CAVE BIRTH

Most caves of moderate to large size are dissolved out by carbonic acid, carbon dioxide dissolved in water. Calcite is only mildly soluble in pure water but it dissolves easily in such weak acid. About half of the carbon dioxide in soils is produced by rotting organic matter and about a third is produced by the breathing of roots. Erosion of a limestone surface in parts of temperate U.S. and Canada occurs at a rough average of two inches (10-100mm) of rock every thousand years. It is only in carbonates and the even more soluble rocksalt and gypsum that subsurface voids can enlarge fast enough to become cave size before surface erosion destroys them. In contrast, although lava tubes generally have only a hardened crust over them of at most a few dozen feet, they can form within hours and so can persist for tens to hundreds of thousands of years before being destroyed by erosion.

Many joints initially may be too small to allow cave formation in
a reasonable amount of time. Pressure solution and hydraulic pumping from temperature or pressure changes and/or earth tides may help enlarge them.
There is an abrupt slowing of the dissolution while water is still far from saturated with calcite. This allows a long distance enlargement of joints before the water becomes saturated with calcite. Otherwise most caves would not form (Palmer 1991).

Once the joint becomes greater than about one centimeter, turbulent flow begins and rapidly enlarges the joint. This is because the speed of flow between the center and side of the channel (slowed by erosion with walls) becomes so great that eddies forms. The wider joints capture more water which widens the joints even further. Such piracy results in one or a few large passages. Water flow through the smaller passages is diverted into the large passages and the small passages stop growing. The first passages exhibiting turbulent flow conditions will enlarge by about a factor of ten times faster than the others, evolving the cave into its mature state (Dreybrodt, 1987).

An increase in joint density over time is due to release of pressure as a result of surface erosion or to conduits continuing to extend laterally (Ford, 1988, p. 37) may facilitated this process. Water flow in densely jointed carbonates may be more diffuse and therefore unable to dissolve out large caves. The flow may be too spread out, resulting in rapid saturation with respect to calcite. Closer jointing may also result in weaker rock and collapse of caves before they grow very large. Caves may be more horizontal because the high permeability quickly allows a fairly flat water table, the area where most of the solution will occur. Thick, pure limestone tend to have few joints compared to limestones or marbles, with thinner layers or impurities.

Most carbonate caves take from 1,000 to 10,000 years to reach a size accessible to people. Most caves begin where fissures are between about 20 microns to 1 millimeter in width (Ford, 1988). A great increase in solution rate from turbulence and other factors begins when a crack reaches about 5 millimeters in diameter. Experiments suggests that without tensional widening this may take about 4,000 years. The shape of the conduit need not change with further enlargement (Ford, 1988, p. 27). A rougher conduit and higher hydraulic gradients will initiate turbulent flow sooner, closer to the 5 millimeter limit.

The first passages exhibiting turbulent flow conditions will enlarge about ten times faster than the others (Dreybrodt, 1987). The wider fractures capture more water which widens the joints even further. Such piracy results in one or a few large passages. It may take a thousand more years for the cracks to reach a diameter of one centimeter and another 4,000 years to reach six foot high passages (Dreybrodt, 1987). Field studies support this total of 10,000 years (Mylroie and Carew, 1987) for a number of caves. Most carbonate conduits require from 10,000 to 100,000 to reach traversable sizes. As piracy continues and discharge increases, cave wall retreat increases up to about .01 to .1 centimeters/year (A. Palmer 1991). After this, increases in discharge rates does not increase solution substantially. This helps explain why cave passages in Oregon Caves tend not to increase downstream as discharge increases.

Compared to carbonate rock, higher solubility and faster dissolution rates in gypsum may shorten the minimum time required for cave formation. Turbulence increases solution even faster than in calcite, resulting in a greater control by joint flow piracy and consequently fewer maze caves.

Caves form along ground-water paths of greatest water flow and acidity.
A compromise between the fastest and easiest routes often is between the steepest water gradient and the direction in which the various cracks, faults, bedding planes or other structural weaknesses point. Similarly, the cross section of cave passages reflect a compromise between hydrodynamic forces that tend to shape them into smooth, streamlined forms and structural rock weakness that allow waterflow easier access. High water velocities and thick, uniform carbonate bedrock promote the hydraulic forms while slow flow and bedrock variations result in complicated cross-sections controlled by joints, bedding, etc.

