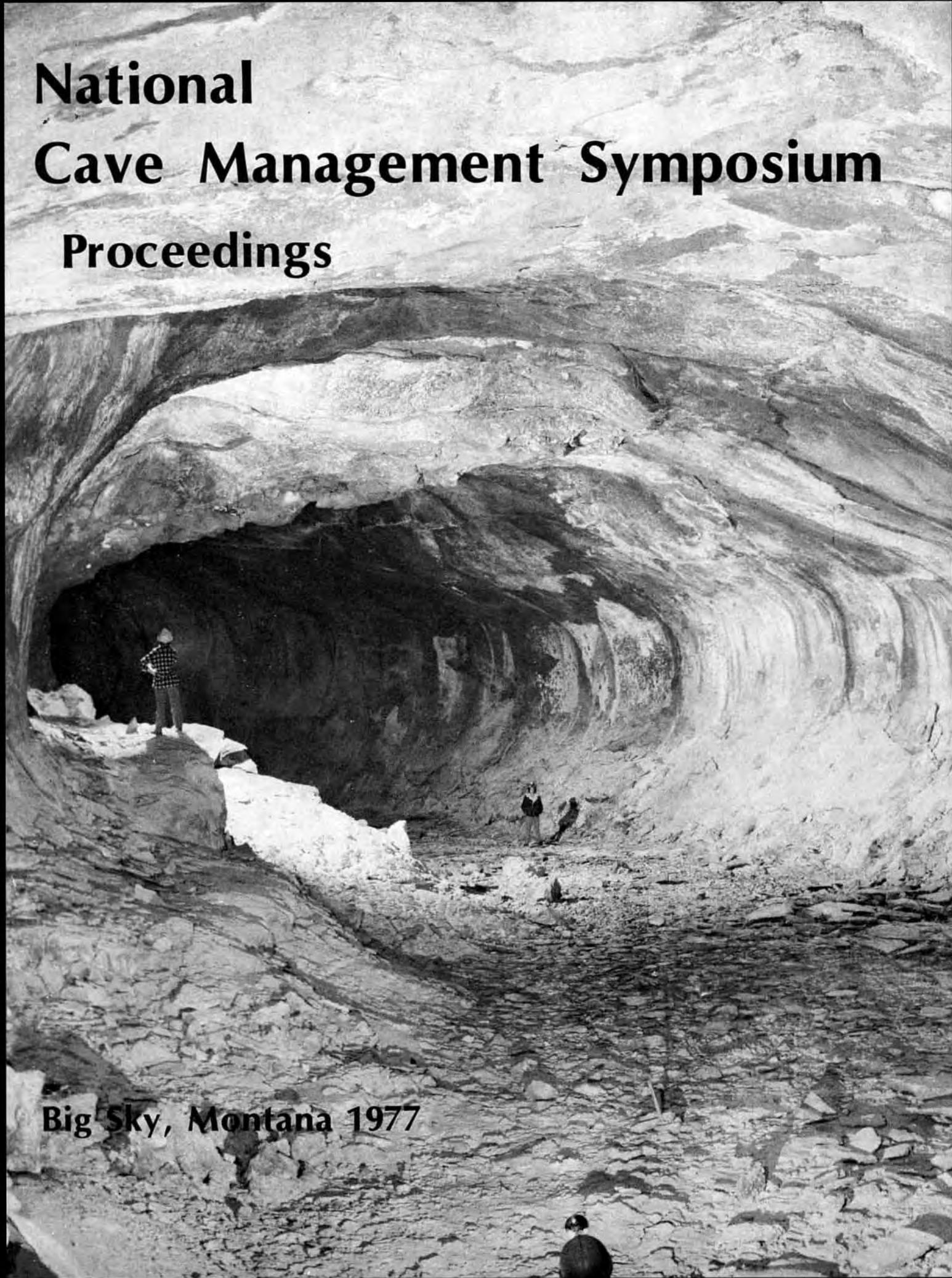


National Cave Management Symposium Proceedings

Big Sky, Montana 1977



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Proceedings

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Caves of the Northwest: A Unique Resource with Unique Management Implications

James Chester*

The term "northwest" is used broadly to include Montana, Wyoming, Idaho, Washington, Oregon, northern California, the southern Canadian Rockies and Vancouver Island.

Much of the subsequent material is from the following sources: *American Caves and Caving* (Halliday 1974); *Guidebook of the 1972 NSS Convention* (Halliday 1972); *Caves of Wyoming* (Hill, Sutherland and Tierney 1976); and *Cave Exploration in Canada* (Thompson 1976).

The 1972 guidebook divides the Pacific Northwest, including Washington, Oregon, northern California, Vancouver Island, and Idaho into nine speleological provinces (Figure 1): the Cascade Mountains; the Columbia Basin of Washington and Oregon; the Tri-State Highlands of Idaho, Oregon, and Washington; the High Lava Plains of central Oregon; the Snake River Plains of central Idaho; the Willamette-Puget Lowlands; the Coastal Ranges and Plain; Vancouver Island; and the Okanogan Highlands of British Columbia and northeast Washington.

The structure of the Cascade Range is speleologically complex. South of Interstate 90 lava caves dominate the cave resource (Halliday 1972). Areas of particular significance are Lava Beds National Monument in northern California with approximately 300 known lava tubes (Knox and Gale 1959), the Mt. Saint Helens Cave Area, and the Mt. Adams Cave Area, near the site of the 1972 NSS Convention. North of Interstate 90, limestone deposits are found in scattered areas, with significant caves at Snoqualmie Pass and a well developed alpine karst in the Dock Butte-Washington Monument Area (Halliday 1972).

The Columbia Basin is insignificant in terms of caves with the exception of some intriguing lava cast caves, one of which is the cast of a particularly unfortunate rhinoceros (Halliday 1972).

Caves in the Tri-State Highlands are in scattered small to extensive limestone deposits. On the Idaho-Oregon border, significant caves are found in Hells Canyon and on McLinery Ridge west of Riggins, Idaho (Halliday 1972). Papoose Cave, an extensive, deep and very beautiful cavern, one of the classic caves of the U.S., is found in this speleological province.

According to the '72 guidebook, "the High Lava Plains of east central Oregon are noted for major tube-containing flows near Bend and Redmond." In the eastern section of this province lava tubes are found near the Malheur National Wildlife Refuge. The Malheur Environmental Field Station sponsors a cave ecology class and an on-going program in this area is the Malheur Cave Research Project.

The Snake River Plains stretch across southern Idaho from Boise to Yellowstone Park. Lava tubes are common features throughout the region. Craters of the Moon National Monument, Crystal Ice Cave, a commercial lava glacière, and the Great Rift are among the most important speleological features in this region.

Caves in the Willamette-Puget Lowlands are primarily limited to littoral caves most of which are small and insignificant (Halliday 1972).

The Klamath Mountains of Oregon and California appear to hold the greatest speleological significance of any of the Coastal Ranges. Oregon Caves National Monument is located in this range. Activity in the California segment of the Klamath Mountains during the past several years has revealed an alpine karst area with several caves of national significance in terms of depth. On the 9th of September, the U.S. depth record, which had stood for 21 years, was broken in the Bigfoot Cave System. Bigfoot Cave and Oregon Caves are the longest known limestone caves in the Pacific Northwest. Major littoral caves including Sea Lion Caves are scattered along the Pacific coast in this region.

Vancouver Island has extensive areas of limestone with numerous caves. The Horne Lake Area caves are highly decorated and challenging. Limestone deposits in the north are difficult to reach but activity there in the past several years has established Coral Cave as the longest cave on Vancouver Island and Maquinna Cave as the deepest (Thompson 1976). In *Cave Exploration In Canada* (Thompson 1976) Coral is listed as the seventh longest cave in Canada while Maquinna is the seventh deepest. The potential of Vancouver Island remains high.

The Okanogan Highlands of north central Washington and southern British Columbia contain considerable limestone but few caves of any length (Halliday 1972).

The Intermountain Northwest consists of the southern Canadian Rockies, Montana and Wyoming.

The longest and deepest caves in Canada are found in the southern third of the Canadian Rockies. Several of the caves in these ranges, including Arctomys Cave, Yorkshire Pot and Castlegard Cave are among the deepest in the western hemisphere. Castlegard, at 13 kilometers in length, is the second longest cave in the Northwest. According to Thompson (1976), only a fraction of the more than 17,500 km² of karst in Alberta alone has been investigated.

Montana's limestone regions are scattered. As in Canada, many caves are being discovered in the heart of the Rockies. Alpine karst areas along the continental divide in Glacier National Park, and the Bob Marshall and Scapegoat Wildernesses are currently undergoing intensive investigation. Some of the deepest caves in the U.S., such as the Silvertip System, and the majority of the longest caves in Montana have been found in these areas during the last few years. Isolated mountain ranges such as the Snowies, Pioneers, Little Belts, Centennials, and the Pryor and Bighorn Mountains also have considerable cave development and speleological potential. The Horsethief-Bighorn Cave System, the longest cave in the Northwest with nearly 15 kilometers of passage, is located in the Bighorn Mountains on the Montana-Wyoming border. French Creek Cave, the fourth longest in the state, is found in the Pioneers. As of 1976, there were 302 known caves in the state. The number is constantly increasing as investigation of the resource continues.

*410 East Aspen, Bozeman, Montana 59715.

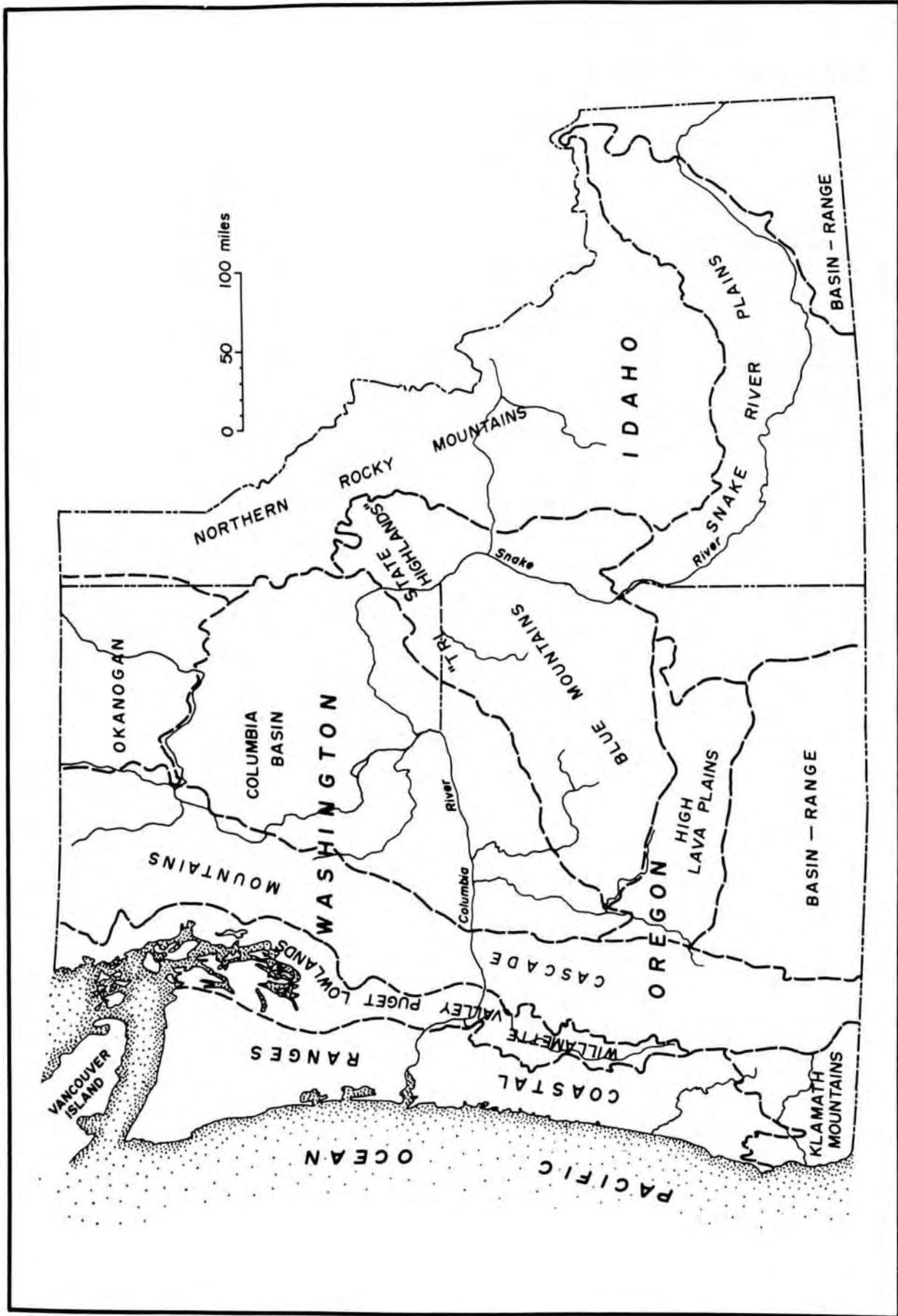


Fig. 1. Nine speleological provinces: the Cascade Mountains; the Columbia Basin of Washington and Oregon; the Tri-State Highlands of Idaho, Oregon, and Washington; the High Lava Plains of central Oregon; the Snake River Plains of central Idaho; the Willamette-Puget Lowlands; the Coastal Ranges and Plain; Vancouver Island; and the Okanogan Highlands of British Columbia and northeast Washington.

If anything, Wyoming's cave regions are even more scattered than Montana's. The areas of most speleological promise in the state are the Bighorn Mountains in north central Wyoming and the alpine karsts of the Teton Range. Of the 245 caves listed in *Caves of Wyoming* (Hill, Sutherland, and Tierney 1976) 101 are located in the Bighorns and 53 are in the Tetons. The Horsethief-Bighorn System is Wyoming's longest cave, while its deepest is Rendezvous Peak Cave, a Teton cave. As in the other parts of the Intermountain Northwest, serious study of the cave resource has merely begun.

It is probably apparent from the preceding that a diversity of form exists in the caves of the Northwest. In fact, the Northwest is probably unmatched anywhere in North America in terms of the variety of different types of caves to be found. The limestone and lava caves are probably the most significant, but spectacular ice caves, glacier caves, steam caves, and littoral caves all vie for manager's attention.

Looking at the Northwest's limestone caves in terms of two standard measures of significance, length and depth, an interesting picture emerges. The cave resource of the Northwest is insignificant in terms of length. Only two caves, the Horsethief-Bighorn System and Castlegard, managed to make the *Inside Earth* (Sprouse 1976) list of the

40 longest caves in the western hemisphere. These two systems were 33rd and 37th respectively. A striking example of the length of the region's caves is to be found in Montana and Wyoming. Only 7 percent of Montana's caves exceed 300 meters in length and 6 percent of Wyoming's. The percentages are probably lower in other sections of the region.

When depth is considered, it's another story; 11 of the 37 deepest caves in the U.S. occur in this area, including the 1st, 4th, 7th, 8th, 9th, 11th, 13th and 14th. When Canada is included the picture is even more impressive. Until recently Arctomys Cave was the fourth deepest cave in the western hemisphere at -522 meters and Yorkshire Pot the 14th. This region had 8 of the 40 deepest western hemisphere caves as listed in *Inside Earth #4* (Sprouse 1976). With the current activity centered in the alpine karst of the area, it is likely the depth resource will continue to be very significant.

When other measures of significance are examined, specific limestone caves in the Northwest are nationally important. Although the caves of the Northwest are not generally known for their secondary mineral deposits, there are some spectacular exceptions in this region. The Horsethief-Bighorn System has one of the finest gypsum displays to be found anywhere (Figure 2). Lewis and Clark Caverns, Papoose Cave, and a number of caves on



Figure 2. Gypsum flower, Horsethief-Bighorn Cave System. Photo by Jim Chester.



Figure 3. Ice formation, Fossil Mountain Ice Cave. Photo by Jim Chester.

Vancouver Island are literally choked with active formations.

The richness of the paleontological excavations at Natural Trap Cave, Wyoming, have drawn wide attention from scientists. Many caves in the Northwest have archeological significance, and many serve as repositories of local history.

Lava tube caves have long been the "sister ugly" of limestone caves. Activity in the Northwest has gone a long way towards dispelling the notion that lava tubes are insignificant and uninteresting. In Washington, Idaho, and Oregon, the most common caves are lava tubes, a cave form found in few other places in North America. Far from being boring, lava tubes in the Northwest are large, complex and extensive. Ape Cave, the subject of another Symposium paper, is over 3 kilometers in length and is the second longest unitary lava tube in the U.S. Halliday in *American Caves and Caving* (1974) discusses tubes with passage widths of 30 meters and heights of 10, 12 or more meters. Lava tubes with multiple levels and numerous branching passages occur in the region. Two of the region's lava tubes appear on the deep cave list for the U.S. Ape Cave is the 13th deepest cave in the U.S. at -215 meters. Two national monuments in the Northwest, Craters of the Moon and Lava Beds, have tubes as their central attraction.

Ice caves or glacières, caves containing ice formed underground, are one of the special attractions of the underground Northwest (Figure 3). This region has a selection unsurpassed anywhere in North America.

Lava tubes are excellent cold air traps resulting in spectacular displays of ice such as commercialized Crystal Ice Caves near American Falls, Idaho.

High elevations are conducive to limestone ice caves. Fossil Mountain Ice Cave in the Tetons and Plateau Mountain Ice Cave in the Canadian Rockies are such caves (Figure 4).

Glaciospeleology or the study of caves formed in glaciers is in its infancy. Its birth occurred in this region with the initiation of serious study of the Paradise and Stevens Glacier Cave System in Mt. Rainier National Park (Figure 5). Between 1967 and 1975 over 22 kilometers of passage were mapped in this system (Anderson 1975).

Sections of the Paradise Glacier Cave System are in firn. The potential for firn caves and even true glacier caves is high in the Northwest and essentially nonexistent elsewhere in North America, excepting Alaska, northern Canada, and possibly some of the high volcanos of Mexico. Just this summer, Montana efforts yielded a modest firn cave in the



Figure 4. Ice formation, Plateau Mtn. Ice Cave. Photo by Jim Chester.



Figure 5. Entrance passage, Paradise Glacier Cave System. Photo by Jim Chester.

Beartooth Mountains, opening the possibilities for a whole new branch of speleology in this section of the region.

Thermal activity in the Northwest, which caused the extensive lava beds and lava caves and the impressive chain of volcanic peaks in the Pacific Northwest, is still influencing our cave resource. Extensive firn caves, formed as the result of thermal activity, occur on the summits of Mt. Rainier, Washington and Mt. Baker, Oregon. According to Kiver and Steele (1975), these two systems comprise two-thirds of the known steam cave systems in the world. A small resource, but significant nonetheless.

Any discussion of the cave resource of the Northwest would be remiss if littoral or sea caves were not at least mentioned. Although such caves are generally not extensive and are probably the least significant of any caves in the Northwest, they are abundant along the coastal areas. Some, such as Sea Lion Caves, are biologically significant. Further scientific study of this type of cave is warranted.

Much of the current caving activity in the Northwest can be called a wilderness experience in that many of the significant caves actually lie in legal or defacto wilderness areas. The Bob Marshall Wilderness, the Scapegoat Wilderness, and the Glacier Park backcountry in Montana, the Tetons in Wyoming and the Marble Mountains Wilderness in California are hot beds of "wilderness" caving activity in the Northwest.



Figure 6. Caver carrying a "humongous" load. *Photo by Jim Chester.*

These types of caving areas are generally very remote high-elevation areas. It is increasingly common for caves to be located and studied which lie at least 8 kilometers from the nearest road and sometimes as much as 50 to 60 kilometers. Remote locations make access to such caves a major logistical problem (Figure 6). As the distances from



Figure 7. Caver getting blasted by a thundering waterfall. *Photo by Jim Chester.*

the road increase, one begins to hear stories of the "death march" and the day everyone's boots filled with blood.

Getting to our wilderness caves is only half the story. The caves themselves present a formidable challenge to the would-be explorer. As a rule the high elevation, remote caves are cold (0-5°C) and technically difficult. Exposure gear such as wetsuits is essential, as long hours are spent working in large amounts of near freezing water (Figure 7). Major vertical traverses require competence with ropes and vertical caving gear. In short, the wilderness caves of our region push the explorer to the limit (Figure 8).

According to the 1972 convention guidebook, ownership of the resource "varies almost as much as the caves themselves." Ownership is shared by various federal and state agencies as well as private individuals and corporations.

Using Montana to point out the diversity of ownership in the Northwest, 19 of the 23 caves over 300 meters long are federally owned, 3 are privately and 1 state owned. There are 11 separate owners or administrators of these caves. Seven of the 10 deepest caves in the state are federally owned. There are six separate owners. The picture is much the same in Wyoming and throughout the Northwest.

At least four cave state parks exist in the region: Lewis and Clark Caverns State Park, and Indian Caves State



Figure 8. Trashed-out, wetsuited caver standing next to a fire after 16-hour wilderness trip. *Photo by Jim Chester.*

Monument in Montana, Lava River Caves State Park in Oregon and Chelan Ice Cave State Park in Washington. Three national monuments in the region feature caves. Conservatively interpreting Gary Soule's (1976) list of U.S. commercial caves, the Northwest has nine commercial caves or cave areas. Private ownership of caves varies from area to area, with the greatest percentage of privately owned caves probably occurring on logging company land on Vancouver Island.

Having pointed out that there is a significant cave resource in the Northwest, some brief, general statements on cave management in the region are in order. Except for scattered instances, the Northwest cave resource has been managed by lack of management. Admittedly, cave management in the Northwest is not the most earth-shaking thing on the minds of the region's cave owners, or even near it. Generally, in this region, visitation of the cave resource has been minimal and any problems associated with this visitation have not been drastic or obvious enough to goad owners into thinking about management. In the few instances where some sort of management policy has been established, the owner has literally been forced into action because problems and potential problems started to surface and didn't succumb to inaction. As work continues in the Northwest and the significance and nature of the resource becomes more generally known, owners are going to have to face the management dilemma. Some of the special cave management considerations in the Northwest that will have to be addressed include: preservation of uniquely fragile ecosystems such as those found in ice caves, glacier caves, and lava tubes; management of caves that lie in legal wilderness areas so as to preserve them in the state required by the Wilderness Preservation Act; and safety and rescue problems associated with the extremely challenging and remote Northwest caves.

Cave management schemes in the Northwest must be

cognizant of the diversity in the resource and must be tailored to the individual situation. It will not be an easy task to implement *useful* management schemes in this region. But, there is one bright spot. The problem is simplified somewhat by the fact that our resource is essentially unspoiled, and is not suffering from the multitude of ills found in other areas. Thus, Northwest managers have a unique opportunity to consider the options before it's a do or die situation.

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Management: A Working Definition

Rochelle Devereaux*

As this title implies, this paper develops a working definition of management. I have decided to concentrate on one cave management situation to illustrate the meaning and applicability of the strategic management concept to cave management. To accomplish this, I will be applying examples for Shelta Cave that could be incorporated into a management plan.

Shelta Cave is owned by the National Speleological Society (NSS) and is located in property owned by the NSS in Huntsville, Alabama. The NSS Board of Directors established a management plan for Shelta Cave after acquiring the property. Recently, however, a request was made for the plan to be reevaluated and a revised management plan submitted for the Board's consideration. The examples I'll be using for this discussion may not appear in the final proposal, but can provide background for future discussions of the management process. This paper is a preliminary outline of the development of a practical cave management program and how it could be implemented. It is a starting point for a continuing discussion of relevant methods for preparing and utilizing management plans.

A definition of terms is necessary for this discussion. Management is a word we've all used and it probably has a lot of different meanings for each of us. This diversity was obvious to me in my research of management texts. However, although there are volumes devoted to discussions of management theories, a basic theme, common to all, appeared and will be applied here as the definition for the concept of 'management.' Paraphrasing from several management sources, management is considered—the process by which a predetermined objective is obtained. This is also referred to as strategic management, as opposed to crisis management, the system or systems developed to realize a defined objective or purpose.

A parallel can be drawn to a chess game. Two people first determine that they wish to play a game of chess. They then establish that the objective is for one to checkmate his opponent. To obtain that objective, each should plan a strategy of moves and countermoves (strategy plan) which will result in a checkmate position. Without strategic movement it will be more difficult to achieve the defined objective. To illustrate this, let's assume that Player A is a strategist, a true chess-player; and Player B is merely a piece-pusher, a player-at-chess, with no particular strategy. Player A brings to the game historical knowledge of the game, the alternative moves for most given circumstances, and a predetermined plan of action. Player B knows how to move the chess pieces and intends to "play it by ear"; reacting to events as they occur (crisis management). In most cases, barring extreme luck for B or lack of skill in A, Player A, the strategist, will win. This holds true in most management situations.

I believe that the strategic management approach is appropriate to cave management because the cave manager

performs the same function as any business manager, and the most successful businesses practice strategic management.

Cave management as such is a relatively recent discipline. It is an outgrowth of perceived needs for control systems for caves resulting from a growing awareness of caves as resources within our Society. Society here is seen as that group of individuals and organizations who share a common interest in caves. Within this society a cave culture has emerged as individuals interact and identify common values, norms and behavior patterns which require cooperative behavior. Within this "cave society" are several distinct subcultures, both formal and informal. This symposium is an example of a formal subculture and an informal subculture could be the activities of individual sport cavers. Subcultures include the various sport, scientific, governmental, commercial and social groups that have developed around an interest in cave resources. This culture and the existing subcultures help define the constraints of cave management through their differing perceptions of cave uses. Among these constraints are: conservation goals, desire for public access to caves, scientific study requirements, sport group requirements and the commercialization of caves. Some of these constraints are evident at Shelta. Scientific study is being carried out alongside the efforts for cave conservation and public access to the cave. A strategic management plan must recognize and deal with these constraints. Few management situations involve only one constraint. Cave management is no exception.

Realizing then that there are many variables and opposing constraints in the cave management process, it is therefore vitally necessary to isolate those issues which are basic to the cave resource. From these issues, the basic premises and policies of the cave management plan may be developed. An understanding of universal premises or principles of cave management provides the cave manager with guides to develop the strategic plan. They provide the basis for developing the objective statement for this plan and allow the manager to concentrate on the policies necessary to achieve the plan. For example, some basic premises for any cave manager might be: 1) the cave is a finite resource; 2) there are natural processes which impact on the formation and destruction of caves; 3) man impacts on caves both directly and indirectly. These examples could apply to any cave. They are universal statements which are valid in the given circumstances.

As previously stated, the primary purpose in developing these premises is to provide the manager with an understanding of the given information in a management situation and to develop the policies to define the management objective. Policies are derived by observing and incorporating repetitious actions or decisions into guidelines for future action. By standardizing the response to frequent occurrences, policies free the manager to deal with new information and situations which do not fall within these guides. They also provide greater assurance that the manager is steering the plan toward the objective. Policies provide the acceptable constraints for *individual* decision

*40548 Mohawk River Rd., Marcola, Oregon 97454

making by providing clearly defined ranges within which the manager operates.

An example of a policy for cave management which could follow from a premise might be: **PREMISE:** The environment in which the biota of Shelta Cave exists is delicately balanced. **POLICY:** In order to assure minimum impact on this balance during research efforts, use of the cave during those periods will be limited to only those people and activities absolutely necessary to carry on the function of the research project.

Effective development and implementation of a management plan can best be achieved through the understanding and use of premises and policies. The objective constraints are refined by these processes to provide the basis for interpretation of the facts of a given situation.

There are five steps in this process: 1) defining the objective statement; 2) developing the strategy plan; 3) designing and installing control systems to monitor the plan; 4) initiating action; and 5) testing the objective through feedback.

DEFINING THE OBJECTIVE STATEMENT

Clearly stating the objective is most important. A concise statement of an objective provides the direction of the management plan, and indicates the boundaries or constraints within which it must operate. This objective statement is derived from the process discussed above. It arises from the premises and policies perceived by the organization initiating the management program to be most important. To illustrate how this may work, consider Shelta Cave. The premise and policy I outlined before would indicate several constraints for the management objective. Inherent in the premise that the cave environment is delicately balanced is the necessity to consider if that is important or even relevant to the management plan. By stating a policy that indicates that minimum impact will be allowed during research efforts, the inference is that this balance is important, and must therefore be incorporated into the objective statement. Considering these facts, an objective statement for Shelta Cave could then be: to maintain, as closely as possible, the environmental balance in Shelta Cave which supports the biota of the cave.

In a given business, the objective could be stated as maximizing profit given production capacity and manpower resources as its constraints. In a governmental unit it can be seen as achieving the results mandated by a given law or group of laws, given the resources allocated by the lawmaking body. The variable nature of the cave resource and the stated values of the group or individual initiating the cave management process will determine the end goal and its constraints. However, regardless of the objective, be it preservation of archeological artifacts, earning a profit for the commercial operator, providing recreational access to the general public, or any other purpose which a cave may be said to have, the **PROCESS** by which these objectives can be realized is the same. This process begins with the development of the strategy plan.

DEVELOPING THE STRATEGY PLAN

The strategic manager, like the chess player, will devise a strategy for obtaining his objective. This strategy evolves from a series of planning and decision making steps which are separate but dependent on those used to define the

objective statement. Planning is the identification of the alternatives for achieving the organizational objective and then deciding how they may best be accomplished. Decision making is the selection of one alternative from several.

Since there are obviously innumerable facts, figures, comparisons and other data which could apply to the strategy plan, a method for determining relevancy of information is the first priority. This is accomplished by developing an opinion or hypothesis. By stating a hypothesis or opinion of what should be, the data to be collected can be evaluated in terms of its relevance to the desired course of action. At this point, the manager can examine past experience, compare similar situations, gather current information, evaluate theories, or simply ask, "what if?"

Keeping in mind that the management process is forward moving, and that it deals exclusively with the future, it is easier to understand why a strategy cannot begin with the facts of a situation. Facts are events that have happened. They reflect only what has been and depend on the perceptions and goals of the manager to give them meaning. Facts may be used to evaluate the past to see if the event could relate to or recur in the future, but they cannot say what the future will be. Strategy planning is a continuum; it is the determination of the wisest course for the future under the circumstances now existing.

When the manager feels that as many relevant ideas as practical have been gathered, the decision process begins. For example, if the Board decided that a revised management plan for Shelta Cave was needed in 2 weeks, the amount of information which could practically be gathered would be limited. However, since the facts which could be relevant to any situation are almost infinite, it would be impossible to attempt a comprehensive analysis before developing any strategy.

When evaluating the relevant data that has been gathered, different approaches should be considered. At Shelta, or any cave, the different possible constraints on the management objective should be reviewed. Should access be limited to scientific pursuits, educational and interpretive programs, sport caving, NSS members only, a combination of any or all of these interests? What strategy is relevant to each of these options? Obviously, all the possible strategies cannot be used at once, nor would that be desirable. However, a valid plan is best decided on by bringing together widely diverging, relevant ideas and data to increase the manager's understanding of the full scope of available alternatives. He must then choose one from these alternatives. This selection process is accomplished by the decision making process.

Decision making is the systematic evaluation of the realities and constraints of the objective statement and the strategies which could be used to achieve it. To effectively accomplish this evaluation, two guides should be used. First, does the strategy satisfy minimum goals for the objective; and second, does it violate the set boundary conditions? As I mentioned earlier, concise statements of these boundary conditions are necessary for effective decisions. These boundary conditions, incorporated in the objective statement, become the constraints that the plan must take into consideration.

Referring again to Shelta Cave, one objective statement for managing Shelta could be to preserve the cave and to provide an environmentally controlled site for ongoing studies of the biota of the cave. This stated purpose has certain limiting effects on other uses for the cave. By stating that the cave will be used as a biological laboratory, access for other purposes will be, of necessity, limited to those

activities and times that will not interfere with those studies. Therefore, the laboratory situation becomes a constraint in the development of the overall Shelta Cave management plan. Any discussion and evaluation of alternative uses or plans for the cave must fall within the stated constraint or boundary of the ability to carry on these research activities.

Before the constraint defining objective statement could be developed, basic premises or principles were needed to guide the manager. This is equally true of the decision making process. Principles are universal statements that are valid. The statement of validity is separate from any value judgment, good/bad. Principles can only be valid for a given set of circumstances and the circumstances determine the relevance of value judgments. Referring back to the premises discussed earlier may help to illustrate this point. These premises were: 1) the cave is a finite resource; 2) there are natural processes which impact on the formation and destruction of caves; and 3) man impacts on caves both directly and indirectly. The statement that the cave is a finite resource is valid for cave managers, but may not be for other people. It would have the value of good or bad only if the person perceiving this principle needed to assign a value judgment to it. However, in this instance, it is seen that the cave is in fact finite and, therefore, this is a valid statement. That man impacts on caves both directly and indirectly is not necessarily good or bad. It is again a valid statement of what has been observed. Value judgments cannot affect the principle itself, but can be applied when developing policies which result from the principle.

As stated earlier, policies are guides for making decisions leading the plan toward its objective. They provide the acceptable constraints for individual decision making by providing clearly defined ranges for the manager. The manager, in essence, makes his decisions by determining boundaries, evaluating the relevant data, and then interpreting the various presented facts and sometimes opposing alternatives for the most viable solution. Decision making involves the risk of making a judgmental error; but the more precise the understanding of constraints, the more likely a satisfactory decision will be made. Everyone who makes decisions will at some point make a mistake in judgment, and uncontrollable outside influences can affect the decision's use, but the fear of error or unknowns should not be justification for failing to explore the situation in depth.

Back to the example of Shelta Cave; I have stated an objective, outlined principles and policies which relate to that objective, so now a decision on how this objective could be achieved is necessary. Assuming input from several sources and alternative plans, the most intuitively sound decision would be to monitor access to the cave to maintain the equilibrium of the environment. This strategy decision needs to be tested against the realities of the situation, which leads to the next step of the management process.

CONTROL SYSTEMS

Once the management plan has been determined, control systems must be developed to monitor actions within the plan. Control systems measure performance and guide the manager's actions toward some predetermined target. They include a means for measuring actual accomplishments; a means for comparing actual performance with the target, and a means of correcting performance to meet the target. Control is the process which provides the feedback the manager needs to assure that decisions are leading toward

his objective. What then are some controls that may apply to the management of the Shelta Cave strategy?

Starting with an evaluation of the current status of the cave and its environment and known biological resources, a data base can be developed to be used in monitoring the management plan. Following this step, the research teams could be required to establish their needs in terms of times of year data will be collected, and the numbers of people who will be needed to collect it. This then provides the manager with the means to hold the researchers accountable for their actions and also assure consistency in evaluating the research team's impact on the cave as information is reviewed.

Once these steps are performed, benchmarks or acceptable limits for variance in the cave environment could be set. These will provide the manager with criteria for evaluating the reasonableness of the program itself. Then the actual systems to monitor these variables in the cave environment should be installed. Setting the time frame in which the set constraints will be followed will provide the manager with an additional criteria for evaluation.

Assuming a 10° variance in the cave temperature is chosen as an acceptable limit, the temperature of the cave would be recorded before anyone was allowed into it. Periodic readings from the thermometer at intervals during the research team's work would indicate if and how much their presence was affecting the cave temperature. Recording these readings, along with the number of people in the group, type of activity performed during the time intervals, and other pertinent information, provide information which could be used to later determine which activities most affect the environment.

The final steps in the monitoring process would be the comparison of the input during the benchmark periods within the time frame allowed, against the base data. If at any time the variance is greater than that which is considered reasonable, the manager would then institute corrective procedures to assure the success of the management plan. (This process is known as management by exception; the manager only acts when occurrences lie outside the policy stated constraints.)

Keeping in mind that the control purpose is to evaluate progress toward and the relevance of, the management objective, in reviewing feedback or incoming data it may become obvious at any time that the management plan is incomplete, inadequate or irrelevant to that stated objective. Or it may become obvious that the original objective was imprecise, has become obsolete, or is no longer desirable or necessary. Without adequate control systems, the management plan can become more of a liability to the achievement of the stated objective than an asset. The greater the understanding of what the control is to achieve, and the more specific the feedback, the greater likelihood that the management plan and its objective will be effective. The management plan and its control systems are the active portions of the management process. It is important to remember that the management process is a dynamic situation, subject to continual change and reevaluation, and that merely stating an objective and devising a plan to achieve it, does not end the process.

INITIATING ACTION

A decision by itself accomplishes nothing. Control features that are not implemented provide no feedback or control. Converting decisions into action requires a manager to answer several distinct questions: who has to know of this

decision? what action has to be taken? who is to take it? and what does the action have to be so that people who have to do it *can* do it? Peter Drucker, in his book "The Effective Executive," states "that although an effective decision is based on a highly conceptual level, it must be convertible into action on a working level." This means that an effective management plan should address the question of what is to be done, who is to do it, and how it should be done, as simply as possible. The manager should also state as comprehensively as possible, both verbally and in writing, the policies and procedures that relate to the plan so that whomever is doing the actual day to day operation may understand the guidelines and constraints for his efforts. This communication with the actual worker should provide a greater assurance that the plan itself will be understood, that the feedback will be relevant to the control process, and that, in case of unanticipated situations arising, this person will be able to determine an appropriate course of action to meet them.

No plan, no matter how beautifully developed, can be effectively implemented if the person who carries out the whole program, or any portion of it, is unaware of the total objective to be reached. For example, in implementing any plan for Shelta Cave, the office staff, as well as anyone else who directly or indirectly deals with the cave, should be told what is to be done, why it is to be done, and by whom and how it is to be done. This will limit the possibility of errors being made which could negate or lower the effectiveness of the monitoring system. The final step in the management process relies heavily on a comprehensive and effective feedback and monitoring system.

TESTING THE OBJECTIVE

I suggested earlier that the objective statement and its strategy plan derive from a hypothesis. In scientific inquiry, the statement of a hypothesis is tested against the results of the experiment developed to test it. The validity of the hypothesis is then proven or disproven or shown to be irrelevant, based on the resulting facts. This analogy is true

also with a management hypothesis.

Objectives are derived from principles which are valid in a given circumstance. Strategies derive from the objective constraints and are monitored by installing and evaluating control systems which provide feedback to the manager. At any point the feedback could indicate a change in the process which may render the objective impossible, impractical, obsolete or undesirable. In other words, the given circumstances are no longer the same and, therefore, the premise upon which the objective was based is no longer valid. If and when this happens, a new premise, valid for the current situation, would create a need for a revised objective statement and strategy plan. The process begins again.

Strategic management is a dynamic, on-going process, requiring constant testing of premises, policies, strategies and data, to assure that the manager's efforts are leading to a predetermined, valid objective.

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Wilderness Caves of the Northwest —A Method of Inventory

Newell Campbell* and James Chester**

ABSTRACT

Special problems in logistics, access, and hazards are involved in making an inventory of caves in wilderness and other isolated areas of the Northwest. Experience has shown that these studies can be made most effectively by following a certain sequence of procedures. These procedures are described and the caves of Glacier National Park, Montana are used as an example.

INTRODUCTION

The recent surge in recreational use of our nation's wilderness areas has led to a tremendous increase in wilderness caving. It is fast becoming necessary to make inventories of caves in these areas; inventories designed to assess the number, size and hazards and the environmental impact of increased cave use. This paper briefly shows how such an inventory can be made, and emphasizes a "quick survey" for the layman manager.

SPECIAL PROBLEMS

Studying caves in the wilderness or other isolated areas involves factors normally not prevalent in studies of more accessible places. The investigator is always faced with a logistics problem. Transporting vast quantities of scientific and other gear many miles to a cave is usually not feasible—at least not without the use of expensive horsepack trains and aircraft. Backpacking personal gear and food is difficult enough without adding caving and scientific equipment. Therefore, any wilderness cave equipment must be lightweight, portable, and easy to use in the field.

The caving season in wilderness areas is usually quite limited. High water from spring runoff, snow cover, and low temperatures restrict cave access to July, August, and September, except in special cases. Trips must be highly organized to accomplish a maximum amount of work in a minimum of time.

Cold water and cave air temperatures (32°-35°F) present a problem. The danger of hypothermia is always present. Rescue, in the event of an accident, would be delayed, difficult, and probably too late.

INVENTORY PROCEDURE

In view of the problem outlined above it has been found that wilderness cave inventories should include the following: 1. aerial reconnaissance; 2. exploration and mapping; 3. scientific observations; 4. assessment of environmental impact; 5. assessment of safety and hazards; and 6. formulation of recommendations and alternatives.

*National Speleological Society, Dept. of Geology, Yakima Valley College, 16th and Nob Hill, Yakima, WA 98902

**National Speleological Society, 410 East Aspen Street, Bozeman, MT 59715

Aerial Reconnaissance

The tremendous amount of effort required just to reach caves dictates that aerial observation be used whenever possible to locate caves, choose access routes, and eliminate large areas from ground search. Fixed wing flyovers using two or three *trained* observers equipped with binoculars, air photos and maps can quickly locate potential areas at a relatively low cost.

Exploration and Mapping

The start of any cave study must involve exploration and mapping. Extreme detail is not needed; compass and tape surveys along with sketches are adequate and can be carried out with a minimum of equipment. The finished maps should show both top and side views and point out special features such as pits, streams, and speleothems. Simplicity is essential.

Scientific Observation

As a minimum a geological, biological, and hydrological investigation should be part of the cave inventory.

Unique geological features, rock type, fossils, and kinds of speleothems should be noted.

The nature of the biospeleological environment and its relationship to organisms present must be ascertained. Where possible, study should be on-site, with a minimum of ecosystem disruption. Limited collections of cave life may be necessary to obtain precise identification. A search for possible endangered species must be made.

