of the rapid release of former high pressure on rocks of the continents. This process has been outlined in another article by the writer.[14]

Investigations by the writer into the nature of the pattern of cross stratification in rocks and unconsolidated material indicate this pattern may have resulted from a process of shattering rather than by deposition of sediments.

According to this alternate explanation the shattering was a result of the release of former high pressure on sediments containing diffused water, which became occluded within the rock as pressure decreased, causing its disintegration. The formerly homogeneous rock was thus converted into clay and sand, and gravel. Development of concretions in the rock before its disintegration, that remained intact during shattering of the matrix around them, accounts for the formation of cobbles and pebbles. These would have been formed in the positions they now occupy, and need not have been transported into the caves from outside.

The pebbles and cobbles found within caves may vary in composition, which has led speleologists to the conclusion they have been brought into caves from other regions. This explanation, of a concretionary origin of these stones, would explain their varying composition. Concretions develop in rocks by the accumulation of small amounts of impurities being precipitated from a diffusion equilibrium in the solid as pressure is released. An explanation of the formation of pebbles and boulders occurring in caves in the places they occupy today solves a most difficult problem in speleology.

Such a disintegration process may have operated at some time in the past, but is nowhere acting at the present time. Caves are only as old as the rocks in which they occur, so the disintegration must have followed the deposition of limestones and other sedimentary rocks where caves occur.

Former high pressures may have existed during the formation of many of the sedimentary rocks of the earth's surface. Some rocks, such as dolomite, seem to be deep-water sediments, and require a former high pressure for the combination of the molecules that comprise the rock. The dolomite molecule is apparently unstable in solution under ordinary conditions.

Lithification of the sediments may have also resulted from the release of pressure, as diffused cementing material crystallized and caused the rocks to harden. The release of pressure on these rocks would have accompanied their elevation from the depths to their present height.

Departure from Uniformitarianism

Clearly these events involve a departure from the usual uniformitarian approach to problems of the past history of the earth, and methods of accounting for its features. But the postulate that former high pressure has existed is not more difficult to entertain than that caves have been through a cycle of phreatic conditions. For the maintenance of prolonged phreatic conditions in high mountains, continents would need to have been submerged.

In both cases, that is, in the postulates that former high pressure has existed and that rocks containing caves have passed through a phreatic cycle, former conditions are supposed to have been different from those existing at the present time. The difference is in the kind of former conditions that must be imagined.

The possibility of a former process of disintegration adds another type of geologic activity to the number of possible causes to be considered in accounting for the formation of caves. This process could be an aid in accounting for the formation of filled passages and chambers, that may have afterwards become excavated by streams or other means. The formation of dripstones in empty chambers would follow.

One feature of the dripstone formations tending to confirm that their growth has begun only after the cave's formation is the fact that they rest on top of the layers of cave fill. They are not found penetrating into the fill, as if they existed prior to the deposition of this material. Nor are fossil dripstone fragments fround within the cave-fill.

This would lead one to conclude that conditions in the past have, in fact, been quite different than those previling at the present time. This observation would apply to all areas where caves occur.

Studies of the present patterns of streams in caverns also show that former conditions, in which the caves were actually formed, were not the same as those existing today. Bretz, in the abstract of his 1942 article, wrote:

> Most living cave streams are misfits, engaged in altering ground plans and chamber cross sections, better to suit their needs, and doing this by familiar procedures of surface streams. The chambers and ground plans undergoing alteration have been inherited from earlier, different, and now vanished conditions to which the caves were adjusted. The alterations are superimposed readjustments to the new conditions.[15]

Former conditions of sedimentary precipitation of the limestones in which caves occur were indeed quite different from those existing anywhere on the earth at the present time. Limestones of great extent are found around the world. Having been deposited beneath the sea, they are now high above sea level. It is supposed that their uplift was accompanied by a release of pressure, providing an environment for the disintegration to occur.