The lower the waterflow rate through the initial bedrock, the more likely the resulting cave will be more irregular as water finds various structural weaknesses to move through instead of taking the most direct route. The more non-horizontal the structural weakenesses, the more likely the cave will be non-horizontal. That is why many passages do not come straight down along slopes; they zig and zag along faults, go up and down along phreatic loops or sideways along bedding planes. Fairly horizontal beds of less permeable material may locally control cave levels until the water can find a faster way down, resulting in a staircase when seen in vertical profile.

In calcite layers with only a small number of cracks or other interconnected pore spaces, horizontal water table caves do not usually develop. Instead, the water may be forced downward due to blockage at higher levels. Steep dip of can impede water flow so that phreatic loops are created, especially where faults or joints guide water to great depth (Ford, 1988).

As most caves mature, developed more enlarged cracks, increased permeability, and partly drain, more horizontal water surfaces and cave passages may develop. Oxidation of organic matter by bacteria near the top of the water saturated zone probably released carbon dioxide that acidifed water at that level (Wood, 1985), especially during back flooding. Cracks tend to decrease in width with depth and so there is more and faster flowing water at the top of the water saturated zone. A convection system may operate in which water heavy with calcium ions sinks and is replaced at water surface/bedrock interfaces with more aggressive water. But at a time when many upper passages with their associated dome pits were forming above the water table, deeper passages probably were forming underwater.

Marbles in the West often are bounded by metamorphics that in some places are pyrite rich. Such contacts may release sulfuric acid, oxidize organics from oxygen-poor waters, change flow rates, or cause mixed corrosion solution from the mixing of waters with different amounts of carbonic acid, all of which can increase solution and cave development. In one study, 18% (10% by lenght) of all caves are found at contacts between soluble and insoluble rocks (Palmer 1991). Solubility of calcite in mixing zones of seawater and freshwater can be increased 50% by the addition of non-calcium ions such as sodium, potassium and chloride (Ford & Williams 1989). Mixed corrosion commonly occurs where different saturated diffuse dicharge waters meet, as in the intersection of bedding planes and vertical fractures. The waters may both be saturated with calcite but if they have different amounts of carbon dioxide then renewed solution can form network and spongework caves. A lesser increase in solution can occur when the waters have the same partial pressures of carbon dioxide but have different temperatures (Boegli 1985).

The most important solution effect, though, for most caves, is acidity. When water flows on or in non-carbonate rocks, the water rarely becomes saturated with respect to calcite. Consequently, when it contacts calcite-rich rock, solution occurs at the boundary. About 90% of caves in one study were epigenic, where water from overlying or immediately adjacent recharge surfaces to springs in nearby valleys (Palmer). Epigenic caves essentially form from the top down.

In contrast are most ramiform caves (with sequential outward branches) and some spongwork and network caves. These hypogenic caves usually are unrelated to surface topography and commonly form from the bottom up due to the upward movement of carbon dioxide from volcanism or redox reactions or hydrogen sulfide into a mixing zone where oxygenation produces sulfuric acid, rapid solution and gypsum deposition. Less aggressive solution around ramiform rooms can produce spongwork passages. Mixed corrosion and a drop in temperature from rising waters can also cause solution although only under the most favorable conditions in the latter case (Palmer 1991).

Since epigenic caves form relatively close to the surface, most may last only a few millions years. A few may survive subsidence and infillings through one or several erosion cycles, as may be the case with a Grand Canyon cave with Triassic animal tracks. Hypogenic caves are more likely to survive longer as they can form very deep and so can escape destruction by surface erosion for a longer period of time.

Mazes are more likely to develop when there are several water inputs, where sediments may block up the faster water flow routes and/or where the hydraulic gradient is low and the subsequent water flow is slow. Slow flow is more likely to create mixed corrosion as two waters saturated with calcite but at different partial pressures of dissolved carbon dioxide meet at intersections of different routes of structural weakeness. The waters mix and caused renewed solution.

However, densely jointed carbonates when under high hydraulic heads (water pressure) from either flooding or artesian conditions can develop into maze caves (Ford & Williams 1989), especially where the flow paths are short (Palmer 1991). Complex branching networks form when there is a high hydraulic head and a short flow path (small block of limestone or marble) as in the case of Oregon Caves. Diffusion of water downward through a sandstone aquifer may create single story maze caves while upward movement of water discharge into a sandstone aquifer may produce multi-story mazes (Ford & Williams 1989).

Protocaves that get most of their water from sinkholes develop branching patterns that join downstream as higher-order passages. These branchwork caves comprise 57% of all caves in one study (Palmer 1991).