Water flow systems, water chemistry, dye tracing of springs, and checks for possible water contamination are important.

In all cases the report must be readable for the untrained, nonscientist cave manager. It should also contain sufficient data so that others can determine if more scientific research is needed.

Environmental Impact

A study of the possible effects of man's intrusion on the cave ecosystem should be part of the report. In most cases, due to low cave visitation, wilderness caves of the Northwest are not environmentally endangered. However, it should not be assumed that this will always hold true—each cave should be evaluated carefully.

Safety and Hazards

An important part of the survey should be to point out hazardous parts of the cave and indicate what equipment is needed and at what times of year the cave is safe to enter. It is *very* important to stress that an accident in a cold, isolated cave could easily result in a death. Most rescue units are not properly equipped for a wilderness cave rescue.

Recommendations

After reporting the results of the cave study, the investigator should make suggestions to aid cave management. Alternative forms of management, along with their expected consequences, would be most useful to the cave manager. The final decision always rests with the manager, but recommendations will assist him in setting up a program beneficial to all concerned.

GLACIER NATIONAL PARK—AN EXAMPLE

In 1975 two caves in Glacier National Park were "discovered" and partially explored by Park employees. Since no qualified Park personnel were available, the authors were asked to study the caves and make recommendations for their use. One of the caves is near a highway but is known to flood. The other is 5 miles from any road and contains a large stream with waterfalls.

The caves were visited briefly in 1975 and additional caves were discovered. An aerial flight was used to determine if other large caves or pits existed and to assess the overall cave potential of Glacier Park. Field work was continued in the summers of 1976 and 1977.

The caves were difficult to explore and map because of

high water, cold temperatures, and technical climbing problems. In 1977 exploration was completed and high quality maps were made. Cave photographs were added to supplement the maps.

One cave was found to have unusual fossils, the other associated with intense faulting and folding. Collections of cave life were made and returned to the lab for identification. Large bones discovered in the caves were field identified. A search for bats and other possible endangered species was made. The hydrology of the cave streams was studied, especially in regard to flooding. Water chemistry was determined and dye tracings attempted. A present and *future* assessment of man's impact on the caves was made and the caves were checked closely for vandalism. The effects of publicity and possible guided tours were considered.

Hazardous areas of both caves were noted, required equipment and special gear described, and general cave safety discussed. Possible rescue operations and procedures were proposed. It was recommended that one cave be left open to explorers but that a cave register be installed and monitored to ascertain visitation patterns. The other cave was to be gated to prevent access during the flood season and to protect important fossils from vandalism.

Results

The entire project took 15 field days to complete. Two large maps and a 20-page report were presented to the Park Service. As a direct result of the study, Glacier National Park now has a well-defined cave policy, scientific knowledge of its caves, control over sensitive parts of the caves, and a means to implement cave rescue should it occur. Copies of the report are on file in the Glacier Park Library at Park headquarters.

The New Melones Cave Evaluation Study: An Example of Management Implementation

Mark Grady* and Mike McEachern**

During the early part of 1977, the New Melones Cave Inventory and Evaluation Study was formed to locate, record, and assess caves which may suffer irreversible and irretrievable loss of significant data as a result of the construction of the New Melones Dam located in Calaveras and Tuolumne Counties, California. Due to the specialized expertise and facilities available through Southern Methodist University's Archaeology Research Program, the U.S. Army Corps of Engineers contracted with the university to implement this study.

In part an outgrowth of the New Melones Task Force of the National Speleological Society (Squire 1972) and the New Melones Cave Committee (Squire et al. 1975) the New Melones Cave Inventory and Evaluation Study was charged with:

- Inventorying the known limestone caves and identifying those with cultural remains and other scientific values.
- Evaluating the significance of the cultural and scientific values of the caves based on criteria developed for the National Register of Historic Places and the National Registry of Natural Landmarks.
- Suggesting reasonable alternative protective and/or mitigative actions for caves having significant values.
- Identifying the nature of project impact, including protective and mitigative actions for all caves within the project.
- Providing a priority listing which identifies, in descending order, those caves for which protective and/or mitigative actions are critical and those for which such actions may be temporarily deferred.
- Providing a set of cost estimates for protective and/or mitigative actions.

Prior to the initiation of field research, an open-ended survey form was developed for recording data for inventory purposes. The 5-page form included 32 major headings which were considered important in determining cave values and impacts for the Stanislaus River Karst Area.

The study, an interdisciplinary endeavor, required a broad-based research team consisting of both paid and volunteer cavers in addition to specialists in archeology, biology, geology, and paleontology. Due to the constrained time frame imposed by the scheduling of the study, it was impossible to have all personnel in the field at all times. Thus, it was often necessary for cavers and other specialists to make observations concerning a range of values during the initial visit to a cave. Caves which were judged to have significant values during the initial visit were then subject to one or more follow-up visits by individuals with additional expertise. Following this procedure, 87 caves were inventoried.

Once the field observations were completed, the task of defining significance was addressed. Eligibility to the National Registry of Natural Landmarks and the National Register of Historic Places is closely related to such concepts as uniqueness, rarity, restrictedness, representativeness, importance with respect to association with scientific discoveries, historical events, and other similar guidelines. For the National Registry of Natural Landmarks, the additional concepts of "scenic grandeur" and "essentially unspoiled" terrain also are important. These concepts may be developed for a particular cave or karst area by comparisons with similar environmental settings on local, regional, or pan regional levels. Thus, a cave may be judged biologically significant and eligible for the Registry based on the identification of a single unique or rare species. On the other hand, establishing scientific and research significance or potential research significance is usually more complex. This can be approached by developing a research framework or model and illustrating how evidence from a cave or karst area may refine or solve problems defined by the model or research goals. Once it has been established that the resource base is significant, then legal mechanisms are open to consideration of responsible conservation measures if that base is threatened.

In developing the significance of the New Melones caves in terms of the National Registry of Natural Landmarks, the entire karst, including areas outside of the project boundary, was reviewed. While many of the caves possessed previously undescribed biota, important paleontological deposits, and unique geological records sufficient for nomination to the Registry, the relative rarity of karst as a part of the regional landscape was considered of major importance in emphasizing the values found in the caves. Central Sierra Nevada karst is limited to small islands or pods separated by intervening areas of insoluble rock that not only isolate communities of cave-adapted biota, but make caves as a phenomenon rare. Accordingly the general lack of caves requires that those few caves which have significant paleontological and archaeological deposits be considered as extremely important data banks for the future. Thus, in the case of the New Melones Project, National Landmark significance was evaluated at a regional level as opposed to a site specific level, although site specific significance was necessarily developed for prioritizing protective and mitigative alternatives.

For the archeological caves in the New Melones Project area, significance was established primarily by documenting the research potential of the caves in the context of a set of research models developed by Moratto (1976:502-09) for open sites within the area. While the significance or uniqueness of the archeological caves could be established independent of the Moratto models, their use allowed the cave data to be integrated with research already proposed for the project area.

In evaluating the significance of individual caves for purposes of scheduling priorities, the following values proved most useful; archaeological, historical, geological, paleontological, taphonomic, biological, esthetic, and recrea-

* deceased.

**1404 Kirkwood Road, Austin, Texas 78722.

Figure 1. List of Archaeological Caves Based on Archaeological Significance Priorities (Most important sites at the beginning of the list).

| | |
|-------------|--------------|
| 1. Cave 010 | 9. Cave 059 |
| 2. Cave 018 | 10. Cave 003 |
| 3. Cave 025 | 11. Cave 032 |
| 4. Cave 005 | 12. Cave 056 |
| 5. Cave 047 | 13. Cave 069 |
| 6. Cave 046 | 14. Cave 024 |
| 7. Cave 048 | 15. Cave 036 |
| 8. Cave 078 | 16. Cave 007 |

tional. With the exception of taphonomy these values have been discussed at previous cave management symposia and need not be covered here. The study of the mechanisms and features of recent bone accumulations as well as interpretation of the modes of accumulation of buried assemblages fall into the realm of *taphonomy*, the science which concerns itself with all aspects of the transition from living to buried assemblages of organisms. Investigations of contemporary accumulations provide the factual basis for the science because the processes of accumulation and the responsible agents can be directly observed or readily inferred from evidence which is not usually associated with long-buried assemblages (e.g. scat, tracks, and vegetational features). Links can then be established between known histories of bone accumulation and features which are observable in paleontological deposits, where taphonomic research potential generally lies.

Returning to the subject of priority listing, a ranked list was compiled for each of the aforementioned values; the most significant caves were listed in descending order of significance. Thus, for archaeology the list displays the most valuable sites at the top and the less significant sites at the bottom (Figure 1). The same approach was taken for paleontology, biology, etc. Despite the somewhat subjective nature of the ranking, all highly significant caves fell at the top of the list while the less significant caves tended to be listed toward the bottom.

The seven ranked value lists were used to develop a table with the values listed across the top of the chart and the caves listed along the side (Figure 2). The number of values for each cave was totalled and then used to generate a multivalue matrix (Figure 3). In the matrix the number of values was listed across the top with the maximum number of values on the right and the caves within each column ranked in relationship to these values. Thus, the most valuable caves are on the upper right part of the matrix and the less significant on the lower left.

Once the criteria defining significance were developed and a relative ranking system generated, it remained to fit this framework to the management situation created by the New Melones Reservoir Project. This required defining how the reservoir project would impact the cave resources, and specifying one or more approaches for alleviating or mitigating this impact.

Much has been made in these symposia about the extent of ignorance about cave management. Whereas this is accurate, there is also a wealth of knowledge available in studying management procedures applied to other aspects of the cultural and natural environment. A basic tenet of these procedures is that responsible management is not reducible to a set of standards applicable to any situation at any time. Management involves the flexible application of

guidelines characterizing the most appropriate procedures known for conserving the resource base under consideration. It is cumulative in nature, project-specific, and involves not only the research potential of the data base, but the wise use of that data base for the overall public good as well.

In taking this perspective, we first directed our attention to the nature of project impact on the caves. Since no preinundation modification of the environment was slated for those areas of the reservoir within the Calaveras Formation, we did not concern ourselves with the ramifications of vegetation removal and other such activities. The direct impact of the project, then, consisted of flooding the karst area and the associated caves. Indirect impacts—those secondary consequences of reservoir devel-

Figure 2. Significance Values for the Caves within the Project Area (Geological values are incorporated within other positive significance categories)

| Cave | Positive Values | | | | | | Negative Values | | | |
|------|-----------------|----------|-----------------|------------|--------------------|-----------|-----------------|------|----------|---------|
| | Archaeological | Historic | Paleontological | Taphonomic | Biological | Esthetics | Recreational | Drop | Rockfall | Bad Air |
| 001 | | | | | | | | | | |
| 002 | | | X | | NA | | X | X | | |
| 003 | X | | | | | | | | | |
| 004 | | | | | | | | X | | X |
| 005 | X | | | | | | | | | |
| 006 | | | X | X | X | | X | X | | |
| 007 | X | | | | | | | | | |
| 008 | | | | | | | | | | |
| 009 | | | | | X | | | | | |
| 010 | X | X | X | X | | | X | X | X | |
| 011 | | | | | X | | | | | |
| 012 | | | | X | | | | | | |
| 013 | | | | | | | | | | |
| 014 | | | | | | | | | | |
| 015 | | | | X | X | | | | | |
| 016 | | | X | | X | | X | X | | |
| 017 | | | | | X | | | | | |
| 018 | X | X | X | ? | | | X | X | | |
| 019 | | | | | | | | | | |
| 020 | | | | | | | | | | |
| 021 | | | | X | | | | | | |
| 022 | | | X | | | | | X | X | |
| 023 | | | X | X | X | | | X | | |
| 024 | X | | | | | | | | | |
| 025 | X | | X | X | NA | X | X | | | |
| 026 | | | | | - Not applicable - | | | | | |
| 027 | | | | | | X | X | X | | |
| 028 | | | X | | X | X | | | | |
| 029 | | | | | | | | | | |
| 030 | | | X | | X | | | | | |
| 031 | | | | | | | | | | |
| 032 | X | | | | | | | | | |
| 033 | | | | | | | | | | |
| 034 | | | X | | X | | | | | |
| 035 | | | X | | X | | | | | |

Figure 3. Matrix of Cave Based on the Number of Types of Significant Values. (Most important cave on the right side of matrix)

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|-----|-----|-----|-----|-----|-----|---|---|
| 001 | 003 | 002 | 016 | 006 | 010 | | |
| 004 | 005 | 015 | 047 | 018 | 025 | | |
| 008 | 007 | 027 | 064 | 043 | 054 | | |
| 013 | 009 | 030 | 066 | 045 | | | |
| 014 | 011 | 034 | 073 | 050 | | | |
| 017 | 012 | 035 | 085 | 051 | | | |
| 019 | 021 | 037 | 023 | 052 | | | |
| 020 | 022 | 041 | 028 | 058 | | | |
| 026 | 024 | 072 | | 077 | | | |
| 029 | 032 | | | | | | |
| 031 | 036 | | | | | | |
| 033 | 046 | | | | | | |
| 038 | 048 | | | | | | |
| 039 | 056 | | | | | | |
| 040 | 059 | | | | | | |
| 042 | 060 | | | | | | |
| 044 | 069 | | | | | | |
| 049 | 071 | | | | | | |
| 053 | 076 | | | | | | |
| 055 | | | | | | | |
| 057 | | | | | | | |
| 061 | | | | | | | |
| 062 | | | | | | | |
| 063 | | | | | | | |
| 065 | | | | | | | |
| 067 | | | | | | | |
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| 081 | | | | | | | |
| 082 | | | | | | | |
| 083 | | | | | | | |
| 084 | | | | | | | |
| 086 | | | | | | | |
| 087 | | | | | | | |

opment—were more difficult to define. Two broad categories were ultimately isolated: the increase in land modification associated with the development and maintenance of reservoir-related facilities and amenities, and the increase in land use traffic as a result of the presence of the reservoir and its ancillary attractions.

All three of these effects would impact the caves in different fashions, thus requiring assessments and recommendations on a particularistic level. For instance, some of the consequences evaluated with respect to inundation took into account the projected results of flooding on cave values recognized for each cave, the point in the inundation scheduling at which that cave would be flooded, and whether partial, periodic, or permanent inundation would result. Reservoir facility development was viewed as requiring consideration of such factors as modification of surface drainage and ground cover, the introduction of pollutants and other extraneous materials into the cave ecosystems, and physical damage or weakening to the structure of the subterranean cavities proper. Increased traffic problems

were assessed in terms of the consequences of intentional or unintentional disturbance of elements of the cave environment by individuals, the potential for injury or death occurring, and other such criteria.

Once project-specific impact considerations had been generated, they were matched with the scheduling plans currently available from the Corps of Engineers. This allowed us to formulate a timetable for mitigating these impacts in an efficient and responsible manner. Again, mitigation recommendations were very particularistic, and were developed in accordance with the projected sequence of deleterious effects on the karst region. Such things as data study integration, for instance, were carefully evaluated in light of the known consequences of flooding on the direct impact zone. The biological studies deemed as minimally necessary before flooding occurred were scheduled to be achieved *before* any substantial archaeological or paleontological research took place in those caves where multiple values existed. Cumulative mitigation time on a cave-specific basis was matched against the flooding timetable in order to provide a realistic schedule of the sequence of study which should take place in those caves to be directly impacted. In addition, a long-term study of the effects of flooding on caves was recommended as an overall management objective.

Facilities maintenance and development considerations emphasized mitigation scheduling in terms of projected timetables for the construction and use of recreational facilities in the karst region, proposed components of these recreational facilities, and the locations of the areas set aside for actual land modification. Mitigation recommendations took into account the proximity of known caves to these facilities, the physical conformation of these caves, their hydrological setting, and their overall sensitivity to changes in proximal surface terrain.

The effects of increased traffic were dealt with in a somewhat different fashion. In most cases, protective recommendations were suggested that were commensurate with the most enlightened information available to us. These included suggestions ranging from restriction of information dissemination to proper cave gating and entrance monitoring. In certain other cases, specific recommendations were made for the conservation-oriented promotion of public use of certain caves. The latter proposals were deemed to be a useful approach to satisfying the marginal interest on the part of elements of the public toward active caving, while instilling in those individuals some indication of the fragile and nonrenewable nature of the cave resource base.

Although as of this writing the strengths and weaknesses of this management plan have not yet been assessed by the Corps of Engineers, and we therefore cannot yet divulge all of the particulars, we are of the opinion that the overall package represents a comprehensive and responsible step towards the integration of cave resources into an overall program of land use planning. As such, it should have some general applicability to other regions as a model of cave resource management. But we urge that the New Melones plan be used with extreme caution elsewhere. Although we have developed a set of management recommendations based on an informed concern for conservation of the karst terrain and associated caves, it is very much a regional proposal. Thus its applicability may be high in terms of being adapted to fit other settings in the western Sierra Nevada Foothills. But it must be kept in mind that responsible management plans are regional and project-specific in nature, and incorporate management concepts and guidelines in unique combinations that make the most

cumulatively beneficial use of conservation approaches to the cave resource base. We *must* avoid the trap of falling into rote perspectives on management simply to facilitate administrative procedures. Caves are by their very nature variable with regard to research potential, esthetic appeal, hazard, and any number of other recognized and unrecognized values. To the extent that appropriate management includes progressive attitudes towards conservation (which in turn is based on the ability to implement management-related research), a cook-book approach to cave resource management is the surest road to conservation stagnation.

We would like to close this discussion with an observation about the effective implementation of cave research. The New Melones project was a truly interdisciplinary research effort—individuals with various specializations worked *together* toward the solution of common goals. Yet it could not have succeeded to the extent that it did without the active involvement of “non-specialists”—cavers, to use the vernacular. From its inception a covert goal of this project was to prove that research and management objectives were most effectively achieved by combining the efforts of cavers as well as cave specialists. Avocational speleologists performed such critical activities as surveying terrain for previously unknown caves, rigging caves requiring direct aid, and in many cases doing all of the recording of observations needed for the evaluative studies. The logistic expertise and local background possessed by these

individuals made them at least as important to the project as those personnel recognized as speleologists by dint of education, and sometimes more so. We are in the hopes that this project will stand as a landmark to the demise of the myth that quality cave research must remain in the realm of research organizations alone.

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Cave Management on the Lincoln National Forest

Jerry L. Trout*

The Lincoln National Forest initiated a Cave Inventory and Classification System in 1971. Since then, the system has been refined several times and we believe it is now a sound working tool. The system is also currently being used by the National Park Service and the Bureau of Land Management in southeastern New Mexico. It is now incorporated in the Forest Service Manual as a Region 3 Supplement and will be used by all National Forests in Arizona and New Mexico. National Forests in other Regions have shown an interest in the system, and it may eventually be adopted Service-wide.

Basic data has been collected and 90 caves have been classified on the Lincoln National Forest. Based on these classifications, the Lincoln is in the process of developing an Action Plan for Cave Management on the Guadalupe Ranger District for the next several years. The following is an outline of the program as envisioned at this time.

A. Classification and Inventory.

1. The present classification system will be used.* Changes may be necessary, however, they will be minor and will not change the general concept of the system.
2. Infra Red Scanning will be conducted in the winter of 1977-78 to evaluate the Forward-Looking Infra-Red Scanner (FLIR) for cave location. The FLIR is mounted in a helicopter and potential cave bearing areas on the Bureau of Land Management, Carlsbad Caverns National Park and the Lincoln National Forest will be flown. The project will be funded jointly by the three agencies. The FLIR has been tested in mapping of fire for the past three years by the Forest Service Equipment Development Center in San Dimas, California. The project engineer feels that it can be used to detect caves under proper atmospheric conditions.
3. Cave Specialists for the Bureau of Land Management, National Park Service and the Forest Service will continue to work closely in the classification program. Exchange of work by the three agencies will continue.
4. The Regional Office and the Washington Office will be encouraged to provide additional emphasis and funding for Cave Management on the National Forest System lands. Close coordination with other land management agencies will be recommended to provide as much uniformity as possible.

B. Administration of Use.

1. Under the authority of existing regulations, 47 caves will require a permit to enter. The Closing Order has been issued by the Forest Supervisor and cave signing has started. The remaining caves requiring a permit will all be signed by September 1978.

2. Use of the more popular caves is excessive during peak caving periods. This excessive use is resulting in damage to these cave environments and in a low quality caving experience. Each cave will be evaluated to determine the maximum party size and number of visits over a given time frame. Evaluation will be based on limiting factors of each cave environment. The caving community will be involved in the development of these limits.
3. Training in cave administration will be provided to Forest Service employees engaged in other resource activities. Five patrolmen, recreation aids, and the lookout make a considerable number of possible contacts a cave visitor may have with people interested in caving. Providing these employees with training in Cave Conservation and our Cave Management Program will enable them to further the cave management program efforts.
4. The Cave Program is presently carried out by a part-time employee who works during the summer months and on weekends the balance of the year. Proper administration of the cave resource requires year-long attention, however, present financing is insufficient to provide a year-long Cave Specialist. But the work load in recreation, fuels management, wildlife and cave management on the Guadalupe could support another full-time professional employee. The district organizational needs will be evaluated in light of the total resource activities and an attempt will be made to provide adequate staffing to administer the Cave Management Program.
5. Gating is needed on several additional caves in the Guadalupe. The gating program has progressed rather slowly due to limited funding and the need to replace existing gates that are damaged or destroyed. Two gates will be installed during fiscal year 1978. The program will be accelerated in future years if additional funding is obtained.
6. Studies and mapping are needed for many of the caves to fully evaluate their contents. Over the years a wealth of information has been gathered by individuals, grottos, the Cave Research Foundation and others but much more is needed. The Forest Service has not provided adequate input into the study efforts of these groups. A listing of information needed by individual caves on a priority basis will be developed. These needs will be made known to individuals listed in the 1976 Cave Management Symposium Proceedings. Attempts will be made to finance the pressing research needs. A central data bank to file and retrieve information on studies which have been conducted is needed at the national level. The National Speleological Society should consider such a program and work with the various land management agencies at the national level to set up such a system.

* 1312 Chico, Carlsbad, New Mexico 88220.

7. The procedure for issuance of Cave Permits by the Bureau of Land Management and Forest Service for caves on the other agencies' lands will be finalized. A standard permit form will be used by both agencies. The Lincoln National Forest and the Roswell District of the Bureau of Land Management have been working on the procedure for approximately nine months. Several legal questions have not been resolved pertaining to liability and authority. The new Federal Land Management Policy Act and the National Forest Management Acts have not been fully interpreted and the required Secretary's Regulations issued. Finalization of the Permit System will depend on resolving these legal questions.

C. Cooperation between Land Management Agencies and the Caving Community.

1. The future of the cave resources on Public Land depends on the amount of cooperation between cave

managers and cave users. Great strides have been made since the First Cave Management Symposium. Even more is needed.

2. In the complex world of Public Land Management, no one user group will ever be completely satisfied with the management direction of the agencies. Through open communication between managers and users, the needs of the resource and the needs of the user can be fulfilled in many cases. I hope the spirit of cooperation which has been achieved through these symposia will continue into the future.

Cave Management Programs must be dynamic to respond to changing needs and increased knowledge of the action. The Action Plan I have outlined will no doubt be revised several times as we gain new insights in the field of Cave Management. Each of you has a responsibility in shaping future management of our public lands. The Forest Service welcomes your input.

A Cave Classification System

Jerry Trout*

This paper will deal with Cave Classification and its relation to the overall program of Cave Inventory, Interpretation, and Management as applied on the Lincoln National Forest, Natural Resource Lands in New Mexico, the Carlsbad Caverns National Park and the Guadalupe Mountains National Park.

I. INVENTORY

The inventory procedure consists of identifying individual cave locations, and, by exploration and study, noting each cave's contents, significance, hazards associated with exploration, and other specific information detailed in a set of guidelines. Uniformity of interpretation can best be accomplished by individuals experienced in caving, using a standard criterion.

II. CLASSIFICATION

The following classification system consists of two ratings, one for contents and one for hazards. It is not expected that any cave will "exactly" fit a category of this classification system, but experience in using the system in the past by the Lincoln National Forest, Guadalupe Ranger District, and the Carlsbad Caverns National Park has proven its worth.

For example, a Class III Cave need not necessarily have a vertical drop up to 15 meters, as long as the other general characteristics are descriptive of the cave. It may be necessary, particularly with large and/or extensive caves, to assign different classification ratings to separate areas within the cave.

All caves will have a two-code rating, such as C-II, one rating for content and one rating for hazard. A cave classification, particularly the hazard rating, should also reflect what a caver encounters to reach the cave, and should be explained under 'remarks' on the card. It is expected that a cave rating might change by the discovery of an item not previously known within the cave, or by the removal of an item responsible for that particular rating.

A. Content Ratings

1. CLASS "A" CAVES.

Caves which contain few or no items of scenic or scientific value. If any such items are present within the cave, they are of the type which cannot, without great effort, be destroyed or removed from the cave. Basically, a cave in which frequent visitation by any and all types of cavers will cause little or no change within the cave.

2. CLASS "B" CAVES.

Caves which contain secondary deposit-type formations of the ordinary type, such as stalagmites, stalactites, columns, flowstone, draperies, and rimstone dams, which are either of such size or are so positioned within the cave that they are not easily damaged and vandalized; or any items of scientific value which are of the type which cavers could not seriously disturb or destroy.

3. CLASS "C" CAVES.

Caves which contain secondary deposit-type formations of the ordinary type, such as stalagmites, stalactites, columns, flowstone, draperies, and rimstone dams which are either of such size, or so positioned within the cave that they are quite susceptible to breakage and vandalism; or any items of scientific value which are of the type which cavers could seriously disturb or destroy.

4. CLASS "D" CAVES.

Caves which contain formations that are of unusual quality or are very delicate and susceptible to breakage, even by well-trained and very careful cavers; or any items of scientific value which are of the type which cavers could seriously disturb or destroy. Examples of Class "D" Cave formations would be selenite needles, gypsum flowers, epsomite formations or crystals, cave helictites, etc.

5. CLASS "E" CAVES.

Caves which contain items of scientific value which could be seriously disturbed or destroyed by frequent visits, or by visits of uninformed cavers as to the item or items of scientific value, i.e., a biological species which has a delicate habitat, or is in danger of extinction in the area or within the particular cave. The items of scientific value could be either archaeological, biological, or paleontological in nature, or rare cave formations.

B. Hazard Ratings.

1. CLASS "I" CAVES.

The Class "I" cave offers the least hazard to the caver. Experience indicates that exploration should be conducted by no less than three cavers, who observe caving safety rules, and use the following basic equipment: hard hats, three light sources per person, boots with nonskid soles, and protective clothing.

The following are general characteristics of Class "I" caves.

- Single, well defined main passageway, with no lateral passages.
- No passageways less than 1 meter in diameter.
- No step-type drops over 1 meter.
- Stable ceiling rocks.
- Stable floor material.

*1312 Chico, Carlsbad, New Mexico 88220

2. CLASS "II" CAVES.

The Class "II" cave contains moderate hazards, and is mostly horizontal in structure. Experience indicates that exploration should be conducted by no less than three cavers, one of which is experienced, who observes caving safety rules, and uses the following basic equipment: hard hats, three light sources per person, boots with nonskid soles, and protective clothing.

The following are general characteristics of Class "II" caves.

- a. Well defined main passageways, with only dead-end lateral passages.
- b. Crawlways less than 60 centimeters (24 inches).
- c. No step-type drops over 3 meters (10 feet).
- d. Stable ceiling rocks.
- e. Stable floor material.

3. CLASS "III" CAVES.

The Class "III" cave contains structural hazards not found in Class I and II caves. Experience indicates that exploration should be conducted by no less than three cavers, two of which have moderate caving experience (including vertical descent and climbing), who observe caving and vertical safety rules, and use the following basic equipment: hard hats, three light sources per person, boots with nonskid soles, vertical descent and climbing gear, and protective clothing with no loose or protruding attachments which might become entangled while doing vertical work. Each caver should have a complete set of climbing equipment. (Note: Vertical equipment may not be needed in some Class III caves.)

The following are general characteristics of Class "III" caves.

- a. Multiple passageways, with straight connecting passages.
- b. Crawlways less than 60 centimeters (24 inches).
- c. Vertical drops up to 15 meters (50 feet).
- d. Unstable rocks on ceilings over 2 meters in height. Stable rocks on passages less than 2 meters in height.

4. CLASS "IV" CAVES.

Class "IV" caves are the most hazardous from the structural standpoint. Experience indicates that exploration should be conducted by no less than four cavers, all of whom have considerable caving experience (including vertical descent and climbing), who observe caving and vertical safety rules, and use the following basic equipment: hard hats, three light sources per person, boots with nonskid soles, protective clothing with no loose or protruding attachments which might become entangled while doing vertical work. Each caver should have a complete set of vertical equipment.

The following are general characteristics of Class "IV" caves.

- a. "Maze-type" passageways.
- b. Vertical drops over 15 meters.
- c. Unstable ceiling rocks on crawlways under 2 meters.

5. CLASS "V" CAVES.

Class "V" Caves are extremely hazardous due to characteristics, such as poisonous insects and/or reptiles, airborne diseases, dangerous gases, flooding, passages requiring cave diving, or any other hazard which requires special equipment to protect the caver. Class "V" caves should only be entered by qualified cavers, with special equipment, and only if there is a real necessity for information which is deemed valuable in relation to the risk involved. The minimum party should consist of six cavers, with two remaining in a supporting position in the event of an emergency. Extra precautions should be taken, and special communications and rescue capabilities available.

III. IDENTIFICATION.

A. Cave Number

Each cave shall be numbered following the guidelines set forth in Appendix A, Item No. 1.

B. Cave Name.

When a cave has an established name, this will be retained. In cases of a cave without an established name, one will be assigned, following the guidelines set forth in Exhibit A, Item No. 2.

C. Cave Marker.

A brass cap will be set at the entrance of each cave. The cave name and number will be stamped on the cap. (The National Park Service will use cave number only.)

D. Aerial Photos.

Cave locations will be pin-pointed on aerial photos. A separate set of photos will be maintained for this purpose.

E. Multiple Use Map Overlay.

Each cave will be plotted on an overlay, along with archeological sites. The overlay will be used as an administrative tool. Locations will be shown with a 3/16 inch circle. The upper half will be color-coded for hazard, and the lower half will be color-coded by contents. The last 3 digits of the cave number will be shown on the overlay.

IV. RECORDS.

A. Individual Cave File.

A file for each cave will be maintained separately from the regular files. The file should contain the following:

1. a. When found.
- b. By whom.
- c. Other people present.
- d. How located, etc.
- e. How and why named.
2. a. Map of area (topo), showing the location of the cave.
- b. Reference to the aerial photo, with the cave entrance marked by pinhole.
3. Directions for reaching the cave entrance.
 - a. Road log by tenths of a mile.

- b. Walking distance, both vertical and horizontal.
- c. Approximate walking time at an average pace.
- 4. Detailed description of hazards present within the cave and on the route to the cave entrance. Include recommended equipment and procedure for reaching, entering, and exploring the cave.
- 5. Detailed description of major features of the cave, including speleothems, biology, hydrology, geology, archeology, paleontology, etc.
- 6. Recommendations on type and amount of use restrictions.
- 7. Map of the cave. Plan view, vertical section, and all survey and computation notes.
- 8. Pictures showing the entrance to the cave, and at least the major areas and features of the cave. The photographer and date taken should be identified.
- 9. Significant Trip Reports.
- 10. Permanent record, listing date of each cave entry, and number of cavers on each trip for cave which requires an entry permit.

B. Coded Card File.

A 5 X 8-inch card will be maintained for each cave. Each card contains 24 elements, and is set up for ADP operations. The elements and codes are listed in the Appendix. The coded cards are filed in numerical order, based on cave numbers.

C. Alphabetical Card File.

A 5 x 8-inch card, with a blue band along the top, will be made for each cave, listing the cave name and number. These cards will be filed in alphabetical order, based on the cave name.

V. MANAGEMENT DIRECTIONS.

A. The U.S. Forest Service and the Bureau of Land Management will use the following:

1. **HAZARD CLASSES.**

- a. Class "I" caves will be left open to the public, with no restrictions.
- b. Class "II" caves will be left open. A sign stating the requirements for exploration will be placed at the entrance.
- c. Class "III" and "IV" will be gated when necessary and feasible. Entry will be by permit only. A sign stating the requirements and where to obtain a permit will be placed at the entrance.
- d. Class "V" caves will be gated when necessary and feasible. Entry will be by permit only. Permits will only be issued after the elements which classify the cave have been fully explained to the applicants. Applicants will have a sound justification for wanting to enter caves of this type.

2. **CONTENTS CLASSIFICATION.**

- a. Class "A" and "B" caves will be left open to the public with no restrictions. A sign stating that it is unlawful to damage cave formations will be placed at the entrance.
- b. Class "C" caves will be gated when feasible. Entry will be by permit only. A sign stating where the permit may be obtained, along with a sign stating it is unlawful to damage cave formations will be placed at the entrance. A Cave Conservation Handout will be part of the permit.
- c. Class "D" caves will be gated when possible. Entry will be by permit only. A sign stating where the permit may be obtained, along with a sign stating it is unlawful to damage cave formations will be placed at the entrance. A

| | | | | | | | | | | | | | | | | | |
|-----------------------|---|---|----|----|----|----|----|----|----|------------|-------------|----|----|---------------|----|----|----|
| CAVE# | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 2. CAVE NAME | | | | | | | | | | | 3. PHOTO # | | | 4. MASTER MAP | | | |
| 5. LEGAL LOCATION | | | | | | | | | | | | | | | | | |
| 6. GEOLOGIC FORMATION | | | | | | | | | | | 7. ALTITUDE | | | | | | |
| REMARKS: | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| INVENTORIED BY _____ | | | | | | | | | | DATE _____ | | | | | | | |

Cave Conservation Handout will be part of the permit. An agency employee will accompany the cavers to certain caves, and this requirement may be one of the permit requirements.

- d. Class "E" caves will be gated when possible. Entry will be by permit only. A sign stating where the permit may be obtained, along with a sign stating it is unlawful to damage cave formations, will be placed at the entrance. Permits will be issued only for bonafide scientific study by qualified individuals. (Similar to archeological permits). It may also be deemed necessary to require that a qualified agency employee accompany each expedition.

B. The National Park Service will use the following:

1. Classification and use of caves will be on the same basis as the Bureau of Land Management and the Forest Service.
2. Certain units of the National Park Service such as Carlsbad Caverns National Park, Mammoth Cave National Park, Guadalupe Mountains National Park and others have specific legislation which regulates entry into caves. In areas which have these constraints, the classification will be the same but entry to caves will be governed by legislation as outlined in the Code of Federal Regulations, Title 36, Chapter 1, or in the area's enabling legislation.

APPENDIX CODING KEY FOR CAVE CARD FILE

Item Number.

1. *Cave Number.* Each cave will be numbered as follows:
 - a. Agency initials.
 - b. State (use Post Office abbreviations).
 - c. Forest, Park, District, County, or other subdivision.
 - d. Cave number, starting with 001.
 - (1) A National Park cave located in the Carlsbad Caverns National Park would be numbered: NPS-NM-CACA-001.
 - (2) A National Forest Cave located in the Guadalupe Ranger District, Lincoln National Forest would be numbered: FS-NM-0803-001.
2. *Cave Name.* Assign name. Make sure name is unused. Some caves are already known by several names. In this case, the following is suggested for final name assigning:
 - a. Historic name or name given by first person discovering cave.
 - b. If 'a' is undeterminable, then use the name that is most descriptive of the cave, or the name that has the least hint to the topographic location of the cave.
 - c. List all "other" names on a separate card, with a reference to the final assigned cave name.
 - (1) List all other names under "remarks" on cave card.
 - (2) List all other names in the Cave File.
3. *Photo Number.* List the number of the aerial photo that the cave is pinpointed on.
4. *Multiple Use Map Overlay.* Indicate if the cave location has been plotted on the Multiple Use Map Overlay.

Y—yes.
N—no.
5. *Legal Location.* State, County, Township, Range, Section, $\frac{1}{4}$ of $\frac{1}{4}$ of $\frac{1}{4}$. For example: New Mexico, Eddy, T. 25 S., R. 22 E., Section 26, NE $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$.
6. *Geologic Formation.* Start with the formation the cave entrance is located in, and then the progressive formations encountered as one would move further into the cave.
7. *Altitude/Elevation of Entrance.*
 - a. Altimeter reading of 4,723 feet—A4723.
 - b. Estimated reading of 4,750 feet, using contours on topo map—E4750.
8. *Type of Cave.*

F—fissure.
L—lava tube.
P—pit only.
R—rock shelter.
S—solution.
T—talus.
9. *Number of Levels.*

1—single level.
2—two levels.
3—three levels.
4—etc.
10. *Dominant Rock Type.*

CO—conglomerate.
DO—dolomite.
GY—gypsum.
HA—halite.
IX—igneous.
TR—travertine.
LS—limestone.
MX—other metamorphic.
SH—shale.
SO—soil.
SS—sandstone.
11. *Type of Entrance.* Code as many as apply, starting with the "main" entrance.

L—large horizontal (10' x 10' or larger; or more than 100 square feet).
H—small horizontal (less than 10' x 10'; or less than 100 square feet).
V—large vertical (same as 'L' above).
S—small vertical (same as 'H' above).
B—side or bottom of sinkhole.
Q—quarry or road cut gives access.
12. *Number of Entrances.*

1—one.
2—two.
3—three.
4—etc.
13. *Length of all Known Passages.*

S1250—surveyed 1,250 feet.
A1400—approximately 1,400 feet.
14. *Pattern of Cave.*

S—single passage/room only.
P—pit only/no passages, or rooms.
R—rectilinear pattern.
D—dendritic pattern, bifurcating.
M—maze, boneyard, solution, anastomosed network.
T—trellis/joint control maze.
15. *Trend of Cave From Entrance.*

N24E—north 24 east.
S17W—south 17 west.
16. *Vertical Relief of Cave.* Highest ceiling to lowest floor.

S368—surveyed 368 feet.
A425—approximately 425 feet.
17. *Water Element.* Code as many as apply.

A—arid, no water.
D—dripping water.
F—flooded.
I—intermittently flooded.
L—lakes present (100 square feet of surface area, plus an average of at least 6 inches deep).

- M—moist earth.
P—pool present (less than listed for lakes above).
S—stream or river system in cave.
18. *Hazards Present.* Code as many as apply.
C—confusing passageways.
G—gases present.
L—loose rocks or cave-in hazard.
V—vertical drops.
W—water with no alternate route.
P—poisonous insects and/or reptiles.
F—flooding.
I—intermittent flooding.
N—none.
19. *Specialized Skills Required.*
C—technical climbing.
D—diving (scuba or air hose).
- R—rapelling, prusiking, cable ladder climbing, etc.
S—swimming requiring wet or dry suit.
N—none.
20. *Cave Contents.* Code as many as apply.
A—archeological (artifacts).
B—biological (organisms).
G—geological (structural, hydrological, genetic).
H—paleontological (fossils).
S—speleothems.
N—none. Cave, shelter or sink or no special attraction or significance.
21. *Type of Protection Needed.*
F—Fence.
G—Gate.
H—sign concerning hazards.
- S—sign concerning protection.
P—permanent closure (dynamite, etc.).
R—remote monitoring.
N—none.
22. *Type of Protection Provided.*
Same codes as Item 21.
23. *Cave Marked at Entrance with Brass Cap.*
Y—yes.
N—no.
24. *Dual Classification Coding.*
Contents—A, B, C, D, or E.
Hazard—I, II, III, IV, or V.
- NOTE:* '0' in any entry indicates—does not apply.
* in any entry indicates—See description under remarks.

A Study of Visitor Tour Preferences at Lewis and Clark Caverns

Stephanie Gilbert*

INTRODUCTION

Lewis and Clark Caverns State Park lies in the London Hills along the Jefferson River about midway between Butte and Bozeman, Montana. The caverns were first preserved as a National Monument then later turned over to the State of Montana in the 1930s to start the state park system. The park is currently owned and managed by the Recreation and Parks Division of the Montana Department of Fish and Game. The caverns, while not significant with respect to size, are purported to be among the most beautiful limestone caves in the Northwest.

Guided tours, in some form, have been conducted through the caverns since the turn of the century. During the 1930s, the Civilian Conservation Corps made the first major contribution to the development of the park facilities, including the entrance road, visitor center, tour trails, and electric lighting system in the cave. A concession building and a train and tram transportation system were added to the park after World War II. From then until 1973, the tour format and content remained essentially unchanged.

In August of 1973, the tramway that carried people up to the cave entrance became inoperable. This circumstance prompted an investigation into an alternative mode of transportation as well as new methods for interpreting the Caverns. It was long suspected that the tram constituted a classic case of the *interpretive gadget* overshadowing the principal park feature. Not only was the tram ride the most memorable part of the tour for many visitors, but it set a *vaudeville* or fantasy mood for the tour. (Memorable does not necessarily connote positive feelings in this case.)

In the summer of 1974, Daniel P. Vincent, caverns employee and a masters candidate in outdoor recreation, undertook a study of visitor attitudes and preferences at the park. The study focused on three areas of visitor preferences: 1) mode of transportation to and from the caverns, 2) interpretive methods used on the tour, and 3) informational content of the tour. Based on his findings, Vincent made a set of recommendations for improving recreational services at the park. This paper discusses Vincent's study and recommendations and follow-up studies conducted to determine the success of the recommended changes.