At the time of uplift, recently precipitated rocks may have been subjected to some tectonic disturbance, that resulted in the formation of joints and fractures within the rock. Many of the limestone rocks of the Appalachians are folded and contorted. The movements accompanying elevation of rocks could initiate patterns of joints and fissures that are significant in determining patterns of cave systems.

Relationship of Caves and Joints

Speleologists have long recognized that most caves follow the patterns of joints in the rock; that they are "joint controlled". The feature was pointed out by Davies: "Plans of most caves in folded rock reflect local rock structures. The passages are joint controlled; faults exert very little influence and a passage rarely follows a fault for any great distance."[16]

The same feature was noted by Bretz in his description of the caves in the Galena dolomite. Bretz was impressed by the relationship of caves to joints, and showed that their patterns could not have resulted from stream erosion. Bretz wrote: "The cave systems commonly are reticulated patterns, faithful delineations of the joint system of the formation, with no integration towards a trellised subterranean drainage pattern."[17]

In harmony with conditions described for a disintegration process of cavern formation, a disturbance initiating the patterns of joints and fractures in rocks would likely have resulted from their uplift. Probably this uplift was accompanied by release of pressure as waters flowed back off the continents and into the oceans. In such conditions each joint or fracture would become a low pressure zone. The rock surrounding joints would be under high pressure, and a sudden fracture in rock under stress would result in release of pressure in the immediate vicinity of the crack.

These conditions would be favorable for a process of disintegration due to precipitation of water diffused in the rock at the higher pressure. When pressure in the vicinity of a crack decreased, the water in the rock would have been expelled too quickly. Expansion probably began before the water diffused out; hence, the rock shattered.

Shattering of the rock in the vicinity of joints and cracks could very well have caused an enlargement of cavities following the pattern of joints. These became passages and chambers filled up with unconsolidated material: sand, clay and gravel.

The release of pressure due to uplift of sediments from depths sufficient to cause diffusion of water within rocks is thus sufficient cause to explain filled cavities in rocks, and account for their relationship with the patterns of jointing.

As the disintegration of rock occurred in the vicinity of a crack, the walls of the crack were converted into unconsolidated material: sand, clay and gravel. Possibly some expansion accompanied this disintegration. The increased volume of the disintegration product would build up pressure in chambers and passages, and eventually cause the disintegration to cease once equilibrium was attained.

Pressure built up by expansion of the disintegration product may have caused some cracks to widen. This would be rather like cracks in rock being propagated by expansion of freezing water in them.

The process of widening of cracks in this manner may have aided in spreading the disintegration, once begun. Cracks may have been extended because of pressure of disintegrated matter in them. If there was lateral movement, the material would settle to the bottom, and subsequent compaction of the unconsolidated material would leave cavities above the layers of fill.

Evidence from Cave Profiles

If disintegration occurred around a vertical crack for example, the pressure of the expanding material inside would tend to push the walls further apart, and extend the crack higher and deeper. The material inside would eventually settle down to the bottom of the cavity, leaving a passage along the top. The caves would thus be mostly filled passages with an empty space at the top. A study of the profiles of caves and their fills shows this disintegration approach may have some merit in accounting for their origin.

Bretz was able to give partial profiles of a number of caves in the Galena Formation, and in one case he included a profile of the cave in its filled part as well as the empty chamber. This was in Crystal Lake Cave, and the profile is given in Figure 1. Bretz reported:

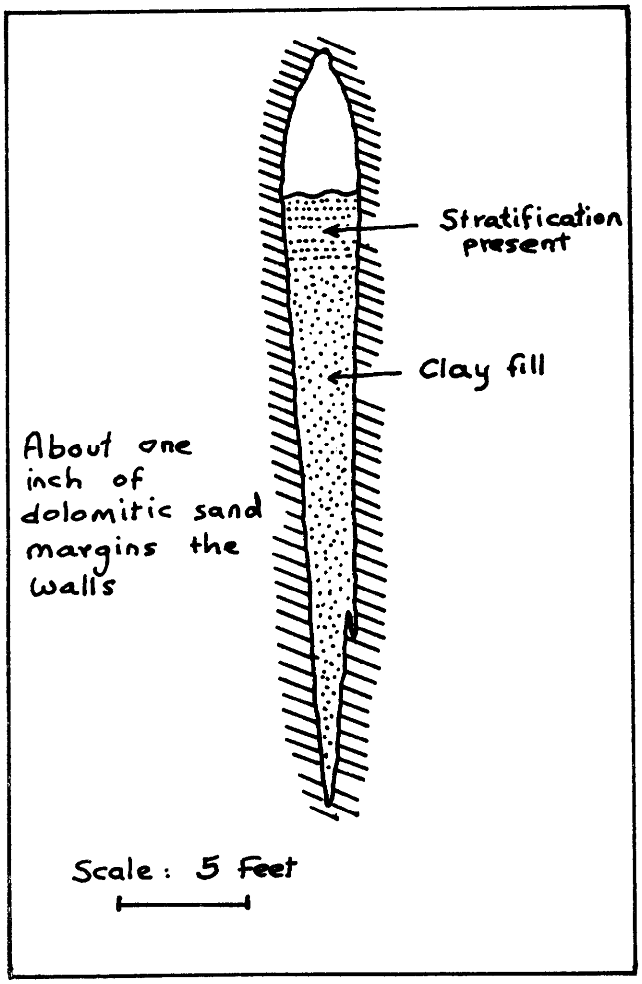

Figure 1. This is a profile of part of the Crystal Lake Cave, a few miles south of Dubuque, Iowa on Highway 52, in which it has been possible to determine the extent of the filled part, as well as the empty chamber. This is adapted from Bretz's work, reference 10, by permission.

> (The section shown) is a special case, a cross section in which it was possible to show extent and proportions of the filled part as well as of the empty chamber. A shaft had been dug here 60 years ago, in search of ore, and was entered in this study by block and tackle and bosun's chair. The gradual downward narrowing to become a slot at the bottom is significant of conditions of origin of the chamber or crevice. With data from some of the mine workings, as reported in the literature, it indicated that the cave floors known in the region are far from stream-determined floors.[18]

Bretz believed that Crystal Lake Cave had never contained a vadose stream.[19] The disintegration explanation given for the formation of filled caverns can account for an empty chamber above a much more extensive filled cave, without any need for either stream action or phreatic solution. The theory also accounts for the joint determined plan of cave systems. It may also explain a trend towards horizontal development of cavern levels, as pressure levels during disintegration would tend to be horizontal.

Caves in some regions trend towards a horizontal development at various levels. This is true even where the bedding of the limestone is tilted to almost vertical. Solution, it might seem, would favor penetration of the rock by water along bedding planes, but development of caves in areas of folded rock does not follow this pattern. White reported:

> Several caves in nearly vertical limestone have been examined. In none of these had solution extended any distance along the bedding in a vertical direction, even though a favorable bed and good partings existed in that direction. Instead the caves are limited to a nearly horizontal zone . . .
>
> These data show that caves tend to maintain their horizontal pattern in spite of structure and lithology.[20]

White gave a list of 77 caves in Pennsylvania, and only three of these had any vertical relief. Others had sloping passages but for the most part were confined to one plane.[21]

The fact that caves cut across inclined bedding and remain generally horizontal would have a possible explanation in the theory of a disintegration process in cavern formation, resulting from the release of pressure during uplift of sedimentary rocks from the depths. The disintegration would occur at a certain level favorable to the shattering process. This level would sink lower with continued decrease in pressure.

The shattering also depends on the rate of release of pressure. If the rate of release of pressure were slow, no shattering would be likely because the water diffused in the rock would have time to escape. The presence of joint systems would also seem necessary for shattering to occur deep within the rock.

Disintegration in the region of a joint system would be almost simultaneous at the same level, and would tend to be in a horizontal plane. Successive cave systems may occur at lower levels, that formed during continued release of pressure. A plane of disintegration would descend as pressure decreased.