Time and the volume of water and soluble bedrock largely controls how big caves become. The size of individual cave passages also depends on how fast is the base level lowering. Water volume is set by annual precipitation and the drainage basin size and direction. A north-facing slope with little plant life reduces evaporation by both sun and plants. Such slopes tend to be steeper due to the buildup of large particles (such as from frost shattering) and lessened amounts of chemical weathering that produces muds that can easily be transported away. They keep snow longer, allowing it to seep into caves instead of running off as surface streams. Steep slopes also increase the speed and solution of water flowing through caves although they may also shunt water off the soluble rocks before all of it can sink in.

STRUCTURE: Structural weaknesses are most likely to be used if they are in the direction of the steepest hydraulic gradient. Joints and bedding planes likely are the most common rock weaknessess used by water forming cave passages. Anastomotic mazes can form entire caves along a single bedding plane but they more commonly are part of branchwork caves that have undergone flooding with aggressive waters. Next in importance are faults because of their often great lateral continuity. One study showed that of all cave passages surveyed, 57% were guided by favorable beds or bedding-plane partings, 42% by prominent fractures and only 1% by intergranualr pores, the latter only significant in reef limestones and poorly hardened grainstones (Palmer 1991). Speleogenesis of these rocks with floodwaters can result in spongework, a cave that looks like swiss cheese.

The tops of anticlines are most likely to have open joints due to a stretching forces and these joint thus provide avenues for water. The troughs of synclines have more closed joints due to compression but such areas can concentrate water flow and thus initiate cave development. High angle normal faults result from stretching and tension and so can guide cave development unless they have been filled with secondary calcite or insoluble residues.

Non carbonates like shale can act as a waterproof seal that concentrates water flow and solution of calcite along the contacts.

ROCK TYPES

The type of carbonate affects the rate of solution and the location of caves.
Dense microcrystaline limestones readily dissolve while beds of sandstone, siltstone, mudstone or coarsely crystalline limestones do not (Kastning, 1991). The more dense carbonates dissolve more easily than the less porous ones, presumably because water limestones with interconnected micropores becomes rapidly saturated whereas more dense limestones with cracks more readily

evolve into caves because the water can travel long distances before it becomes saturated or because it can travel along adjacent porous beds.

CAVE TYPES

Most caves in map view are branchwork caves. They look like a branching river in three dimensions. They tend to form from discreet points of input, as from sinkholes.

Network caves can form in a variety of ways, from joints nearly perpendicular to each other, to diffuse discharge from sandstone, to hypogenic upwellings.
Diffuse discharge or flooding can be superimposed over hypogenic upwellings to form networks. Network caves lack the individual recharge sources of branchwork caves (Palmer 1991).

Maze caves can form from ascending waters, either from phreatic loops or from rising thermal waters. Multiple levels can be created because different rock layers have different joint orientations separated by blocking layers of chert or clay (Ford 1989)

Late stage flooding superimposes features over all types of caves. Aggressive waters forced into side passages not parallel to the main water flow can enlarge them. Standing floodwaters can produce bevels (large notches on walls), bedding-plane anastomoses and flood-water injection features that can quickly evolve into bypass conduits (Palmer 1991).

Caves with great extent in profile view are more likely to be hypogenic and/or vadose in origin. Drawdown vadose caves are those guided by an early network of conduits and tend to be the first type of vadose cave to appear. In deeply dipping rock, the vadose portion may run down the dip of the rock while the phreatic part may be a combination of downdip and along fractures, resulting in phreatic loops. Invasion vadose caves tend to be steeper than the drawdown type. They may form from new streams invading karstic rock (as in glacial drainage disruptions or the retreat of a caprock) or where the initial permeabilty if already high, as from fracture due to rapid uplift (Dereck & Williams 1989).

SPELEOGENS

Pendants, scallops, and potholes mostly occur in the lower sections of caves where stream flooding scours out these features. Scallops are cusp-shaped depressions dissolved out by turbulent streams. Potholes form on the floor from the grinding of pebbles swirled by the stream. Pendants are sharp pointed rocks hanging down from the ceiling or walls. Sharp pointed ones tend to form in areas of rapid erosion, such as from very acidic or turbulent water. The stream cuts down into its floor so fast that even sharp points are left high and dry before they can be eroded away.

Large crystals had room to grow in some of the cracks in the ceiling and so did not dissolve as quickly as the smaller crystals of the surrounding marble. They now stand out as palettes, raised lines of calcite reliefed out by the condensation of carbon dioxide-rich water vapor. Intersecting palettes are called boxwork.