All 3 years of preference surveys used a self-administered questionnaire. The questionnaires were given to all visitors 12 years old and up taking the self-guided tours, as well as adults on randomly selected guided tours. A response rate of 98 percent was maintained throughout the study. In my talk today, I will generally omit references to specific data or statistical manipulations, and will confine my remarks to reporting the verbal findings.

* Lewis & Clark Caverns, P.O. Box 10024, Three Forks, Montana 59752

**This variance between first-time and return visitors was prevalent throughout all segments and years of the study. The repeat visitors were consistently less satisfied with the operations and more strongly bent on maintaining the status quo.

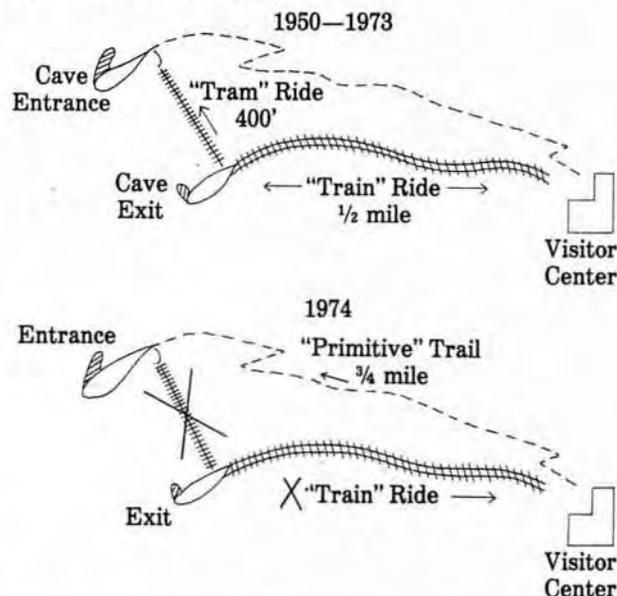
MODE OF TRANSPORTATION

The section of the study relating to the mode of transportation is fairly site specific. However, it has some interesting ramifications that may relate to the paper on access design to be given later in the symposium. (See page).

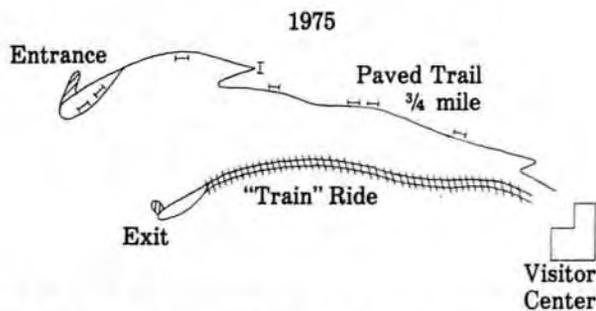
Prior to the demise of the tram, visitors rode a *train* from the visitor center to the cave and then rode a tram 300 vertical feet up to the cave entrance (see illustrations). They walked three-fourths mile through the cave on a 90-minute guided tour and rode the train back to the visitor center. During the first year of the study, the tourists walked from the visitor center up an unimproved foot path 0.75 mile to the cave entrance, took a tour, and rode back to the visitor center on the train. There was sufficient interest in the walk, even in that primitive state, to warrant further investigation. So, by the second year of the study, the trail to the cave entrance was widened, paved and equipped with well-spaced benches. The third season saw the addition of interpretive signs to the trail, but also saw the loss of the return train ride. The tour then was completely on foot, 2 miles in length and approximately 2 hours in duration.

Throughout the 3 year study, the visitors were questioned as to their enjoyment of the walk and their preference for mode of transportation. In the initial year, the first-time visitors derived greater enjoyment from the walk and expressed stronger preference for walking than did repeat visitors.**

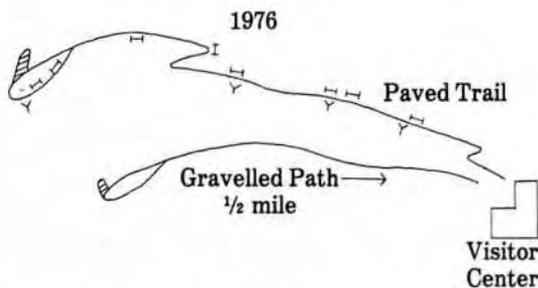
Although visitor preference generally leaned toward riding, most visitors enjoyed the walk over the primitive foot path. Based on these findings, the Department of Fish and Game decided to upgrade the trail and continue to survey visitor preference.



1974—Train and tram ride to entrance replaced by a primitive 3/4 mile path. Return to visitor center by train.



1975—Trail to entrance widened and paved; benches added. Return to visitor center by trail.



1976—Interpretive signing added to upper trail. Train discontinued; rail bed gravelled for 1/2 mile walk back to visitor center.

This proved to be a wise decision. The results of the 1975 surveys showed visitors favored walking over riding. The preference for walking was even more pronounced by 1976 despite the additional 0.5-mile walk back to the visitor center. The success of the walking tour was a function of the attractiveness of the trail, lowered visitor expectation to ride, renewed interest in nature as well as physical fitness, and simply a passage of time.

As an offshoot of the study, Vincent noted that tourists taking the self-guided tours enjoyed the walk to the entrance more than the tourists who were escorted by a tour guide. He inferred that the visitors enjoyed the walk more if they could pace themselves rather than being herded at an *average* pace. Vincent therefore recommended that the tour begin at the cave entrance with the tourists walking up the trail at their leisure and meeting the guide at the entrance. Chaos was minimized through the use of a phone connecting the entrance area with the ticket seller and guide force at the visitor center.

* One member of the Symposium audience rightly questioned the validity of the transportation survey because only those visitors who took the tour were surveyed. In 1976, we conducted a survey of people who came to the visitor center and did not take a tour. Those not taking the tour amounted to less than 3 percent of the total visitors in the period surveyed. Of this 3 percent, 1.3 percent did not take the tour because of the length of the walk; 0.9 percent, lack of time; and 0.8 percent, a variety of reasons ranging from inclement weather to no dog sitting service. Of course we have no way of surveying those people who know about the long walk and, as a consequence, do not come to the park. Ticket sales dropped 16 percent between 1973, the last year of the tram, and 1974, the first season of walking and also the worst summer for gasoline shortages. Since 1974, the park has had a steady increase in visitation and has surpassed the 1973 base figure.

Two other interesting items were noted by long-term seasonal employees. One was that visitors were more willing to take the tour in inclement weather when they walked as opposed to when they rode to and from the cave. The other was the phenomenal drop in stretcher cases in the cave. According to several employees, a visitor had to be carried from the cave once every 2 or 3 weeks when the tram was operational. To date, only one visitor has been carried out of the cave since the loss of the tram—through four seasons. The walk to the entrance has served to weed out those who should not physically be on the regular tour.

The park ran a special short tour for the elderly and the handicapped before the train was taken out of operation. These visitors were carried by train over to the cave exit area where they had a flat walk into the last room on the tour, which so happens to be the largest and most spectacular room on the tour. The park has temporarily suspended these tours because of litigation involving the old train and tram system. The tours will be resumed upon settlement of the lawsuit and installation of a suitable transportation system for these special visitors.*

INTERPRETIVE METHOD

Three interpretive methods were tested in Vincent's study (1974 only): guided tour, self-guided tour with tape-recorded message, and self-guided tour with guides stationed along the trails. Descriptions of the tours are quoted from Vincent's thesis.

"The guided walking tour is the one method that had been used at the caverns since the first tours were made available to the public many years ago. On this tour, the guide led his group through the caverns on a predetermined route, stopping at certain locations to give interpretive speeches. The information disseminated was in the form of a prelearned recitation.

"One self-guided tour method employed the stationing of guides along the cave trail at strategic locations. Their task was to meet and mingle with visitors and discuss and answer questions about cave history, ecology, geology, and fantasy as the visitors walked through the cave at their own pace.

"The other self-guided tour method used taped interpretive messages. Tape recorders were given to each party when they purchased tickets and collected after the tour as they boarded the train. In addition to the tapes, four guides were stationed along the trail to answer questions and maintain surveillance."



View of Paradise Room in Lewis and Clark Caverns. Photo by Stephanie Gilbert.

The strengths and weaknesses of each method were thoroughly researched and discussed as part of the thesis study. Visitors were surveyed as to their satisfaction; the answers ranged from very satisfied to undecided to very unsatisfied.

As expected, most visitors were in the satisfied or very satisfied categories with all three methods. However, analyzing the extremes in responses, it appeared that the guided tours were significantly more satisfying to visitors than were either self-guided tours. Between the self-guided tours, the tape recorded messages were better accepted than the stationed guides. (Perhaps that had something to do with the discomfort of the guides.)

Vincent recommended that guided tours be continued at the caverns for the immediate future. He further recommended that research be continued on other interpretive methods, as the increased visitation at the park may make it difficult to maintain a high quality on the guided tours.

Both recommendations were taken. The park has maintained the guided tours and has launched on some new interpretive planning. The plans include better signing along the trail, a more complete brochure, and new visitor center displays focusing on the cave environment and speleology. These plans will hopefully come to fruit prior to the 1978 season.

The time is fast approaching when management is going to have to choose between several options for dealing with the peak season crowds. Some of those options are: a lower quality *rushed* guided tour, a partially automated tour, or a limit to the number of tourists handled in any one period.

INFORMATIONAL CONTENT

As we move into the final topic of study, informational content, let me mention that Lewis & Clark Caverns are the only commercial or show cave operations in the state of Montana. Consequently, the management does not have to be concerned with what the competition is doing.

To assess visitor preference for informational content, Vincent had a single tour guide present five separate tours ranging from almost exclusively fantasy to predominantly factual (i.e. scientific and historic) tours. Fantasy in this instance refers to a running patter of humorous comments, puns, and jokes primarily aimed at the adult visitors. The guide was allowed to vary from his memorized texts to answer questions only.

Again, the visitors seemed fairly well satisfied regardless of the content. However, the visitors were *most* interested in the tours that contained a majority of scientific and historic information.

From this segment of the study, Vincent recommended that the tour format be revised to include more factual information. He further suggested that a more extensive training program be undertaken for the guide force.

Subsequently, management made an extra effort to amass the most current scientific information about the caverns and made this information available to the guides—a never-ending process. A preseason guide training session was organized and a training manual written.

Through the next summer, both the tour guides and the returning tourists were gradually weaned from the fantasy-oriented tour to the factual. By the 1976 season, the tours were running about 95 percent factual information, most of which was scientific (something like a lab lecture). The follow-up survey showed that the tours still pleased over 80 percent of the tourists but that the tours were a bit shy in both the historic and fantasy areas.

The history associated with the caverns is quite a muddle and a not very interesting one at that, so that we've been unable to expand the tour content along those lines. The park has taken the cue, though, for historical topics in our campground evening programs.

To deal with the fantasy interest without going overboard, the management reorganized the guide training. Emphasis was placed on two areas: an appreciation and understanding of the caverns and responsiveness to the visitors. No set tour was memorized, but a core of basic factual information was given somewhere on the tour. The manner and timing of presentation was left up to each guide.

The guides were encouraged to individualize their tours, not only to suit their personality but also to suit the particular tour group. (It seemed to take a new guide about two weeks to become familiar enough with the cave and the scientific data to be really flexible with the tour group.)

Much to my chagrin, no surveys were run this past season to assess the success of this method of guide training and content flexibility. The results might have proved very interesting as our guides ran the gamut from educational presentations to tongue-in-cheek *alternative* theories. It is my hope that this individualized type of tour will enhance the mass educational nature of our new displays, brochures, and signing for the coming season.

In closing, let me mention that absolutely no demographic data was collected in this series of study, other than to separate first-time visitors from returning ones. Since our visitors come in a mixed bag, neither Vincent nor myself deemed it necessary to separate visitor preferences by age, sex, income level, or geographic area. It was interesting to note that the first question asked by the interpretive planning team was the demographic profile of our visitor. We hope we provided them with something better.

The Management of Horsethief Cave

Roger D. Inman*

BACKGROUND

The Horsethief-Bighorn Cave System is located in Little Mountain, approximately 14 miles northeast of Lovell, Wyoming. Little Mountain is a minor anticline radiating from the Bighorn Mountains. The cave system straddles the Wyoming-Montana border adjacent to the east side of Bighorn Canyon.

The Horsethief-Bighorn Cave System presents several unusual management situations because of its two known entrances, the physical connection between the caves, its location in two states, and its management by two different government agencies.

The entrance to Horsethief Cave (Figure 1) is located a few feet south of the Wyoming-Montana border and is managed by the Bureau of Land Management (BLM). The entrance to Bighorn Caverns is in Montana, a few hundred feet northeast of the Horsethief Cave entrance and is managed by the National Park Service. A connection between Horsethief Cave and Bighorn Caverns was discovered about 1968. The connection was not publicized and was plugged with concrete by cavers. Although other connections have been rumored, none have been documented. For practical purposes, therefore, Horsethief Cave and Bighorn Caverns are being managed as separate entities. The caves each provide different cave experiences. Bighorn Cavern is a dry cave with a vertical entrance requiring ropework and Horsethief Cave contains many wet formations and has a long crawlway for an entrance.

Prior to 1970, Horsethief Cave was thought to be insignificant. In October 1970, with the discovery of Denise's

Crystal Crawl, the cave was found to be sizeable. By April 1977, some 26,700 feet of passage had been surveyed and mapped. This represents less than half of the known passages. Members of the Vedauwoo Student Grotto of the National Speleological Society have discovered, surveyed, and mapped most of the passages.

As the known areas of the cave increase, the cave becomes more nationally significant in terms of size. Horsethief Cave is also considered by many to be the most decorated cave in Wyoming and Montana with many fragile and interesting formations. The wild, natural condition of the cave, the opportunity for surveying and mapping, the potential for discovery of passages and the many interesting formations combine to make Horsethief Cave an important recreation resource.

Although the cave is remote and sometimes difficult to reach, the BLM records about 500 visitors per year. This figure is undoubtedly low since the general public can traverse the first 1,000 feet of the cave without obtaining a permit or entrance key. The major single user of Horsethief Cave is the National Outdoor Leadership School of Lander, Wyoming. The school offers caving classes in its curriculum and utilizes the cave several times a year. Members of various regional grottos of the National Speleological Society also regularly utilize Horsethief Cave.

MANAGEMENT

The BLM recognizes Horsethief Cave as a frail and irreplaceable resource. Significant hazards to public safety are also present. Locking up the cave to protect the cave and public would have been justifiable. However, the cave also contains many challenges and rewards that make it attractive to speleologists and cavers. The BLM has adopted a policy of allowing recreational use of Horsethief Cave so long as it is not detrimental to the cave's ecosystem. Horsethief will remain as a wild cave with no improvements, modifications or commercialism.

It must be remembered that many caves are controlled by managers who have no knowledge of caves or interest in caving. To aid managers in making decisions about cave management, information must be systematically and reliably documented. An accurate picture of what is in a cave is essential to making management decisions. After several coordination sessions, the local BLM and Park Service offices adopted a common set of criteria for hazard and resource inventories to be used in the Horsethief-Bighorn Cave System.

The BLM has hired temporary cave rangers for the past three summers to perform inventory work and conduct studies in Horsethief Cave. The cave rangers have been members of local student grottos with a good knowledge of Horsethief Cave.

Hazard inventories identify such things as dust conditions, unstable ceiling rock, maze passages, high dropoffs and pits, radiation and other possible hazards to visitors. This does not mean that all hazards to cave visitors must be identified or eliminated. Caving is recognized as a hazardous activity,



Figure 1. The entrance to Horsethief Cave, a few feet south of the Wyoming-Montana border.

*Area Manager, Shoshone Resource Area, Bureau of Land Management, Worland, Wyoming

and the BLM does not have a responsibility to protect cavers from all dangers. However, we do attempt to advise them of potential hazards they may encounter.

The resource inventories identify cave decorations, frail or unique characteristics, areas with high susceptibility to damage, and areas which have been vandalized or damaged. Horsethief Cave contains many frail and unusual formations which require careful cataloging. Damage and vandalism have been negligible.

All inventory information is tied to the cave survey system. With this information, the cave has been divided into zones based upon common characteristics. Cave visitors can be informed of unstable areas, maze passages, dust conditions, radiation hazards, constricted areas, restricted areas and closed areas by use of zone designations.

Because of the tightly constricted crawlways the caver must pass through to get to most of the cave, very few novice cavers enter the cave beyond the crawlways without experienced companions. These crawlways have been a definite factor in maintaining the high quality of the cave beyond (Figure 2).

Horsethief Cave is gated about 1,000 feet beyond the entrance in a narrow crawlway (Figure 3). In order to enter the cave beyond this point, the visitor must obtain a key from the Worland district office of the BLM. The visitor must fill out an application to enter the cave and assume the risks associated with cave use. The waiver system is set up to be used through the mail, if necessary. No fee is charged for the use of the cave except for commercial use such as the National Outdoor Leadership School. No guided tours are given. A limit has been set on the number of visitors per year based on past use and groups entering the cave are limited to a maximum of eight people. We also request at least one experienced caver be in the group. This has been done as a conservation measure until more is known about the cave and the effects of visitor use.

The caver's equipment and experience is checked and he is advised of hazards, restrictions on travel within the cave and checkout procedures. A small handout map is given which shows the zones referred to in the hazards information. This map is not of sufficient scale or detail to provide more than a general outline of passages. No other



Figure 2. The tightly constricted crawlways have been a definite factor in maintaining the high quality of the cave beyond.



Figure 3. Horsethief Cave is gated about 1000 feet beyond the entrance in a narrow crawlway.

maps are distributed, thus preserving the wild cave experience. The checkout procedures inform the BLM when the cavers are safely out of the cave. Failure to comply with the checkout procedures will result in denial of future use for the violator. If the visitor does not comply with the restrictions, it will also result in the denial of future access to the cave. A post-use questionnaire must also be returned and is used to determine the area of the cave visited and the radiation exposure. The radiation zones are marked in the cave by small red signs placed in the passageways. Since we do not have the manpower for close supervision, our cave management program relies heavily on the integrity of the cave visitor, which has—to date—been commendable.

Failure to check out is usually the first indication of a lost or injured caver. The first effort is directed at telephoning to see if the caver is safe and failed to follow checkout procedures. If no contact can be made, the county sheriff will be notified and search efforts will be initiated. Extended search efforts will rely heavily upon volunteers from the local grottos and communities who have generously offered their assistance. If injuries have occurred, the method of rescue will depend upon the location of the injured caver and the type of injury. The same constricted crawlways which provided protection to the frail resources of the cave become a formidable obstacle if a caver becomes injured. To date, no serious injuries and only two lost caver incidents have been reported.

To establish a form of control on our management plan, we have established permanent photographic monitoring points. These permanent points are photographed and analyzed at least annually to evaluate the effects of visitor use on the cave. These photographs will aid in detecting damage and changes to the cave ecosystem and establishment of optimum visitor-use levels. The photomonitoring system has been in use for three years.

OTHER FACTORS

Future management may be affected by several outside factors. One factor is that some of the Horsethief Cave System extends into the Crow Indian Reservation in Montana. These reservation lands are presently administered by the National Park Service as part of Bighorn

Canyon National Recreation Area. By an informal arrangement, the BLM manages all of Horsethief Cave and the Park Service manages all of Bighorn Caverns.

Archeological and paleontological deposits have been discovered in Horsethief Cave and may further influence management. These have not been fully evaluated and test excavations are needed to determine their significance.

Mining operations could also be a factor in future management. The public lands in the vicinity of Horsethief Cave are covered with mining claims located under the General Mining Law of 1872. Uranium has been mined from the area in the past and exploration activity is continuing. Withdrawal of 448 acres around the cave from further entry under the general mining laws is being considered by the BLM. Any withdrawal would be subject to valid existing rights and therefore would not terminate any of the existing mining claims without due process. Withdrawal would preclude the location of additional mining claims.

SUMMARY

In summary, the Worland district of the BLM is managing Horsethief Cave as a wild cave. Recreational caving is allowed so long as it is not detrimental to the cave ecosystem (Figure 4). Entrance to the cave is on a permit basis. Failure to follow the permit procedures will result in the denial of

future cave use. As a conservation measure, visitor use is limited to a level based upon historic use. Future management will be determined as a result of studies which are now being conducted.



Figure 4. Recreational caving is allowed so long as it is not detrimental to the cave ecosystem.

Cave Management at Buffalo National River: The Beginning

M.R. Fletcher*, L.L. Mintzmeyer** and K. Whizenant†

ABSTRACT

Buffalo National River is located in North-central Arkansas and has long been known as a significant karst area. Caves have been used for a wide variety of activities ranging from moonshine manufacture to garbage disposal. Upon completion of land acquisition, the National Park Service will manage many caves with significant speleological resources, several species of endangered animals and significant archeological and paleontological sites. Research on cave location and preliminary classifications for values and hazards began in the spring of 1977 under a contract with the Cave Research Foundation. This paper discusses current and future research activities and the general framework of cave management for the future at Buffalo National River.

INTRODUCTION

Buffalo National River in North-central Arkansas was created by an act of Congress in 1972 to preserve one of the most beautiful free-flowing rivers in the United States. The area was created primarily as a recreation area, although its natural and cultural resources are substantial features which must be considered and managed. In addition to its scenic beauty, the area has long been known as excellent cave country and many caves were known along the river prior to its acquisition by the National Park Service (NPS). The NPS has realized the problems associated with cave management since the beginning of land acquisition but limited staff and more pressing priorities have taken precedence over actual cave management. Furthermore, at this writing, there are still many caves in private ownership which have not yet been acquired or examined by the NPS.

In the spring of 1977, the NPS contracted with the Cave Research Foundation (CRF) to do a preliminary survey of the caves under NPS management along the nearly 100 miles of river. The contract called for a survey of the known caves with both hazard and value classifications for these caves, a preliminary biological survey, and cave management recommendations. Currently, there have been 27 caves examined by the CRF and preliminary biological investigations have been initiated in 18 of these.

IMMEDIATE NEEDS

Two areas of concern come immediately to mind: the protection of endangered species and the protection of visitors. After the preliminary classification is completed, there must be a survey for both Indiana and Gray Bats which inhabit the caves along the Buffalo. These species are currently on the Fish and Wildlife Endangered Species List and another species of bat (Ozark Big-Eared Bat) is

currently being considered for protection under the Act. Bat Cave near Boxly, for example, is reputed to contain a substantial number of Indiana Bats in winter months but the cave has not yet been acquired by the NPS. Depending on the results of this survey, caves or sections of caves may be closed to all entry during certain times of the year. In addition, the biological survey being conducted may well reveal other species which are threatened or endangered. For example, the Cave Salamander, although not particularly uncommon in the area, must be afforded some protection.

Secondly, there must be some form of protection provided to the visitors to the caves on the river. In order to accomplish this, mapping must be completed on all known caves. It would be foolish to issue a permit for a party of novice cavers and not have maps of the cave they intend to visit. The hazard and value classification developed jointly by the BLM, U.S. Forest Service and the National Park Service will be used extensively for management purposes. The hazard classification is also designed to act for the protection of cave visitors. The tragic death of a young man in 1976 in Bat Cave reaffirms the need of the NPS to be assured that cavers who do vertical work in the caves in the Buffalo National River at least have the proper clothing, equipment, and attitudes.

Cavers are among the most individualistic of groups and frequently resent attempts to regulate their activities. However, the NPS has a strong commitment to visitor safety and must insist that proper precautions be followed in cave exploration. Besides the standard caving gear such as light sources, helmets, proper footgear, and so forth, everyone must have their own set of vertical gear and will be required to present this gear for inspection and demonstrate the use of it before they will be issued a permit to visit a cave requiring vertical work. As cavers become known to the park staff, the requirements for presentation of vertical equipment may be relaxed to some extent.

CAVE ENTRY

The NPS has received many inquiries regarding cave entry. Many ask, "Will permits be required for all cave entry?" For the foreseeable future, yes. Trip reports will be required, as well. However, future surveys may well reveal caves that have no significant physical hazards and no

* Regional Biologist, NPS, Southwest Region, Box 728, Santa Fe, N.M. 87501

**Superintendent, Buffalo National River, Box 1173, Harrison, AR 72601

† Resource Management Specialist, Buffalo National River.

particularly outstanding geological or biological values. In this case, some caves may, at a later date, be designated as general public use caves and could be visited by novices with little hazard to them and little damage to the resources. Some method of transmitting a strong conservation message must still be developed.

A number of inquiries have been received regarding Fitton Cave. This cave is well known as one of the largest and longest in Arkansas and has been under private ownership and strict protection for the last few years. One common question is, "Will the NPS offer guided tours of Fitton Cave?" Perhaps, in the future; however, there are a number of problems. First, there is some question as to whether or not Fitton should be opened for regular visitor use. There are numerous commercial caves in the vicinity; Blanchard Springs Cavern a short distance away, for example, has extensive development and excellent interpretation. Second, the configuration of Fitton Cave would make it extremely difficult to conduct tours without extensive modification of the cave. Third, extensive damage has occurred to the unique features of the cave in the most logical areas for cave tours. Additionally, although radon standards for caves are being worked on, the levels in Fitton would require monitoring of personnel who work in the cave and a substantial commitment of equipment and training to maintain a monitoring program.

Another question commonly asked is, "Will the NPS issue permits for groups to visit Fitton Cave and, if so, what will be carrying capacity for the cave be on any given day?" There are, as yet, no complete maps for Fitton Cave and maps that do exist either contain substantial errors or are incomplete. This could be an area where serious, competent cavers could be of significant assistance to the Park and have an opportunity to utilize their caving and mapping skills. Mapping of the numerous caves on the Buffalo will be an ongoing project for many years. Individuals and groups who can produce accurate maps will be encouraged to practice their skills. The matter of determining a carrying capacity for Fitton Cave will have to wait until more information has been gathered. Preliminary estimates indicate that somewhere between 25 and 40 persons could use the cave at one time; however, much remains to be done before this figure can be quantified.

FUTURE AND LONG-RANGE CONSIDERATIONS

Although the extent and values of the caves along the Buffalo are currently unknown, preliminary NPS estimates run as high as 60 caves with over 100,000 feet of passage. Future management of this resource will be shaped by the mandates and policies of the NPS. Although incomplete in many facets, the general policy of cave management in the NPS is as follows:

"The National Park Service will manage caves for the perpetuation of their natural, geological and ecological conditions, and historic associations.

Developments such as artificial entrances, enlargement of natural entrances, pathways, lighting, interpretive devices, and excavation of elevator shafts are permissible only where necessary for general public use when such development will not significantly alter conditions perpetuating the natural cave environment or harm historic resources. General public access by tours of suitable duration and interest will be limited to a representative sample of a cave.

No surface development above caves will be undertaken which would significantly alter natural cave conditions in-

cluding sub-surface water movements. Caves, or portions of caves, may be closed to public use or restricted to access by conducted tours when such actions are required for human safety and the protection of cave resources. Caves, or portions of caves, may be managed exclusively for research and access limited to approved research personnel."

From: Management Objectives of the National Park Service,
July, 1975.

These, then, are the general guidelines and framework which will shape the management policies for cave use at Buffalo National River.

There are several long-range projects that should be undertaken at Buffalo National River that could very well include the cooperation of both "sport cavers" and professional speleologists. First, the mapping of the caves along the river is a long-term project that the NPS has neither the expertise available nor the manpower to accomplish the task. This project could be "farmed out" to various interested speleological groups such as grottos of the National Speleological Society, the Arkansas Association for Cave Studies, the Cave Research Foundation, or others. Second, a photographic record of formations in selected caves from carefully selected photo points could provide a visual record of vandalism, speleothem removal, and other factors which could lead to the degradation of the cave resources. These base-line photographs will be invaluable in the future. Third, competent cave biologists will be needed to assist in the survey of cave life on the Buffalo. Some excellent preliminary work has been accomplished but much remains to be done. Fourth, there are significant cultural values associated with caves on the river. Although amateur archeologists have poked around in shelter caves on the river, no complete survey of the archeological or paleontological values has been accomplished. Fifth, although a great deal is known about the quality and other physical parameters of the river water, little is known about the recharge areas or movements of subsurface water through the adjacent karst area. Studies on the movements of contaminants from sinkholes and sinking streams outside the park will greatly enhance the understanding of the hydrological regime in the area.

SUMMARY

In conclusion, the general cave management policies for Buffalo National River in the near future will be:

1. There will be no substantial development of caves on the Buffalo River in the foreseeable future. Since Blanchard Springs Caverns has considerable development and excellent interpretation, and there are numerous privately owned commercial caves in the area, there seems to be no real need to develop additional caves within Buffalo National River.
2. All entry into caves within the boundaries of Buffalo National River will require a trip permit. The trip leader will be required to submit a comprehensive trip report for each trip.
3. Entry into caves must have some demonstrable benefit to the management of caves by the NPS staff. Mapping, biological survey work by competent speleobiologists, photography of selected areas of particular scenic or scientific value, and other information-gathering activities which can provide information for management purposes will be carefully considered by the NPS staff.

The Management Plan for the Lava Caves Area on Mt. St. Helens

David Seesholtz*

Mt. St. Helens, a snowcapped mountain in the Cascade Range of Washington state, has a lava flow, on the southwestern slope that contains some of the most important lava tubes and tree casts in the United States. This area is only about 1½-hour drive from Portland, Oregon, and 2½ hours from Seattle, Washington, which puts it in easy access of several million people.

Since the mid 1950s when the Swift Dam was constructed to the south of the lava flow and logging roads were built into the area, the interest in, and visitor use of, the area has grown from almost nothing to 50,000 visitors per year.

The Gifford Pinchot National Forest recognized the importance of the area, and began planning for its management in the mid-1960s. At that time many of the lava tubes, tree cast areas, and outstanding resources of the lava flow and surrounding area were inventoried, and a management plan was written and approved.

In the early 1970s it was recognized that the lava flow should be planned in conjunction with the very unique and scenic area to the north, a region which included the unroaded section around the snowcapped peak, Spirit Lake, and the Mt. Margaret backcountry. Public meetings were held in two small cities near the area to seek advice on how the local citizens and users of this area wanted to see the area managed. Following these meetings, a plan was written which proposed that this area, a total of 52,700 acres, should receive official classification as a Scenic Area. This classification would insure that all future management would be directed toward enhancement of the scenic qualities of the area. The plan also sets specific management objectives for each portion of the area, and proposes use restrictions and facility developments.

The proposed planning area was subdivided into 4 units on the basis of user needs served. The Mt. Margaret Unit to the north is 13,300 acres of high craggy peaks, mountain meadows, and clear lakes. It provides a quality recreation experience for those who prefer backpacking or horse trips. This area has been selected as a New Study Area for Wilderness.

Farther south is the Spirit Lake Unit. This unit contains 6,630 acres. Spirit Lake, 1,262 acres in size, is the center of activity. The campground, picnic area, organizational camps, and boating facilities are all designed for a recreation experience around the water. Some expansion of present facilities is planned but emphasis is primarily on improving what is already here. This area is heavily used and overcrowded on weekends.

The St. Helens Unit consists of 18,790 acres of perpetual ice fields, craggy rock outcroppings, steep pumice slopes, and rock-strewn flats. The peak of Mt. St. Helens which juts upward to 9,877 feet is the central point of this unit. The primary management objective for this unit is to provide visitors with the opportunity to find isolation from the

mechanization of civilization and to test outdoor and mountaineering skills. The major development planned is a trail around-the-mountain at timberline.

Finally, we have the Lava Caves Unit of 13,980 acres. This area was significantly changed about 1800 years ago by activity from Mt. St. Helens. A massive lava flow cooled as it flowed over the area leaving many tubes and tree casts. The most famous lava tube is Ape Cave which is 11,212 ft. long. (Over 2 miles long this cave is one of the longest unitary lava tubes in the United States.)

The cave was discovered in 1956 by loggers and in 1968 a stairway was constructed to improve safety for unguided exploration by the public. The upper portion of this cave has a lot of rockfall and is not recommended for inexperienced cavers. The stairway is constructed to direct the major portion of the traffic into the ¾ mile lower section of the cave. This cave has received heavy visitor use on weekends and holidays. Vandalism, littering, and other acts of depreciative behavior are common occurrences. The uninformed and unconcerned visitor has left his sign on the cave walls, and unknowingly changed the cave ecology.

Since Ape Cave has already been heavily used and most of the fragile formations have been removed or destroyed, it will continue to be used to satisfy the general public's demand for an afternoon caving experience. The existing displays at the cave entrance will be replaced with more permanent metal photo type displays. A self-guided tour explaining the features of the lower cave, such as the lava ball and the cave's origin, will be provided in brochure form. A weekend naturalist will be assigned to the site.

As we do not have the financing at the present time to provide these services, the Oregon Grotto has been providing some of these services through the volunteer program. On weekends throughout the summer, Grotto members have been stationed near the cave entrance to register visitors and inform them of good cave conservation and safety procedures. They also helped produce a brochure about the cave and design several posters that present messages on safety and cave conservation. As a result accidents have been less frequent and litter and vandalism reduced.

The upper portion of the cave is on private land. Following a land exchange which will acquire this area for the government, some improvements will be made at the upper entrance to make access safer. A trail is planned to link this entrance to the parking lot at the lower entrance.

Ole's Cave on the south end of the lava flow is similar in length to Ape Cave. This cave was discovered in 1895 by Ole Peterson, an early settler who had a ranch along the Lewis River south of the lava flow. He would guide visitors to the cave where he had a cabin constructed near the upper entrance. This cave is noted for having been the first commercial cave in Washington state. The cabin site will be inventoried as a historical site and submitted to the State Historical Preservation Officer for consideration for the State Register.

*St. Helens Ranger District, Gifford Pinchot National Forest, Washington

Access to the cave is presently very primitive. Approximately 1½ miles is over a very rough powerline access road, and then a ½ mile trail hike. Although the cave was heavily exploited by Ole's commercial venture, it is presently receiving very little use due to the poor access. The plan is to retain at least a ½-mile hike to the entrance to this cave and to give it no publicity.

Little Red River Cave, north of Ape Cave, is also one of the longer known lava tubes. This cave contains several dropoffs and many fragile formations. The cave has been closed to the general public by a gate, and entrance is by permit only. Permission to enter is being granted only to a few for scientific study. A logging spur was built to within a hundred feet of the cave entrance before the entrance of the cave was known. This spur has been blocked off and revegetated and the entrance is now difficult to find.

Lake Cave, about 1 mile from Ape Cave, is receiving an increasing amount of use. Due to dropoffs and narrow passages, the cave is unsafe for the inexperienced. There are some fragile formations remaining. The cave entrance is currently on private land. However, this land will be acquired and the entrance to the cave gated. In the interim, warning signs will be posted on the principle access route to the cave alerting visitors of the dangers.

There are numerous smaller lava tubes scattered throughout the lava flow that are poorly accessed. The plan is to allow use of these tubes but not to publicize their locations or improve access to them.

Scattered over the area and particularly numerous around Lake Cave and Long Mountain are the tree casts. These casts, both vertical and horizontal, were formed by lava encasing standing and fallen trees. These trees rotted away leaving molds of the forest that occupied this area over 1800 years ago. A picnic area has been developed in the lava cast area near Lake Cave. This picnic area attracts many viewers to look at the casts. The casts are on private land until a land exchange is finalized.

An interpretive trail will be constructed through the lava casts. The trail will eliminate the dispersed walking throughout the area that is presently causing damage to the fragile plant life. Safety devices will be installed where necessary to protect the visitor.

Trails and interpretation are also planned on the lava flow to point out unique geology such as Christmas Canyon where in 1933 on Christmas Day the lava broke off into the Lewis River Canyon in large chunks; or, to point out the plant succession on the lava flow such as lichens struggling for survival on the rocks or hardier trees making an attempt to survive; or, to explain the occurrence of an unusual arrangement of lava. Interpretive trails and brochures are a high priority item in the plan after the land exchange.

An area of unusual botanical interest within the unit has been officially approved as a Research Natural Area. As a result of the plan, the Goat Marsh area of 1,195 acres is now set aside to observe how nature will take its course in this wet marsh—Noble Fir type—if undisturbed. The area is very excellent habitat for elk and in recent years has attracted a lot of hunting pressure. Two small lakes at the south end of the marsh provide fishing opportunities and beautiful views of Mt. St. Helens. A jeep trail into these lakes will be closed to all traffic, and the boundary of the Natural Area will be signed.

Just north of Goat Marsh is an exceptional grove of Noble

Fir trees. Silviculturalists say that this stand has the highest per acre volume known of any stand of Noble Fir. This stand will be set up as a Botanical Area for study.

Another area of unusual interest is Grass Lake. Located on the west edge of the lava flow, this lake was formed when the lava flow blocked the drainage. Now, Cougar Creek flows into this lake with no visible outlet to the lake. The meadows created by the lake provide excellent habitat for elk. The plan is to avoid any development such as roads or trails that would encourage more visitors to this area.

The headwaters of the Kalama River have their beginning in this area. This is an unusual place because the water just bubbles out of the ground. A small campground has been constructed at Kalama Springs and is popular in late summer as a berrypicking camp and during hunting season for hunting camps. There are no new campgrounds proposed within the area. Caving is primarily a day-use activity and the campgrounds developed at the reservoirs to the south will provide the camping needs for the visitor. A lot of roadside camping occurs during hunting season. This use is having an impact on the environment and will be discontinued at some time in the future.

Two small lakes, in addition to those mentioned at Goat Marsh, are located within the unit. McBride Lake is directly across the road from the Kalama Springs Campground, and provides 5 acres of water for fishing. Blue Lake is a small lake adjacent to the Noble Fir grove mentioned earlier. It will receive no development other than to continue maintaining the Toutle Trail No. 238, which provides access to the lake.

This area is increasing in popularity for snowmobiling and other winter uses. Approximately 20 miles of roads within the unit have been designated as a part of the Mt. St. Helens snowmobile routes. Road No. N83, depending on snow depth, is the principle take-off point and is often congested with snowmobiles and parked vehicles. A new parking area will be developed in the future. One objective in selecting a new location for a winter parking area will be to have it beyond the access road to the caves. Most of the snowmobiling will then occur beyond the caves area. The use by cross-country skiers is increasing, and in the near future a plan will be made cooperatively with the different type of users to determine which areas will best accommodate which type of users. The existing St. Helens snowmobiling brochure will be revised to show the new winter use plan.

The planning on the Lava Caves Unit began in the early 60s. At that time over 50 percent of the land was in private ownership. Today, less than 25 percent is privately owned due to land exchanges. After an exchange that is now in progress with Weyerhaeuser Company, about 10 percent will remain in private ownership. The final plan includes the acquisition of all lands within the lava caves area by the Forest Service, except for 360 acres in the southeastern corner. (This belongs to Pacific Power and Light Company.)

This plan is certainly not static, as planning is continuing for the area. Presently, a land use planning team is examining the Green-Spirit Planning Unit, a much larger area that contains the Mt. St. Helens Scenic Area. They will again be asking the public for input. Alternatives for management of the area will be reexamined and an environmental statement filed. Following approval of the Final Environmental Statement for this planning unit, the area will receive the proposed classification.

Management of Ape Cave, the Second Longest Unitary Lava Tube in the Continental United States

Ellen M. Benedict†*, Mary L. White†** and James Wolff†***

ABSTRACT

Ape Cave, 11,215 feet long, is in the Gifford Pinchot National Forest, southwest Washington, within easy reach of a million people. This most heavily used wild cave in the Pacific Northwest is one of nine major caves on Forest Service and private lands in the 9-mile-long lava flow between the base of Mt. St. Helens and the Lewis River. Recognizing the problems of heavy visitation and vandalism, coupled with fragile features and/or safety hazards, the Forest Service and the Oregon Grotto formulated a two-step management plan: 1. Temporary volunteer services by Oregon Grotto cavers along with a series of land exchanges; and 2. A future visitor center, campground and trails between Ape, Lake and Ole's Caves. Lack of money has deferred construction or staffing of a visitors center at Ape Cave. As an interim measure, a Forest Service Volunteer Program staffed by Oregon Grotto cavers began four summers ago. Cavers are at Ape Cave each Saturday and Sunday from Memorial Weekend to Labor Day. The volunteers register visitors; answer questions; hand out brochures and litter bags; offer suggestions about safety, equipment, clothing and conservation. This volunteer program has decreased vandalism and littering and pressure has been directed away from more sensitive, fragile and hazardous caves of the system.

INTRODUCTION

Mention in the Pacific Northwest that you are a caver and you are apt to be asked, "Have you been to Ape Cave?" In the minds of the general public you are not much of a caver if Ape Cave isn't in your cave bag—even the questioner or his friend has probably looked down into its dark sinkhole.

Ape Cave, the second longest unitary lava tube in the continental United States (Halliday, 1977), is in Skamania County in southwestern Washington within easy reach of a million people (Figure 1). Its upper entrance is on Weyerhaeuser Timber Company land, while its lower, main entrance is on Gifford Pinchot National Forest land. This most heavily visited wild cave in the Pacific Northwest has a mapped length of 11,215 feet and a vertical extent of 700 feet. Despite the record length, it is only *one* of *nine* major caves located on either Forest Service or private lands in the 9-mile-long lava flow extending between the base of Mt. St. Helens and the Lewis River.

Increasingly heavy visitation and vandalism in the area, combined with the growing realization that several of the caves of the flow contained fragile features and/or safety hazards for the noncaving public, has resulted in a long-term, two-step management plan developed through the mutual cooperation of the St. Helens Ranger District and the Oregon Grotto of the National Speleological Society

†Oregon Grotto, 13402 N.E. Clark Road, Vancouver, Washington 98665.

*Department of Biology/Environmental Sciences, Portland State University, Portland, Oregon 97207.