Gravel Terraces: Inside, Outside of Caves

An interesting correspondence between the levels of caves and the levels of gravel terraces in surface valleys in the region was noted by Davies.[22] This correspondence may be interpreted in the disintegration theory, that the gravels were formed by disintegration of bedrock during a release of former high pressure in the region. The correspondence between levels of gravel terraces inside and outside caves may be due to the simultaneous formation of the gravels at the same pressure level.

This phenomenon would be difficult to account for by depositional processes and the principle of uniformitarianism. Both gravels in caves and in surface valleys may occur at multiple levels, and these levels are spaced similarly in cave systems and in surface valleys. Davies wrote:

> Distinct multiple-level passages occur in four of 277 caves in folded rocks in West Virginia. With no significant exceptions these passages maintain uniform slope and vertical spacing in the caves. In checking the elevations of the passages against sur-

> face features there is a close tie between the vertical spacing of river terraces and the vertical spacing of cavern passages within a region.[23]

The network pattern of cave systems, their correspondence with joint systems, and their generally horizontal levels are all well suited to the theory of a disintegration origin, due to release of former high pressure on sedimentary rocks during uplift, and the subsequent excavation of passages and chambers by streams.

Other features of caverns mentioned by Davies may also be easily explained in a disintegration theory of origin. Among caves in folded limestone in the Appalachian region, Davies wrote, major caves occur along the valleys, and cavern passages decrease in size and become more numerous in portions of the cave away from the major surface valleys.[24]

In the disintegration process, pressure levels underground would be affected by the presence of valleys. These levels would be depressed in the vicinity of a valley, as pressure decreased in the region. The plane of disintegration would follow the surface of equal pressure, and so caves may be expected to slope upwards from their exits in the sides of valleys.

Also the widening of joints by expansion of material disintegrating around them would be most probable where the joint ran parallel to a valley. Rocks enclosing joints parallel to valleys would yield more easily than those enclosing joints normal to surface valleys. Expansion of the disintegration product in joints away from the sides of the valleys would be more limited because of confining pressures, and so cavern passages would tend to be smaller away from valleys.

Hollows, Potholes, and Other Holes in Caves

The theory of a disintegration process causing the formation of filled caverns accounts for many features of caves that have been previously attributed to the effects of solution processes. The presence of hollows in the roofs of caves, and high in their walls has been cited as evidence that caves have passed through an epoch of phreatic conditions, when water penetrated all the joints of the rock and filled the caverns completely. The hollows and pockets in the roofs of caves, to have been formed by solution, would require a former phreatic state.

Describing Crystal Lake Cave, in Iowa, Bretz wrote:

> Almost wholly, the roofs are original and preserve the solutional patterns. Pockets, (somewhat resembling irregular potholes upside down) are common, some of them so complexly and irregularly developed that they penetrate into one another and produce arches and bridges. Solution to make these roof pockets occurred only because the cave was full of water at all times, not as a vadose stream may in flood time fill it to the roof. Were the latter the case, air would tend to occupy such pockets, and there could be little solution.[25]

The roofs of some caves contain large cylindrical structures like potholes, called dome-pits. In some cases they contain horizontal flutings on the walls. Caves with cylindrical structures of the shape of potholes were described by Bailey in central Tennessee. These potholes, up to 15 feet in diameter and 40 feet high, had walls that were "gracefully carved by the water".[26]

Although the presence of potholes in caves is generally taken as evidence of effects of corrasion by water, facts presented by the writer in another article discount this assumption.[27] Potholes may actually have a quite different origin. For the cylindrical structures to have been formed in caverns by corrasion would require stream currents in restricted passages, with velocities that are incompatible with known causes and present conditions.

Potholes in caves of southwest England were studied by Ford.[28] Potholes and remnants of potholes in the walls of caves above the level of present stream activity led him to conclude that the streams that formed the potholes were larger than the streams there today.

In the opinion of the writer the larger streams postulated to have existed in caves during the formation of the potholes would be unlikely because the size of caverns in former times must have been smaller than at present. Also the horizontal levels of caves containing potholes could not have given rise to currents of sufficient strength to erode deep potholes in rocks. Some speleologists have supposed that greater stream velocities existed in caves in the past, causing pothole erosion, due to hydraulic pressure from an undetermined source.