Floodwaters can stagnate for several weeks. It can dissolved the walls at the water's surface, where much of the decomposing organic matter floats, decays, and adds acid. Water heavy with dissolved calcium may have sunk only to be replaced with water capable of dissolving more calcium along the water surface/cave wall interface.

In slow flow situtations, density currents develop in which water rises to the top of the cave passage and dissolves calcite, forming a flat roof even in areas of steeply dipping strata and then become so heavy with dissolved calcium that the water sinks along the side of the passage producing cave walls that slant or dip towards the center of the passage (more solution and indentation near the top of the passage because solution can still take place there)

Paleocaves and paleokarst occur when a new cycle of erosion or deposition begins that is different than the conditions that formed the cave. Ocean transgression may flood the caves and fill them with sands. New material may be deposited on top of the caves. Even when filled with breccia, the former caves may be sites for increased water flow and concentration of various metals such as uranium and barite and minerals such as silica.

ACID DEW

Atmospheric corrosion is the process by which warm, moist air rising in a cave condenses on colder surfaces and, by absorbing carbon dioxide, dissolves ceilings, walls, and cave formations. The convection is driven by a geothermal gradient between the top and bottom of a cave. The process in most caves is minor; the maximum solution often may be measured in inches on the side of certain formations. Condensation water on ceilings become organized into thick and thin layers due to surface tension. The thicker ribbons develop turbulent flow and dissolve out parallel rills. Increased flow and slope angles increase the spacing of the rills. Condensation water can still occur in the highest parts of caves in summer but large entrances when present flush out substantial carbon dioxide and so prevent most or all atmospheric corrosion.

Atmospheric corrosion could also be applied to glacier caves. The main mechanisms for their enlargement is sublimation and melting due to airflow. Remelting from hot air is also a form of atmospheric ocrrosion in recently formed lava tubes.

MECHANICAL EROSION

Eventually surface erosion breaches a cave and slowly turns it into a grotto.

In some Canadian and U.S. caves, some of flowstone mounds show missing plates of calcite facing towards the nearest entrance to the surface. These may record Ice Age frost wedging, a time when January temperatures may have been more than enough to freeze the entire cave. Only formations near cave entrances show ice damage as only those areas thawed in summer and refroze in winter. Cave of the Winds in Colorado records muds with imprints of ice crystals. Summers 25,000 years ago were comparatively warm (and winters much colder) because the earth's axis was more tilted. There often has been very little deposition in the last ten thousand years so this frost damage often is not covered over with new flowstone.

PLEISTOCENE

Many North American caves have undergone reflooding. Silts and gravels shaped by frost heaving or a rising ocean level from meltwater raised the base level of surface streams. Insoluble residues, breakdown and glacial debris also blocked cave or spring outlets. Less commonly, as perhaps with the Black Hills caves, volcanic ash falls also blocked outlets. The resulting floods enlarged side passages and etched bevels, horizontal notches on cave walls.

SEDIMENTS

Most sediments in caves result from the insoluble residues of the solution process or clastics from glaciation, etc. Some iron and manganese oxide sediments may be from precipitation from biological action and oxidation. Rarely, some sediment may be injected into overylying paleo-cavities from underlying strata (Hose & Esch 1991). Large amounts of silt in the sediments of many northern caves suggest that glacial grinding or periglacial activity such as permafrost processes and loess may have contributed sediments during the Pleistocene.

The plugging of former sinks by glacial debris can lead to a late state vadose invasion phase in a mostly phreatic cave, especially if a eroding caprock allows surface streams to become karstified. This most open happens in mountains areas of rapid uplift where vertical fractures are relatively open (Ford & Williams 1989:269).

Where the floor and lower walls of a passage are shielded by sediment, bedrock solution is concentrated upward in a process known as paragenesis. As the passage grows, more sediment is deposited, so the flow velocity is kept roughly at the threshold for sediment transport.

DATING

Minerals can record time as well as temperature. Unstable uranium atoms are "overweight" if you will and release particles at constant rates. This changes the uranium into another element called thorium. Since uranium is soluble in the water, whereas thorium is not, calcite crystallized from water at first contains uranium but no thorium. As time passes, uranium decays to thorium. The thorium to uranium ratio thus increases over time at a constant rate and can be dated. Unlike most calcite formed on the earth's surface, calcite in caves tends to be very dense and waterproof. Therefore, compared to surface calcite, cave calcite is much less likely to have uranium leach out and thus give a wrong calculation for the age of the calcite.