**3803 N.W. Lincoln Avenue, Vancouver, Washington 98660.

***St. Helens Ranger District, Cougar, Washington 98616.



Figure 1. A typical Sunday afternoon at Ape Cave. Photo by anonymous scoutmaster.



Figure 2. Symbols of the Ape Cave Volunteer Program—a cooperative effort between the Oregon Grotto and the Forest Service. Photo by Susan Foster.

(Figure 2). The plan includes: 1. Temporary volunteer services by Oregon Grotto cavers, along with a series of land exchanges between the Forest Service and private owners, and 2. A future visitor center, campground, and trails between Ape, Lake and Ole's caves. Ideally, a visitor center at Ape Cave, staffed with full time Forest Service naturalists, would have opened during the early 1970s, but budgetary considerations have deferred the construction or staffing of such a facility. In the interim, an ongoing summer weekend Forest Service Volunteer Program staffed by Oregon Grotto cavers was started in 1974. The type of volunteer program described in this paper could serve as a model for other areas with a strong group of organized cavers and a cave with similar management problems. In order to understand the management problems of the area, let's look at what has happened at Ape Cave since its "discovery."

RECENT HISTORY OF APE CAVE

Ape Cave, although formed about 2000 years ago in lava flowing down Mt. St. Helens (Hyde & Greeley, 1973), was only officially "discovered" in 1946 by Lawrence Johnson (per. comm.) of Amboy, Washington. Mr. Johnson, a catskiner, was logging cedar poles and noticed a tree stump projecting into the air—stump up. He got off his cat to investigate and found the large lower entrance sink of Ape Cave. Elk hunters had apparently "unofficially" discovered the cave even earlier. John Cvetich of Vancouver, Washington tells of a fall hunting trip during the early 1940s when his party visited the cave and saw about 100 bats on the ceiling (Foster, 1977).

By 1952, Ape Cave had been thoroughly explored by the St. Helen's Apes, a rugged hiking club under the leadership of Harry Reese of Ariel, Washington. The cave was named for this group who built massive log ladders to descend the two drops into the lower 2-mile-long main passage. Here they found passage with high ceilings and frequent, large breakdown blocks, especially in the upper three-fourths of the cave. The St. Helen's Apes enlarged a tiny skylight in the upper end for a second entrance so they wouldn't have to go back to the original entrance each time they explored the cave. A loosely strung, single strand wire fence was built around the main entrance and a few directional signs were posted to indicate the route to the Cave.

Ape Cave, mapped at 11,215 feet in 1958 by the Washington Speleological Survey, was described in detail by Bill Halliday in his 1963 *Caves of Washington*, a publication of the Washington Division of Mines and Geology, which is still being sold. Halliday also described Bat, Lake, Little Red River and Ole's Caves in the same lava flow. During the 1960s, a rash of articles appeared in the popular press calling attention to the uniqueness of Ape Cave and the thrill of exploring its depths. It was repeatedly billed as the "longest lava tube in the U.S.," which it was as far as anyone knew at that time.

By August of 1968, Portland's *Sunday Oregonian* featured an article entitled "Lands Traded to Make Recreational Area Where Caves Exist." After an exchange of 13,500 acres, the Forest Service had title to 80 percent of the land of the projected Mt. St. Helens Lava Cave Recreational Area. The same article mentioned an expanded parking lot at Ape Cave, a split rail fence around the main entrance, and a new metal ladder leading down into the lower main passage. An accompanying picture showed the new stone stairway replacing the old log ladder into the first level. Now only darkness and fear prevented the ever-increasing hordes of visitors from entering Ape Cave, trampling the sand formations, carrying out lava ribbons and drip speleothems (Wolff, 1977) and depositing their trash and human waste, piece by piece, in the damp, dark passage. By the early 1970s, Ape Cave was indeed on its way to becoming a "Lava Sewer" as hundreds of pounds of trash were dumped in the cave by the ever-swelling masses of humanity enjoying an afternoon caving experience!

In 1973, the Oregon Department of Geology and Mineral Industries published a "Geological Field Trip Guide, Mount St. Helens Lava Tubes, Washington" by Jack Hyde and Ronald Greeley. This guide not only provided the names and measurements of 14 caves in the 9-mile flow between the base of Mt. St. Helens and the Lewis River, but included a full page map with topographical lines showing the locations of 11 caves. Visitation and vandalism steadily increased. Oregon Grotto clean-up trips removed over 250 pounds of trash from Ape Cave (Nieland, 1975, Woods, 1976), and nearly 40 pounds from Ole's Cave (Nieland, 1975).

APE CAVE FITS CRITERIA FOR POPULARITY

Ape Cave and gradually many of the caves of the St. Helens Lava Flow were being very heavily visited. Why were they so popular? Wilson (see paper this Proceedings) in an analysis of data from over 4000 entries in a cave register program in three eastern states, observed that in order for a cave to become popular, it must fit certain criteria: 1. Have high caver appeal, 2. Lack man-made obstacles, 3. Be convenient; and 4. Be publicized. Ape Cave easily qualifies on all four accounts. First, it was originally popular with "regular cavers" as a result of its various lava features, such as the Meat Ball Formation (Figure 3), lava speleothems, and delicate sandcastles (now destroyed). It has lengthy, easily negotiated passages and its entrances were and are easily accessible. Second, the Forest Service had erected no obstacles to entry—in fact, by improving the site and access and by posting directional signs, the Forest Service had encouraged visitation. Ape Cave is also clearly marked on the Gifford Pinchot National Forest Service map. Third, Ape Cave is within 100 miles of the greater Portland-Vancouver metropolitan area, and within 250 miles of the greater Seattle-Tacoma area. Also there are good, well surfaced roads to the area and camping facilities are within 15 miles of the cave. Fourth, Ape Cave has been much



Figure 3. The "Meatball" in Ape Cave. *Photo by Charlie and Jo Larson.*

written about in newspapers, discussed in *Caves of Washington* (Halliday, 1963), mentioned in the 1972 NSS Convention Guidebook (Halliday, 1972), and featured in a major geological guide (Hyde & Greeley, 1973). No wonder visitors flock to the area—even those without lights, heavy clothes or proper footwear.

By the 1970s, cavers and the Forest Service feared that most of the caves in the Mt. St. Helens flow would soon be "filled" with trash and otherwise vandalized, unless some positive actions were taken to halt the ever-increasing damage. Could public attention be focused primarily on Ape Cave and away from the more delicate and/or hazardous caves? *Something had to be done immediately—and at low cost.*

APE CAVE FOREST SERVICE VOLUNTEER CAVER PROGRAM

The Oregon Grotto was asked in 1974 by the Mt. St. Helen's Ranger District to participate in an educational program by providing caver volunteers to contact visitors at Ape Cave (White, 1974). At first, the volunteers were unsure of themselves but were eager to cooperate with the Forest Service, the major cave owner in southwestern Washington. Two cavers agreed to be at Ape Cave from 10:00 AM to 4:00 PM each Saturday and Sunday from Memorial Day weekend through Labor Day weekend. Notices about the volunteers were posted in local stores and at the cave (Appendix I). Volunteers signed Forest Service release forms, picked up Forest Service arm bands and were ready to start working.

During the first season (1974), volunteers attempted to lead tours through the cave (Forney, 1974). This didn't work because: 1. Most people weren't interested in a tour, 2. They weren't interested in detailed information about the cave—most questions consisted of "Why is it dark?" "Where are

the bats?" "Oh! Ick!" "Why is it so cold?" "Who built the cave?" 3. While volunteers toured 20 to 30 people through the lower third of the cave (about one and one-half hours trip), another 20 to 30 people would enter the cave (Pope, 1974). The next plan of attack was for one volunteer to lead a tour and the other one to stay at the entrance answering questions, if any were asked. After a day at Ape Cave, it was realized just how little the general public knew about caves, especially lava tubes, and just how little the cavers knew about how to enlighten the public (Lonergan, 1974). By the end of the first summer, the volunteers realized that tours weren't very useful and that something else would have to be devised if the littering and vandalism were to be lessened.

The second summer (1975) both volunteers stationed themselves at the entrance to answer questions. The problem, then, was how to get the public to ask questions? There must be some way to attract the attention of tourists other than to bodily attack them. After all, who wanted to stand there all day and not do their job of talking to the public? If the weather was clear, one cooked in the sun and if it rained, one drowned under the dripping overburden.

In early June of 1975, it was our (EMB & MLW) turn. We puzzled over the situation. We didn't want to spend six hours being ignored. So we decided to have each party of tourists sign their names, hometown and number in party in an old lab notebook. We also displayed our cave packs, boots, clothes and carbide lamps on a small camp table (Figure 4). Our ploy was to ask if they had ever seen a carbide lamp work. Several flints were worn out that season, but this approach worked! People actually stopped to *talk and asked questions!* By the end of that Saturday we were amazed to add up a *total of over 400 visitors* to the entrance of Ape Cave between 10:00 AM and 4:00 PM. The Forest Service was even more amazed; they knew that Ape Cave had heavy visitation, but this was the first time that they had any figures on the amount of visitation. People were coming to Ape Cave from all over the United States and even from foreign countries. From then on a register has been kept.

While the basic approach during the third and fourth summers (1976 and 1977) has been the same (less the lighting of the carbide lamp), certain improvements have been added. Jim and Libby Nieland wrote and printed the Ape Cave Brochure (now printed by the Forest Service),



Figure 4. Portable display of caving gear used to entice tourists to ask questions of Ape Cave volunteers. *Photo by Ellen Benedict.*



Figure 5. Before scene: Ape Cave volunteer giving group with six-pack a litter bag. Photo by Susan Foster.



Figure 6. Two hours later: Filled litter bags. (Note empty six-pack which tourist proudly carried out in his litter bag.) Photo by Susan Foster.

which is handed out free of charge (see Appendix II). Ape Cave Register pages have been printed. The volunteers in registering 300 to 800 visitors each weekend answer questions and offer suggestions about safety, equipment, clothing and conservation. A litterbag is now given to one member of each party entering the cave, with the request that the party pack out their own trash and any other items which they see (Figures 5 and 6). Many an ill-equipped adventurer on a Sunday caving experience has been discouraged from hiking the upper, more hazardous end of Ape Cave. Others have gone back to their cars for more lights and wraps. Vandalism and littering have sharply decreased and pressure has been directed away from the more sensitive, fragile, and hazardous caves of the area.

As a result of volunteer supervision, maintenance and upkeep have been improved. For example, at the suggestion of the volunteers, a cyclone fence was installed around the top of a hazardous 20-foot high open stairway, so dogs and children would not fall to the floor below. More litter bags and pack-it-out signs were added in the parking lot, improved interpretive signs have been installed, and a permanent register was placed at the entrance. Loose rails in the fence, broken locks on restrooms and vandalized signs

were repaired. The volunteers regularly pick up litter from the parking lot and the cave entrance; thus, the program has not only helped to reduce vandalism and littering at Ape Cave, but it has served to improve communication between the cavers and the Forest Service, by increasing awareness of people pressure to the area.

SUMMARY

The Oregon Grotto has provided two caver volunteers for each Saturday and Sunday from Memorial Day weekend through Labor Day for the past four summers (1974-1977). This is about 10 weekends per summer or about 40 weekends in all. The pair of volunteers have contacted 300 to 800 people in a weekend. The 4-year-old Forest Service Caver Volunteer Program at Ape Cave has been one means of coping, at low administrative costs, with serious management problems in a high-use cave area. It should be emphasized that the services provided by the caver volunteers have not followed predetermined patterns, but are the result of the cooperative efforts of both the Forest Service and the cavers. The actual way that the cavers handle their time at the cave has evolved through trial and error by the cavers themselves.

To conclude, the caves of the Mt. St. Helens Lava Flow are in an area of recreational development. We may not be able to protect these caves forever, but we are educating the public in terms of conservation and safety, and encouraging people to visit Ape Cave instead of the more fragile or hazardous caves of the area.

The program has helped reduce vandalism and littering at Ape Cave and has served as a valuable exchange of information between the cavers and the Forest Service. It is one functional means of coping with serious management problems. A similar program could be used in other cave areas with comparable management problems.

ACKNOWLEDGMENTS

A few parts of this paper were first presented by James Wolff at the 1977 Western Speleo-educational Seminar, Vancouver, Washington under the title "Ape Cave Volunteer Program." A highly revised version, similar to the one here, was presented by Mary White, again under the title "Ape Cave Volunteer Program," at the Conservation Session of the 1977 Convention of the National Speleological Society, Alpena, Michigan. We appreciate the help of Jo Larson, Librarian of the Oregon Grotto Library, for her help in locating materials on the history of Ape Cave. We are deeply indebted to Charlie and Jo Larson, Susan Foster, David Jones, and Charles Stephens, all of the Oregon Grotto and David Seasholtz of the Mt. St. Helen's Ranger District, for providing slides to illustrate the formal presentations.

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APE CAVE



There will be a Forest Service Volunteer to provide information about this unusual cave on weekends.

10:00AM to 4:00PM

Follow road signs from Hwy. N90 for 3 miles North from Swift Creek Reservoir to the cave entrance.

For additional information contact St. Helens Ranger Station. Phone 238-5244

Volunteers by the Oregon Grotto of the National Speleological Society.

APE CAVE

EQUIPMENT YOU WILL NEED

To safely explore the cave you should carry at least two sources of light. A Coleman lantern provides ample light to see the features of the cave and to watch your footing. A flashlight with strong batteries can be used to spotlight features and will provide a back-up light in case the lantern fails. The temperature in the cave stays near 42°F all year. Wear a sweater or jacket. Sturdy shoes should be worn, the lava floor is sharp and rough in many sections.

PROTECTING THE CAVE ENVIRONMENT

The cave environment is very delicate and must be carefully protected to avoid damage. Unlike the surface environment which in time will heal its wounds, a cave once damaged is destroyed forever. For this reason it is important to avoid littering the cave, collecting "rock samples" or any other acts which will mar the cave. Please avoid the use of railroad flares or burning paper to light your way. The residue from these substances is deadly to underground forms of insect life. If bats are found roosting, as they sometimes are in winter, they should not be disturbed. Waking bats during their hibernating season will cause certain death since there are no insects for them to feed upon to replace lost energy. Leave nothing but footprints, take nothing but pictures, kill nothing but time.

APE CAVE

Ape Cave is widely known as the longest unitary lava tube in the continental United States and has a length of 11,215 feet. The cave was discovered in 1946 by Lawrence Johnson of Amboy, Washington while logging in the area. Following discovery, the cave was extensively explored by a local group of young outdoorsmen who called themselves the St. Helens Apes. The cave was named for the organization.

LOWER CAVE

The cave is divided into two portions by the main entrance. The downslope portion of the cave extends for approximately 4000 feet before termination in sand fill. Easily traversed, it is recommended for most visitors.

UPPER CAVE

Upslope from the main entrance travel is difficult, involving nearly 7000 feet of passage floored mostly by breakdown. Breakdown is the rock rubble caused by collapse of the passage walls and ceiling. The upslope portion is recommended only for **well equipped** explorers. For those who do explore upslope it is possible to exit from the cave's upper entrance. Please refer to the cave map for additional detail.

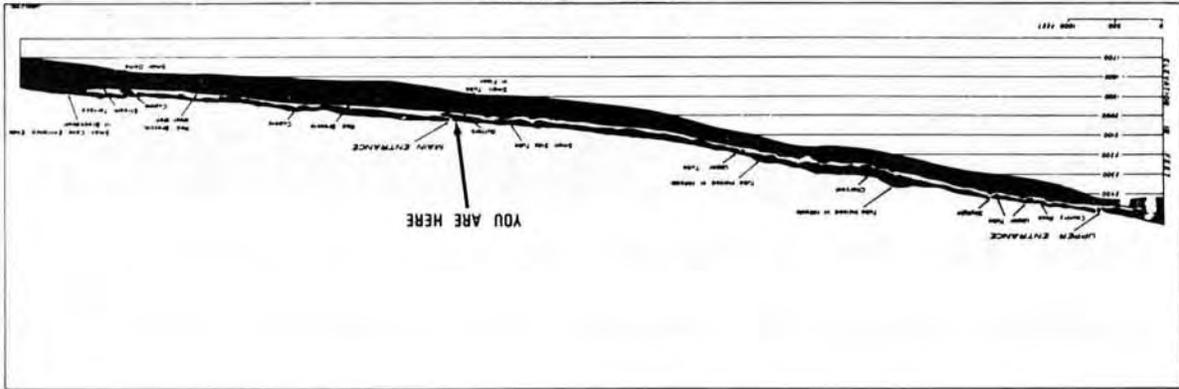
GEOLOGY

Mt. St. Helens has been one of the most active Cascade Range volcanoes in recent times. Writings of early settlers describe eruptions of the volcano from the mid-1830s through the mid-1850s. The Ape Cave basalt flow occurred during a single eruptive period about 1900 years ago and reached a maximum length of nearly nine miles. Highway N90 crosses the toe of this flow just east of the powerhouse below Swift Creek Dam.

FORMATION OF THE CAVE

Lava tubes such as Ape Cave form in flows of pahoehoe basalt. This type of lava is very fluid and moves readily down slope. Lava tubes are the crustified over feeder channels which conduct lava to the advancing front of the flows. This crusting over takes place near the vent then gradually works its way down slope along the lava stream. The crust first starts as a thin ledge-like protrusion extending inward from the sides of the channel over the flowing lava. Eventually the ledges meet to form a continuous span across the channel, which is gradually thickened and strengthened by surges of lava breaking through the crust and spreading out as thin surface overflows. Addition of lava linings to the underside of the span provided still more support.

APE CAVE



FEATURES OF APE CAVE

Lava is an excellent insulator, so once the lava stream is rooted over it is possible for the lava to flow through the tube for many miles with little loss of heat. In the case of Ape Cave and other caves in the area which carried lava for long periods of time, the lava stream was able to erode downward cutting into the pre-flow land surface. For this reason many portions of the cave have passages with a high narrow cross-section. Where sections of the wall lining have fallen away it is frequently possible to see the old land surface below the overlying lava. This is identified as a zone of hard reddish soil which has been baked red by the heat of the lava to give the appearance of fired construction brick.

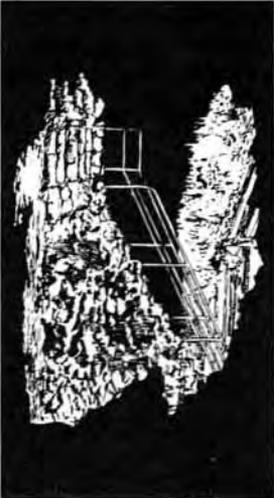
Once the eruption ceased and lava drained from the tube, the cave was left as we see it today. Following the cave's draining, hot gases caused melting of wall surfaces (much like a very hot oven) and the formation of a dark shiny glaze. In many places the glaze slumped while still molten to form a pleated pattern of ripples. During this period lava stalactites formed on the ceiling and stalagmites formed on the floor where globules of dripping lava fell from stalactites above. Lava formations are not common in the cave and where they do occur are small and **very fragile**. The few formations which originally existed in the cave have been largely removed or broken by inconsiderate visitors in the past. If formations are observed extreme care should be taken to avoid touching them so that others might also enjoy their discovery in the future.

Lateral 'flow marks' (minor ledges) along the walls mark stages of lava decline in the tube. When the lava level dropped then stabilized for a period of time a flow mark was produced along the wall.

In the lower portion of the cave can be seen the Lava Ball. This is a block of solidified lava which was carried along on top of the lava stream and became wedged in a narrow portion of the passage. When the flow receded the block was left as an arch twelve feet above the floor.

At the lower end of the cave the passage is divided by a lava diaphragm with both an upper and lower level. The lower level is blocked by sand which is being washed in through creeks in the walls and ceiling and carried to this point by a seasonal stream. In the upper level are a series of holes extending downward to the level below, and surrounded by bubble-rings. These were caused by molten lava surging up from below, then retreating.

Once the cave started to cool, breakdown of the walls and ceiling began to occur. This breakdown was mostly caused by the contracting cracking of the cooling tube walls. No recent collapse has been noted since the cave's discovery in 1946. Where breakdown has extended to the surface an entrance or skylight was formed. Seldom is the cave roof more than 20-30 feet thick.



Lower Entrance. Where breakdown of the cave ceiling has extended to the surface, entrances are formed.

At most times of the year a breeze can be felt at narrow parts of the cave. This wind is caused by the relative difference in density between the air inside the cave and that outside. During the summer months the air inside the cave is cooler and denser than that outside. As a result the cool dense air flows from the upper portion of the cave and pours out the lower

entrance. In the winter the reverse is true and the warmer air inside the cave rises, in a chimney effect, and flows out the upper entrance. Air currents as great as 7 mph have been recorded.

NATIONAL SPELEOLOGICAL SOCIETY

This brochure is provided free through the courtesy of the Oregon Grotto of the National Speleological Society. The society is dedicated to the conservation, exploration and study of caves. For information about the society write to: National Speleological Society, Cave Avenue, Huntsville, Alabama 35810.



GUIDELINES FOR SAFE CAVING

1. Leave trip plans—destination, time of departure, expected time of return—with a responsible person at home.
2. Wear heavy shoes and hard hats. Hard hats protect cavers' heads from low ceilings and falling objects; mounted lamps on the hats leave the hands free for climbing.
3. Each caver should have a minimum of two sources of light.
4. Keep the group together.
5. Don't collect cave formations, artifacts or animals. Do collect litter.
6. Never go caving alone.

This brochure is yours to keep. However, as there is a limited supply, if you do not wish to keep it, please return it.

Cave Management for Endangered Bats and Other Purposes by the St. Louis District, Corps of Engineers at Meramec Park Lake, Missouri

John T. Brady*

The Meramec River begins in the Missouri Ozarks and flows northeast for about 200 miles to its confluence with the Mississippi River just south of St. Louis, Missouri. The basin embraces an area of approximately 4,000 square miles. The principal drainage system consists of the Meramec River and its two tributaries—the Bourbeuse River flowing through farming country to the north, and the Big River flowing through the lead mining area in the south.

The combination of topography, geology, and climate have been favorable to the formation of caverns and sinks in the Missouri Ozarks. There are over 3,000 known caves in Missouri with at least 225 located in the Meramec Basin including 61 known caves on project lands. Some provide habitat for cave-dwelling bat species.

Meramec Park Lake is one of five reservoirs authorized by Congress in the Meramec Basin and is the only one where construction has been started. The dam would be located on the main stem of the Meramec River at mile 108.7 near Sullivan, Missouri, approximately 65 miles southwest of St. Louis, Missouri. The project purposes, as stated in the authorizing document, are: flood control, recreation, water supply, water quality, fish and wildlife conservation, navigation, and area development. In September 1972, the Sierra Club filed suit against the Meramec project with one allegation being an inadequate environmental impact statement. In September 1973, a revised and supplemental final environmental statement was filed with the Council on Environmental Quality. This document recognized the existence of both *Myotis sodalis* (the Indiana bat) and *Myotis grisescens* (the gray bat), and possible impacts that might occur to these species, including the inundation of some caves. *M. sodalis* was placed on the federal endangered species list in 1967, whereas *M. grisescens* was not placed on the list until 28 April 1976. This was based on information collected by Dr. Richard Myers, Kansas City bat biologist, in the late 1950s and early 1960s.

In September 1974, the Sierra Club's lawsuit was amended to include an alleged violation of the Endangered Species Act. About the same time, the Department of Interior requested that the project be halted because of possible adverse impacts to *M. sodalis*. After numerous meetings and exchanges of letters, the Corps and Interior Department decided to have a joint, comprehensive study of cave-dwelling bats in the Meramec Basin. The Missouri Department of Conservation also became a participant. In March 1975, the United States District Court at St. Louis, Missouri, ruled in favor of the defendants, stating that the

evidence failed to show that present activities in constructing the Meramec Park Reservoir are adversely affecting Indiana bats in the project area. This decision was appealed to the United States Court of Appeals for the Eighth Circuit. In April 1976, this court upheld the lower court's decision and in doing so expressed its observation that Congress had considered the positive and negative impacts of the project prior to appropriating funds and that the Court did not wish to interfere with the intent of Congress. During this time, the St. Louis District of the Corps acknowledged the need for more studies to gather information relative to continuing construction activities.

The Meramec Project has been very controversial. President Carter, as part of his Water Resources Project Review, deleted it from the fiscal year 1978 budget request. Congress has supported the President in this deletion. Prior to action by the President, the Corps of Engineers had purchased over 27,000 acres of land; the future of the project is uncertain at this time since Congress still has the option to fund the project in future years. The first concern of construction activities on endangered species was the possible impact of seismic and construction blasting on hibernating *M. sodalis* in the vicinity. A survey was conducted, under contract with the Corps of Engineers, by Mr. Joseph Werner, a former student of Dr. Myers, to locate all caves in the immediate area of construction and to determine if they were being used by *M. sodalis*. Nineteen caves were investigated in a 4.0 km radius of the damsite and 8 were found to contain bats of the genus *Myotis*. *M. sodalis* was positively identified from 2 of these caves, including a large hibernating group containing about 20,000 individuals.

After the locations of the bats were determined, the next question was how large of a vibration could a hibernating bat tolerate without being disturbed. To answer this question, the St. Louis District assembled an interdisciplinary team in February and March 1975, directed by Dr. Richard Myers. The team consisted of biologists, geologists, geophysicists and engineers. Biologists from the U.S. Fish and Wildlife Service and Missouri Department of Conservation also participated.

The hypothesis tested was that hibernating *M. sodalis* would not be disturbed by vibrations of a magnitude that were normally caused by natural events. Available data indicated that particle velocities with magnitudes up to 0.01 inches per second occurred naturally on windy days. To put this in perspective, human perception begins with particle velocities between 0.1 to 1.0 inches per second, and damage to structures occurs at 5.0 inches per second.

A few *M. sodalis* were located in a cave adjacent to the construction area. Holes had previously been drilled near the cave for seismic tests and geological exploration.

*Wildlife Biologist, Environmental Studies Section, U.S. Army Engineer District, St. Louis, Missouri



A cluster of Indiana bats (*Myotis sodalis*). Photo Credit: St. Louis District, Corps of Engineers.

Charges were placed in these holes to produce progressively increased particle velocities near a hibernating *M. sodalis*. The bat was monitored by a remote sensing infrared thermometer that automatically printed out its external temperature on a strip-chart recorder. In addition, ultrasonic sounds were monitored using an ultrasonic receiver. Visual observations were made of the bat from a distance of 4.5 to 5.0 meters.

The magnitude of each charge was recorded by the geophones placed near the subject bat, against the rock wall of the cave. The seismic recording equipment was operated by personnel from the Corps of Engineers Waterways Experiment Station in Vicksburg, Mississippi.

Communications between Dr. Myers and personnel operating the strip-chart recorders and powerpack for the infrared thermometer, about 45 m away, were accomplished by earphones and throat-microphones. From this point to the surface crews, communications were handled by a series of relays using two-way radios.

The results of this study indicated that blasting, which produced a particle velocity up to 0.02 inches per second in

the substrate on which a *M. sodalis* was hibernating, did not disturb the bat. This was the highest particle velocity produced. Dr. Myers found that the most disruptive force acting upon the bats during this study was the presence of people near the bats. He reported that there seemed to be a direct correlation between human activity and arousal of hibernating bats. This report is available from the St. Louis District.

As a result of this study, all blasting contracts have been limited so that the produced vibrations will not exceed 0.02 inches per second at important bat caves during critical periods, such as hibernation. The St. Louis District has purchased equipment to monitor these vibrations.

During the first five months of 1975, a long-term study was designed by personnel of the St. Louis District, the U.S. Fish and Wildlife Service, Missouri Department of Conservation and the University of Missouri. A number of bat researchers were consulted and Dr. Richard LaVal was chosen to conduct the investigation through the University of Missouri. The study was conducted under the authority of a federal endangered species permit issued to the Kansas

City Area Office of the U.S. Fish and Wildlife Service and was funded by the Corps of Engineers. It was done to help fulfill the Corps of Engineers obligations under the Endangered Species Act of 1973.

The study was started in July 1975 and was completed in February 1977. The purposes were to study the life history and ecology of bats of the genus *Myotis*, emphasizing *M. sodalis* and *M. grisescens*, and to determine the impacts that will be caused by construction and operation of Meramec Park Lake. The conclusion and recommendations of this report do not necessarily represent the position of the Corps of Engineers.

The results of this study indicate that of the 28 caves inundated permanently by the normal pool, 3 are used by *M. grisescens* and *M. sodalis* and of the 19 caves inundated periodically by the flood pool, 4 are also used by these two species. The study also indicated possible adverse impacts to *M. sodalis* and *M. grisescens* from increased human disturbance and loss of foraging habitat.

In addition to identifying impacts, the study also recommended measures for protection and management that should be taken whether or not the project was

completed. These measures would help reduce losses currently taking place as well as help offset any future losses caused by the project. The main thrust of the recommendations was cave protection. This included preventing public access to important bat caves by using gates or fences, sealing bat caves that would be inundated, and public acquisition of important bat caves that are on private land.

In partial response to these needs, the St. Louis District has begun a cave management program for caves on Corps property. One cave was gated in the fall of 1975 and one cave that has a hibernating population of 10-15,000 *M. sodalis* was gated in October 1976. This cave has been designated critical habitat by the Secretary of the Interior. The design of these gates was developed by the St. Louis District and was coordinated and refined with the help of Dr. Myers, Dr. LaVal, and Dr. Stephen Humphrey, bat authority from the University of Florida, as well as the U.S. Fish and Wildlife Service and the Missouri Department of Conservation. There is evidence that gates may exclude *M. grisescens* from caves, so these caves may require fences.

In order to discourage the public from entering ungated bat caves, the St. Louis District has provided warning signs



Dr. Richard Myers and the author examining bat monitoring equipment. Photo Credit: St. Louis District, Corps of Engineers.



A single Indiana bat (*Myotis sodalis*). Photo Credit: St. Louis District, Corps of Engineers.

at Dr. LaVal's request. Signs, however, have been marginally effective. The St. Louis District will continue to protect important bat caves on project lands. In addition, the District plans to meet with appropriate federal and state agencies to discuss other possible actions that could be taken.

Because of the impact that the project may cause to these federally-endangered bat species, the St. Louis District has entered into the formal consultation procedures proposed by the U.S. Department of Interior in the *Federal Register* (Vol. 42, No. 17, 26 January 77). We have been informed on 13 May 1977 by the Regional Director of the U.S. Fish and Wildlife Service for Region 6 that their threshold examination indicates that the construction of Meramec Park Lake may jeopardize the continued existence of the Indiana bat and gray bat. The Fish and Wildlife Service will eventually arrive at a final "biological opinion" which will state if, in their opinion, the project is likely to adversely impact these two species. The "biological opinion" may also contain recommendations for changes or modifications to the action to minimize the effects.

The St. Louis District has also developed an interim policy to manage all the numerous caves on its property. The St. Louis District will prepare a Master Plan Appendix which will provide the basic framework for cave management on Corps property.

If funding is continued in the future, cave inventory will be performed. The inventory will include physical, biological, and cultural information as well as a survey and the preparation of a map for each cave. This information will be used to classify the cave into one of the following categories.

a. *Commercial Caves*. This kind would be operated by a government agency or leasee using an interpretive plan and tour guides trained or approved by the Corps.

b. *Interpretive Caves*. This includes caves controlled by Corps personnel for scientific, educational, and interpretive uses. Entry would be permitted only when accompanied by Corps personnel.

c. *Fragile Caves*. This includes caves with features easily

susceptible to damage or injury such as fragile speleothems, delicate life forms, or archeological remains. Responsible small groups would be permitted entry.

d. *Wildlife Caves*. Includes caves used by threatened or endangered species. Critical habitat caves will have entry prohibited. Other caves may be entered only at those times and under those conditions which would not prove harmful to the organism.

e. *Technical Caves*. These include caves having features requiring specialized equipment or advanced caving expertise. Only experienced individuals with adequate equipment in a group size no smaller than four will be permitted to enter.

f. *Hazardous Caves*. Including caves having features or aspects hazardous to human life that are generally not related to caving expertise or equipment. Caves will be gated when feasible and entry will not be permitted except under carefully monitored conditions.

g. *Open Recreational Caves*. Caves containing no threatened or endangered life forms, hazardous conditions, or formations easily susceptible to damage.

Cave permits will be required for use of any caves on project lands. In addition, regulations governing the use of caves will be posted on all bulletin boards and will accompany cave permits.

To protect the cave resource, the surface use of project lands will be carefully planned so that adverse effects on underlying or nearby cave systems will be minimized.

If the Meramec project is continued as authorized, attempts will be made to salvage biological and archeological information. In some cases, rare organisms may be transported to other suitable caves, although special care must be taken to avoid upsetting the ecosystem of a cave by introducing exotic species. In addition, a ranger with an appropriate background whose primary responsibility would be to coordinate the management of cave resources will be assigned to the project.

By implementing this interim policy, the St. Louis District is attempting to balance the demand for recreational caving with the need to protect a fragile resource.

Residential Development Above Devils Icebox: A Conflict of Land Value Attitudes

Gene Hargrove*

ABSTRACT

Devils Icebox, Missouri's sixth largest cave, has been in the path of urban development since 1967, when the creation of a state park, centered around the entrance features of the cave, transformed the 1200-acre sinkhole plain still outside the park into the most attractive area for residential development in Boone County, Missouri. County level action through zoning and sewage regulations failed because of pressure from landowners engaging in land speculation. Recognizing no social, moral, or legal responsibility for protecting the cave or the park, landowners have claimed the right to do as they like with their property regardless of the consequences. State level action was initially more successful culminating in a state commitment to purchase the entire sinkhole plain; however, now that all surface areas of high multi-purpose recreational value have been acquired the land purchase program has come to a halt. State officials, focusing on the public health dangers of the polluted cave stream, have failed to recognize the value of the cave or its importance to the integrity of the park. The ineffectiveness of preservationist arguments based on the cave's aesthetic, scientific, and recreational value point to a need to educate the public to the value of caves in order to facilitate political action of this kind in the future.

Devils Icebox, Missouri's sixth largest cave, is located in Boone County, Missouri, about 15 miles south of Columbia, Missouri. The cave was well known in the late nineteenth century and was explored to some degree in the 1890s and extensively in the early 1920s. Modern exploration and mapping of the cave began in the 1950s and was largely completed by the early 1960s. The cave was one of the first wet caves ever explored and techniques developed in the cave's 0.5 mile water passage have been applied in other Missouri caves and throughout the United States. The "Icebox raft," a strange contraption made of wood and old inner tubes, still used in some water passage caves around the country, was, for better or worse, invented by Devils Icebox explorers.

The cave's 1250 acre sinkhole plain was settled in the 1850s and put to use for agricultural purposes. By the beginning of the twentieth century a small community called Pierpont had formed in the center of the sinkhole plain. After roads were improved, however, Pierpont became little more than a place name on Missouri maps as local residents left the town and moved to the city of Columbia. Housing construction over the cave remained minimal and relatively static until 1967 when "Rock Bridge State Park," named after one of the cave's entrance features, drew attention to the sinkhole plain once again. Urban expansion north of Columbia was very difficult because glaciers during the Ice Ages had removed most of the top soil making it impossible for city sewers to be built without extensive blasting in solid rock. With the establishment of the park, urban expansion, rather than following an orderly development southward, began to focus on the gently rolling, aesthetically pleasing, but, nevertheless, structurally

unstable sinkhole plain in the Pierpont area. Because of its distance from the city of Columbia, city sewers were not planned for this area until the late 1990s.

The citizens group, which raised the money for the park, had briefly considered purchasing much of the sinkhole plain, which could have been bought at that time for about \$100 an acre in contrast to the \$2500 an acre minimum now expected by landowners. The group, however, saw little value in owning the sinkhole plain and, feeling that a state park needed flat water recreation to be successful, acquired instead a large area to the northwest where it was believed a dam could be built across the Little Bonne Femme Creek creating a recreational lake. Since the construction of this dam proved infeasible from an engineering standpoint, this area remains an undeveloped and unused part of the park.

The Missouri State Park Board also considered sinkhole plain purchases when it first took over the park from the citizens group, but these plans were abandoned in favor of higher priority land purchases in other parts of the state.

Just before the park was established, the state received its first request for permission to build a subdivision over the cave. After a cave radio survey, conducted in 1966, demonstrated that the cave ran under the proposed subdivision, the Missouri Geological Survey, which then regulated such matters, informed the applicants that a central sewer system would be required. Since the costs of such a system on karst land is prohibitively high, the project was abandoned. The state, however, could not control the construction of individual homes and construction of this kind has continued uncontrolled at an accelerated rate.

In 1970, Geoffrey Middaugh, then a graduate student at the University of Missouri/Columbia, came upon a horrible smell in a vertical shaft known ever after as "Smelly Dome." Middaugh made a preliminary study of the cave (Middaugh, 1971) which concluded that there was some evidence that

* 6270 Famous Avenue, St. Louis, Missouri 63139.

animal or human wastes were beginning to pollute the cave. Just after Middaugh left the university, I formed an NSS Conservation Task Force (CTF) and began working on the problem. The CTF was completely unsuccessful at county level. Despite a great deal of lobbying, about half of the sinkhole plain was zoned rural residential permitting houses every two and a half to three acres. At state level, however, the CTF succeeded in getting the Missouri State Park Board to agree to purchase most of the sinkhole plain over a number of years. To date, about \$400,000 has been spent, but, unfortunately, no purchases have been made or planned now for two years.

When lobbying and presenting scientific information, it was necessary to present general arguments justifying the need to preserve the cave. These arguments were often countered by opponents who, because of their backgrounds, interests, and attitudes, perceived and reacted to the issues involved in very different ways. In this paper, I will review some of the arguments for and against the preservation of Devils Icebox as put forward by my opponents and myself.

At the outset, it should be noted that the problem of justification is ultimately a problem of value. I tried to highlight this point in my subtitle, "A Conflict of Land Value Attitudes." While "A Conflict of Land Use Attitudes" might be a more conventional way of speaking which comes more easily to the tongue, it is not appropriate here since use is one way of valuing land, but not the only way. This is particularly important in the case of Devils Icebox since the cave has almost no land use value in any ordinary sense.

At the county level the issue was not so much the preservation of the cave, but rather the preservation of special rights which the local landowners believed they possessed. Many of them told me on many occasions that they had worked and improved their land and, in this way, had acquired ownership rights which permitted them to do whatever they wanted with their land regardless of the consequences. As I have shown elsewhere (Hargrove, 1977b), this view originated in John Locke's theory of property first published in *Two Treatises of Government* in 1690, and was passed on to the American farmer by way of Thomas Jefferson's land reform activities and by a series of nineteenth century land laws—in particular, various pre-emption acts and the Homestead Act of 1862. Locke believed that people acquired ownership of land by putting their labor into it and that once they had established ownership to their land they had the right to do with it as they pleased, thinking only of their own benefit. According to Locke, the landowner's right to and over his land was a natural right—a right which the landowner would have even in a pre-societal state of nature. Society, Locke claimed, was created as a matter of convenience to help landowners protect and enjoy their property rights, but not to limit or infringe on these rights. Although landowners on top of Devils Icebox cannot express their views in quite this way, they, nevertheless, are in complete agreement with Locke's view that their property rights take precedence over all social, moral, or legal obligations or limitations.

The Boone County Court was very responsive to this point of view and, despite pleas by the CTF and the State Park Board for protective agricultural zoning of the sinkhole plain until the state could buy it, the court zoned all of the land in the Pierpont area rural residential permitting residential development on lots of 2.5 to 3.0 acres depending on the sewage facilities available. Landowners had no objection to the State Park Board buying their lands for inclusion in the park, but did not want any limitations placed on their land speculation activities. They reasoned that residential zoning

would make the situation more critical and, thereby, encourage the state to purchase their land more quickly and at higher prices. Some of the sinkhole plain was zoned for agricultural use restricting housing construction to 10 acre lots, but only because the landowners in these areas were more interested in farming than in engaging in land speculation.

At the state level, officials from various agencies not directly responsible for the state park—for example, the Missouri Geological Survey, the Missouri Clean Water Commission, and the Attorney General's Office—generally shared many of my preservationist attitudes and provided considerable help and advice which was at the same time consistent with the activities and interests of their agencies and approved by their superiors. In contrast, no one that I coordinated with in the State Park Board Office seemed to possess any nature preservation attitudes and the staff generally provided as little assistance as it could without appearing to be blatantly obstructive. During the first 2½ years that I attempted to coordinate with the park board office staff, no one in the office showed any interest in familiarizing themselves with the situation. When at last I was ready to make my presentation to the Missouri State Park Board itself, park board officials begged me to delay my presentation one additional month so that they could at least study the situation in order to have something to say at the meeting.

By the end of the month the State Park Board Office was ready to endorse the CTF's land purchase plan and, subsequently, about \$400,000 was spent on acquiring 296 acres, about one-fourth of the sinkhole plain. These purchases, nevertheless, were restricted to sections of the sinkhole plain which would make suitable additions to the park's surface areas and no purchases were made or planned which would halt residential development around Pierpont or give protection to the surface areas directly over the cave's main passages—the point of the CTF's effort.

In part, park board officials' early indifference to the fate of Devils Icebox stemmed from their personal lack of preservationist sympathies, but it was also related to their general assessment of the gravity of the situation. They had concluded in advance that my study of the problem would be no more conclusive than Middaugh's earlier preliminary report. Put another way, they believed that the situation had clearly not reached a critical level, that there was no way to predict just when this level would be reached, and that it was always possible that residential development would stop of its own accord short of this critical level. Having reached these conclusions, they were not inclined to spend money on Devils Icebox, or to even think about the problem.