Some remarkable examples of potholes and dome-pits in caverns were described by Davis.[29] In Mammoth Cave, Kentucky, dome-pits occur up to 50 feet wide, and from 10 to 200 feet high. These are vertical, cylindrical cavities with arched tops and deep bottoms, with fluted walls resembling potholes. They frequently occur along joints or small faults. Like potholes, they tend to broaden at the bottom. Davis wrote, describing Shelby's Dome in Mammoth Cave: "Shelby's Dome rises sheer 145 feet over the floor of Bottomless Pit, the walls being in most places absolutely vertical."[30]

In some places the dome-pits connect two or more levels. Davis thought the possibility of their formation by solutional processes unlikely. He called the problem of their excavation "a puzzling matter".

Gaping Gill, a famous dome-pit in England, is a vertical shaft 360 feet high. It is narrow, elliptical in shape and contains flutings on its walls. These shafts are also referred to as "pitches" in England.

Another deep vertical shaft known as Proventina occurs in the Pindus Mountains in N.W. Greece. Altitude of the shaft is 1,840 m., and dimensions are 200 m. deep, 25 m. × 33 m. wide. This was described by Eyre as "the cleanest shaft I have ever seen."[31]

These vertical cylindrical cavities in caves are difficult to explain either by corrasion or solutional processes, but the possibility of a disintegration process related to release of former high pressure may aid speleologists in accounting for the specific features. A process of disintegration within rocks, beginning at a crack at depth and proceeding during a continuing release of pressure, may proceed vertically downwards and upwards from the crack at the same time.

Each succeeding surface exposed by disintegration of the preceding surface would have become subject to shattering; and the surface of disintegration would have moved upwards and downwards into rocks at higher pressures containing diffused water that precipitated out near the exposed surfaces, continuing the disintegration in a vertical shaft maintaining the same diameter. Flutings on the walls could be records of successive levels of the surface of disintegration.

Initially these shafts would have contained fill but this evidently has been eroded away or compacted since the time of formation. It would seem from the theory of disintegration that vertical shafts would be more likely to form in the floor of caves than in the ceilings, but must in most cases be buried in the fill.

Caves in Non-Carbonate Rocks

The concept of a process of disintegration within rocks during a former elevation of the continents from depths of burial under water would account for the formation of caves in carbonate and non-carbonate rocks equally well. Caverns have recently been reported in rocks that are not normally regarded as soluble, in Lower Precambrian sandstones and quartzites of the Venezuelan Guiana Shield.[32]

These caverns occur in mountainous regions. They are not just small openings but huge cave systems. A cave in Cerro Autana is 395 meters long with labyrinthine passages. The entrances are located in a cliff 1,000 m. high and are 150 m. below the summit of the mountain.

Shafts up to 400 m. in diameter and 370 m. deep occur in the Sarisariñami mountains. Other caves occur on Guanay mountain, and a huge one was reported near Roraima mountain. A cave system with over 1,000 m. of passages is known to exist in the Maria Luisa mountain.

Cavern enlargement in Frost Creek Cave, California was two thirds greater in non-carbonate schists than in the limestone section.[33] These facts and their interpretation in the terms of usual corrasional and solution processes would appear quite mysterious. However the concept of a disintegration process, as significant in cave formation, may help clear up these problems in speleology.

Implications of Disintegration Theory

The disintegration process outlined in this article requires a former deep burial of the rocks in which caves occur, now found high above sea level. The rate of elevation of these rocks would need to be rapid for the effects described.

The possibility of such events in the past, which are not apparent anywhere on earth at the present time, should be determined from studies of the Earth's features. The writer is of the opinion that past causes should be considered that are at least sufficient to explain the effects. This is not to deny the reality of causes such as corrasion and solution, that are in operation at the present time. The process of disintegration should be considered along with these causes as possible explanations for the features of caves.

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