UPLIFT

Recent or ongoing mountain uplift can rejuvenate the streams and remove most of a cave's silt and gravel. Stream erosion then enlarge caves a little more.
Caves in Alaska display mussels high on their ceiling and suggest that uplift has moved them out of reach of the ocean.

DECORATION

When surface erosion breached a cave, carbon dioxide gas escapes to the surface and decoration begins. As each water drop entered a cave, it loses carbon dioxide and deposits crystals of calcite in dripstone and flowstone, limestone cements can look like melted wax. Lesser water flow, aided by evaporation, formed knobby cave "popcorn" and twisted, worm-like helictites and vermiculations.

Since the amount of carbon dioxide in most caves with large connections to the surface is much less than that found in soil water, the dripping water loses carbon dioxide to the cave air. This usually reduces the carbonic acid enough so that calcite is deposited.

The rate, seasonality, and location of precipitation can cause either solution or deposition of calcite in a cave. Large amounts of rainfall or snowmelt may build up enough of a hydraulic head to move water through the overlying carbonate bedrock so quickly that the carbonic acid doesn't have time to be neutralized or equilibrate with the carbonates. Consequently, when the water reaches the cave it may continue to dissolve carbonates. Alternately, very slow water flow may develop air gaps that move more carbon dioxide into the water. Especially if this water mostly moves through non-carbonates it will be very aggressive when it reaches a cave and could continue to dissolve carbonates.

Moonmilk is a textural term for a very fine, white cave material that absorbs a lot of water. Moonmilk is soft, plastic, and pasty when wet, but hard, crumbly and powdery when dry. Wet moonmilk looks and feels like white cream cheese when rubbed between the fingers; dry moonmilk resembles talcum or chalk powder. Moonmilk is from 40 to 70% water, making it very plastic and slippery.

Caves with higher temperatures, with dolomite wallrock and/or high evaporation commonly have hydromagnesite (Mg5(OH)2(CO3)4.4H2O) or aragonite moonmilk. Less commonly huntite, nesquehonite, or dolomite moonmilk is present. When the magnesium to calcium ratio approaches 4 to one, crystal growth of calcite is poisoned entirely and aragonite precipitates in its place. The amount of water entering the cave, growth kinetics, the ratio of carbon dioxide to carbonate ions and the total carbonate availability may also in part govern crystal form.

Inorganic aragonite precipitation commences after fluid magnesium to calcium ratios exceed values of 1.5 (Gonzalez, 1988, p. 98). At ratios of 2.5 and higher, aragonite becomes the dominant phase. As degassing of carbon dioxide decreases in importance and as evaporative concentration of Mg increases the Mg/Ca ratio in the water, aragonite becomes the dominant phase because carbonate ion concentrations are not sufficient to precipitate high-Mg calcite (Gonzalez, 1988, p. 99). The presence of strontium may enhance aragonite precipitation by strontianite acting as seed crystals. Corrosion and clay surfaces may also enhance aragonite formation (Craig et al 1984). The lack of aragonite in many northern caves suggests that there has never been high rates of evaporation or that any aragonite formed during drier periods has converted to calcite during a wet period such as exists today in many places.

Soft, wet muds of more than 90% microscopic calcite have been called Mondmilch (Fischer, 1988) while carbonate muds with less than 90% calcite have been callled moonmilk. Mondmilch probably forms by rapid crystal growth, likely aided by evaporation and organic activity. Most western caves with near-freezing temperatures have Mondmilch but no or little moonmilk.

Organic action probably plays a role in the deposition of some Mondmilch. The origin for the names Mondmilch and moonmilk comes from its association with the moon, both being silvery, mysterious, and associated with dim areas. Peasants in Europe used its mysterious properties for centuries to heal infected cuts in livestock. Some believed that magical gnomes put Mondmilch in caves for people to use. Much Mondmilch sampled does contain actinomycetes, the main producers of antibiotics that humans use. Mondmilch often contains other bacteria such as Macromonas bipunctata. This microflora probably assists in breaking down the minerals in the wall rock and adding them to the Mondmilch. Long diagonal grains of Mondmilch are aligned with the crystal structure and appear to form along bacterial filaments. Scavenging of organic acids by certain organisms could cause calcite to precipitate as Mondmilch.