This disinterest, however, was more than a case of poor preservationist attitudes or bad judgment. Even after the State Park Board approved the purchase of sinkhole plain lands to protect the cave and the park, the park board office staff continued to show little enthusiasm for the project. Since this reluctance has continued through a reorganization of the State Park Board into the Department of Natural Resources' Division of Parks and Recreation and through a change of administration which has brought in strongly preservationist and conservationist leadership, it has become obvious that there are other more significant factors which inhibit action favorable to the preservation of Devils Icebox.

These factors appear to be closely related to the nature of the work of the Division of Parks and Recreation. Like the State Park Board Office before it, it is responsible for

providing recreational activities on state lands. As a result, it quite naturally places high value on land in terms of its recreational use. Moreover, since the division operates on a limited budget and must make difficult choices about where to spend its money, it tends to buy lands which have a high recreational value or use. The division seeks the greatest good for the greatest number with the greatest good defined occupationally as high multi-purpose and intense recreational use. Not only are these land purchase preferences a direct result of the tendency of recreational specialists to view land in terms of recreational use, but they are strongly reinforced by the political necessity of justifying land purchases to the legislature which wants state agencies to get the most for their money. Since lands with high multi-purpose recreational value are easier to justify and, therefore, pass legislative review more easily, the Division of Parks and Recreation tends to make these kinds of purchases in preference to land with little or no recreational or multi-use value.

Unfortunately, this scheme of things makes it difficult for the division to justify additional sinkhole plain purchases. Since access to the cave is difficult requiring special equipment and experience, few people have the desire or the ability to visit the cave itself. Thus, whatever recreational value the cave may have—qualitatively, it has a low recreational value quantitatively. In addition, land purchases made in the Pierpont area for the purpose of halting residential development have no recreational value at all—at least, not until the state is willing to purchase and remove the existing houses in the area.

When I started working on the Devils Icebox project, I immediately perceived that it would be difficult to provide arguments for preserving the cave which could overcome both local and state level opposition. My own reasons for wanting to save the cave were aesthetic, scientific, and recreational. I had spent a large amount of my time in the middle and late 1960s in Devils Icebox and had found it aesthetically and scientifically interesting and a substantial recreational challenge. While I couldn't honestly describe the cave as beautiful, it was most certainly awesome, or, in nineteenth century terminology, sublime. While aesthetic, scientific, and recreational values are recognized in some contexts as reasons for preserving natural objects, they are not, however, especially good reasons for preserving a cave. Even strongly preservationist-minded people in the local area were not at all sure that caves are worth saving. Thus, my reasons were really something more like motives than justifications. They helped people understand what I was trying to do, but did little to convince them that what I was doing was right.

It was especially difficult for residents of Boone County to accept preservationist arguments based on the aesthetic, scientific, and recreational value of Devils Icebox because the local community knew very little about caves in general and almost nothing about Devils Icebox in particular. In accordance with what is still more or less the policy of the National Speleological Society, Missouri cavers had maintained a very low profile in Boone County and had tried to keep the very existence of Devils Icebox as secret as possible. It was believed that Devils Icebox was a dangerous cave and that publicity about the cave could lead to deaths as inexperienced people attempted to traverse the water passage. In addition, there was concern that publicity could result in cave vandalism. When the water pollution problem arose, the local citizenry was little prepared to accept Devils Icebox as the largest and most impressive natural feature of Boone County and one of the most important caves in the

State of Missouri. Attempts were made to inform the public with a well-publicized slide show and talk at the county library and by the publication of a special issue of *Missouri Speleology* (Hargrove et al, 1973) providing photographs of the cave and describing in detail the problems involved. A serious credibility gap, nevertheless, always remained reducing the effectiveness of these preservationist arguments.

An attempt was made to enhance these arguments by proposing a small development of approximately ¼ mile of the cave. The CTF report presented a discussion of this possibility with maps, photographs, cost estimates, and an impact statement which emphasized what had to be done to protect the life of the cave. We proposed that the tour be free and focus on conservation education, particularly the geology and biology of the cave and the water pollution problem. Unfortunately, however, local cavers and other environmentalists were not enthusiastic about this idea and I was not able to draw much attention to this possibility without risking the alienation of local people already favoring the protection of the cave. The existence of this proposal in the report, however, made it easier to counter arguments that the cave had benefit for the few and not the many. One little old lady, for example, showed up in county court one day to state that the cave had little value except to rich people like myself who could afford to buy special equipment and hire guides to make safaris into the cave. While I had mixed emotions about this project as well, I am still convinced that such a development would have had very beneficial effects educationally and probably would have discouraged potential home builders once they took the tour.

Another set of arguments, which we used to some extent, concerned the danger of the water pollution to the life of the cave. Unfortunately, since the half mile water passage had inhibited biological research in the cave, there was virtually no biological information available on Devils Icebox. There being far too little time to conduct a full-scale biological survey, we concentrated on two kinds of animals: the bats and the pink plenaria, a kind of flatworm first discovered in Devils Icebox. It was obvious that Devils Icebox was used by bats as a nursing site and that it was an important stopping place for migratory bats; however, the use of the cave by bats turned out to be so complex that we were not able to come up with many specifics on such short notice. We also tried to find a flatworm expert willing to say that Devils Icebox was critical to the survival of the pink plenaria, but, because of rumors of pink plenaria elsewhere, no one was willing to make such a statement. In any event, it soon became evident that bats and worms were not considered very good reasons to halt residential development over the cave.

In the end, the CTF was forced to focus almost exclusively on the public health aspects of the water pollution problem. After extensive amounts of water testing in the cave, we were able to demonstrate conclusively that the contamination was coming from residential development and not from wildlife or agricultural animals. Since the rate of development over the cave could not be accurately computed, we could not predict when the situation would be so critical that the public could no longer be permitted to visit the Rock Bridge and the Icebox entrance; however, we proved that individual sewage facilities were not suitable for houses built on the sinkhole plain. The key to this argument was large amounts of phosphorus found in water falling from Smelly Dome and from another dome directly under the Pierpont intersection. All individual sewage devices depend on percolation through the soil. The Missouri Geological Survey

had long maintained that percolation would not normally occur on Missouri sinkhole plains. Had any percolation occurred on the Devils Icebox sinkhole plain, the large amounts of phosphorus would not have appeared. Thus, we were able to argue that this sinkhole plain was a normal sinkhole plain completely unsuitable for residential development which did not utilize city sewer lines.

The argument then continued along economic lines. Assuming twice as many roads with complete residential development and assuming that the cost of the sewers would be three times as expensive as ordinary sewers because of special engineering problems and pumping stations to move the sewage, the cost of the sewers was about three million dollars equaling the cost of outright purchase of the entire sinkhole plain, houses and all. It was then argued that purchase of the entire sinkhole plain was not necessary to halt residential development and that the current level of degradation of the park and the cave system could be tolerated. Seen in this way, a partial land purchase program appeared to be the cheapest and surest way to control the situation while at the same time leaving much of the sinkhole plain in private hands.

Although this argument was strongly endorsed by the Missouri Clean Water Commission and was accepted by the Missouri State Park Board at the time, I have always regretted that I had to use it as the primary justification for saving the cave because, in reality, it is not a justification for protecting the cave except as a means to saving the park. When engaging in the Devils Icebox effort, I had hoped that my experiences there would provide a model for solving similar problems in other parts of the state, which the Missouri Geological Survey estimates to be one-third to one-half karst. Actually, however, I only succeeded in showing how to go about saving a cave when its entrance happened to be the main feature of a state park.

In addition, there is a serious weakness in the gradual approach which I championed. Although partial purchase over a period of years represents the best and cheapest reconciliation of all interests—the farmers can still farm, the local residents can still live there, the speculators still get their money, and the state spends as little as possible—it has the drawback of maintaining the situation at a stable, noncritical level which makes it difficult to give land purchase a high priority. For example, before the state agreed to the land purchase program, I made a prediction about the rate of development based on construction in progress and lots already sold. Because of the land purchase program, many landowners who had been planning to build chose instead to await purchase of their land by the state. Ironically, the fact that these people did not build has recently been taken as evidence that I had overestimated the rate of residential development and that the reduced rate does not warrant additional land purchases. Judging by this kind of thinking, it may be that problems confronting American democracy can only be solved at the height of a crisis and only to the extent that they are solved during the first wave of corrective action.

This sort of problem, I believe, also helps to demonstrate the weakness of a preservationist argument based on the preservation of a natural object solely as a means to preserving something else. Probably, the partial land purchase policy can only be truly effective if at least part of the goal of the policy is the protection of the cave for its own sake as well as the protection of the park.

One possible way to make this shift while still retaining water quality as the primary argument is to draw attention to the importance of the cave system as a whole to the park

visitor's enjoyment of the cave's entrance features, the main attraction of the park. In Yellowstone National Park, for example, the vast and unvisited forests greatly enhance the park visitor's enjoyment of what he sees from his car and from the walkways near the parking lots. In much the same way, knowledge of the existence of an extensive cave system greatly enhances the Rock Bridge State Park visitor's enjoyment of the cave entrance. When a tourist looks at the entrance of Devils Icebox or climbs down into the entrance pit and looks upstream into the darkness he is thinking about more than what he immediately perceives. He is also thinking about the large cave system beyond; this is an important part of his total park experience. Commercial cave owners have always been very much aware of this aspect of cave aesthetics and that is why they always make some mention of vast unexplored regions beyond the commercial paths, whether real or imaginary. Now suppose that the pollution problem some day reaches a level which dramatically damages the cave but still permits visitors to look at the entrance features from a suitable distance. Most certainly, knowledge of the degradation of the system as a whole will significantly reduce the visitor's park experience, if it does not ruin it completely.

Also, there is nothing wrong with preservationist arguments based on aesthetic, scientific, or recreational value. As I have argued elsewhere (Hargrove, 1976), cave conservation, though late in coming, is developing in a way which parallels the development of nature preservation and conservation attitudes in nineteenth century America. If this is correct, then an educational program aimed at disseminating cave conservation values could make political activity on behalf of cave protection much easier in the future.

My experiences with Devils Icebox suggest that the general public is already close to accepting cave conservation values as part of the nature preservationist repertoire. Rural landowners frequently asked me if Devils Icebox was beautiful and asked it in a way which indicated that they were searching for a reason to justify their personal support of my effort. As a matter of fact, it was really only the landowners over Devils Icebox who spent their time dogmatically reciting their special pre-societal rights, and even among them there were signs of preservationist sympathies. On one occasion, for example, a large number of farmers from the sinkhole plain came into county court for the purpose of shouting so loudly every time I tried to speak that I couldn't be heard. Yet, afterward, these same farmers crowded around me to talk with me about Devils Icebox. Many of them had brought old postcards and photographs and other historical items for my examination and comment. Though concerned with their financial interests in their land and ready at the drop of a hat to talk about their property rights, since early childhood these same people had also possessed a natural curiosity and wonder about the cave.

The conflict of land value at Devils Icebox was, thus, on one level, a conflict between preservationist attitudes of the environmentalist from the city of Columbia and the Lockean land attitudes of the local landowners, but, on another level, it was also a conflict within the landowners themselves. If caves are to be saved, it is necessary to educate rural landowners to the value of caves for only then can we expect progressive action in the area of county zoning and the firm support of the state representatives and senators of these constituencies, when state agencies propose purchasing land with low multi-purpose recreational value simply to protect a cave for its own sake or in some rather abstract sense to maintain the integrity of a park.

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Potential Liability of the United States from Persons Exploring Caves on the Public Lands

John D. Erdmann*

This paper emphasizes the concept of negligence law known as "Duty of Care" as it applies to managers and cavers. By seeking to meet our duty of care requirements, we will be anticipating all foreseeable problems and thereby eliminate many conditions and circumstances which contribute to accidents.

Before beginning, I would like to wonder out loud whether we really know the extent to which the lands many of us administer contain caves. I have a preliminary United States Geological Survey map which shows the location of karst features in the lower 48 states. I was truly surprised to see the extent of cave locations. It appears that we may be sitting on a large number of undiscovered caves. Should any of you wish to examine the map or learn where you may write to obtain copies, please drop me a line. The office which is preparing this map is very interested in receiving comments.

Now for a discussion of tort law as it relates to cave exploration! "Tort" is the lawyer's word meaning a private injury or wrong. It connotes a violation of duty imposed by general law, usually common law, although it can be statutory in origin. The "tort-feasor" is the wrong-doer. The law imposes "liability" to correct the wrong or compensate the injury to the extent possible.

A suit against the United States for injury sustained by a person during his exploration of a cave located in lands administered by the Federal Government would be based on the fact that the United States is the owner of real property. The theory of the case would most likely rest on concepts of negligence on the part of Government personnel. Although this paper was originally written with only the public lands administered by the Bureau of Land Management in mind, most of the comments will apply equally well to the Forest Service and the National Park Service.

At common law, the sovereign government cannot be sued unless it gives consent. An official of the Government could be sued in his private capacity only if he was not acting within his government capacities at the time the injury was caused. In years past, the only way to compensate a government-caused tort injury was through a private bill in the Congress. It wasn't until 1946 that sovereign immunity was waived for tort actions by passage of the Federal Tort Claims Act (28 U.S.C. 2674). This statute allows a private individual to sue the Government for the tortious acts of its agents and employees as if it were an individual citizen. The Act provides as follows:

The United States shall be liable, respecting the provisions of this title relating to tort claims, in the same manner as a private individual under the circumstances, but shall not be liable for interest prior to judgment or for punitive damages.

Since 1946, the context for analyzing the obligations and duties of Government personnel vis-a-vis cave explorers has been the common law of negligence. Few states have codified the common law rules of negligence regarding the ownership of property, none that I know of in the Rocky Mountain states. Specific statutes may impose strict liability for the use of dangerous substances or the manufacture of hazardous products, but such statutes would be inapplicable to naturally occurring phenomena. It is not uncommon for city and other local governments to pass ordinances attempting to impose minimal duties of care on landowners, for example, an ordinance requiring a homeowner to shovel the snow on his sidewalk. However, it is unlikely that ordinances of this type would pertain to locations where the caves on public lands are situated. The applicable rules, therefore, are those derived from a long history of decided court cases involving negligence of many types and descriptions which can be found in all jurisdictions. Although cursory research has not disclosed any case exactly on point, it is safe to extract from many related cases those general rules that would apply to any negligence suit in which the United States would be a potential defendant by virtue of its status as an owner of real property.

A claim of negligence depends in the first instance upon the concept of duty. A duty may be defined as an obligation to conform to a particular standard of conduct toward another to which the law will give recognition and effect. One case law definition states that negligence is the failure to observe, for the protection of the interests of another person, that degree of care, precaution and vigilance which circumstances demand, whereby the other person suffers injury.

The best defense against a claim of negligence in the circumstances of cave exploration would be the doctrine of assumption of risk. In order for a person to assume a risk, he must have *actual knowledge of the danger and an appreciation of the peril in which he is placing himself*; his exposure to the risk must be voluntary in such a way that other persons who have a duty of care are assumed to be relieved of their duty.

The essential question is whether the potential plaintiff's interests are entitled to legal protection against the potential defendant's conduct in view of the applicable factual situation. The question cannot be discussed in the particular context of cave exploration, however, without reference to one more general rule.

In the common law of negligence there has been a historical distinction between action and inaction on the part of a defendant, or "misfeasance" and "nonfeasance." For the former, a relationship between the parties at suit is assumed; but for the latter it is necessary to find some definite relationship between the parties of such a character that social policy justifies the imposition of a duty to act. Without exceptional circumstances, the law ordinarily does not require a person to be his brother's keeper. In a case of

*Legal Assistant, Wyoming State Office, Bureau of Land Management, U.S. Department of the Interior

inaction, the question becomes whether the defendant has gone so far in what he has actually done, and has gotten himself into such a relationship with the plaintiff, that the interests of the plaintiff have begun to be affected adversely, as distinguished from a mere failure of the defendant to confer a benefit upon the plaintiff.

Before the Government's duties toward cave explorers can be set out, the explorers must first be characterized as trespassers, licensees or invitees because the duty of care is different as to each category of potential plaintiff. As to caves on the public lands and in National Forests, we can safely assume that we are not generally dealing with trespassers for two reasons: First, historical practice has been to allow the public at large a right of access for purposes of casual occupancy which do not result in significant disturbance. Second, and this reason applies to National Parks as well, the Government has acted to control access to many caves into which entrance is allowed only by permit or in the company of a guide. A trespass situation could result only from an unauthorized entry of a cave that is plainly marked as not open to public access. Likewise we are probably not dealing with invitees unless our own business purposes are involved in the exploration activity. However, for example, if the Bureau were to engage the services of a consulting cave researcher, it might be possible for him to be characterized as an invitee. For most of the typical situations not involving unauthorized entry or Government initiated research, the characterization of the explorers would probably be that of licensees.

The traditional rules for duty of care pertaining to natural hazards are that the property owner is under no obligation to the trespasser, that he is required to warn the licensee, and that he must take all reasonable affirmative steps to protect the invitee. Historically, the safest approach for an owner of land containing natural hazards has been to do absolutely nothing about the hazards; the land owner was deemed not to have an affirmative duty to remedy conditions of purely natural origin. On the other hand, if the land owner were to alter the condition of his land, such as by erecting a structure, the condition would no longer be regarded as a natural one; the land owner could then be held liable for any injury resulting from his negligence. Even as to trespassers, the traditional rules have been modified by exceptions for frequent trespass, a discovered trespasser, children, attractive nuisances, and any foreseeable trespass where the cost of prevention is completely outweighed by the risk of injury. As to the licensee, permission to enter upon the land carries with it no obligation requiring the owner to inspect the land to discover dangers which are unknown, nor to give warning or protection against conditions which are known or should be obvious to the licensee. Protective measures are required only for the invitee. As to any person, however, the landowner cannot set a trap; that is, he cannot give the appearance or assurance of safety if he knows of a dangerous condition. Nor can he create an increased risk of harm by allowing frequent use when he could take affirmative steps to prevent the risk of harm. These considerations depend upon the locality, the seriousness of the danger, and the ease and expense of preventing the risk of harm.

Because the Government has installed locked gates at the entrances to many caves and has sealed or otherwise barred other points of dangerous exposure, and because the Government now asserts authority to regulate access by the use of permits, any persons allowed to enter these caves should be deemed as a licensee toward which the personnel authorizing entry have the highest duty of care generally

required for a licensee. In order to achieve consistent regulation, I would advocate that the permit procedure should apply uniformly to all caves which have been sealed. The traditional rules would still apply to all other caves which remain in a totally natural state.

The problem of allowing some caves to remain in their natural condition is complicated by the affirmative mission of the various Government agencies to carry out the purposes of the Preservation of Antiquities Act (16 U.S.C. 461-467). By this Act of Congress, the Secretary of the Interior is required to preserve and protect items of archeological and paleontological interest as well as unique objects of scientific interest such as the natural rock formations in caves. If Government personnel have any suspicion that a cave contains any items required to be protected and that there is a likelihood of entry which could lead to destruction of the objects requiring protection, then all necessary steps should be taken to prevent any uncontrolled access. I am unfamiliar with the National Park Service statutory authorities, but suspect that they require a similar approach. I am also unsure of how the Forest Service cooperates in realizing the objectives of the Antiquities Act. Perhaps this topic deserves further discussion.

In the context of our present analysis, I can at least say that the Bureau of Land Management does not have the luxury of doing nothing in order to rely on the traditional rules of negligence liability applicable to owners of real property containing natural hazards. Our concentration must instead be placed upon doing all that is reasonably possible to insure that cave explorers are fully informed of all known risks and hazards, and that we do what we can within the limits of funding and personnel to insure that no injury occurs to those persons who are allowed to enter the caves on the public lands which the Bureau administers.

As explained, all managers have a duty to give adequate warning of all known perils to all persons allowed to enter caves where access is controlled by our actions. A negligence suit against the United States would be decided upon the factual evidence indicating whether or not an injured party was adequately informed such that he voluntarily assumed the risks which had been explained to him. The use of a waiver of liability form would be only one piece of evidence and would not be determinative of the issue. Even if an injured plaintiff had signed a waiver, the United States could still be liable if Government personnel did not adequately explain all known facts about the hazard that resulted in the injury. Another piece of evidence that could be crucial would be the standard practice as exercised with all other persons who enter the particular cave. For example, if testimony from several other persons permitted to enter the same cave establishes that Government personnel routinely warned of certain dangers, then the inference would be that the injured plaintiff was similarly informed despite his denials. In order for the doctrine of assumption of risk to operate to reduce the duty of care independently of any warnings, the injured plaintiff must have had *actual knowledge* of an unexplained hazard which resulted in an injury. This is a difficult fact to prove. It would be preferable for us to insure that we always have an opportunity to explain all known hazards in advance so as to have satisfied our required duty of care.

The duty of care owing to a person who intends to explore a cave at the request of the Government is much higher than that owing to a licensee. The obligation in this situation would be to actually protect the invitee from all known hazards. One possible approach would be to provide a guide

during the actual exploration and research activity. It would also be advisable to have the researcher execute a cooperative agreement whereby he specifically assumes certain risks described in detail; such a list of assumed risks should state that it is illustrative only and not inclusive. The cooperative agreement should be based upon principles of contract in order for there to be a sound reason for the explorer/researcher to be willing to assume the risks. There should be a flow of consideration both ways between the Government and the invitee; for example, the agreement should be on a business footing and both parties should have reason to benefit from the bargain. If these requirements cannot be met, then the Government should not request the services of a researcher whose status might be interpreted as an invitee. The only sure way to meet the required standard of care, which would be to seek to actually prevent all possible injury, would be to deny access.

Before turning to the specifics of the procedures which could be used by Government personnel, two additional points of general discussion need to be mentioned: First, the duty of care concept in a negligence suit is one based upon reasonableness in view of the circumstances; the ultimate fact issues must turn upon jury determination. What is reasonable is what twelve selected people say it is. Second, the defense of contributory negligence might be available based upon suitable facts. However, it would be preferable not to investigate such a defense because it assumes that the Government cave manager has been negligent and that the United States will be found liable unless the defense can be proved.

In summary, the general guidelines are as follows:

1. The Government should seek to prevent unauthorized entry of caves on lands owned by the United States. The Antiquities Act probably requires the use of a permit procedure.
2. A person who enters a marked and sealed cave without a permit should be considered a trespasser. Once the trespass is discovered, however, he should be treated as a licensee in so far as our duty of care is concerned.
3. The Government should not rely at the outset upon waivers of liability and defenses to a claim of negligence. We should seek to meet our duty of care to all persons given a permit to enter caves under our control by instituting adequate warning procedures.
4. The Government does not have an absolute duty to protect a cave explorer unless he has been requested to enter the cave for benefit of the Government. In this situation, a waiver of liability statement should be included in a cooperative agreement drafted on principles of contract.
5. The duty of care owing to all persons who obtain permits to enter caves is that we inform them of all known hazards and that we seek to establish that the cave explorers have an actual understanding of the risks they face.
6. Any additional steps that we can take within limits of funding and manpower to protect cave explorers should be undertaken as appropriate even though they may not be strictly required in satisfaction of our duty of care to licensees.

These statements complete the bulk of my paper. I have a few additional thoughts on search and rescue operations which will follow. First, however, I would like to discuss some specific comments which were directed to the Bureau's Worland District Office in response to a request for review

of the permit form used by that office. Some of the comments might well apply elsewhere. In keeping with the tenor of this paper, my emphasis was placed on the effectiveness of the warnings given, rather than on the waiver of liability in the permit form.

- The permit form could be both an application and grant of permission. The application portion should reference only one cave per form and give an expected exit time. Each person who will be entering the cave should be required to complete an initial questionnaire which seeks to determine the level of his experience and competence. Once on file, this questionnaire could be referenced in future applications. The application should also state that certain listed information brochures or pamphlets have been read in their entirety. (Each cave or portions thereof which will be visited can have a separate set of warnings based upon a Bureau inventory of hazards.)
- The application should contain some documentation resulting from an interview with Bureau personnel that confirms that the applicant has understood the warnings given him and that he has or will obtain adequate equipment.
- It is important to obtain complete names and addresses as now required for completion of the form in use.
- The waiver of liability statement could be reduced to a simple statement that Bureau personnel have explained the hazards involved, both as to cave exploring generally and as to the specific cave or portions thereof intended to be entered, and that the applicant is knowingly and voluntarily assuming the risks.
- The paragraph which refers to the Protection of Antiquities Act should set out more clearly what activities are permitted and which are prohibited. The penalties of the law should be described and accurately cited. Disturbance as well as removal should be discussed.
- No permit should be given to any person who is under the age of sixteen. Where children are concerned, the law imposes an absolute duty of care requiring protection similar to that imposed for an invitee. Even a young teenager is not usually deemed capable of fully understanding the potential risks of dangerous activities and would therefore not be able to assume any of the risks involved. An applicant between the ages of 16 and 18 should have consent of his parents or guardian. Persons 18 and older can be deemed to be adults for purposes of assumption of risk so long as they appear to be possessed of normal mental capabilities.
- The radiation hazard known to exist in some of the caves is the type of hazard which should be fully described in a separate leaflet which will be distributed with the informational packet given to an applicant to read before his permit is approved. The form should contain a blank space for recording total exposure. Each cave explorer could then be required to present his last issued permit at the time of making a new application in order to prepare an updated record. The Bureau should not have to keep a separate record of each individual's

exposure. The information leaflet should explain the dangers of smoking in connection with radiation exposure. (Separate exposure records for Bureau employees should be maintained as appropriate.)

- The keys to the gates on the caves should be under the control of only one office and a limited number of people. If an office in the vicinity is not feasible, then all applicants should be required to come to the Worland District Office to obtain their permits and keys. An alternative would be to use combination locks on which the combinations are changed frequently. Combination locks would have the advantage of not having to account for lost keys. On the other hand, the return of a key in the mail or by personal delivery can signify that all persons are safely out of the cave. No matter what system is used, a check-out procedure is essential and each applicant must be made aware of its importance.
- If adequate notice is given to all applicants in advance, it would be appropriate to refuse to give a new permit to an explorer who fails to inform Bureau personnel of his return or who has intentionally destroyed or removed natural objects from the cave without permission. In any case of this type, a letter should be sent to the explorer which allows for an answer or explanation on his part.
- All permits should be prepared in duplicate with one given to the applicant along with any appropriate information brochures and the other retained in the office of issuance. The permit copies and any other related records should be retained for seven years.
- Except for the age limitations discussed above, no person or group should be denied a permit based upon a lack of experience or a character judgment so long as a required number of persons in his group has some experience in cave exploration. We should not try to be overly critical in judging who has experience so long as his application contains statements that reasonably support the applicant's interpretation. (I should add here that I was not even considering the possibility that an individual would want to enter without companions.)

I am afraid that each of these comments could lead to a full discussion. Perhaps they can be kept in mind for a future workshop or two.

In conclusion, we should observe that even if our duty of

care has been met as to all persons seeking to enter caves under our management, an occasional accident will still occur; or perhaps a spelunker will fail to return as scheduled. The question then becomes to what extent are we obliged to, or to what extent do we intend to become involved in search and rescue operations.

The traditional common law is that no person, including a property owner, is obliged to initiate a mission of aid, no matter what the moral outrage for his failure to do so. In the situation involving a lost or injured cave explorer on United States Government lands, the appropriate official charged with the general police powers affecting public safety would be the local sheriff. Under the new BLM Organic Act, the Bureau has funding authority to participate in search and rescue operations, but we are without implementing regulations. I am unfamiliar with the Park Service and Forest Service procedures. I imagine the situations are similar in that, in the last analysis, it is a matter of policy as to the extent that Government personnel should become involved.

The caution to be kept in mind is that, once aid is volunteered, the rescuers become liable for any negligence in conducting the rescue. The nebulous standard of conduct is the reasonable man test: What would a reasonable man do under similar circumstances? In an actual suit that goes to trial, that question will be answered by the jury. If the situation is truly an emergency, that fact likely will be taken into account.

The fear of a negligence suit should not paralyze Government personnel into inaction, however. So long as they are performing within a broad definition of their duties, any liability would not attach personally, but would be borne by the Government. Also, by virtue of having a search and rescue operation plan in effect, or by virtue of some other inconspicuous action, a situation may have been created inadvertently wherein we would be deemed to have already undertaken an obligation to carry out the rescue. Therefore, Government personnel should consider first their own personal safety, then act to call for help and to notify the sheriff. Upon confirmation that their agency stands behind their efforts, a search and rescue operation can then be initiated as directed by the local police authorities. Only in the most extreme situations involving an immediate risk to life should a Government employee act without attempting to first report to his supervisor, and then only when his action will probably be successful without risk to himself. However, in no circumstances should he enter a cave alone.

I would hope that all would use good common sense in any of these perilous situations. When we come right down to it, that's all I've been discussing.

Everything You Always Wanted to Know— And More—on Caving Liability!!

Hugh W. Blanchard*

Initially let me discuss very briefly the risk of liability to the average caver. At the risk of oversimplification, liability ultimately depends on the caver's own negligence or absence of same. There are several common misconceptions in this area. One is that fellow club members of the negligent caver may also be liable simply by being members of the same club. This is not correct. Mere membership in the same organization does not make fellow club members liable for the negligent act. Liability attaches only to that person or persons who are actually responsible for the injury.

Another common misconception, sometimes known as the IBM syndrome, is that incorporating the caving club will somehow lessen the dangers of liability. Again, this is not correct. Incorporation may be desirable for other reasons. For example, it is necessary in some states for an organization to be incorporated in order to receive legal title to land. However, incorporating the caving club does not affect a member's liability for negligence in the slightest.

If a caving club has fairly frequent training sessions including climbing practices for its members and guests, it should consider having trainees sign waiver of liability forms. This, of course, will not remove all danger of liability especially when active negligence is a cause of the injury. Also a minor can subsequently disaffirm such a waiver. In most states today a minor is a person under 18 (Moral—never trust anyone under 18). However, an intelligently drafted waiver signed both by the minor and his parents shows at least that the minor and his parents were put on notice concerning possible hazards and diminishes the prospects of future lawsuits.

I am not aware of any negligence insurance available for cavers at nominal cost. Doubtless, such insurance is obtainable but only at a price which few cavers would be willing to pay.

I will now attempt to summarize the main problems relating to landowners' liability. Fear of lawsuits is undoubtedly the main reason why owners place their caves off-limits.

Traditionally under the common law, a landowner owed varying degrees of care depending on who entered his land. The highest standard is owed to:

INVITEES: These are business visitors who come on the land at the owner's invitation for a mutual business purpose. The owner has a duty not only to warn them of known dangerous conditions but also to make a reasonable inspection of the property to discover unknown dangers. Visitors paying admission to visit a cave are invitees.

LICENSEES: This class of persons enters the property with the owner's consent only for their own purpose and not

for the owner's benefit. The owner has a duty to carry on activities with reasonable care but need not make any inspection to discover unknown dangers. Cavers exploring a wild cave with the owner's consent and not paying admission would be licensees.

The lowest standard of care is owed to:

TRESPASSERS: The owner need only refrain from intentional harm, such as setting traps, against trespasser entering his land without permission and has no duty to keep the land in a safe condition. There are several qualifications to this general rule of nonliability to trespassers. One, the so-called "attractive nuisance" doctrine, provides that trespassing children are legally viewed as licensees if the attraction, usually dangerous machinery, is an artificially created trap. This doctrine is not in effect in all states and, even in the states adopting it, it is not applicable to "natural" conditions of nature such as caves. The owner, in some states, also owes a duty of reasonable care to known or constant trespassers and is obligated to warn them of known dangers. Thus in some states, cavers entering a cave with the knowledge but not the consent of the owner would be legally classified as licensees.

In recent years courts in many states have abandoned the old classifications of invitee, licensee and trespasser in favor of a simple rule of requiring reasonable care. Under this doctrine the landowner must maintain his property in a reasonable safe condition considering all the circumstances. I suspect that this change will be largely one of semantics and that only rarely will the legal result be different than under the old nomenclature.

Within the past 20 years or so the state legislatures of all but two or three states have passed so-called "Sportsmen's Laws." Such statutes limit the liability of landowners who permit the public to use their land for recreational purposes without charge. The landowners' duty of care under these statutes is similar to that owed a trespasser. These laws are not uniform and differ considerably in their language. Very few specifically mention cave exploring as one of the protected recreational activities. Some others include a general statement that all recreational activities are included. However, most contain a list of protected activities invariably including hunting, fishing and hiking but do not mention cave exploring. This may cause problems as we will see.

It should be mentioned in passing that the Federal Government's liability for injuries occurring on Federally-owned land is governed by local state law.

Let me now discuss a recent case which highlights the problems of landowners' liability and may contain some clues to possible solutions.** The so-called Knox Cave case started on May 3, 1975 with a trip to Knox Cave, New York by six cavers led by two NSS members. Knox had been a commercial cave until 1958. Since then it had become the most popular wild sports cave in the northeast with literally thousands of cavers visiting it over the years. Its entrance lies at the bottom of a steep sinkhole and it was regarded as a safe cave with no reported injuries despite the large

* Chairman, NSS Legal Committee, 1828 Alpha Ave., South Pasadena, CA 91030.

**Grateful acknowledgment is given to NSS Legal Committee Member James W. Harbison, Jr. who provided the writer with much of the information on this case and was prepared to submit an amicus curiae brief if the case had gone to trial.

amount of traffic through it. However on that tragic May morning just after four of the cavers entered the cave, a one-ton block of ice fell 25 feet from the sinkhole edge squarely on the two remaining cavers about to enter the cave. One of the cavers, a young man, was killed instantly. His companion, a 19-year-old coed, was severely injured and rendered a paraplegic.

Several months later the injured caver, through her attorney, filed a 15 million dollar damage suit against the cave owner alleging a breach of due care. The cave owner was a well-to-do New York physician who had acquired the cave along with 190 adjoining acres at a tax sale seven years before. The owner had enjoyed fine relations with northeast cavers and permitted them free access to the cave. Several years before, the cave had been briefly gated and "no trespassing" signs had been posted. However, both the gate and signs had long since disappeared by the time of the accident. Apparently, waiver forms had never been required to enter the cave.

The doctor had insurance on the 190 acres but immediately after the filing of the lawsuit, his insurance company regretfully informed him that his insurance policy did not cover the accident since the coverage was only for "vacant land" and in their opinion "vacant land" did not include owning a cave frequented by a substantial number of cavers (Moral—You will never have any problems with insurance companies as long as you faithfully pay your premiums and never make any claims on the coverage). Needless to say, the discovery that he was uninsured came as a surprise to the doctor who immediately filed suit against the insurance company to determine the status of his coverage. A trial resulted with the New York Supreme Court finding in the doctor's favor by holding that the land was unoccupied and unused even though it included a cave. The Court also held that the fact that the doctor allowed experienced cavers to use his cave without charging admission and permitted them to install a platform and ladder in the cave did not alter the "vacant" quality of the land.

With this hurdle behind him, the doctor and his insurance company now prepared for trial on the question of his liability. However, just prior to trial, his insurance company felt it more prudent to settle the case out-of-court for a reported settlement of \$325,000. Thus ended the Knox Cave case with no decision ever rendered as to whether the owner was negligent.

One cannot help but wonder what would have occurred

had the case gone before a judge and jury. I personally regard the suit as quite weak since no one apparently had been aware of the falling ice hazard prior to the accident. However, it must be admitted that the jury would doubtless have been sympathetic to the plight of the paralyzed girl. Another complicating factor was whether cave exploring was included under the New York Sportsmen's Statute. The statute listed a number of recreational activities including hiking but did not mention cave exploring. It would, of course, have been argued that the caving party was engaged in hiking particularly since the accident actually occurred just outside the cave entrance. However, the counter-argument would be that courts generally construe this type of statute narrowly since it is contrary to the common law. Under a narrow construction, it is quite possible that the judge might have ruled that hiking is not the same as cave exploring.

At any rate, following the conclusion of the lawsuit, the doctor, for some strange reason, decided he would be happier without owning a cave and offered it to the NSS. The NSS, in August of this year, finally agreed to accept ownership but will probably pass title on to a suitable New York caving group as soon as the New York cavers can set up a nonprofit corporation. Like many other states, New York does not permit unincorporated organizations to receive title to land.

Are there any lessons which can be learned from this sad story? I suggest there are several. One is that any landowner always faces a potential risk of being sued for injuries occurring on his land. Even if the injured person's case is very weak, it still needs to be defended and that involves attorney's fees. Thus the NSS should take a very cautious stance in acquiring caves in its own name. Even if the landowner has insurance, that does not necessarily mean he will have coverage when he needs it most. A cave may be well protected with gates and "no trespassing" signs and several years later all of these may have disappeared. Finally the fact that almost all states have Sportsmen's Laws may not be of much benefit unless it is very clear that such statutes unquestionably include cave exploring. Obviously, suitable amendments to include cave exploring should be done when needed.

I have endeavored in this article to avoid legal citations and statute references. The interested reader may find references to additional articles dealing with caving liability in the May 1977 *NSS NEWS*, p. 112.

Cave Restoration—An Underview of Correcting Overviewing

Katherine Rohde and Ronal Kerbo*

Chrome handrails, asphalt trails, underground lunchrooms and big old brooms. Hundreds of bright lights, little dead cave mites, pennies in pools and a thousand groups from a thousand schools. Chewing tobacco, cigarette smoke, someone at the back of the tour taking a toke. The Tomahawk in Sonora is gone. Carlsbad is full of emory chips and Mammoth has its share of lint. Don't despair. Don't give up. Here they come. Clear the way, the White Tornadoes, the cleaning knights. With pail, hook and ladder, enter the cave restorer.

Imagine that you are standing in a newly discovered cave. The light from your lamp is the first to illuminate the wonders of that stone wilderness. The view is like none you have ever seen. Now remember the times you have stood in a cave that has been developed for public use. At first glance the cave seems to be undisturbed, but a look beyond the stalagmites and stalactites reveals crushed popcorn, dusty stalagmites and muddy footprints across the flowstone. Knowing what a virgin cave is like, you may stand asking yourself, trying to imagine what this cave looked like before, before the first people walked across a floor that had known no footprints, before the darkness had been pierced by an explorer's feeble light.

I remember a time that I was allowed to enter an area in a backcountry cave at Carlsbad Caverns National Park. It is a very small area, no more than 200 ft. long and 20 ft. wide. An area with long transparent soda straws, floors of active white flowstone and rimstone dams with yellow calcite crystals growing on them; it is like many places we have seen in other caves. We entered this room in stocking feet, touched nothing, took only photographs and left no footprints to show our passing. We left the room and pulled our ropes up behind us. This area is now off limits. What good does this do? Why not enter it again? Is it wrong for this small area to remain unsullied by the touch of man? By saving this little sphere of underground wilderness, we will never have to guess at its former beauty. It is now the way it looked when light first entered there and can serve as a reminder of what all caves should look like. This small area need never know the cave restorer.

Cave restoration is like having to unscrew something you have already screwed up. Any cave with asphalt trails, electric lights and cables, lunchrooms and elevators is certainly not in a natural state. If you start with a virgin cave and develop it for public use, you are faced with a responsibility to try and maintain the cave in as natural a way as possible. We are failing to meet this responsibility. We have let destruction in the name of development gain the upper hand. We know we have failed because we need restoration.

Before beginning a restoration project, careful thought must be given to what you are setting out to do. What are your limits going to be? How far are you going to go? Does restoration mean that only areas next to the trails are restored or will you also try to work in damaged areas off the trail, out of the public eye?

Restoration can be discouraging, frustrating and, if you are not careful, a vicious circle. Where does one begin and even more puzzling, where does one end? It is easy to say, "It is ended when the cave is gleaming from ceiling to floor." But, there is more to a cave as a total environment than shiny stalactites and stalagmites, crystal clear pools and glistening frozen waterfalls. Yes, in some areas this is what should be, but in other dead areas the speleothems may not be alive and active. They may even be covered with a dull, chalky, spalling coating, not looking the way we want them to appear. Yet that is also the cave. It is possible to dissolve the covering with strong acids or to scrub these dry speleothems and maybe eventually reach that shiny inner portion, but in doing so you are destroying possibly several thousand years of growth. That is not restoring the cave. That is destroying what is there and creating something else.

We don't know very much about our caves. Much of what we talk about is pure guesswork. We think they are old, very old. They hold many secrets. One of these secrets that we are trying to unravel is the unique ecosystems. These stone wildernesses are the dwelling places of very specialized lifeforms, life that has adapted to an environment of total darkness and minimum energy. How easy it is for man, the intruder, to crush this fragile life. How easy it is to say the cave should look a certain way and to spray chemicals with total disregard for life, as fragile and as little of it as there is, to produce a shining, glistening and artificial cave.

Carlsbad Caverns certainly presents a unique problem in cave restoration. Its size is overwhelming. This size makes it difficult to decide where to begin and the question of how far to go is an even more difficult decision. Add the element of fifty-four years of public use and as one other cave manager said when he was consulted, "It is depressing."

Nevertheless, we have made a start at Carlsbad Caverns. The project was begun with some basic understandings. The most important of these is that any cave restoration that takes place will be done only after careful study of each area to be worked and repaired. It is to be restored, not destroyed and recreated. Every method that is used is experimented with to see first, its reaction with the cave and second, its effectiveness at relieving the problem. Every method and action is also carefully recorded for future reference.

We started with the algae. Before introducing any chemicals into the cave we consulted with a biologist as to possible reactions and effects of the chemicals with the fauna found in the areas to be cleaned. We wanted to remove the unnatural algae growth, but not at the cost of our cave

*Carlsbad Caverns National Park, 3225 National Parks Highway, Carlsbad, N.M. 88220.

dwellers. Biospeleologists come from all over the world to study the life forms found in Carlsbad Caverns and we do not feel justified in possibly destroying the animals in the name of restoration. We set out bait transects and counted the species and numbers found in each transect. We then sprayed selected areas with a chemical that had already been tested to see that it did not destroy any of the rock, but did remove the flora. After spraying the transects, bait was again placed in the area and a population and species count made.

