CAVE FORMATION

Determining the Age of What Is Not There

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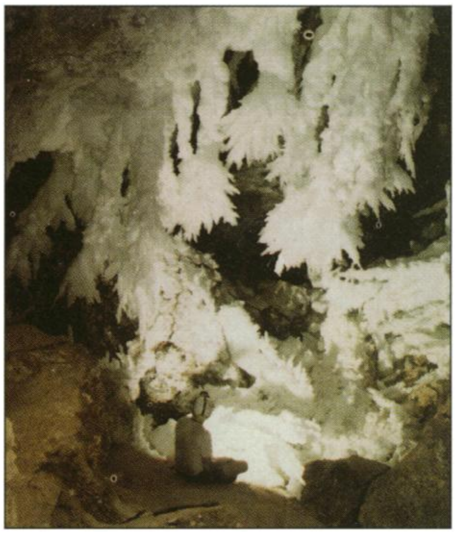
Perhaps more than any other science, geology is concerned with the age of things and the timing of events. From the grand questions (how old is Earth) to the pragmatic (when will the next earthquake occur), geologists find themselves working over time scales that vary by about 10 orders of magnitude. One of the most difficult tasks has been determining the ages of caves. On page 1919 of this issue, Polyak *et al.* present results that yield the age of a limestone cave (*1*), a feat not possible until this work. The importance of such dating is more than scholastic: Caves serve as repositories for historical geologic and climatic information that may not be found anywhere else.

Caves present a peculiar difficulty, because we are attempting to study something that is no longer there. By definition, a cave is a natural open space in rock that is big enough for a human being to enter. Although caves can be formed by many processes, the majority occur in limestone rock when a naturally acidic solvent (ground water) migrates through the rock. The solvent dissolves the surrounding rock that it contacts, the solution is carried away, and a cave is born. During later stages, other materials sometimes partially fill this void. Because we cannot (as yet) date empty space, we must instead constrain the age of the cave using evidence in and around it.

Two such major constraints always hold in dating caves. Because the cave is formed in existing rock, it must be younger than the rock in which it is found. Likewise, anything found in the cave must have been deposited after the cave formed. So, if we can date material in the cave, we know the cave must be older than the date determined. This latter relation has been successfully used many times to determine a minimum age for the formation of a cave, but problems abound. Two classes of materials provide useful dates: secondary calcite deposits (stalactites, for instance), which form through the seepage of ground water into the cave (see figure), and clastic sediments (such as silt and clay), which are carried into the cave by surface streams. Dates from calcite deposits have been determined for many caves, mainly by



Dating empty space. Gypsum "chandeliers" in Lechuguilla Cave, New Mexico. Massive secondary crystals such as these may occur in caves associated with sulfuric acid dissolution.

uranium-series isotope measurement (*2*). The deposits are less than ideal because they record events that may have happened a long time after the cave void formed. In addition, the technique has commonly been limited to ages less than about 400,000 years. Enhancement by mass spectroscopy has pushed this limit back to 700,000 years in some cases (*3*). Techniques such as electron spin resonance and thermoluminescence approach a range of 1 million years in such materials (*4*). Dating of clastic deposits in caves has likewise been fruitful, particularly by paleomagnetic methods, recording dates as far back as 7 million years (*5*). The timing of clastic material deposition is usually more closely related to that of actual cave formation than is that of calcite deposits. This link is a desirable relation, but correlation with the global record is required, yielding less precise ages than calcite dating. Cosmogenic isotope dating of quartz pebbles in cave deposits is a recent development that may provide for more precision up to the 5-million year mark (6).

Polyak *et al.* (*1*) have neatly circumvented the problems inherent in the above-mentioned techniques. They used a new strategy in Carlsbad Cave and other caves in New Mexico. Rather than dating materials transported into the cave, they identified a clay mineral (alunite) that actually formed in situ during cave growth. Alunite, which is found in the floor, walls, and pockets in the studied caves, is datable by means of $^{40}Ar/^{39}Ar$ measurements. This work has resulted in the first determination of the actual age of development of a limestone dissolution cave. The technique is applicable to those limestone caves that formed by sulfuric acid dissolution.

Implications of this work go beyond the philosophical pleasure of assigning an age to empty space. Because they are "roofed over" and protected from surface erosion, caves preserve information that is not found in the surface environment. In the case presented by Polyak *et al.* (*1*), the ages of five caves at varying elevations were used to construct a history of relative water table decline over the last 12 million years. These data provide information on landscape lowering, incision rates, and mountain uplift. Such long-term information is crucial (and generally unobtainable) for paleoclimatic, paleohydrologic, and geomorphologic studies. These studies seek to predict future climate change, landscape stability, water supply decline, earthquake recurrence intervals, and so on. The possibility of extending this work to other regions is provocative and sure to be undertaken.

Carlsbad and Lechuguilla caves are two of the most famous caves in the world, recognized for their size and beauty. It is particularly satisfying that this technique could be first applied to these world-class natural treasures. I suspect that while we scientists revel in the numerous potential applications of this technique, it may actually be the Carlsbad Cave tour guides who are most immediately grateful for these results. For at last, they will have the answer to that question asked by so many of the 600,000 tourists that visit Carlsbad each year: "How old is the cave?"

References

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