Evaporation and intermediate rates of seepage probably aid moonmilk formation as the largest concentrations of Mondmilch often are found in relatively dry areas that have fairly high air flow and intermediate seepage rates. The absence of much mondmilch under flowstone, etc. suggest most mondmilch has recently formed due to higher evaporation rates as a result of entrance enlargement. Rapid evaporation causes rapid crystallization, resulting in very small crystals. Organic coatings may then prevent the smaller crystals from dissolving and larger crystals from growing larger, a recrystallization process that normally happens in dripstone and flowstone. Some of the drier Mondmilch in some caves apparently has recrystallized into a hard rock but the crystals are still microscopic.

Siliceous moonmilk may form in part from evaporation around shafts that intersect lateral passages (M. Palmer 1986).

Iron and manganese oxide speleothems and stains also may form from the bacterial use of associated organic acids (Peck 1986). These include the manganese oxides of todorikite, birnessite as speleothems and sediments and psilomelane and birnessite as stains. Iron oxides, especially goethite, may be composed of slender, curved rods likely from iron-precipitating sheath bacteriam such as *Leptothrix.* The sulfur isotopes of some mirabolite suggest bacteria is also involved (Yonge & Krouse 1988).

Colors in formations, such as browns, reds, oranges and yellows, may come from or humic substances such as fulvic and humic acids and humin. The heavier humic substances (fulvic and humic acids) decrease and iron iron and lower molecular weight humic substances increase the further south one goes in North America, resulting in differences in colors (White 1984). Although pure calcite can be transparent, trapped air bubbles and crystal surfaces reflect light and give formations a milky look.

DECORATION RATES

The most rapid growth in the world may have been a soda straw in Jewel Cave in Augusta. It grew over an inch a year and then stopped growing. Data gathered from many caves reveal that the rate of growth is variable, but it is never much over 2 millimeters per year and may average only a little more than a tenth of a millimeter a year.

The world's record length for a soda straw that has been precisely measured is in Kartchner Caverns in southern Arizona. It is 21 feet and two inches long. Another long one is in Strong's Cave in Australia. It is probably around 22 feet long (6.8 meters) (Hart and Surridge, 1974). The theoretical limit is 26 feet, after which a soda straw would fall from its own weight (Hart and Surridge, 1974). Since it may have grown fairly fast between 1960 and 1974, the one in Strong Cave may have already fallen.

If water stays on a stalactite a few hours, most of the calcite will come out of the water. But if the water stays only a few seconds, most of the water containing dissolved calcium will continue to fall to the floor of the cave. As it hits the floor, turbulence increases carbon dioxide loss and calcite is deposited. A stalagmite is any conical deposit formed by dripping water. Wide stalagmites indicate fast flow rates and are common in many caves. Stalagmites with their tops flattened have droplets falling from a great height, resulting in splattering and/or solution.

DECORATION LOCATION

Cave formations grow more rapidly with an entrance nearby to flush out carbon dioxide and evaporate water. Then, carbon dioxide in cave water can seep out into the cave air. This reduces the carbonic acid and so calcite crystals drop out of solution. Because calcite is relatively soft for a mineral, touching these formations can easily damage them. Glistening drops of water on walls facing into the cave suggest that acid dew has dissolved limestone, another reason why few formations exist in a cave's first room. Ice wedging also destroys cave formations next to an entrance.

Notice how most of the flowstone can cover one side of a passage in a mountain cave. That is the direction in which water moving down the mountain has been intercepted by a passage that lies parallel to the surface slope. The next passage may have much less flowstone because it is at right angles to the slope and therefore cannot capture as much water.

Winter airflow from the outside evaporates water leaves behind calcite on formations facing entrances. The reverse also occurs. Warm air rises up from the cave's bottom, condenses water on the higher, colder formations, and thus dissolves the calcite, leaving various layers exposed, like onion skins.

HUMAN IMPACTS

What happens on the surface affects the caves beneath. The amount of carbon dioxide in the air has increased worldwide by at least 30% in the last 100 years, probably largely due to human use of timber and fossil fuels. Over half of the wood cut in the U.S. and Canada is burned or used in ways that quickly put carbon dioxide into the air. And it takes several centuries for newly planted trees to restore the balance -- if they are not cut down.

Since carbon dioxide dissolved in water forms a weak acid, the increase of carbon dioxide could dissolve formations. Such solution may be increased by human-caused drought and increased water intake by shrubs spared through fire suppression. Both create air pockets, allowing for increased carbonic acid through absorption of carbon dioxide before water enters a cave.