Fauna were also collected and subjected directly to cave rock that had been treated with chemicals to see their reaction. As yet we have no conclusions on the various substances we use in the cave. The studies are continuing, but we are attempting to use the chemicals with regard to cave life.

We have used Calcium Hypochlorite diluted with water to remove some areas of algae. After the algae has been sprayed, the area is checked periodically for reoccurrence of the flora. Records are kept and, as a result of a year of work and documentation, we have been able to predict when the algae begins to reappear and, if not get ahead of it, at least keep up with the problem and at the same time not destroy the cave and its life.

The removal of blast tailing and trail fill was also begun. In order to make accessible certain areas of the cave, tunnels were blasted through cave walls. Rather than remove the tailings from the cave, they were emptied on the floors of the cave and covered with silt. In order to facilitate traffic flow through the cave, trails were constructed through pools and over flowstone. The first trails were constructed of natural cave silt mined from various locations in the cave. In later years when the trail system was upgraded for safety and convenience, the new trails in places deviated from the original routes. These old trails were not removed, but left, often right next to the new trail.

We are lucky at Carlsbad Caverns in that there is photo documentation of the cave since before its development. These pictures have helped in making decisions as to what is natural and what is not. Silt is found naturally in places covering flowstone and it is not a part of our purpose to remove silt occurring naturally. When it has been determined that an area of fill or silt has been placed there in the development of the cave, then it is removed. Many wheelbarrows full of rock and silt have been pushed out of Carlsbad Caverns, but this like the removal of algae is still in its infancy. However, we can see a difference in the areas that have been cleared. Flowstone and old pools hidden for many years are once again uncovered.

Another problem caused by the development of the cave and more specifically by the millions of visitors who have used the cave is dust and lint accumulation on speleothems. This has been allowed to build up over the years with little attempt if any to dust off and remove the lint. Now on many active flowstone and stalagmites, the lint is permanently

enshrined under layers of calcite. It has been decided not to use strong acids to dissolve away the calcite to remove the lint. Such action would destroy many years of growth. We also have large sections of cave trail passing through profusely decorated sections of cave. Hundreds of stalactites and draperies are covered with fragile and delicate cave popcorn, cave coral, helictites and aragonite. The dust and lint has been allowed to accumulate there until many times the speleothems are covered in a fuzzy black blanket. So far, no satisfactory method of removal has been found that does not include removing and breaking off the popcorn while dusting the formations. We have begun with use of water to wash dust and lint from active areas. Whisk brooms and soft paint brushes have been utilized to remove lint in dry areas that have no easily damaged popcorn or decoration. When dust and lint has been swept off an area, it is collected in plastic sacks and removed from the cave. People using the cave produce the dust and lint and this aspect of restoration, like the algae, is one that will require periodic cleaning to keep up with the problem.

Documentation is very important in the restoration project at Carlsbad Caverns. In the past, a few halfhearted attempts at removing algae and washing lint off some active speleothems were made, but in trying to gather information as to when an area was cleaned, methods or chemicals used, there was no recorded data. It is important that complete records be kept for future use. We document all action taken including time, equipment, chemicals and methods used for each area of the cave that is cleaned or treated. By having this written record, it is possible to develop a plan of future cyclical restoration. It will aid future restorers as to the various methods tried and their results. Most important, written documentation will help to insure that old mistakes are not made over and over, adding to the destruction of the cave.

Too often, the manner in which we develop the cave is the first step in the failure of our responsibility. Rather than working with the cave as it is and has been, we try to force the cave to conform to our standards of comfort and ease. We try to change the cave to what we think it should look like and be. We can help, not just by talking about new methods of cave restoration, but in finding new ways of cave development so that restoration becomes simply a periodic clean-up rather than an attempt to put back what is gone and destroyed.

Let us not forget to give these mysterious pits and wondrous openings in the earth the respect they deserve. Many of us were first led underground by the marvel and adventure of it all. The people who come after us should be given this same chance. Forethought in development and seeing that restoration does not usher in a new dawn of destruction should be our goals. I once watched a shaft of sunlight penetrate the opening of Devil's Sinkhole. It illuminated, probed, searched and then left, with no trace of its entry. Let us all try to be to caves that shaft of light.

Comments on "Restoration of Wild Caves"

Charles A. Plantz*

The use of hydrochloric acid, alias muriatic acid, to clean cave walls, produces calcium chloride (CaCl_2), which may have bad effects on the cave floor. I recently did a partial search of the chemical literature for effects of CaCl_2 on clay and published findings in the newsletter of the Escabrosa Grotto of the National Speleological Society (1978). I will summarize the literature briefly.

Calcium chloride has been applied to dirt roads to lay dust. Most of the dust-laying effect is due to the deliquescence of CaCl_2 (it absorbs moisture from the air). In addition there is a chemical hardening effect. Rain removes the CaCl_2 from the road. "Water does not, however, always carry away as much of the salt as might be supposed, owing to the peculiar absorbent qualities of many rock powders" (Hubbard 1910).

Calcium chloride is recommended to prevent landslides caused by quick clay. About one kilogram of CaCl_2 will stabilize 907 kilograms of clay. Laboratory tests showed an increase in shear strength of both quick clay and normal clay. The strength increased with time.

Large amounts of CaCl_2 were put in boreholes in the ground near Stockholm, Sweden, and after 2 years the CaCl_2 was found to have diffused sideways away from the holes to a distance somewhere between 67 and 100 cm (Talme 1968).

Electron microscopy of clay treated with CaCl_2 for times of 1 day to 16 weeks did not indicate the formation of any new material, but as curing progressed the particles were bonded together by the calcium ions to form larger and larger stacks. Some of the very small particles may have been attacked at their edges (Garber 1971).

None of the literature mentioned cave soils, but it seems likely that they too would be hardened. Part of the effect would be permanent and part would be reversible if the CaCl_2 were washed out by water percolating through the floor (if it could be washed out completely).

Some of the Arizona cavers have concluded that I was trying to tell them they had picked the wrong acid. That's not what I meant; my plea was for using whatever acid more carefully and in smaller amounts.

Although hydrochloric acid is not completely benign, it may be the best acid for cleaning cave walls while

minimizing side effects. With careful use, its benefits should outweigh disadvantages. In previous discussion of this paper, another Symposium participant has said that he used dilute sulfuric acid to clean cave formations, and that this treatment left a coating on the formations which was desirable in that it hindered regrowth of algae under the cave lights. This is an advantage only for commercial caves and most people would conclude that coatings were undesirable in wild cave restoration. The coating was undoubtedly calcium sulfate, which, as Rane Curl has pointed out, is a normal cave mineral. Normal it is, but it is not found at all places in all caves. Furthermore, calcium sulfate is almost completely insoluble in water, so that, unlike calcium chloride, normal cave water circulation would only remove it very slowly, if ever.

I hope there will not be an explosion of chemical experimentation on caves due to the increasing popularity of cave cleanup trips. Many acids, paint removers and other solvents could be used for cave cleanups, but their side effects, particularly over periods of many years, are completely unknown. It is mostly by luck that there was even a small amount of information about CaCl_2 in the chemical literature. If cave restorers wish to show their ingenuity, why not experiment instead with portable power tools, such as rotary wire brushes or sanders?

Massive restoration projects should not only be massive, but well thought out.

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*National Speleological Society, 2242 E. Water St., Tucson, AZ. 85719

Horsethief-Big Horn Cave System vs. Uranium Mining: A Short Synopsis of Managing Conservation Efforts:

Wayne M. Sutherland*

ABSTRACT

The Little Mountain Caves Conservation Task Force (LMCCTF) organized in 1974 when uranium exploration activity on Little Mountain increased near the Horsethief-Big Horn Cave System. Virginia Nuclear Inc. conducted an extensive exploration program consisting largely of drilling numerous test holes which could have destroyed parts of the cave. The LMCCTF effectively implemented a selective publicity and letter writing program, bringing the existence of the caves and the interest of a large number of cavers to the full awareness of Virginia Nuclear. However, this program also led to some alienation of local miners due to misunderstandings concerning the task force objectives. Virginia Nuclear avoided the cave after becoming aware of its existence and importance. Finding of insufficient quantities of uranium resulted in Virginia Nuclear leaving the area.

Horsethief Cave is located on Little Mountain on the west flank of the Bighorn Mountains, east of Lovell, Wyoming, and a few yards south of the Wyoming-Montana border. The cave gained importance with the discovery of large amounts of new passage during the fall of 1970. A road used as access to the cave was built by uranium miners during the uranium boom of the 1950s. Some uranium mining has gone on since that time, but only on a very small scale. Uranium claims blanket the area which, south of the Wyoming-Montana border, is administered by the Worland District of the Bureau of Land Management. Land north of the Wyoming-Montana border is owned by the Crow Indians and is administered by the U.S. National Park Service in connection with Big Horn Canyon National Recreation Area. Some small parcels of land near the entrances to Horsethief Cave and Natural Trap Cave were withdrawn from mineral entry before the Little Mountain Cave Conservation Task Force (LMCCTF) was formed; however, preexisting claims were not affected.

The LMCCTF of the National Speleological Society (NSS) was organized in 1974 to protect caves on Little Mountain. The LMCCTF gained NSS support early in 1975. The hasty beginnings of the task force grew from recognition that Virginia Nuclear, Inc., was in the process of exploring for uranium through drilling and would possibly mine the area of Little Mountain overlying or immediately adjacent to the Horsethief-Bighorn Cave System.

Initial efforts of the LMCCTF centered around writing letters to people who had some form of control over the management of the land above and near the cave. This included the Bureau of Land Management, National Park Service, Wyoming Department of Environmental Quality (DEQ) and a number of Wyoming political officials. Due to the hastiness with which the problem was attacked, the task force neglected a matter of prime importance: that of talking to the local miners and establishing communication with

Virginia Nuclear. This mistake led to some hard feelings, and was interpreted by the local miners to suggest that the LMCCTF was created for the purpose of closing down all uranium mining on Little Mountain, which was not the case.

After the initial flurry of letter writing, the LMCCTF gained much sought-after NSS support. Recognition and support by the NSS helped point out the national interest in saving the Little Mountain Caves. Those who initially thought the LMCCTF to be only a small number of local cavers began to realize that the cave system was important to many cavers nationwide.

During this same period of time attempts were made to set up communications with the local miners and Virginia Nuclear. These attempts were successful to a limited degree. The local miners were contacted several times, but still were not completely comfortable with cavers. Letters to and from Virginia Nuclear did not flow easily until Virginia Nuclear was in the process of leaving Little Mountain.

The next effort of the task force was to expand its publicity to cavers through notes in grotto newsletters and the *NSS NEWS*. The task force also printed a small pamphlet which discussed the situation and suggested that some areas of land surrounding the caves be withdrawn from mineral entry. The withdrawing land suggestion should probably have first been discussed with the BLM; although this mistake was not serious compared to the earlier slighting of the miners.

Follow-up response to this publicity was a flood of letters by NSS cavers and others, which made all parties concerned with development near the cave realize its significance. Feedback from the BLM, DEQ, and others indicated a successful program.

The LMCCTF was offered assistance by Friends of the Earth (FOE) including the use of their attorney, the Sierra Club, and other environmental organizations. This was appreciated; however, the LMCCTF felt that this aid should be kept in reserve and used either quietly or as a last resort. The LMCCTF did consult with the FOE mining attorney on some minor points. These organizations were not used because the FOE and the Sierra Club have a bad reputation

* Box 1118, Buffalo, Wyoming 82834.

with the miners because of their prominence in environmental conflicts involving other mining areas, and involvement of these conservation organizations could not take place without the non-caving public getting involved.

Throughout the campaign, the LMCCTF tried to maintain a low profile to the general public concerned. The LMCCTF believed that greater publicity would have the adverse effect of bringing more visitors to the caves. Also, making the situation public could have worsened the adverse effects of not having contacted Virginia Nuclear and the local miners initially.

A discussion session concerning the problem was arranged by the Worland District of the BLM in conjunction with a BLM advisory board meeting during Fall, 1976. Interested groups represented included BLM, LNCCTF, Virginia Nuclear, and their legal consultants, several grottos, local miners, and others. This meeting brought out pertinent information for all concerned and clarified the viewpoints of those present. Mainly, however, the meeting brought input to the BLM which could be used for making management decisions.

Apparently, Virginia Nuclear was interested in a large-scale uranium mine, and they indicated at the meeting with the BLM that resources for such a mine were probably not present; however, their investigations were not complete at that time. They did agree to stay clear of the known cave with their exploratory drilling program. It was indicated to members of the task force that letters generated throughout their efforts had assisted that decision. Local miners stated at the BLM meeting that they believed uranium and the Horsethief-Bighorn Cave System were mutually exclusive, and that if Virginia Nuclear left the area, they would continue to mine uranium, avoiding the known cave system in the process.

Virginia Nuclear avoided the cave with their drilling program and finally gave up all their interests in Little Mountain during the summer of 1977. The LMCCTF was successful in saving the cave system for the present time, but can only claim victory by default. If Virginia Nuclear had found the large amounts of uranium they needed, they quite possibly could have mined it with probable accompanying damage to the cave system.



Formations, Bighorn-Horsethief Cave System, Montana-Wyoming. *Photo by Jim Chester.*

Achievement of Cave Management Goals Through Access Design

Dr. Thomas J. Gallagher*

ABSTRACT

The design of the access to a cave influences the visitor physically and psychologically, and can be used to help achieve management goals. Access ways are discussed as a means of controlling the number and type of visitors and enhancing the visitor's experience. Physical demand (exertion), psychological demand (uncertainty), and benefits (esthetics) are discussed. General design criteria are presented.

Natural resources in many situations are only as valuable as the culturally built facilities, such as roads and utilities, which bring them to us, or us to them. In the case of outdoor recreation, roads, parking areas, and trails make it possible to get to and use lands of recreational value. These access ways, which initially seem vital to bring people to the resource, may eventually cause serious problems of social crowding, vandalism, and excessive disturbance of the natural environment, such as found at Yosemite National Park and Mammoth Cave. Well intentioned trails to remote back-country have become "hiker highways," often leading to the destruction of the scenic beauty they made accessible. Less considered access ways, such as forest logging roads, have recently become a major issue in the Pacific Northwest due to the uncontrolled vehicle movement they allow. Access design has both the potential to provide for human needs and values, and the potential to cause serious social and environmental problems. Careful planning of access ways is necessary to assure the most appropriate use of our natural recreational resources.

Caves are rapidly becoming a more visible part of our national recreational resources. The increasing interest in caves evident through the 1970s may, however, only be the introductory phase in a massive increase in active caving. (Imagine for a moment the effect on the public of a movie, similar to *Deliverance*, that concerns caving.) Decisions concerning cave management goals must soon be made for the vast number of caves on public land that are now essentially lying fallow. As the population grows, and the caving phenomenon increases in popularity, pressure will be placed on all known caves. Access design, with the capability of influencing the visitor both physically and psychologically, will be a major factor in whether management goals for these caves are met.

Emphasis throughout this discussion of access design is placed on trail design and the associated landscape from a parking area to a cave. It is felt that this discussion will have the most relevance to noncommercial caves on public lands, but some ideas will also relate to commercial caves. Before examining access design in detail several associated points must be made.

First, placing cave management emphasis on access ways is particularly relevant as compared to other types of recreation area management. Caves, for practical, ecologic,

and esthetic purposes, are wilderness areas—that is, they frequently show few signs of human change (Watson, 1972), and moreover, changes (when desired) are often excessively costly or difficult to build. Alteration of a cave with an entry gate, lights, paving, or other devices is usually undesirable to many people from an ecologic and esthetic viewpoint. Unlike the design of a scenic overlook, for instance, the management alternative to "harden" the site is often not available. Cave management, particularly in the public sector, and particularly in the West, is primarily an event that occurs outside of the cave itself.

Second, access design should be sensitive to the potential change it might cause in the cave itself, such as interruption of normal ground water seepage by overhead impervious parking surfaces. This aspect of access design is not covered in this paper.

Lastly, preparation of this paper has followed an extensive, and unrewarding, literature search. It would be pleasing to provide numerous references to other papers on the access issue; however, very little has been done on this subject. Recreation researchers have touched upon the problem obliquely in studies of the wilderness areas (McKillop, 1975); recreation managers have noted excessive trail use, often by off-road vehicles; and landscape architects, who know intuitively about access strategies, seldom write and never conduct supportive research. Perhaps the issue is outside of traditional interest areas, or perhaps it is simply so close to us we fail to focus on it. After all, everybody knows how to design a trail, don't they? It is however a complex and serious issue, and one that is particularly relevant to the cave manager.

PHYSICAL FACTORS

Perhaps the most obvious influence on users of any facility is the required investment of energy, excluding subsidized forms such as occurs when driving an auto or riding an elevator, to get there. It is common for people to complain about the intervening space between their parking space and their destination, whether a store, a beach, or a cave. The importance of this concern for distance is supported by commercial development policies where substantial interest is given to spatial parsimony, and is supported in theory by various "economic rent" and "gravity" models used to explain geographic aspects of park use. The amount of work, or the exertion investment, required to reach a cave will

* Humboldt State University, Arcata, California.

undoubtedly influence the gross number of visitors. While this seems a very obvious point, it is one commonly ignored in park design where roadways and trails often lead visitors effortlessly to highly valued and often easily destroyed resources such as tidepools. The potential value of space and elevation as a cave management tool should be carefully considered in formulating a design. Parking areas should be located far away from caves incapable of withstanding extensive use; a steep hike will also reduce visitor numbers. A more hardy and/or interested group of visitors will be the result.

Experience from regional park design shows that 100 meters is the walking limit for over half of the visitors, and distances over 1000 meters, or elevation gains of over 60 meters, exclude most visitors. The actual distances depend upon the attractiveness of the destination. For highly valued caves identified for preserve status, and lacking other management tools such as guides or visitor centers, trail distances should be measured (if a trail is even built) in kilometers, not meters.

Exertion should be viewed as both a real and a perceived phenomenon. While distance plus the increase in elevation defines the boundaries of the work to be done, the perceived distance may be substantially different because of the ease or difficulty of movement. Routes over broken terrain require more "work" than those over more continuous land forms. The condition of the trail surface, such as deep sand, loose cobbles, or mud, can also influence the visitor's sense of space and elevation. It is usually desirable to have the beginning section of the trail as difficult as later sections. The attraction of casual visitors along an initially easy, but eventually laborious route, can thus be prevented.

For most wild caves the separation of cave and parking area can have several important secondary benefits. The most important of these is safety, the park and cave managers' nemesis. From observations in coastal parks it appears, but has not been proven, that the accident rate decreases as parking areas are moved away from such dangers as shoreline bluffs. Although visitor numbers decrease with distance, it is apparent that visitors gain a sense of responsibility for their own safety as they move farther from the context of human development. A parking area near a cave entrance can give a false sense of safety, encouraging spontaneous rather than considered use of the cave.

A second benefit that is provided by a high level of exertion is the reduction of vandalism. Convenient access, particularly by auto, aids the person interested in destructive activity. Not only does convenient access invite more people, but it invites people "just driving around" or "just passing through"; in general, those who have less commitment and less preparation to use a cave properly.

In a related vein, it has been proposed by psychologists that people appreciate goals they achieve proportional to the work required to achieve them. Studies by Festinger (1957), and others since, support the concept that as physical exertion increases appreciation of the final goal also increases. For many visitors, then, appreciation of the cave may be encouraged and vandalism reduced, by careful attention to exertion investment.

Commercial or other high use caves, with their specific goal to attract visitors in large numbers, cannot of course require high levels of exertion. A direct approach, with a more scenic alternative route, would seem more appropriate. An approach that is too brief, however, may lack interest and the buildup of intrigue that can help achieve a satisfied visitor. When it is not possible to place parking

conveniently close to such a cave it is possible to reduce the apparent distance by providing a series of points of interest which attract the visitor along the trail, and provide occasions to briefly rest.

PSYCHOLOGICAL DEMAND

The decision to visit a cave involves an evaluation of the effort to be required psychologically as well as physically. For many people, particularly the inexperienced in the outdoors, the mental effort required to assure a safe journey may outweigh any potential benefits. Most caves require a great deal of effort and concern by the casual visitor: indeed, numerous people will simply not enter a cave because of the mental effort required. To a lesser degree, most natural environments require a similar type of effort. It has been proposed in research by Kaplan (1975) and Gallagher (1977) that urbanites, or people inexperienced with nature, are very concerned with the amount of effort required to make sense out of a place. The level of uncertainty along an access route can be used to attract or repel the urban visitor. This level can be readily manipulated through route location and design techniques.

Vision is the key to environmental understanding for most people, and it is the removal or provision of specific visual characteristics of the landscape that help the visitor feel secure. Provision of open space, and the associated lines of sight, increases the visitor's ability to look ahead and to see what is coming next. Similarly, ground surface textures can aid or hinder the visitor's ability to see. Finer textured surfaces, such as lawn, allow quick recognition of dangers such as wildlife. Combining open space with fine textured ground surfaces, which is very typical of the traditional park landscape, provides the greatest sense of visitor certainty, and should be considered where urban visitors are desired.

The sense of certainty and safety is also influenced by the order or arrangement of the visual environment. An ordered environment makes sense to the viewer; that is, its form and other visual features follow some obvious logic. The common style of landscape design that orders the environment with repeated forms, harmonized materials and colors, and even specimen (symmetrical) trees assists the visitor in understanding the landscape, and hence in achieving security.

A final factor which influences the visitor's sense of safety is the arrangement of landscape materials, such as brush and lawn, into distinct zones with a crisp edge in between them. The presence of edges, signifying the clear separation of identifiable subunits of the landscape, helps the visitor to sort out the available environmental information and make sense out of it more rapidly.

Visitors, due to individual differences related to prior experiences, can be attracted or repulsed by their orientation to uncertainty. Most people (the general public) appreciate a safe environment and will relate positively to the above-mentioned landscape characteristics. But for a few people with substantial experience in natural areas (this includes most serious cavers), uncertainty and the associated risk is an attraction. For this group an environment that is difficult to understand, that allows the practice of making sense, is valued for the cognitive challenge it provides. Thus, access ways that provide the sense of safety most people enjoy can be expected to receive use by the general population, but access ways that demand a good deal of cognitive effort, that require a studied approach, can be expected to attract the serious caver.

PSYCHOLOGICAL BENEFITS

The psychological benefits an access way provides, including attractive sights, sounds, touch, and smell, are most valuable in helping the cave manager to achieve the goal of maximum visitor satisfaction. The provision of esthetic elements along a trail can enrich the total experience both by supplementing and contrasting to the cave experience. Cave managers may encourage additional visitors by development of these extra attractions, and may also act to reduce the number of visitors by not providing them. Given the value of esthetic experiences in the modern world, only the trail head zone should be considered for nonesthetic development, thus eliminating the attraction of people in search of esthetic satisfactions along a trail to a cave. Upper sections of trails should always be located and designed to take maximum advantage of the esthetic elements of the landscape.

Referring again to the research by Kaplan (1975) and Gallagher (1977), it has been shown that people are attracted to landscapes with certain visual qualities. The less experienced urban people find beauty in understandable landscapes; those with the qualities of open space, fine texture, order, and edge. More experienced outdoors people find beauty in landscapes that are diverse or complex, and mysterious. The complex landscape offers a great deal to look at in terms of things, colors, shapes, textures, and patterns. The mysterious landscape encourages movement by always suggesting that something interesting is just around the next turn or through the next thicket. Landscapes that combine all six elements have been found to have high preference from both groups of people. It has also been found, not unexpectedly, that people of all types enjoy scenic natural landscape elements such as large trees, large rocks, lakes and streams, wildlife, and seasonal colors.

The opportunity to hear pleasant sounds from wind, water or wildlife; the opportunity to touch interesting plants or rocks; the opportunity to be touched by cool mist or warm sun, or to experience enjoyable movement—a designed pattern of rest and motion—all add to the total esthetic experience. While these may seem perfectly obvious experiences for incorporation into trail design, they are far too often ignored by designers interested in their prime destination, or lacking an adequate site inventory.

These trail experiences can enhance the cave experience by offering a powerful contrast: the ordered to the disordered, the dark to the light, the quiet to the loud, the safe to the dangerous, the enclosed to the expansive. The trail access can best be designed only from an awareness of the experience found within the cave. The opportunities to positively influence visitors by outside-the-cave design are limited only by the designer's imagination.

CONCLUSION

Design of an access way can influence visitors in a variety of important ways. But not all cavers, or caves, lend themselves to control by access design. Personal experience has demonstrated that the typical NSS member will cross almost any obstacle, the most notable exception being private property, to reach a cave of interest. For the true caver, access design that discourages the general public should have limited impact. Many caves, by virtue of the surrounding landscape or the presence of existing development, would be difficult to plan for. Existing trails frequently used by local people often defy easy change, and too often existing roads provide easy access to all. Undoubtedly, a vast range of management strategies will be required to accommodate the variety of problems that exist. It will always be desirable, however, to consider access design as one potential method of achieving each cave's management goal.

Perhaps the greatest problem at this time concerning the application of access design ideas is the absence of cave management goals. It is only upon such goals that design solutions can be developed. Unfortunately, management goals conclude a process of information gathering and assessment that is only now beginning for many caves. When the process of inventorying and setting goals for caves has been completed, and perhaps classes of caves established, then specific guidelines for access design for each class can be prepared. Given the nonrenewable nature and wilderness quality of our cave resource, and the increasing level of use, it is essential that cave management, and access design, be studied and implemented.

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An Interpretive Concept for Nakimu Caves

John G. Woods*

ABSTRACT

For 30 years National Parks operated a public cave tour programme at Nakimu Caves, Glacier National Park, Canada. This service was discontinued in 1935 and capital developments in Nakimu were abandoned. With the opening of the Trans Canada Highway in 1962, interest in the cave system was renewed. Studies conducted during the 1960s showed that Nakimu is a karst resource of national importance and has one of the greatest potentials for the development of a karst oriented public education (interpretation) program in Canada. In 1975 the area was identified as one of several interpretive management units in Glacier National Park and a unit concept was prepared. Unlike previous proposals this concept stressed the educational value of Nakimu and utilized a communications model to analyze the problem and determine a "best-fit" development option compatible with parks objectives. In 1977, the Nakimu Caves Interpretive Management Unit Plan was approved and implementation planning commenced. The concept included guided "semi-wild tours" of the surface and subterranean features for strictly regulated small groups and off-site developments including a publication and film for people without the inclination or physical ability to visit these caves.

OBJECTIVES AND CONSIDERATIONS

For some 30 years National Parks operated a public cave tour program at Nakimu Caves in Glacier National Park, Alberta, Canada. This service was discontinued in 1935 and the capital investments in Nakimu were abandoned. With the construction of the Trans Canada Highway in Glacier, interest in the cave system has been renewed. This paper evaluates Nakimu as a potential educational resource and proposes ways and means of interpreting Nakimu to the Canadian public.

Nakimu Caves have been intensively studied by the cave research group of McMaster University headed by Dr. Derek Ford. Their written reports and maps provide an excellent information base on the system (Ford, 1967; Ford et al. 1971). These studies have shown that Nakimu is a resource of national and international importance. The cave research group describes them as "... the most dynamic and scenic example of a vadose (stream cut) cave that is known to us in North America" (Ford and Quinlan 1973). They also point out that Nakimu is potentially the most important Canadian cave system for the development of a public education program. Nakimu is relatively accessible to the Trans Canada Highway; it is still actively enlarging; it exhibits a variety of karst features and processes and, the feasibility of cave tours have already been demonstrated by our former cave tour operation at this site.

There have been many proposals for the development of Nakimu as a "Tourist Attraction." The present planning project has looked at Nakimu in a much different manner. The area has been identified as an interpretive management unit within Glacier National Park (MacFarlane 1975, MacFarlane and Woods 1975). Our goal is to identify the interpretive value of Nakimu and to present a plan for the development of interpretation in the unit.

Unit Objectives

Policy Objective

To provide a communications program which encourages the general public to understand, appreciate and enjoy the karst landscape story of the Nakimu Caves Interpretive Management Unit in Glacier National Park.

Service Objectives

AWARENESS. To make the general public aware of the story of the karst landscape of the Nakimu Caves.

INFORMATION/ORIENTATION. To make Glacier National Park visitors aware of the story of the karst landscape of the Nakimu Caves and to orient them to the interpretive opportunities available to experience this story in Glacier National Park.

PRESENTATION. To interpret the karst landscape of the Nakimu Caves on-site to interested park visitors.

PARTICIPATION/EXPERIENCE. To provide on-site visitors with a first-hand experience with the karst resources of the Nakimu Caves.

FEEDBACK/DIALOGUE. To permit park audiences to respond in a meaningful, measurable way to their experiences with the programs and facilities of the Nakimu Caves I.M.U.; and to establish and maintain a dialogue with individuals and agencies interested in the heritage resources of the Nakimu Caves.

Planning Considerations and Constraints

Nakimu's active nature, variety of features and relatively easy surface and underground access make it the area of greatest potential in the National Park system for the development of an on-site interpretation program on caves (Ford, 1975).

National Parks operated a cave tour program at Nakimu from 1906 to 1935. At that time the caves were modified in several areas by tunnelling and stairways. Use of historic tourist routes to and within the caves would result in very little new damage to the resource base. Remains of the former cave developments are severely deteriorated and constitute a considerable hazard for cave visitors.

*Chief Park Naturalist, Mount Revelstoke and Glacier National Parks, Box 599, Revelstoke, B.C. V0E 2S0

It is not possible to interpret the cave resource at Nakimu in isolation from the regional setting and surface features in a karst landscape.

An excellent information base exists on the caves as a result of the McMaster group research. The caves have been mapped in detail. Considerably less is known about surface karst features and the biology of the system.

The Nakimu Cave system contains outstanding features whose fragility limits the scope of interpretive development alternatives for the system. There have been numerous proposals and pressures to develop Nakimu as a "tourist attraction," including a number of proposals from commercial interests. Development of the Nakimu Caves has long been an "issue" in Glacier National Park. This plan is the first to emphasize the system's interpretive value.

The Guidance Committee on Planning (Nicol et al., 1965) "... felt the Nakimu Caves were a special attraction of national interest and hence the tours and interpretation should be operated by the department."

Access to the caves is a key element in the development of this unit. Access affects the character and level of use in the caves and the surface resources of the Cougar Valley. Snow-free visitor access is seasonal (e.g. 100 days,

June-August) and involves a potential bear-encounter hazard for foot traffic.

Nakimu and associated sections of the Cougar Valley-Balu Pass area are a recreational and semi-wilderness resource. The Cougar Valley-Balu Pass trail system is one of the most popular back-country trails in Glacier. Cavers have much interest in the wild portions of the cave system. Examination and resolution of these uses is beyond the scope of this interpretive plan. A master plan for the caves and the Cougar Valley-Balu Pass area is required.

The Cougar Valley is not serviced by power, water or sewage utilities.

Present regulations prohibit entry into National Park cave systems without written permission of the Superintendent. This regulation and the unfamiliar nature of caves make them a resource inaccessible and unknown to park visitors. At Nakimu we have an unparalleled opportunity to expose park visitors to this form of natural heritage.

STORYLINE

Nakimu Caves form part of a karst landscape in the Cougar Valley of Glacier National Park. The caves are



Nakimu Caves. *Photo by John Woods.*

approximately 427 m. above the highway and 11 km. from Rogers Pass. They range in elevation from 1494 to 1707 m.

The essential characteristic of a karst landscape is the presence of vertical and underground drainage (Sweeting 1973). This drainage through a limestone bedrock develops the surface and subterranean landforms which characterize a karst area. At Nakimu numerous surficial and subterranean karst landforms are conspicuous. Here water has infiltrated the limestone bedrock and created disappearing streams and cave systems.

A review of the available literature on Nakimu and karst suggests for the subdivision of the Nakimu story into four components:

Message No. 1: Conditions leading to the development of alpine karst at Nakimu.

Message No. 2: Surface features in a karst landscape.

Message No. 3: Subterranean features in a karst landscape.

Message No. 4: Life in a karst landscape.

Message No. 1. Conditions Leading to the Development of Alpine Karst at Nakimu

Karst landscapes are solution landscapes (Sweeting 1973). They are formed when the bedrock is partially dissolved by water. Limestone is the most common soluble rock and, therefore, karst landscapes are most common in areas of outcropping limestone.

There are three basic requirements for the development of a karst landscape:

1. An outcrop of soluble rock.
2. A moist climate.
3. Sufficient relief to promote downward circulation of water.

Three basic requirements can be readily observed in the Nakimu Unit.

The Nakimu karst system has developed in an exceptionally pure limestone outcrop resting on older, more resistant rocks in the Cougar Valley (Ford, et al., 1967). This bed is approximately 1.2 km. wide and up to 185 m. thick. This thickness of limestone is unusual in the region and is the result of tectonically thickened layers of Badshot Fm. limestone in the core of a syncline structure in the Selkirk Ranges, known as the Ventego syncline (Wheeler, 1963). Cavern development has been aided by the existence of inclined bedding planes, faults, and joint systems in this limestone outcrop.

Nakimu is in the interior wet belt of British Columbia. Extrapolation of climatic data from two nearby stations (Rogers Pass and Mount Fidelity) give the Nakimu area a probable mean annual precipitation in the range of 163 to 224 cm. and a mean annual snowfall in the range of 1002 to 1703 cm.

Nakimu limestones lie in a mountain valley between 1494 and to 1707 m. above sea level and are surrounded by the rugged relief of the Selkirk Mountains. This relief promotes the circulation of water to and through the limestone outcrop.

Limestone is only slightly soluble in pure water (Sweeting 1973). However, it is relatively soluble in acidic water. Water charged with carbon dioxide is acidic. Water can be charged with carbon dioxide in two ways. First, carbon dioxide in the atmosphere dissolves directly into precipitation. Since the concentration of carbon dioxide in the free atmosphere is only about 0.03% this can only account for a

slight increase in precipitation acidity. However, water passing through the soil atmosphere can become highly charged because soil bacteria can increase the carbon dioxide level up to 21%.

In the solution process, water, carbon dioxide and limestone react to form calcium and bicarbonate ions in solution. These ions are transported through the karst system by moving water.

In one study the waters at Nakimu were shown to contain about 14 parts per million of calcium ions above the caves (Ford et al., 1967). These waters are capable of holding more than this concentration of ions and therefore react with the limestones at Nakimu. An additional 8 parts per million are added by the passage of Cougar Creek waters through the system. This rate of solution is increasing the volume of Nakimu Caves by 0.16 to 0.33 m³ per day during the summer. Ford considered this to be a high rate of erosion reflecting the acidity, volume and speed of the cold mountain waters passing through Nakimu. Cougar Creek and its tributaries are conspicuous both above and below ground. These waters are fed by rainfall, meltwaters from glaciers farther up the valley and spring melt of the snow pack.

Several other landscape processes have been important in the development of the landscape we see at Nakimu today. Glaciers have carved a U-shaped valley above the caves and glacial meltwaters feed Cougar Creek. Stream erosion has produced many small scale features both above and below ground. Rock collapse and frost shattering are important in several areas such as the Gorge.

Message No. 2. Surface Features in a Karst Landscape

The action of water sinking underground has produced several features which are characteristic of a karst landscape. These features have not been formally studied but several are obvious:

Dolines: Dolines are closed depressions (dimples) of small dimensions (Sweeting 1973). They are a diagnostic surface feature in a karst landscape. At least two types of dolines can be seen at Nakimu. The closed hollow just south of Cougar Swallow is probably a solution doline. The Gorge is a collapse doline formed by the breakdown of part of the cave roof during the last glaciation (Ford et al. 1967).

Swallow Holes: These are areas where surface water disappear underground. They are also known as sinkholes. Several swallow holes are conspicuous at Nakimu. Cougar Swallow is located at the point where Cougar Creek first enters the limestone outcrop and enters it via a bedding plane. Gopher Creek Swallow is a vertical shaft swallow hole where Gopher Creek enters a joint and disappears into the cave system.

Risings: Risings (springs) are locations where water reemerges from the bedrock. At Nakimu the risings of Cougar Creek below the Gopher Bridge Cave and below the Main Cave are conspicuous.

Several other surficial features are apparent at Nakimu which are not purely karstic in origin. They include:

Potholes: These are circular depressions in the bedrock which have formed as a result of corrosion. Pothole grinders (hard rock) have drilled these potholes into the limestone under the power of rapidly moving water. Potholes are obvious at the surface along The Flume ground in the Cathedral.

U-shaped Valley: The upper Cougar Valley is a typical U-shaped valley resulting from former glacial erosion.

Glaciers currently occupy the headwaters of the valley and their meltwaters feed Cougar Creek. The U-shaped valley is conspicuous from Cougar Swallow.

V-shaped Valley: Below the Main Entrance the V-shaped valley of Cougar Creek. V-shaped valleys are typical of areas dominated by river erosion. It is important to note that in the landscape sculpturing process it is very rare for one type of erosion to be exclusively responsible for the landscape. At Nakimu, the landscape is a result of a complex interaction of karstic, glacial and fluvial processes.

Message No. 3. Subterranean Features in a Karst Landscape

The underground circulation of water has produced the Nakimu Caves in the karst limestones of Cougar Valley. These cave passages have a combined length of more than 5 km. They have a vertical displacement of 335 m. They are the longest caves in British Columbia and the second longest in Canada (Ford and Quinlan 1973). The oldest landforms within the caves are of a greater age than any known landform elsewhere in Glacier National Park.

Cave development at Nakimu has a complex history which dates back to the last interglacial period (Ford et al.). The result of this lengthy period of formation has been the development of sets of interrelated caves which are collectively known as the Nakimu Caves, (e.g. Gopher Bridge Cave, Mill Bridge Cave, The Temple Cave and Main Cave).

Cave features can be divided into two main groups: erosional features and depositional features (Sweeting 1973).

Erosional Features

PHREATIC PASSAGES: Phreatic passages are formed below the watertable. They are rounded, often circular passages formed by the forced flow of water through flooded voids. Since all parts of developing phreatic passages are in contact with running water, solution of the limestone takes place in all directions. Phreatic passages were formed at a very early stage in the development of Nakimu. This original development may have begun between 100,000 (Ford, et al., 1967) and 35,000 (Ford 1976) years ago.

The early phreatic passages at Nakimu followed bedding planes and are readily observable along the old tourist route through the cave. Scallops are small solution scoops in limestone walls. They are characteristic features in phreatic passages and are conspicuous in many areas of Nakimu. The smallest scallops known anywhere have been measured in Micashist passage (Goodchild, 1976).

VADOSE PASSAGES: In time, phreatic passages either enlarge to the point where underground water only partially fills them or the volume of water reduces and the passage becomes only partially flooded. When this occurs solution erosion of the passage roof ceases. Downward and lateral solution continues and vertical trench-like passageways develop. Vadose passages are typically V-shaped or A-shaped and often produce vertical shafts. Both solution and mechanical stream erosion take place in vadose passages. Vadose areas of Nakimu feature underground rivers, waterfalls, and pothole systems. The fact that visitors can still see Cougar Creek thundering through vadose passages makes Nakimu one of the best places anywhere to interpret caves. The caves are still forming and visitors can see the action of water for themselves.

PARAPHREATIC PASSAGES: Occasionally the water level in a phreatic passage will lower and vadose erosion will commence. Subsequently, the passage may flood again and revert to phreatic erosion. When this occurs the passages exhibit both phreatic and vadose characteristics and they are termed paraphreatic passageways. A good paraphreatic passage can be seen at the Slanting Way (Ford 1976).

BREAKDOWN PASSAGES: Breakdown chambers are formed by roof collapse. The major breakdown cave at Nakimu is in the Dropping Cave/Witches Ballroom area. This area is located on the fault line which separates Mill Bridge Cave from the Main Cave. Breakdown passages in the area have been prompted by frost shattering.

Depositional Features

The deposits within Nakimu fall into two broad groupings: calcareous deposits and noncalcareous deposits. The study of these deposits is equally important to the study of the erosional processes in understanding the evolution of the karst landscape at Nakimu.

CALCAREOUS DEPOSITS (SPELEOTHEMS)

Moonmilk: Moonmilk is a soft paste-like deposit on the cave walls which is composed of crystals of calcium or hydromagnesite. These crystals are thought to be produced by the action of bacteria on the cave walls. Moonmilk forms impressive "cauliflower" formations throughout Nakimu. The Nakimu moonmilk displays are considered to be among the most extensive in the world. (Ford 1975).

Stalactites, Stalagmites and Flowstone: These are all features formed by slowly dripping water precipitating calcium carbonate on the walls and floors of the caves. Stalactites hang like icicles from the ceiling. Stalagmites are built up from the cave floor. Flowstone forms calcium curtains along cracks in the ceilings. Although these formations are visible at Nakimu they are uncommon and poorly developed. The most likely reason for this is that the rapid water flow through most of Nakimu inhibits calcium precipitation.

Collapse Blocks: These are limestone blocks which have fallen from the ceilings. Existing passages sometimes enlarge by collapse. Many collapse blocks are obvious in the Witches Ballroom.

