Geological Information

Solution Caves

Solution caves are formed by the removal of bedrock by circulating groundwater and by underground streams. The water transports the bulk of the rock material right out of the cave in solution. Most rocks, even the highly soluble ones, contain a certain residuum of insoluble material which must be transported mechanically by the water. Most solution caves are in limestone. Less frequently they occur in dolomite or gypsum. Small caves form in massive salt deposits. The only requirement is that the bedrock be soluble. Most caves in Pennsylvania occur in limestone and it is the limestone caves that achieve the largest sizes and contain the most interesting and attractive mineral deposits.

Karst Topography

The term Karst describes a landscape of characteristic landforms and subsurface features produced primarily as a result of solution of the underlying bedrock. The solution process is accompanied by other processes, particularly slumping of soil and bedrock materials, transport of insoluble debris through subterranean routes, and some mechanical wasting of slopes. Karst features form on many types of rocks if soluble components are present. Karsts on limestone are most commonly described, although extensive karsts occur on gypsum, salt, chalk, clastic rocks with soluble cements, and indeed any rock on which the solution process can act.

Cave Rooms

One common feature shown on most cave maps is the cave "room". Cave rooms are a very diverse class about which relatively little can be said. The usual "room" is a place in which the cave widens or heightens above the average passage width through which the explorers have been traveling. Among the many diverse origins for room may be listed:

1. Intersections of several passages
2. Places where breakdown has fallen while groundwater was actively circulating. This stopping process leads to some very large dome-shaped rooms.
3. "Rooms" consisting of a fragment of a large conduit reached through a cave system consisting of much smaller conduits.
4. "Rooms" formed by vertical solution and intersected by smaller horizontal passages. Various dome rooms formed by shafts or complexes of shafts are of this type.
5. Actual widening of horizontal passages. Such irregularities in the shape of cave passages occur, but the causes are usually not known.

The cave room is much like the overall cave pattern itself. Any particular room is a feature unique to that particular cave and must be interpreted on the basis of local conditions.

Chemical Deposits in Caves

Perhaps the most attractive features of caves are their mineral deposits. In the constant environment of the cave, mineralization processes can proceed uninterrupted over long periods of time. The result is a wide variety of mineral features known as "cave formations" or in more recent literature as "speleothems". The section that follows discusses those minerals that occur in Pennsylvania caves and some of the speleothem forms. More than 80 different mineral species have been found in caves. Most of these, however, require rather special conditions or rather special water chemistry. This information is limited to the more common minerals that would be expected to deposit from cold limestone groundwater.

Carbonate Minerals

The most abundant species in cold limestone groundwater are calcium, magnesium, and carbonic acid. It is not surprising to discover that carbonate minerals make up the bulk of cave deposits. The carbonates that form in caves are:

Calcite	$CaCO_3$	Huntite	$CaMg_3(CO_3)_4$
Aragonite	$CaCO_3$	Hydromagnesite	$4MgCO_3$-$Mg(OH)_2$-$4H_20$
Dolomite	$CaMg(CO_3)_2$	Nesquehonite	$MgCO_3$-$3H_20$

All are white crystalline materials and identification can be done reliably only by X-ray diffraction. Calcite is by far the most common. Probably 90% or more of all speleothems are composed of calcite. Aragonite occurs in many Pennsylvania caves. Dolomite, huntite, and the hydrated magnesium carbonate minerals are rare.

Mineral Deposition

The process of calcite deposition is the reverse of calcite solution. The source of water and carbon dioxide is the infiltration water from the soils that overlie the cave. Rainfall seeps into the soil where biotic activity is high. The carbon dioxide pressure in the soil may reach values as high as 0.1 atm. The soil water becomes very acid but (if the soils are depleted in calcium carbonate) accumulates little dissolved carbonate. Continuing its downward course, the water then reaches the broken rock mantle zone at the base of the soil. Here it reacts with the carbonates in the mantle material and approaches saturation between CaCO3 and the high CO2 partial pressure. A considerable quantity of calcium carbonate is taken into the solution.

The downward percolating water now leaves the soil and mantle zone and makes its way into the limestone bedrock along joints and fractures. Because no additional carbon dioxide is available at depth and because the water is already highly saturated, the solutional attack on the joints and fractures is likely to be small. Solutional modification of these diffuse flow paths takes place very slowly or in situations where reactions in the mantle did not go to completion. Now suppose that the joint intersects the roof of an underlying cave passage. The cave atmosphere has a CO2 pressure of a magnitude higher than that of the surface atmosphere but much smaller than the CO2 pressure of the seeping water. The water percolating through the cave roof is supersaturated with respect to the cave atmosphere. The CO2 is therefore degassed from the dripping or seeping water into the cave atmosphere, building up the necessary super-saturation in the solution necessary for carbonate minerals to deposit.

The model described above was used to explain carbonate deposition in Luray Caverns, Virginia. It seems to be widely applicable. The CO2 loss model provides an explanation for the observation that the cleanest, most coarsely crystalline, and seemingly the most rapidly growing dripstone occurs where evaporation is non-existing. Caves without entrances (which have been open by excavation) or segments of a cave channel blocked by water traps are known to have some of the most spectacular formations. Another cause of deposition can be evaporation but apparently interferes with high-quality crystal growth.