NON-CALCAREOUS DEPOSITS

Ice: Although the temperature of the cave is a relatively constant 1 to 2°C the year-round, parts of the caves are cold enough to freeze water during part of the year. The most noteworthy area in this respect at Nakimu is the Dropping Cave and Witches Ballroom just within the Gorge entrance. Here the temperature drops below freezing in the late fall and early winter until the Gorge Entrance becomes blocked by snow and ice. Freezing temperatures cause dripping water to form ice "stalactites," "stalagmites" and "ice curtains." These formations begin to melt when warm air enters the Gorge Entrance in the spring and persist until mid-summer.

Clastics: Clastics are rock fragments which have been moved individually from their place of origin. During the advance of the last ice age sections of the cave were probably filled with rock debris and clays swept into the caves by glacial meltwaters. After the ice retreated, the underground waterways started to excavate these clastics from the cave. However, much remains in several areas.

Clastics provide the abrasive material necessary for mechanical stream-bed erosion. Incredibly smooth pothole grinders are impressive clastics within Nakimu.

Message No. 4. Life in a Karst Landscape

Very few forms of life inhabit Nakimu Caves. This is probably a function of their high alpine situation and cold climate (Fenton, 1976).

There are no obligatory cave dwellers (e.g. blind cave fish) and all animals collected in the caves have probably strayed into the system or use it as a temporary refuge. The only conspicuous animal encountered in the caves is the Bushy-tailed Woodrat.

The biology of micro-organisms in the system is unknown. Bacteria are believed to participate in the formation of moonmilk.

The Nakimu karst impresses people as a curiosity—caves excite the imagination. Karst areas are not well known in Canada and thus many people are interested in visiting caves to fulfill their needs to see and learn about something different.

In 1904 Charles Deutschmann encountered the caves while on a hunting trip in Cougar Valley (Brown and Goodchild 1971).

The government took an interest in Deutschmann's find and purchased his rights to Nakimu in 1905. Furthermore, they took immediate action to open the caves to the public and hired Deutschmann as the first guide and caretaker. Between 1906 and 1935 the caves were maintained as a tourist attraction. Stairways were constructed, paths leveled and some minor blasting work done. Guides conducted small parties through the caves using the brilliant flame of an acetylene lamp.

Access to the caves was primarily by hiking or horseback up the Cougar Valley bridle trail constructed in 1906. Later visitors had the option of making a circle tour by approaching the caves from the Balu Pass trail. From 1914 to 1923 a stage coach visited the caves via the Tally-Ho Road.

It is a common misconception that the caves were developed and operated by the C.P.R. In truth, the first direct C.P.R. investment came in 1923 when they constructed a teahouse at the caves. However, there was always a close association between the C.P.R.'s Glacier House and the National Park cave operation.

The C.P.R. probably played the principal role in providing access to the caves by horseback and stagecoach.

Excursions to Nakimu were the fashion of the times in early 20th Century Glacier National Park as the following quotes reveal:

"At the caves is a government building especially adapted for campers, with cook stove and other conveniences."

"Parties desiring to camp can make arrangements by writing to C.H. Deutschmann, The Caves, Glacier, B.C." (Wheeler and Ayres, 1914).

"A two day camping trip may be undertaken as follows: From Glacier House via Balu Pass to the Nakimu Caves, exploring Bear Creek and Cougar Valleys, spending the night at Camp, visiting the "Caves" and arriving at Glacier in time for dinner the following evening." (Wheeler and Ayres, 1914).



Nakimu Caves. Photo by John Woods

"One of the most exciting day trips from Glacier House after 1905 was the expedition up to the Nakimu Caves, where the custodian would provide refreshments and a tour of the natural wonders." (Brown & Goodchild 1971).

"... Far from a modern tourists' impression of a visit to a commercial cave. Parts of the route involved crawling, squeezing sideways through narrow slots, some quite strenuous rock climbing and, of course, the descent of the gorge, still made by a knotted rope." (Brown & Goodchild 1971).

At the peak of their development, the Nakimu tours included short tours of the Gopher Bridge Cave and the Mill Bridge Caves and a relatively ambitious tour from the Gorge to the artificially opened Main Entrance. Problems with ice formations between the Gorge entrance and main cave passages ultimately led to the construction of St. Peter's Stairway down the adjacent Pit Entrance.

Nakimu Caves were officially closed to the public in 1935. Reasons for their closing probably include the depressed economics of the time and the decline in park visitation after the closure of Glacier House in 1925.

In the early 1960s interest in the caves was rekindled with the construction of the Trans Canada Highway within 2 miles of Nakimu. Nakimu's lure had not diminished and the 60s saw a stream of development proposals from the public and private sectors. Many of these proposals stressed that Nakimu was the key to Glacier National Park and its development essential to attracting visitors. However, to date no proposal has been implemented. Why? First, almost all of the proposals are extremely costly and involve a significant encroachment by man in the Cougar Valley.

Administrators have learned to take a cautious approach to wholesale developments in National Parks. Would unlimited public access destroy the alpine meadows above the caves? Would the increased human activity force the Grizzly Bears from Cougar Valley? Would the proposed underground manipulations of the landscape by tunnelling, lighting and elevator construction destroy the very natural values that the park was endeavoring to preserve?

These questions have forestalled decision making and motivated additional research. From 1965 to 1967 a team of McMaster University cave specialists were employed to study the caves. They reported on the geomorphological history of the system and confirmed the suitability of the system's development as a tourist attraction.

More recently, the emphasis in development planning has shifted away from considering Nakimu as a tourist attraction. Instead, its unique potential value as a public educational resource has been brought into focus. These studies have shown that no other cave in Canada and few other caves in the world are better suited to showing people the dynamic karst processes which sculpture parts of our landscape. How this point of view will affect the future of Nakimu Karst remains to be seen.

VISITOR ANALYSIS

To fulfill our unit objectives, media must be designed to reach three major target groups: the general public of Canada, interested park visitors and school groups. Canadians must have the opportunity of learning about Nakimu as part of the national heritage in National Parks.

Only some park visitors will have the opportunity of seeing Nakimu on-site. These will be highly motivated visitors in average health. They will form a part of our "recreational traffic" sub-group. An important characteristic of our on-site group will be their lack of experience in caves. Therefore, all tours must be guided and the department must supply special equipment (e.g. helmets and lights).

In the interests of conservation, it will not be possible to offer cave tours on a mass audience basis. We will offer a once-in-a-lifetime experience to interested park visitors. There will be no large scale promotion to enlarge the market.

Opportunities to experience the Nakimu story, therefore, must be also developed for park visitors who cannot experience the caves on-site.

RESOURCE SENSITIVITY

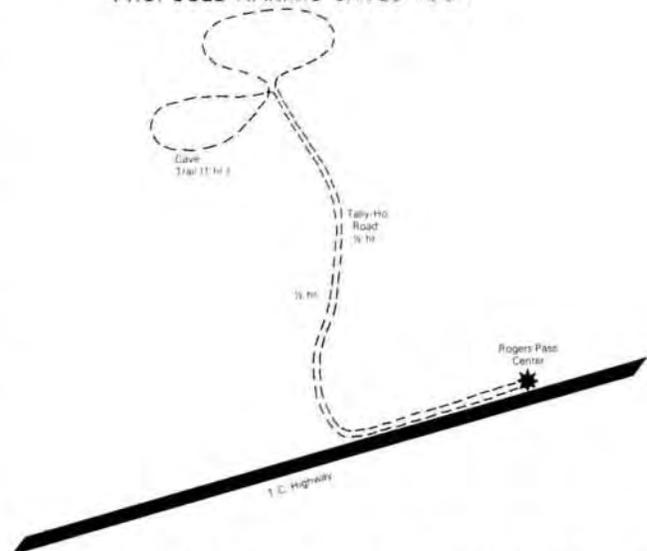
Areas of Possible Concern

Cave formations: Cave formations (speleothems) are very delicate and once broken or mutilated are lost forever. To eliminate impairment of the formations we propose to: allow access to supervised groups only, and to use only part of the existing "tourist route" thereby capitalizing on existing impairment without encroaching on wild areas.

Cave life: Dr. Fenton (1976) surveyed the system and feels that there are no delicate biological systems in the caves. He warns, however, that installation of artificial lighting may stimulate algae growth on cave walls and formations. We do not plan on installing such lighting so this is not a potential problem.

Surface vegetation: The caves are in the upper area of the Subalpine Engelmann Spruce—Subalpine Fir Biogeoclimatic Zone and are adjacent to impressive floral meadows in the Upper Cougar Valley. This area could prove vulnerable to excessive foot traffic resulting in vegetation damage and soil erosion. To reduce this problem we propose limited access by small supervised groups only, and construction of high standard trails which would be used exclusively.

PROPOSED NAKIMU CAVES TOUR



Grizzly Bears: The Cougar Valley is frequented by grizzly bears and there is a potential for adverse interactions between bears and man. To reduce this problem we propose 4-wheel drive access up the valley on the existing Tally-Ho road and limited access by small supervised groups only.

APPROACHES TO INTERPRETATION

Off-Site Development

Proposal

A 15-minute movie would be produced interpreting the overall story of the Nakimu karst system. The film would be used for T.V. specials, for N.F.B. distribution, for distribution to special groups and schools, and for occasional in-park use. The film would emphasize interpretation of the actual Nakimu karst system (as opposed to the "adventure film" approach taken in the film on the Castleguard Caves) and would be strictly nonpromotional in nature.

A publication to complement the film would be produced and distributed with the film, in response to inquiries and in the park publications system. The publication would provide an illustrated overview of the stories of the Nakimu karst system and would identify the interpretive cave tour and reservation system.

Rationale

The team feels that this approach is required to effectively communicate the active nature of the Nakimu karst system to off-site audiences. The film medium combines an ability to convey an active process with a presentation format easily accessible and adaptable to mass media, school, extension and park audiences. A publication is effective as an ongoing, easily accessible reference, with take-away value to off-site and on-site audiences alike.

On-Site Development

Rehabilitation

The deteriorated former tour developments (stairways, ladders, handrails) constitute a considerable hazard for cave visitors. All such material must be removed except for a representative section in a nonhazardous location to be used in interpreting cave history. This is viewed by the team as a baseline proposal for all options.

Proposed Cave Tour

SCENARIO

Interested park visitors in Glacier National Park wishing to take part in the Nakimu tour would be required to

register their intent in a reservation system operated out of would be booked partly on a first-come-first-served basis and partly on advanced reservations. Reservation booking partly on advanced reservations. Reservation booking would probably involve a fee of \$2.00 to \$3.00 to help control the reservation system and recover operating costs.

Tours would be limited to a maximum of 15 visitors accompanied by two naturalist guides and would be about 3 hours long. Initial operations would consist of eight tours per week over a snowfree season of ten weeks (July to September). This level of operations could be expanded in the future to a maximum carrying capacity of 14 tours per week, for a total of 140 tours per season. Further expansion beyond this level would require a total reassessment of resources, development plans, and impact on cave and valley resources.

All tours would begin at the Rogers Pass Center. Visitors would be transported in a four-wheel-drive van or bus (17 passenger) via the Tally-Ho road to a point near the Main Entrance of the cave system (see flow diagram). The trip from the Center to the end of the road would take about 30 minutes.

Visitors would then be led on a 45-60 minute above ground tour of the surface features above Nakimu Caves before being conducted into the cave system.

The underground tour would proceed along a restored section of the former underground tour route, highlighting the various passages and features seen along the way. After a total underground time of about 1 hour the tour would exit via the main cave entrance, and would proceed out of the valley by van to the tour's end point at the Rogers Pass Center.

RATIONALE

The cave tour concept is seen by the planning team as being a once-in-a-lifetime experience for park visitors. A tour to a relatively remote and outstanding feature such as Nakimu caves will undoubtedly make a lasting impression on all participants.

This on-site approach takes advantage of existing developments in the valley and cave system. We advocate utilizing only part of the former underground route, and the existing Tally-Ho right-of-way. For reasons of public safety and aesthetics, all debris from the former tour development would be removed except for a small representative section to be used in interpreting the cave's history. Stairways and paths would be renovated entirely within the former tour route. No new routes would be constructed in the cave and the old route would be renovated to minimize contact with fragile features. No fixed lighting or motorized aids would be used underground. Unsafe areas of the cave (e.g. Dropping Cave) would be avoided. Less than one kilometer of new or reconstructed surface trails would be required. This concept is essentially an updated version of the former tour conducted by the park and the C.P.R., and proposes no irreversible development.

Various access options to the caves were considered including: aerial lifts, horse-drawn carts, narrow-gauge railway, public road, restricted road and hiking.

The planning team felt that the best access option was a park-operated vehicle on the Tally-Ho road. This road would be a restricted use road for park cave tour purposes only.

Selection criteria for access options were:

- The access mode should not operate as an end in itself (e.g. horse-cart system novelty would draw visitors).

- Carrying capacity of the access mode should not exceed the carrying capacity of the cave tours (e.g. as in aerial lift).
- Access mode should not impair other resources in the valley.
- All access to the cave area must be supervised.
- The access mode should involve minimal interaction with wildlife in the valley (e.g. bears).

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Cave Management in Western Canada

Philip R. Whitfield*

Cave management in Canada is very much in its infancy. In this field, as in so many others, we look southward to see the United States already facing problems which will not confront Canadians for several more years, and we therefore have a golden opportunity at sessions such as these Cave Management Symposia to learn and profit by the American experience. In this spirit, I hope that participants in this symposium will feel free to offer comments and suggestions on existing and suggested Canadian cave management practices in order to help us improve our performance in this area.

I. A SURVEY OF CAVE MANAGEMENT ACROSS CANADA

Although this presentation focuses on Western Canada, a brief survey of cave management activity across the country is included in order to place the Western situation in some sort of context. It should be stressed that the following information may not be comprehensive, as it was either drawn from only a few published sources or solicited only from representative agencies of each provincial government and from selected caving clubs.

A. Newfoundland

1. Caves—Potential is little known but geology shows great promise.¹ One 600 m long cave reported.²
2. Caving Organizations—None known.
3. Cave Management—None known at Government or private level.

B. Prince Edward Island

1. Caves—Minimal potential.³
2. Caving Organizations—None known.
3. Cave Management—None known.

C. Nova Scotia

1. Caves—About 30 known caves, excluding sea caves.⁴
2. Caving Organizations—Halifax Caving Club (formerly Nova Scotia Speleological Society)
3. Cave Management—Hayes Cave (Hants County), 366 m long, in gypsum anhydride; surface area Crown land, proposed for Provincial Park; low recreational value but contains large bat colony (6,100 recorded in 1972); N.S.S.S. (Moseley) in 1972 and 1976 proposed grille gating to protect hibernating bats from numerous visitors to cave⁵; site now designated an I.B.P. Ecological Reserve and Nova Scotia Dept. of Lands and Forests has agreed to set cave aside as a bat preserve; Halifax Caving Club and Nova Scotia Museum Science Department have planned construction of a gate, but gate not yet finished as of September 1977. Access policy intended to protect bats; cavers will probably be able to visit during the summer months when bats are absent.⁶

D. New Brunswick

1. Caves—About 15 known caves, most in limestone; further potential.
2. Caving Organizations—Small, informal caving group in St. John.

3. Cave Management—None except for sealing of entrance to Archies Hole (300 m long, near Havelock) by a cement company in 1968; no access.⁷ (Apparently a case of terminal management!)

E. Quebec

1. Caves—over 200 known caves, further potential.
2. Caving Organizations—Société Québécois de Spéléologie (S.Q.S.), a province-wide society with 8 member clubs and over 400 members. Club is highly organized, with a training school, a karst research commission, a publications commission and a cave management commission. Club receives financial assistance from the Quebec Government (Secretariat of Sports) which provides such administrative services as offices, staff, office equipment, printing, etc.⁸
3. Cave Management—The several commercial caves of Quebec are obviously under conscious management, and the S.Q.S. is apparently in a good position to become involved in cave management, owing to its existing support from the Provincial Government. However, the subject of Quebec cave management is probably best dealt with in detail by a spokesman for the S.Q.S., as there is probably a fair amount of information to impart and I labour under the handicap of Western Canadian monolingualism.

F. Ontario⁹

1. Caves—About 100 known caves, largest of which is over 2000 m long.
2. Caving Organizations—5 active groups with a total membership of about 100. Karst Research Group (McMaster University research students led by Dr. Derek Ford); McMaster University Climbing and Caving Club; Toronto Caving Group (about 60 members); Carleton University Caving and Climbing Club (10 members); and Guelph University Caving Club (10 members).
3. Cave Management
 - a. Specific Cases
 - (1) Bonnechere Caverns—253 m long, S.W. of Pembroke, Southern Ontario; privately owned and commercialized in 1965; former and alternative river channel of Bonnechere River; virtually no speleothems. Management has diverted river from tourist route by dams and has installed plank walkways and coloured lights; guided tours.
 - (2) Collingwood Caves—privately owned and commercialized cleft caves in Southern Ontario.
 - (3) Flowerpot Island National Park—contains remnant littoral caves from earlier higher lake level, largest of which is 400 m in length; some speleothems. Management has provided self-guiding trails, steps and signs, and features receive the legal protection of the National Parks Act.
 - (4) Bruce Peninsula Caves—S.W. Georgian Bay area; relatively small solution and littoral caves on Provincial Crown land; Ministry of Natural Resources is aware of caves and locations are not advertised, but use is not regulated. Some legal

*Regional Planner, Kootenay Region, Parks Branch, British Columbia Ministry of Recreation & Conservation, 303 Victoria Street, Nelson, B.C., Canada

protection is provided by the Niagara Escarpment Act and the area has been assessed for possible designation as a Nature Reserve.

(5) Cavern Lake Bat Cave—about 100 m long, in granite, 70 km Northeast of Thunder Bay. Managed by Division of Parks as a Nature Reserve for the purpose of protecting the resident bat population; cave is not advertised, and "visitors are discouraged during bat hibernation," but the cave is not gated.

(6) Warsaw Caves—small fragments of a rectangular system and large segments of passage in breakdown, northeast of Peterborough, Southern Ontario. Managed by the Otonabee Conservation Authority, Ministry of Natural Resources, which publishes a brochure and posts "Enter at Own Risk" signs; Moonmilk some 30 m from entrance is exposed to vandalism.

(7) Moira Cave—a complex horizontal maze, over 2000 m long (longest in Eastern Canada), north of Belleview, Southern Ontario. Private land; Toronto Caving Group is pushing for blocking of incompatible surface uses, application of pollution control laws; TCG hopes to protect cave, which contains both bats and speleothems, from publicity, but a register placed by the group in the cave reflects high caver use. TCG has also posted a warning sign in the passage approaching the bat hibernacula and called for a closed season on caving there in the winter months; the Ontario Government is aware of the problems at Moira, but obtaining provincial control of the land is reported to cost over \$200,000.

b. General Directions in Cave Management

The Toronto Caving Group leads other Ontario caving organizations in concern for practical cave management measures. The Group has held at least one Cave Conservation Seminar (March 1976) and spokesmen demonstrate strong concern for better cave management. Quoting Kirk MacGregor from "Cave Exploration in Canada" (1976):

"Unfortunately Ontario has been a good example of what happens to easy, accessible speleothem caves that are not gated: Rockwood Cave, Godfrey Crystal Cave, and Plantagenet Cave have all been stripped by vandals or rockhounds. Destruction is continuing in such partly preserved caves as Hope Bay, Tyendinaga and Moira. Most of the damage seems to be the work of children, some of whom have been seen carrying stalactites away from caves. The future looks bleak for all caves in Ontario, and it is to be hoped that if any more good speleothem caves are found they can be gated. Speleothems are not the only disappearing cave feature. Bats are declining in numbers in the province, too, partly because of disturbance during hibernation."¹⁰

In addition to its involvement with Moira Cave, the TCG has undertaken garbage collection in caves and is recommending a closed season on caver access to Little Stream Cave (St. Edmund's System, Bruce Peninsula) to protect its bat population from disturbance during hibernation.

A spokesman for the Park Management Branch of the Ontario Ministry of Natural Resources has indicated his Branch's philosophical support for management of caves to preserve and protect their

fragile environments. However, there, as elsewhere, it would appear that legislation and designation by government do not by themselves provide practical protection for the caves.

G. Manitoba¹¹

1. Caves—None known.
2. Caving Organizations—None known.
3. Cave Management—Not applicable.

H. Saskatchewan¹²

1. Caves—None known.
2. Caving Organizations—None known.
3. Cave Management—Not applicable.

I. Yukon and the Northwest Territories

1. Caves—Numerous caves known in the Nahanni Region, N.W.T., up to 1900 m. in length; potential of most of Canadian North as yet unreported.
2. Caving Organizations—Nahanni explorations undertaken by Quebec cavers and by D. Ford's Karst Research Group.
3. Cave Management—Many of the Nahanni area caves are within a National Park. National Parks Act Section 34a prohibits entry to any cave in a National Park without written permission of the Superintendent. Parks Canada's cave management policies are broadly directed toward the preservation of the cave resource and the protection of park visitors. In practice, this means that Parks Canada field staff, generally with little knowledge of cave resources, presently prefer to err on the side of caution in protecting the resource and the visitor, and grant access permission only to those carrying out legitimate scientific studies. However, there appear to be no physical barriers to access for anyone choosing to disregard the risk of being prosecuted if caught in these caves without official permission.

J. Alberta

1. Caves—Of the relatively few caves known in the Alberta Rockies, Castleguard is the most significant, being, at 13.1 km., the most extensive cave known in Canada. Largely because of access difficulties, the full potential of the Rockies is still unknown and probably untapped.
2. Caving Organizations—The Alberta Speleological Society based on Calgary and Edmonton (about 15 members), includes a number of ex-McMaster cavers, maintains a low profile and discourages active recruiting.
3. Cave Management
 - a. Specific Cases
 - (1) Plateau Mountain Ice Cave—Relatively short cave near Calgary in a Natural Area under Provincial Parks jurisdiction. The cave's exceptionally fine ice crystals suffered increasingly heavy damage from melting and breakage over the years after it came to the attention of McMaster cavers in 1967. The cave was gated by the Alberta Government in 1972 and access is limited by Parks Permit to qualified researchers meeting appropriate restricted conditions. Alberta Parks disclaims any liability for accidents to visitors approaching or within the cave. Under this management prescription, the ice crystals apparently are recovering. There have been no known break-ins.
 - (2) Castleguard Cave—Within Banff National Park and subject to National Parks Act Section 34a prohibiting access to any cave in any National

Park without permission of the Superintendent. Film about exploration of cave proposed by Derek Ford and co-sponsored by Parks Canada in 1974. Cave gated by Parks Canada in 1975, largely out of concern for safety hazard to inexperienced public attracted to cave by film. (Note, however, that climbing over the gate is probably easier than negotiating most of the rest of the cave!) There appears to be no formal access policy, but the Superintendent's practice presently appears to be to grant access only to scientific parties, usually on the recommendation of Derek Ford.

b. General Directions in Cave Management

Alberta cavers, particularly those with a British or McMaster background, commonly express strong philosophical opposition to access controls on caves and to cave gates in particular. In his introduction to *Cave Exploration in Canada* (1976), editor Peter Thompson deplors the fact that "... by installing these gates, over-zealous cavers and government bureaucrats are encroaching upon the individual's freedom of access to caves, especially in the National Parks."

Parks Canada's treatment of Castleguard demonstrates an awareness of the cave as a Park resource, but a confusion as to the best management of the resource. Sponsorship of the film reflects some desire to make the public aware of the cave, although in retrospect, Parks Canada officials may well wish that the production had aimed at interpretation of the cave's features rather than at the adventures of its intrepid explorers. However, the very ineffective gating of the cave seems to constitute a hasty attempt to withdraw to the safest and most comfortable management ground: the easiest way to ensure conservation of a cave and guarantee public safety is to close the cave. This approach may be defensible in the short term, but it ignores the fact that a Park Agency's mandate is not only to conserve resources, but also to present them for the understanding and appreciation of the people. Two observations might be made at this point: first, that a sign at the cave entrance would have been cheaper, less aesthetically offensive and no less effective than the easily passable Castleguard Gate; and second, that Parks Canada must take a more realistic look at its management policies for Castleguard, as the present policy of virtual closure is not only philosophically indefensible in the long term but is actually unrealistic even in the short term owing to the ease with which the National Parks Act and the gate can be circumvented.

Fortunately, it would appear that the Alberta Parks' management of Plateau Mountain Ice Cave has been successful, in that the ice crystals are recovering and even the anti-gate local cavers apparently have no objection to the closure. Whether some long-term policy of interpretation or limited general access has been or will be worked out is not known at present.

K. British Columbia

1. Caves—

a. Rocky Mountains—This area includes nationally significant caves such as Arctomys (522 m deep) in Mount Robson Provincial Park and Yorkshire and Gargantua in the Crowsnest Pass area. The British

Columbia Rockies undoubtedly have considerable further potential.

- b. Interior—Nakimu (Glacier National Park) and smaller systems in Bowron Lakes Provincial Park and Cody Caves Provincial Park; considerable further potential.
 - c. Vancouver Island—Over 500 known caves, largest mapped being 1455 m; considerable further potential.
2. Caving Organizations—
- a. Alberta Speleological Society/McMaster cavers—Largely responsible for most of work in Rockies and at Nakimu since 1967.
 - b. Vancouver Island Cave Exploration Group (VICEG)—A registered provincial society, approximately 40 members since 1970, low public profile, emphasis on cave surveying; maintains close liaison with logging companies, government agencies and American caving clubs. Accepts gating as means of controlling access to exceptionally fragile caves in threatened circumstances.
 - c. Canadian Speleological Society of British Columbia Region (CSS/BCR)—A registered provincial society; number of members uncertain, but probably around 30 in Victoria, Vancouver and central Island chapters; actively seeks media publicity; emphasizes new exploration and discovery; is responsible for discovery of many important caves on Northern Vancouver Island; good liaison with logging companies, and some levels of government; relatively weak ties with other caving clubs in area, often strained relations with VICEG. Gating attitudes similar to those of VICEG.
 - d. British Columbia Speleo-Research—Membership under 10, based on the Lower Mainland, relatively inactive, policies similar to VICEG's.

3. Cave Management

a. Specific Cases

(1) Nakimu Caves—Recently, as a result of progressive interpretive planning and improved dialogue with cavers, the Superintendent of Glacier National Park has outlined a procedure by which cavers may obtain an access permit. Basically the procedure restricts access to research scientists and responsible and experienced cavers endorsed by recognized authorities on caves, requires that cave visitors have a self-rescue capability, and retains discretionary powers for the Superintendent and the Warden Service. Other caves in this park and in other National Parks are not covered by this policy statement. Future management directions at Nakimu are dealt with in John Woods' presentation to this Symposium on the interpretive planning for the caves.

(2) Arctomys Cave (Mount Robson Provincial Park) and the Limestone Caverns (Bowron Lakes Provincial Park)—the British Columbia Parks Branch recognizes the value of isolation as a means of limiting access to these fairly durable but potentially hazardous caves and pursues a deliberate policy of doing nothing to publicize them or improve access. At the same time, no effort is made to control access artificially, i.e. by permit. Cave registers might be employed in future to monitor use levels.

(3) Cody Caves—Accessible by some 12 km of poor road from Ainsworth on Kootenay Lake.

Established as a Provincial Park in 1966, Cody Caves (actually a single cave some 900 m in extent) received two fixed aluminum ladders and one aluminum catwalk in 1967 to overcome potentially dangerous drops but otherwise remains open and undeveloped. Visitors are advised that they enter the cave at their own risk. Vandalism, in the form of graffiti and speleothem marking, breakage and removal, has occurred throughout the cave, but worthwhile speleothems and interesting boxwork remain, particularly in the partially-hidden rear section of the cave. In 1976, on the approach to the cave, Parks Branch erected a safety and conservation oriented interpretive sign, including a map of the outer half of the cave. Plans call for a gate to be installed as soon as possible at the halfway point so that access to the rear portion can be controlled to halt deterioration. Access will be available to experienced, responsible cavers or groups guided by such cavers or by a Park Naturalist. The outer half of the cave will remain wide open for self-guided interpretation and recreational caving. Visitation is presently over 600 per year.

(4) Horne Lake Caves—Accessible by some 14 km of good gravel road from Qualicum on Vancouver Island. The caves are included in a small Provincial Park and management prescriptions vary. The Parks Branch advises visitors that they enter these caves at their own risk.

—Euclataws Cave—Discovered 1968, gated by Parks Branch 1970, closed to public 1971; about 580 m in length; outstanding concentration of speleothems, unique in Western Canada. The cave is managed as a Nature Conservancy or Ecological Reserve, accessible only under special conditions to expert speleologists, the products of whose work can be used in future as part of a continuing interpretive and educational program offered in conjunction with tours of Riverbend and the Old Horne Lake Caves. No confirmed break-ins. Visitation under 10 per year.

—Riverbend Cave—Discovered 1967, gated 1971 by VICEG with Parks Branch materials and support; about 450 m in length; excellent speleothems with some pre-gate damage near entrance. Several pitches, up to 15 m, make this a sporting cave, while the location of speleothems makes it less vulnerable to wear and tear than Euclataws. Access is granted to experienced and responsible cavers or to properly equipped parties guided by such cavers or by qualified Parks staff. Party size—minimum 3, maximum 6-8, depending on destination. The relatively undamaged nature of this cave offers an excellent contrast to the heavily vandalized Old Caves which are wide open to the public. There has been one successful break-in (1977) with no noticeable damage to the cave. Visitation is presently under 200 per year.

—Horne Lake Main Cave (about 150 m) and Lower Cave (about 75 m)—Known since early 1900s and heavily vandalized in the past 30 years; managed as "sacrifice" caves, open to all comers for recreational aspects and interpretation of impact when contrasted with Riverbend. One, marginally adequate interpretive sign. Visitation, over 2,000 per year.

—Parks Branch contracted with VICEG to offer the general public guided tours of the Old Caves and Riverbend in 1973 and 1974-75. Visitors were equipped with lights and hard hats, split into parties of 6-8 and taken to two or more caves. Riverbend bottoming parties were given ladder practice in advance. 2-3,000 visitors took advantage of this unadvertised program each year it was offered and obviously came away with a greater understanding and appreciation of caves. The program was discontinued for lack of funds, but VICEG continues voluntarily to guide some visitors on an appointment basis and to conduct periodic clean-ups in the Old Caves.

—Proposals for Horne Lake Caves Park include better surface trails, parking facilities and interpretive signing and eventually, perhaps, construction of a caves interpretation centre. Because of the concentration and variety of caves and the central location of the area for Island populations, this Park offers an excellent site on which to focus Parks Branch cave interpretation. There has been very limited published publicity by Parks Branch to date but Paul Griffiths of CSS/BCR has privately published a good guidebook to the caves and the Parks Branch intends to produce a brochure for Horne Lake and Cody after facilities are improved.

(5) Cascade Cave—Located on private logging company land near Port Alberni, V.I., within 100 m of well used back road to Horne Lake. 1087 m in length 1975, with further passage since mapped; excellent speleothems including pink and purple-tinged stalagmites; potentially hazardous to novices owing to pits (including 10 m entrance pit), water hazards and unstable sections. Gated and managed since 1972 by VICEG under agreement with landowner, MacMillan Bloedel Limited. Access policy: Open to experienced and responsible cavers or properly equipped parties guided by such cavers upon signature of liability release to landowner and VICEG. VICEG requires that visitors use the one established route through the cave and avoid entering already explored fragile areas. A sign at the cave entrance advises that the cave has been gated to protect its speleothems and because of its hazards to inexperienced or ill-equipped visitors. Names and addresses are given for access information. VICEG is prepared to provide equipment and guides to anyone interested in viewing the cave. Under VICEG management, wear and tear has occurred along the cave's main line, but most of the cave remains in good condition and periodic clean-ups and scrub-downs help to reduce cumulative impacts on the travelled routes. One successful break-in has occurred since 1972, with the resulting red spray-bomb arrows being erased immediately afterwards by VICEG. Average visitation, under 200 per year.

(6) Candlestick Cave—Located on Provincial Crown land in a MacMillan Bloedel Tree Farm Licence near Kelsey Bay, V.I.; accessible by logging road; 395 m in length; contains what is probably the most outstanding concentration of helictites of any known cave in Canada. Entrance camouflaged and gated by VICEG in November 1976 upon recommendation of MacMillan Bloedel

road engineers and with agreement of B.C. Forest Service. Managed by VICEG. Access policy: Only 3 people in cave at one time, one of whom is a VICEG member familiar with the cave; in fragile areas, only one person to move at one time, observed by the others; no touching of walls unless urgently necessary; no touching of speleothems; clean clothes and boots to be worn in the cave; any unnaturally deposited mud to be scrubbed off along route; keep to the standard, marked route; leave hard hats at start of decorated section to improve vision and sensitivity; record all visitors' names in entrance register and note any breakages and responsibility for same therein (obviously clumsy offenders may not be permitted to return); sign at entrance advises that cave has been gated to protect its fragile speleothems and gives names and addresses for access information. VICEG will guide any interested persons into the cave as long as pressures on the cave do not reach an unacceptable level. Cave remains well preserved to date, no break-ins. Visitation under 75 per year.

(7) Upana Caves—Located on Provincial Crown land near Gold River, V.I., accessible in short walk from logging road; several small caves with numerous entrances and a total length of perhaps 500 m, few speleothems but caves are of interest owing to variety of levels and passage types; CSS/BCR used these caves as the subject of an experimental "open house" in 1976 to acquaint area residents with caves and caving and generate interest in the cave potential of the area; in 1977, Paul Griffiths and Karen Bischoff of CSS/BCR produced a polished, concise brochure on the caves which included information on cave formation, cave life, cave deposits and caving safety, as well as a cave survey and a questionnaire on attitudes to caves and cave conservation practices. Information on the public response to this program has not yet been published.

b. General Directions in Cave Management

As the foregoing cases show, government agencies in British Columbia seem to have made some advances in Cave Management in that they have been able to state their objectives for various caves and take some concrete steps to realize them.

The Interpretive Management Unit plan for Nakimu promises a program which will both preserve and present to the Canadian people the natural resource that is the cave. In the interim, the Park Superintendent has publicly stated his guidelines for access and, by gating the artificial entrance, he plans to put himself in a position to manage the cave actually and not merely theoretically by application of the National Parks Act, Section 34a as in the past.

The Provincial Parks Branch has not gone nearly as far as it could or should have with developments to educate Horne Lake and Cody Caves visitors about the cave resource and to protect the resource itself. Fortunately, its employment of gates on Euclataws and Riverbend has retained the potential for variety and depth in future interpretive programs, without sacrificing whatever current benefits the public may gain from free access to the Old Caves and controlled access to

Riverbend. The Branch has also recognized that isolation can be an adequate and effective management tool for preserving the character of caves such as Arctomys, the Limestone Caverns, and the small caves of Top-of-the-World Park in the Southern Rockies. Unfortunately, however, the Parks Branch, like other Provincial Government agencies, has no practical answers to the pressing problem of how to protect or present the many caves constantly being turned up by B.C. caving clubs, particularly on Vancouver Island.

Moving to the caving clubs, one finds that members of both major provincial clubs, VICEG and CSS/BCR, are becoming increasingly concerned with and involved in cave management problems. The approaches taken by the two clubs are not necessarily incompatible, but reflect the philosophical differences which continue to divide them.

CSS/BCR places considerable emphasis on the discovery of new caves and regularly uses media publicity to raise public consciousness of caves, both to get a long-term conservation and safety message to the public and to garner a public feedback on new cave leads. Society members, Paul Griffiths in particular, have arranged to instruct courses in cave exploration at a number of Island and Lower Mainland community colleges, and former students of such courses now constitute the active core of the group.

The CSS/BSR regularly seeks remuneration from various levels of government and from private companies to sustain its caving activities, which focus mainly on exploration and inventory. At the present time, CSS/BCR members are working on two cave inventory projects on Northern Vancouver Island, one for the Municipality of Gold River and the other for the Mount Waddington Regional District. Upon completion of its inventories, the CSS/BSR apparently intends to seek the involvement of various levels of government and resource users to develop management for selected caves.

Beyond providing advice to logging companies on the protection and interpretation of specific caves in their operating areas, the only known CSS/BCR venture into direct cave management was the installation of a barrier in the resurgence entrance of a well-publicized, potentially deep cave near Gold River in 1976. A sign at this "gate" advised of the existence of an alternative entrance (location not specified) and gave names and addresses for access information. This barrier was forced out by water pressure within several weeks of installation and has not been replaced.

VICEG spends more time in surveying than the CSS/BCR and thus tends to have more complete documentation of fewer caves (Island length and depth records are based on VICEG surveys, though some CSS/BSR discoveries may eventually prove more significant after survey). In keeping with its hesitations about wholesale publicizing of caves and caving, VICEG has often moved quietly into direct management of caves when it feels that this is in the cave's best interest. The most obvious and perhaps controversial examples of VICEG's actions are the gates on Riverbend, Cascade and Candlestick Caves and the group's participation in

the gating of Papoose Cave in Idaho. In each of these cases, the club believed that regulation of access was urgently required for the welfare of the cave and that a gate was the only practical means of achieving such regulation. The assumption by a caving club of direct management responsibility for caves, as VICEG has done at Cascade and Candlestick, is apparently unique in Canada.

Far from believing that gates are a panacea for all cave management problems, however, VICEG pursues a number of other approaches as well. Information on cave conservation and safety (slide talks, displays, etc.) is supplied to public groups and the media upon request. A brochure containing general information on cave formation, conservation, safety and on the club is available for interested groups or individuals, e.g., in response to verbal or written enquiries. Cave tours for groups expressing interest in caves have been offered by the club at Horne Lake and elsewhere since at least 1970, and from 1973 to 1975, the Horne Lake guiding program was formalized and supported by the Parks Branch with contracts totalling \$8,000.00.

Uneasy about the treatment often afforded caves in the media, VICEG and B.C. Speleo Research have preferred to aim their information/education work at persons already displaying some interest in caves and caving. Thus, membership has been built on personal contacts and guiding programs have relied less on publicity than on people already intending to visit the caves. Cave information is circulated within the caving community but is otherwise restricted, to maintain for as long as possible whatever benefits can be derived from secrecy. When it becomes apparent that a cave is threatened by conflicting resource use, the policy of VICEG and BCSR is to make available to Government resource agencies and resource companies at no charge surveys, inventory and assessment data and recommendations on possible management measures. In several areas on Vancouver Island, logging companies have responded to such quiet approaches by re-routing new roads, adjusting cut-blocks and instructing staff to report any further cave discoveries for investigation by cavers.

Aware that an increasing number of persons not affiliated with caving clubs are visiting many of the Island's more accessible caves, VICEG has prepared notices on waterproof paper which carry safety and conservation messages and are designed to be placed inside such caves. The notices can be used by any caving organization as there is a blank space at the top for the cave name and several lines on which the name of the nearest caver or contact group can be written. Again, the intent is to get the message to those actually visiting the caves and hopefully to establish contact between these individuals and organized caving groups.

Summary

Manitoba and Saskatchewan apparently have no caves to be managed. Newfoundland remains a *terra incognita*.

Quebec has several commercial caverns, but no caves under government management,¹³ and possible S.O.S. cave management ventures are not known to the writer. In New Brunswick, cave management consciousness is apparently so low as to be negligible. Caves in the Yukon and Northwest Territories may fall under the legal protection of Federal Government legislation, but specific policies seem to remain unstated and management success is actually assured only by isolation and a lack of pressure on the resource. Nova Scotia cavers have awakened their government to a recognition of the need for cave resource management, but tangible progress is slow. Ontario appears to have sympathetic government agencies and adequate protective legislation, but as Kirk MacGregor notes, legislation alone cannot ensure the conservation of irreplaceable cave resources and more practical management measures are already overdue in most cases.

In the West, Parks Canada has to date followed the conservative policy of closing its caves to all but scientists, relying only on the rather nebulous threat of prosecution to achieve this closure. The Nakimu example hopefully indicates a positive trend to devise more imaginative policies appropriate to particular caves and to guarantee the implementation of these policies by more realistic and practical controls. The Alberta Government's only venture into cave management is a mercifully simple and uncontroversial case, but Alberta Parks' preparedness to install the gate and set forth realistic terms governing access to Plateau Mountain Ice Cave reflect a good understanding of the issues involved and the management prescription required. Whether the Alberta Government sees any role for itself at other caves, such as the heavily visited Canyon Creek Cave near Calgary, is not known.

The British Columbia Parks Branch's cave management record reflects a see-sawing between initiative and inertia which has resulted in some positive steps being taken but inadequately followed through. Two parks have been established specifically to preserve and present cave features, yet neither has been properly developed to achieve these ends. Practical access controls have been applied to permit the management of two caves according to different prescriptions appropriate to each, but no direct responsibility has been assumed by the Branch for continuing interpretation or adequate visitor facilities. Branch Natural History Objectives recognize the importance of caves, but other priorities and limited funds have dictated that expenditures on cave management be negligible. In theory, the Branch plans to add outstandingly significant new cave discoveries to its system, but such action may not be desirable in practice unless accompanied by a total commitment to proper management.

British Columbia caving clubs have long recognized that the present level of government participation in cave management is inadequate to protect the resource over the long term. The CSS/BCR has called for government financial support of cavers involved in the inventory and assessment phases of Cave Management, and has managed to obtain this kind of support through contracts at the municipal and Regional District government levels. For its part, VICEG has called for better management of caves already singled out by the government or opened up by caver activity, has done voluntary and contract work to further this end, and has plunged directly into cave management itself on its own resources and responsibility.

II. CAVE MANAGEMENT FUTURES IN WESTERN CANADA

The views that follow are my own, and do not necessarily reflect attitudes of any provincial government agency or caving organization.

In my opinion, the future of Canadian Cave Management rests in the hands of the Canadian caving community. Cavers must be prepared to extend their interest in caves to include a strong sense of responsibility for caves, both in cavers' own conduct underground and in their de facto position as the "cave experts" in society. If cavers are sincere in their often-professed concern for the conservation of caves, it is not enough merely to seek out and explore new underground challenges, for this is a symptom of the kind of selfish consumerism which would rapidly destroy our species, let alone the values of caves. Recreational caving is certainly legitimate, but even the recreational caver must realize that the quality of his experience will be irreversibly degraded if care is not taken to conserve the cave's values and resources. It is therefore incumbent upon all cavers to be aware of the impact that their conduct may have upon the caves, to try to assess what levels of impact might be acceptable in the longer term, and to give thought to practical ways of keeping impacts below these levels. Assuming responsibility for such consciousness and forethought might seem an onerous task, but if it is not accepted by the cavers who most use the resource and claim to understand and appreciate it, cave conservation is clearly doomed and many cave values will be forever lost.

In Western Canada, the vast majority of caves lie on Provincial Crown lands, most of which are under Forest Service administration. Many of the discovered caves are relatively inaccessible and appealing primarily only to cavers. In such cases some consensus within the caving community about conduct appropriate to each cave should be all the "management" required. Matters such as access improvements or marking, party sizes, frequency of visits, avoidance of sensitive areas and the use of bolts, explosives or passage markers might be considered in this process. Such a consensus should be clearly understood and adhered to, however, as in such cases the sincerity, responsibility and performance of cavers themselves is on the line. The unfortunate weakness in this approach is that it depends upon voluntary co-operation by all cavers, and in Western Canada at least, such co-operation has often been lacking. One can only hope that cavers will realize what is at stake and make a greater effort to work together to make self-regulation successful.

Although caver forethought and self-discipline could provide adequate "management" for the majority of caves, the appropriate Provincial resource agency, usually the Forest Service, should be informed of cave locations and recommended management prescriptions on the understanding that this information would remain "in-house." Cave information incorporated into the Forest Service folio system and planning process offers an opportunity to consider cave resources in the overall land management picture. Government resource managers, advised by cavers, may then be able to avoid or at least mitigate such potential conflicts as improved access, hydrological disturbance or physical disruption of cave entrances. In most cases, as I have suggested, these caves are unlikely to receive much use from outside the caving community and government involvement need not extend beyond surface management questions. The situation becomes more complicated if cavers feel either that general public attention will unavoidably be

focused on a cave or that a cave has qualities which require special management for the long-term benefit of the public and the cave.

In British Columbia at least, the government is most unlikely to become involved on a large scale with direct management of caves. The Forest Service can reserve forest land for recreational use and could provide interpretive signs or limited service facilities at a cave, but has no legal mandate, funding or physical means to protect cave resources. Forest Service recreation site status might therefore be applied to durable caves whose primary value to the public would be for recreational experiences. Obviously, however, relatively few caves would be ideal for this sort of prescription. Further, it is unlikely that Forest Service staff could be spared to undertake any cave clean-up work, such as removal of graffiti or garbage, with the result that such caves could tend to become "sacrifices," most valuable for focusing attention away from other caves. The Parks Branch, though well equipped with protective legislation and intensive "people management" powers, considers itself too limited in funds or staff to engage in intensive cave management at more than a few key sites. Parks practice to date also reflects an attitude that caves are somewhat out of the mainstream of public recreation and conservation priorities, so even those few key sites tend to receive only budgetary leftovers.

Obviously, government preservation agencies must be made more aware that the non-renewable nature of the cave resource demands a higher priority for proper management than many of the more popular but relatively renewable resources on the surface. Perhaps only a mobilization of public opinion can achieve this goal, and for this reason I cannot rule out greater publicity about caves by cavers. My great concern is, however, that, if too much cave publicity is generated in the absence of adequate cave management mechanisms, the resource may already have suffered irreparable damage long before government takes any action. I suggest that nothing but direct cave management action by cavers can fill the present vacuum, and that, if this responsibility is not assumed by cavers, at least temporarily, the future for Canadian caves is bleak.

My own experience suggests that government agencies welcome advice, assistance and even direct involvement by cavers in cave management issues, both because of the agencies' general lack of expertise on the subject and because such assistance is often offered without a price tag attached. As stated above, cavers should work closely with resource agencies and resource users to inject cave inventory and assessment data into overall land use planning, zoning and scheduling. Appropriate caves capable of withstanding public impact should be introduced to the public, with suitable interpretation of their recreational and educational values. If the Forest Service, a Regional District or municipal government or a resource company is prepared to take on this responsibility or fund such a program, so much the better, but if not, cavers should be prepared to go ahead on their own as the CSS/BCR has done at the Upana Caves. In the case of exceptionally vulnerable, threatened caves, assuming no action or interest by the Parks Branch, cavers should again be prepared to take the initiative with appropriate action, as VICEG did in its gating of Candlestick.

Given the absence of constant unanimity and co-operation among cavers and the fact that the cave resource is not theirs to dispose of willy-nilly in any case, I would qualify the foregoing recommendation by proposing that the cave management actions of cavers should be made subject to

approval and review by the government resource agencies which are ultimately responsible to the public and to posterity. Thus, if cavers wish to apply special management to a cave, particularly if it affects public use as at Candlestick or Upana, legal authority should be obtained from the appropriate resource agency. This authority might take the form of a Forest Service Special Use Permit, a formal lease of Crown land, a letter of authority or memorandum of agreement or perhaps a Park Use Permit. It would define the prescription to be applied, confirm that it was deemed to be in the public interest, supply the legal power to enforce it, and provide for review in the event of problems or complaints. If necessary, an inter-agency committee could be struck initially to set forth guidelines governing such procedures, but, essentially, responsibility for management of specific caves could be delegated to applicants by the individual resource agency concerned.

In cases of caves on private land or under private jurisdiction it is likely that government agencies would lend their support to cavers urging cave management action upon the landowner. The example of Cascade Cave indicates that, in British Columbia, corporate landowners and managers are already receptive to cave management proposals unless their own interests are obviously threatened.

If cavers are to try filling the present void in Canadian cave management, many of them would like some financial assistance to facilitate the work. Precedents already exist in external support obtained by McMaster cavers, VICEG, and the CSS/BCR, primarily for specific projects ranging from inventory to interpretation and scientific study. However, while cavers may ask that someone place a dollar value on the information they gather, government agencies, already pressed for funds, may ask in return why they should pay for data gathered as part of what is for most Canadian cavers a keenly pursued recreational activity. It may indeed be unreasonable at this point to expect society or government to pay well for information about a resource they do not properly appreciate. Better perhaps for cavers to supply the information *gratis* in most instances to help foster an appreciation of the resource and of the efforts "believers" are prepared to make on its behalf. Again in my experience, voluntary assistance to government agencies and resource companies by cavers has often brought useful reciprocal but non-monetary assistance in various forms, including access to maps, publications, mapping and copying facilities and valuable contacts.

If these benefits are considered too trivial, cavers might prefer to seek support through government grants to recreation groups, a procedure apparently successful in Quebec. Additionally, the contract proposal approach can always be tried, though rejection of such proposals will leave the caver in an extremely awkward position. If he does not undertake the project unless paid, he will still realize better than anyone what values may be lost. If he does the project without remuneration, he will feel ridiculous offering his completed work again to the original potential buyer at no charge, but will know that failure to do so would probably block the best practical use of the work. My own personal choice as a caver would be to volunteer all information gathered in the course of caving that I had undertaken as recreation. Any work not conforming to my own interests or priorities might or might not be done unless a contract were offered.

It bears repeating that the suggested direct involvement of cavers in cave management demands a high degree of responsibility on the part of members of the caving community. Communications among caving organizations

must be improved if inter-club misunderstanding and friction is not to undermine dealings with third parties and efforts to conserve the caves. As Canada has no national caving organization and many of its independent clubs differ in their approaches to cave management problems, considerable regional variations must be expected and specific disagreements within regions, if irreconcilable among cavers, must be laid before the responsible government agency for adjudication. I do not call for nor expect all Canadian cavers blindly to fall into line on cave management issues and solutions. I do however expect them to be fully aware of the impacts their own conduct may have on caves and to be prepared to take an active role in determining the long-term destiny of these caves in whatever ways they feel will be most beneficial. Perhaps only time will enable us to distinguish between the successful and the unsuccessful efforts at cave management. One thing is clear, however: with no efforts at all, the chances of success are slim indeed.

Summary

The overall cave management record of Government agencies in Western Canada, though perhaps better than average in a relative sense, remains very poor in absolute terms. Although Federal and Provincial Park services acknowledge a growing awareness of the cave resource, other priorities, limited funds and understandable ignorance about caves reduce the likelihood of government cave management activities keeping pace with the pressures on the resource in the immediate future, particularly in the Provincial domain. If these pressures are to be countered, cave users themselves must take the initiative in management action by obtaining where necessary delegated authority from resource agencies. Having achieved some degree of effective management to protect the resource, cavers may turn greater efforts toward public education about caves to generate as soon as possible wider distribution of a sense of responsibility for their conservation. The need for caver involvement in cave management will not end once caving ethics become as widely accepted as wilderness ethics, but greater public and government awareness and interest will then ensure that cave values have a far better chance of survival than they have in the present climate.

Footnotes

- 1P. Thompson, Ed., *Cave Exploration in Canada*, Canadian Caver Magazine, Edmonton, 1976, p. 17.
- 2Thompson, *op. cit.*, p. 8.
- 3Thompson, *op. cit.*, p. 17.
- 4Thompson, *op. cit.*, p. 8.
- 5Max Moseley, N.S.S.S., Proposal for a Bat Preserve in Nova Scotia (Revised), Halifax, 1976.
- 6Thompson, *op. cit.*, p. 10.
- 7All New Brunswick information from Thompson, *op. cit.*
- 8Thompson, *op. cit.*, p. 1-2.
- 9Information from Thompson, *op. cit.*, Ontario Park Management Branch, and Kirk MacGregor (TCG).
- 10Thompson, *op. cit.*, p. 53.
- 11Correspondence from R.D. Thomasson, Dept. of Renewable Resources, Gov't. of Manitoba, 29 August, 1977.
- 12Correspondence from J. Jozsa, Dept. of Tourism and Renewable Resources, Gov't. of Saskatchewan, 30 August, 1977.
- 13Correspondence from Gaston Goulet, Quebec Directorate of Parks, 25 August, 1977.

Basic Considerations in the Management of Ice Caves and Glacier Caves

Dr. William R. Halliday, M.D.*

By definition, glacier caves are caves—natural cavities—in and/or beneath a glacier or firn; ice caves are caves in which ice forms and persists through much or all of the year. Perhaps they also include caves intruded by moving ice. Glacier caves may or may not be ice caves. Ice caves occasionally have small glaciers within them. One other term should be mentioned at the onset: *glaciere* (pronounced glah-si-ehr), which refers to ice caves and also to cold-trapping sites of other kinds, such as mines.



Management of glacier caves (caves in or beneath glaciers) includes both the caves themselves and the glacier surface. Photo by Charles H. Anderson, Jr.

The Montana symposium is an appropriate place for a discussion such as this, as these caves are predominantly found in high latitudes and high elevations. Yet in the United States they occur as far south as central New Mexico, Kentucky, and Tennessee. In the United States, ice caves are predominantly lava tube caves, but solutional, tectonic, and talus caves containing ice also are important. As a group, glaciers and glacier caves are considered public attractions from New England to the Pacific Coast states; from Washington state to New Mexico. They occur on private property, on state, federal, and other public lands and present many of the common problems of cave management, plus a few of their own.

The common denominator of glacier caves, ice caves, and non-spelean glaciers is the special importance of subterranean or subglacial meteorology, especially in the form of ablation, which not only is the major speleogenetic process of glacier caves but is the cause of much ice speleothem deposition and disappearance in glaciers. Ablation is largely responsible for their beauty, interest, and size. Thus it is only common sense for the principles of management of glacier caves and ice caves to be especially oriented to speleometeorological principles.

*1117 36th Avenue East, Seattle, Washington 98112.



Because glacier caves often are spacious and inviting, yet present special hazards, their management needs special attention. W.R. Halliday photo.

Consider a few illustrative problems:

About 20 years ago the U.S. Forest Service installed a very nice series of steps in Arnold Ice Cave, Oregon, so that visitors could easily and safely descend the steep ice flow from the entrance to the bottom of the cave. The last photo I saw showed most of the steps and much of the handrail supports buried in ice.

In Idaho's Shoshone Ice Cave, the problem was just the reverse. Russell Robinson has nicely documented what happened when the entrance of this ice-plugged lava tube was enlarged enough for ablation to take over. His booklet has very nice old photos showing the ice melting back and back, until it wholly disappeared in especially hot summers. Under his management, the ice is now making a good comeback.

More tragically, two deaths in the Paradise Ice Caves of Mount Rainier are known to have been due to lack of management based on speleometeorology. In one case, a hiker unexpectedly broke through a thin roof and fell into the Paradise River; the other case was due to flakefall, which will be discussed later.

For simplicity, I am going to approach my topic from the standpoints of: (1) protecting cavers and other visitors; and (2) protecting the caves. Offhand, I have difficulty in thinking of other areas in which management of these very special caves differs from that of other caves.

From the standpoint of protecting cavers and other visitors, there are certain obvious differences between glacier caves and ordinary glaciers, but the areas of overlap are also important. Protection of visitors from hypothermia is a problem in both. Usually, hypothermia is more serious at least potentially in glacier caves than in ice caves, because of: (1) wind chill; (2) dripping water; and (3) running water,

all of which are rarely present in American glaciers. On the other hand, some Canadian glaciers extend deep into the permafrost zone, where heat loss from contact with rock or soil can be extremely rapid. At the near-zero (Celsius) temperatures encountered in ice and glacier caves, heat transfer can be very rapid and even minor injuries require special thermal protection. In both types of caves, minor injuries due to slipping are more likely than in "ordinary" caves, because of the slickness of ice floors—a problem often overlooked despite its obviousness. Hypothermia is discussed at considerable length in my *American Caves and Caving*, so I will not take up time on it here.

Closely related to waterchill aspects of hypothermia in these caves is the sudden and currently unpredictable emptying and damming of subglacial or englacial lakes. The development and sudden release of hydrostatic heads of as much as 100 meters has been described in the second edition of my *Depths of the Earth*; again I see no need to repeat what can easily be read. Glacier caves apparently vary tremendously in this regard. The maximum sudden flood of the Paradise Ice Caves observed to date apparently was barely more than a foot.



An explorer admires a magnificent ice column in the Paradise Ice Cave system of Mount Rainier, Washington, not noticing the danger of flakefall (right ceiling). *Photo by Charles H. Anderson, Jr.*



This entrance to the Paradise Ice Caves system, with more than 16 miles of passages, opened unexpectedly during a recent summer, nearly 1/2 mile from the closest usual entrance, just out of the photo to the right. It led directly into the most complex part of the cave. *Photo by W.R. Halliday.*



In some areas, the entire floor of glacier caves is composed of flakes fallen from the ceiling. *Photo by Charles H. Anderson, Jr.*

The unique danger of glacier caves (including those in firn) is flakefall. Flakes are long, thin slabs of ice weighing a few ounces to many tons. These flakes gradually separate from the ceiling and walls, and eventually peel off with a deafening crash if they are sizeable. They remain a hazard even to the experienced glaciocaveologist because they usually remain attached at one end until the moment of collapse, and are very difficult to detect from that end. A loud creaking or groaning frequently precedes their fall, but not always. In the final stages of glaciocaveogenesis, sizeable areas of the glacier snout or lower body are transformed briefly into a 3-dimensional maze of flakes. Flakes also contribute to temporary damming of subglacial streams as just discussed, and occasionally their fall triggers huge waves in subglacial lakes.

A possible danger of geothermal caves in firn is that of noxious gases, especially sulfurous. Such caves are so rare and the gases so annoying that, to date, the only recognized danger in the United States would be to a person injured in the steam caves of Mount Baker in Washington state.

A potentially significant hazard resulting from meteorological factors is getting lost in glacier cave passage mazes because of constant enlargement and modification of the passages—especially small ones. Glacier caves appear to be in a constant state of change, with their processes, and those of the surrounding ice, much more complex than simplistic descriptions of glacier retreat and advance would suggest. Search parties should always expect to find newly passable passages as well as newly collapsed passages.

Ablation also mandates one specific change in visitor control. If ice screws are used to demarcate areas open to the public, knowledge of the rate of ablation is necessary to determine how often they must be checked out. In the Paradise Ice Caves, at times this has had to be done daily. Otherwise, visitor control presents few problems that would not be present in similar surface terrain, at night.

From the standpoint of protection of these caves and their vulnerable beauties, knowledge of speleometeorology and its application to individual caves is equally important. The foredoomed wooden steps in Arnold Ice Cave might have had a favorable cost/benefit ratio from the standpoint that descending to the bottom of the cave had recreational value for ordinary visitors (although this was largely or entirely offset by its destruction of most of the scenic values of the great ice slope). However, those planning its installation failed to note that in this particular ice cave, the ice was

increasing in quantity as a result of cessation of ice mining. Unless something dramatic has occurred in the past year or so, the steps are now nothing but a scenic pollutant.



Glacier caves contain transient ice speleothems of great beauty. *C.H. Anderson, Jr. photo.*

The situation at Arnold Ice Cave is unusual, however. In most glaciers, the beautiful ice speleothems are not only fragile and transitory, but in a state of natural decline—the reasons are more complex than originally believed and too much so to discuss here. Every additional source of heat is at least a potential threat: carbide lamps, gas powered lanterns, visitors' bodies. In some cases—the Paradise Ice Caves are a good example—the ice speleothems are transient anyway and little is lost by permitting visitors in large numbers. In other cases, frost crystals a foot wide may not tolerate a single visitor's body approaching closer than a few feet. I don't know of any practical way to quantify these matters. All I can suggest is careful observation and special protection for those caves which prove to be extra-vulnerable. The beauties of our greatest ice caves in some ways are even more vulnerable than those of calcite. And again, application of speleometeorological principles to individual stations should yield many innovative solutions.



Little Ice Cave, Montana (limestone cave). *W.R. Halliday photo.*

Most American ice caves (caves in which ice forms and persists) are on public land. Although the caves vary



Big Brush Creek, Uave, Utah (Limestone cave). *W.R. Halliday photo.*

greatly, management of their ice content is uniformly dependent on spelean meteorology.

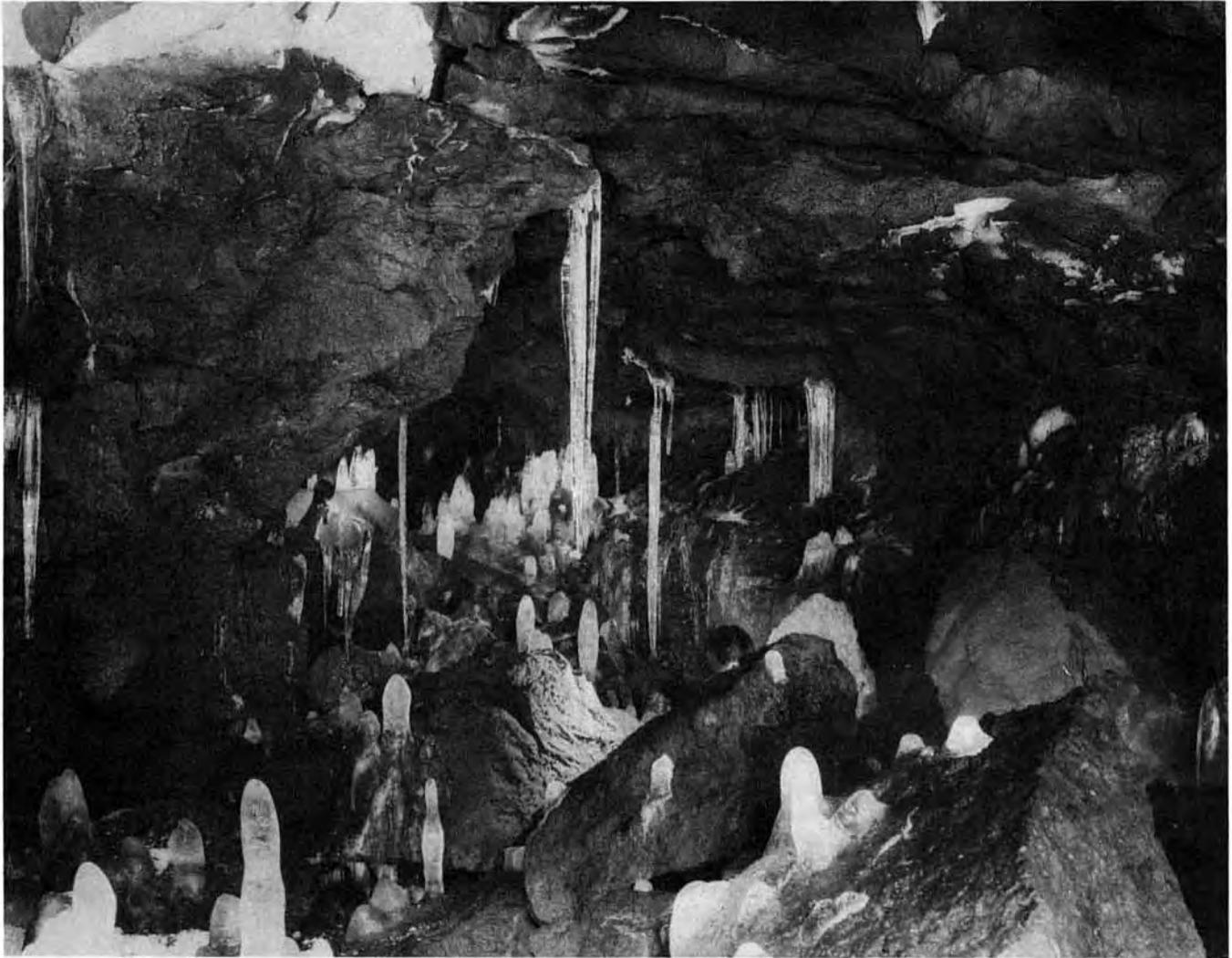
Of course, it really isn't that simple. There is a great deal yet to be learned about speleometeorology. I don't understand why the ice is where it is in Little Ice Cave, Montana (between the ice-free entrance and the ice-free majority of the cave which isn't much different from the icy section).



Crystal Ice Cave, Idaho (tectonic cave). *Photo by James Papadakis.*

There is even more to be learned about glaciopedology, truly in its infancy, in which we are cautiously advancing from one glacier to another, still finding radically different factors beneath each new example. I am sure that others with different ice and glacier cave experience will have worthwhile ideas. I hope that those of you with such

experience will not hesitate to get in touch with me—hopefully being familiar with the pertinent sections of *American Caves and Caving* and the new edition of *Depths of the Earth*. These fields are even more challenging than speleology as a whole. This paper deals only with some fundamentals, and we indeed have much to learn.



Ice Cave, Trout Lake, Washington (lava tube cave). *Photo by John H. Lincoln.*

Special Management Considerations of Lava Caves

James Nieland,* Libby Nieland,** and Ellen Benedict†

ABSTRACT

Unique features of lavatube caves are only beginning to be recognized. For years they have been relegated to a "step-child" relationship to limestone caves. Even now few speleologists study lava caves; most regard them as sterile curiosities. Unique features of lava caves are little studied or remain unidentified. Like limestone caves they possess a wealth of valuable information to geologists, biologists, archeologists, paleontologists and historians. Management problems arise primarily from a failure to recognize their significance. For years they have been left to manage themselves. As a result they have been dynamited, dug up, used as trash dumps, spray painted, and their formations removed by rock collectors. Fires have been set in guano deposits, cave animals trapped or killed, and delicate sand formations trampled into oblivion by careless visitors.

Lavatube caves occur mostly in the western United States; nearly all are found west of the continental divide, primarily on publicly owned land. The burden of management, therefore, falls mostly on government agencies.

In the past, management has mostly been undertaken without consideration of all potential effects upon the caves. This has often resulted in unnecessary damage. Two caves, Lava River Cave, Oregon, and Ape Cave, Washington, had at one time delicate sand castles. Both caves were developed so the public could easily view these features. It took only a few years to trample these sand castles into rounded sand humps. To effectively evaluate and manage cave resources, caves must be inventoried for their features and significance. Management decisions need to be made accordingly.

A number of management approaches and alternatives are available. Many lava caves are located far from human habitation and are thus protected by obscurity. These are best managed by being allowed to remain obscure with as little attention being drawn to them as possible. Caves with a history of use are the ones that warrant most management concern. These have been managed in a number of ways. They have been gated with access being granted to groups with an agency guide, and they have been commercialized, or developed for self-guided tours. Caves of special significance have been included in national monuments, in federal research natural areas, or placed under special use permits for scientific studies. The challenge is how to get away from the "band-aid" approach to lava cave management.

INTRODUCTION

This third National Cave Management Symposium is to emphasize the basic tools and methodology necessary for implementation of many of the management ideas presented at past conferences. When we were asked by the symposium committee to prepare a paper on "Special Management Considerations of Lava Tubes," we immediately realized that the formal treatment of this topic has, like most aspects of lava caves, lagged far behind similar considerations about limestone caves. In fact, to our knowledge, this topic has never before been seriously considered at a formal conference.

All caves, regardless of geological origin, should be considered in terms of safety hazards and of conservation of geological, biological, archeological and historical resources. There is a further management consideration with lava caves: relatively little is known about their resources. This in itself creates a very special management problem.

VULCANOSPELEOLOGY: A RELATIVELY NEW FIELD

In the past, most lava caves have generally been regarded by the public, scientists, owners, and managers as sterile curiosities—dark underground tunnels of little interest, as compared to the beauty and grandeur of vast limestone caverns. This "step-child" relationship to limestone caves is partially responsible for the current lack of information about lava caves. Little human energy and financial resources have been devoted to the discovery, exploration, study and management of lava caves; vulcanospeleology is a relatively new field with apparently much that is still

*U.S. Forest Service, St. Helens R.D., Cougar, WA 98616

**NSS, Box 9, St. Helens R.D., Cougar, WA 98616

†Department of Biology/Environmental Sciences, Portland State University, Portland, OR 97207

unknown (Halliday 1976; Senger 1977a, 1977b). Further, there are few vulcanospeleologists; thus information is accumulating very slowly. An important facet of this problem is that many lava caves are located in relatively isolated areas of low population density where land is primarily devoted to other major resources, such as cattle or timber production. As a consequence, many lava caves have been without management. It is unfortunate that several lava caves with unique nonrenewable resources were exploited long before anyone realized that they contained anything of value (Benedict 1973, 1974a). Stated in another way, there may now be a need to protect *lava cave resources that have not even been recognized as resources*.

MANAGEMENT CONSIDERATIONS OF LAVA CAVES

Management of any cave must first of all start with an understanding of its significant features and potential or actual use pressure. Therefore, examination and inventory are essential steps preceding management decisions. A cave must be inventoried for its resources and its susceptibility to vandalism—intentional and unintentional. Well-meaning visitors can destroy irreplaceable resources. Each cave, or group of caves, possesses special features which must be evaluated by individuals trained to recognize their significance.

Geologic Resources

Lava caves, like other caves, are landforms which have been invaded by biotic species including *Homo sapiens*. Geologic aspects are no more important than biological or cultural values in a cave inventory, but are more apparent. There are two important subdivisions to be considered in management decisions: public safety and geologic features.

1. PUBLIC SAFETY.

Many lava caves contain large masses of unstable breakdown. Others have loose ceiling blocks, ice slopes, or pits; all of which pose a threat to inexperienced explorers. Lava caves with safety hazards may need to be gated (Little Red River and Dynamited Caves in Washington) or posted with warning signs (Guler Ice Cave, Washington). Caves with hazards should not be marked on maps or have their routes posted with directional signs.

The Deschutes National Forest in Central Oregon has a classification system of four grades of difficulty which indicate the degree of hazard. This information has been published in a descriptive booklet (Purcell 1977) about fourteen local caves and is on sale at Lava Lands Visitor Center, Bend, Oregon. The publication in a widely circulated periodical, *The Ore Bin*, of safety hazards in the Saddle Butte Lava Tube System—rockfall, rattlesnakes, and lack of water (Ciesiel and Wagner 1969)—is another instance of warning the public. Still another method is being used at Ape Cave on National Forest land in southwestern Washington. The Oregon Grotto of the National Speleological Society provides a free brochure (Nieland and Nieland 1975) which gives "Guidelines For Safe Caving" and describes the routes for "most visitors" and "only for *well equipped* explorers." Whatever the technique used to safeguard the public, it should be based on use pressure and the degree of hazard.

Safety hazards can be created where none existed. Arnold Ice Cave is 60 feet deep and has a long ice slope extending from just below the entrance to the lowest point in the cave. In 1963 the Forest Service opened the cave to the public by

constructing a wooden stairway on the top of the ice. Since then the ice has continued to build up and now only the very top of the railing projects above the ice. The stairway is now a safety hazard. The construction of the stairway at Arnold Ice Cave is an example of poorly advised management of a lava tube.

2. GEOLOGIC FEATURES.

A virgin lava cave often contains fragile and easily destroyed primary and secondary formations of unusual beauty. Once gone, all that remains are dark, often featureless walls, ceilings, and breakdown blocks. No wonder such violated caves are held in low esteem as dull and uninteresting—hardly worthy of special consideration or protection. Not all lava caves are like this. Some contain delicate drip lava stalactites and stalagmites, gypsum crystals or sand castles; these features, once destroyed, will never grow back.

Only within the past 10 years (Halliday 1976) has much attention been given to the study of the process of lava cave formation and to the types of features found therein. There is still considerable disagreement about the exact processes (Niewenhuis 1975) but certain facts are clear. Lava tubes form in a very fluid, high olivine magma which, as it flows down an incline, may form a channel, crust over and drain, forming a lava tube. Surges in the lava volume may add linings to the inside of the tube. In places the lava may also break through the roof and flow over the surface, thus increasing the thickness of the roof. Erosion of sediments and soil beneath the tube may contribute to the depth of the cave. Collapse of wall linings frequently exposes the underside of the flow and the pre-flow country rock. Lava in which lava tubes form is called pahoehoe (pa-hoy-hoy), a Hawaiian term.

Entrances normally are of two types: sinkholes caused by the collapse of thin roofs, and skylights which never roofed over. Sinkholes are the most common type and generally form due to the contraction cracking and collapse of the walls and roof during cooling of the tube. This stage of cooling is responsible for most of the breakdown found in caves. Later collapse is less frequent.

Many of the interesting features of lava caves are very subtle. For example, flow marks are longitudinal lines which represent temporary levels of molten lava, somewhat analogous to bath tub rings (e.g. Lava River Cave, Oregon). A lavafall forms where the flow drops over a steep slope or a short drop. These lavafalls sometimes result in overhanging pits, as in Dynamited Cave. Ripple marks and waves are often formed in lava floors. Occasionally a tube-in-tube or an arch forms inside a larger tube where a secondary flow crusted over and drained. These features are not especially fragile.

Formations are of two general types: primary ones formed by molten lava, and secondary ones developed through the weathering of the basalt, precipitation of minerals, and the sculpting of various types of cave fill. None of these formations are renewable so great care must be taken to preserve their beauty.

Lava stalactites and stalagmites are of several types. Ribbon stalactites develop by the sloughing of glazed surfaces and the dripping of remelted lava from the walls and ceiling. Where lava is thrown from a passing stream onto walls and ceilings, and drips off, spatter stalactites form. Tubular stalactites, or lava "soda straws," develop through the degassing of walls and ceilings where degassed lava is forced from the wall or ceiling at small fixed points and cools to form tiny hollow stalactites. Stalagmites build up where globules of lava drip to the floor. Lava roses



Julie McKinney on a lava tongue in Deadhorse Cave, Washington. *Nieland Photo.*

develop where lava is forced upward by the degassing of the floor. Lava formations of these types may be seen in excellent states of preservation in Arco Tunnel at Craters of the Moon National Monument, Idaho and in Lavacicle Cave in the Deschutes National Forest, Oregon. Admission to both of these caves is strictly regulated.

Secondary formations of silica, calcium carbonate and gypsum precipitate on cave surfaces. Silica formations are common to caves in moist climates, while calcium carbonate and gypsum are typical of lava caves in the more arid regions. These minerals precipitate into stalactites, stalagmites, ribbons, crusts and popcorns. Sometimes basaltic walls, in very old lava tubes, are sculpted into "boxwork" formations by kaolinization, another type of weathering, e.g. Saddle Butte Lava Tube system.

Medium-use caves are ones frequently visited but not especially well known. These are the caves that managers and/or owners should be most concerned about, since they are probably little supervised and are very susceptible to damage. Here, some trash clean-up and simple improvements may be necessary. Medium-use caves can turn into high-use caves by posting location signs, improving roads and by advertising of various types, intentional and otherwise. Brochures describing good conservation and safety practices can be beneficial in preserving these caves. It is especially important in medium- and high-use caves that the public be made aware of the unique values of lava caves, otherwise they do not realize that the rocks, formations, and artifacts that they remove are nonrenewable resources.

High-use caves are generally well known to the public and often are indicated on maps of various sorts. These caves may be developed as tourist attractions and may have many thousands of visitors per year. Many are located in areas with other little known caves and are frequently termed "sacrificial" caves. These sacrificial caves are often ones on which public attention has been focused in order to draw attention away from other nearby, less-visited caves which contain delicate formations or safety hazards. Many visitors are satisfied with a single cave experience and do not wish to visit a second cave. Management of visitors is more easily handled at one cave than at several scattered ones. By concentrating the public at one cave it is also much easier to provide good interpretive programs at less administrative cost.

CONTEMPORARY MANAGEMENT PRACTICES

On the surface, it would appear that most lava caves are left to manage themselves. Regardless of appearances, this idea may not be entirely true since "nearly all cave owners, public or private, exercise some degree of control over their caves" (Larson 1976). It seems most useful at this point to give some examples of lava caves with comments about their management. The following categories are somewhat arbitrary but are a means of systematizing the gradients of control applied to caves.

Unattended Wild Caves

1. PASSIVE CONTROL.

Many lava caves are left unattended and their existence is virtually ignored by their managers, at least as far as the general public is concerned. The cave location is not publicized, nor are roads constructed to encourage entry. On the other hand, nothing is generally done to discourage public entry, unless it is feared that visitors will be harmed, that too much trash will accumulate, or that humans will injure other resources such as timber or cattle. Matz Caves and Lava Top Butte Ice Cave of the Deschutes National Forest are good examples of this type of control. It could be argued that these caves are being actively managed by the Forest Service because attention is focused on other nearby caves.

2. CONTROL BY NEGATIVE ACTIONS

These lava caves are unattended but entry is discouraged by either physical or psychological means. Gates are the prime physical means of preventing entry and have been used at Little Red River and Dynamited Caves in Washington. Psychological control involves convincing would-be visitors that the cave or area is undesirable. For example, The Saddle Butte Lavatube System on Bureau of Land Management land was either unknown to BLM or disregarded, which seems more likely, until 1967 when news articles described a forty-mile long cave in the Oregon desert (Larson 1977). An immediate survey was launched by the BLM and the Oregon Department of Geology and Mineral Industries to ascertain the truth of these reports. The longest cave was found to be only 100^y m, and the area and caves were described as hazardous due to potential rockfall, rattlesnakes, no landmarks, and no water (Ciesiel and Wagner 1969). While these reports were a bit overly dramatic there is some truth in them. This type of management has been relatively effective in keeping most people out of these caves, except for a few locals, fur trappers (coyote and bobcat), and speleologists (benedict et

al. 1977b; Larson 1975b). Speleologists have now surveyed over 3963 m of passage in 17 named caves of the system. The caves are for the most part well protected.

3. CONTROL BY POSITIVE MEANS.

Entry to these caves is actively encouraged. South of Bend, Oregon there are a large number of lavatubes administered by the U.S. Forest Service. Here roads have been built and signs posted directing the public to the entrances of Skeleton, Wind, Boyd, Arnold Ice and South Ice Caves. Stairways have been constructed where necessary for public access, and trash cans provided. The location of these caves is clearly indicated on the Deschutes National Forest map and a leaflet about the caves is handed out upon request at the Forest Service office. A new booklet (Purcell 1977) is being sold which describes these caves and cautions visitors about safety hazards and conservation needs. At the caves themselves there is no monitoring of use by attendants. The result is ever-increasing vandalism with increased public use.

Cave fill, generally volcanic sand and pumice, is frequently carried into a cave by water through cracks and the entrance. Mud flows can also sweep into entrances. These fills may be eroded by dripping water into miniature badlands resembling small castles and turrets. The sand formations are among the most delicate seen in lava caves and are very susceptible to damage when touched. Lava River Cave, Oregon, and Ape Cave, Washington, once contained excellent examples of sand castles which are now destroyed due to being walked upon.



Nieland Photo.

Ice, a secondary formation, precipitates in caves that reach freezing. Icicles, sheets covering walls and delicate frost crystals form in lava caves, while large frozen ponds cover the floor. The ice can be retained all year if the cave happens to be a cold-air trap.

Biological Resources

The biological resources of lava caves are, without doubt, the most poorly studied and least understood of those discussed. Prior to the 1970s lava caves were considered nearly barren of unique species, especially of cave-adapted organisms. Several troglobitic invertebrate species had been described from lava tubes before this decade but were virtually unknown until Peck's (1973) review of the fauna of western lava caves. Although no troglobitic amphibians, fish, or crayfish are reported, it is now apparent that there are a number of small invertebrates inhabiting these caves (Benedict 1973; Crawford 1974; Senger 1977a). Cave adapted species include millipedes, several pseudoscorpions (Benedict 1977b), flatworms, amphipods, isopods, harvestment and an ice beetle. A number of other invertebrates are frequent cave visitors. Lava caves also serve as important refuge for nontroglobitic mammals such as porcupines, woodrats, mice, bats and even bobcats (Benedict *et al.* 1976; Nieland 1977). Birds, such as great horned owls, ravens, and swallows, use the daylight and twilight zones for nesting and roosting. Not many large bat colonies have been found in lava caves, but bats do use them and should be considered in management decisions. Poachers Cave, in southern Washington, is an important hibernaculum for *Myotis* sp, and a maternity cave for *Plecotus Townsendii*. Bat Cave, also in Washington, has significant use by bats. The present management plan for the cave is aimed toward retaining a low-use pressure to protect the bats.

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Several lava caves, especially in arid regions, contain fern and moss gardens. Fern Dome in southeastern Oregon and Fern Cave in Lava Beds National Monument are two exquisite examples. Here, beneath skylight entrances, grow moisture-requiring ferns and mosses, while the surface soil supports sagebrush-grassland communities. Even in mesic regions, such as southwestern Washington, the daylight zone supports fragile communities of ferns and mosses. These significant and fragile gardens will not tolerate much foot traffic (e.g. Ole's Cave, Washington).

Although it is common knowledge that nearly all energy of a cave is derived in some form from the surface, the amount appears to be especially limited in lava caves. Organic materials blow in through the entrance, seep in through cracks, or flow in with water. In the Hawaiian lavatubes, Howarth (1973) has found that tree roots are a very significant source of energy. Roots may also be important in western lava caves according to our recent observations in Deadhorse Cave in southwestern Washington. Here a millipede was observed feeding on a slender 50-cm long root growing down from the ceiling. The overburden of a lava cave averages 6-8 m in thickness so roots of trees and shrubs can penetrate into a cave. Bat, woodrat and insect dung, as well as animal corpses also supply energy; even humans contribute their share. It is especially important that in cave clean-ups organic materials be left, otherwise, an important source of energy is lost to the energy-limited cave ecosystem.

It should be emphasized again that the biota of western lava caves is virtually unstudied and consequently unknown. Although lava caves apparently lack the showy troglobitic fish, crayfish and amphibians, they do provide habitats for

very unusual species of tiny cavernicolous invertebrates. Several of these may ultimately be classified as rare or endangered species. The amphipod *Stygrobromus hubbsi* in Malheur Cave, Oregon, has been proposed. All too often past management decisions were made without considering the effects upon the troglobitic invertebrates. What were the effects on the population of troglobitic millipedes (Shear 1977) during the experiment by North American Aviation to determine if heat could be detected through the basaltic overburden by infrared photography? During this experiment railroad ties were burned to heat steel rails approximately 100 m in from the entrance of Derrick Cave, Oregon (Larson 1977).

How do lava caves with cavernicoles differ from those without, and how can one tell if significant invertebrates are present in a cave? These questions are not yet answered but are the subject of several cave studies: Malheur Cave (Benedict *et al.* 1976a), Deadhorse Cave (Crawford *et al.* 1977), South Ice Cave in central Oregon (Kamp 1973) and Derrick Cave in central Oregon (Benedict 1977a). Eventually, this type of study may provide a rapid method for the inventory of biological resources. For example, the Owyhee River Cave in the Saddle Butte System exhibits a relative humidity, in the true dark zone, of less than 65% (Benedict 1974b, 1977c). Troglobites which require very high humidities would not be expected to inhabit this portion of the cave, although this particular cave is very important as a refuge for nontroglobitic vertebrates (Benedict *et al.* 1977).

Special training is required to assess resources, as one may incorrectly assume that a cave is barren of significant biota. Future "rare and endangered species" as yet undetected may be present. Biological resources, important to the cave ecosystem, not only occur in the cave but around the entrance and on the surface above the cave. If trees or other shrubby plants whose roots extend into the caves are removed from the surface, an important energy source may be destroyed and biota may starve. Management must be based on the premise that a unique endemic cavernicolous species may inhabit a cave, even though none have been seen during a cursory examination.

Cultural Resources

Some lava caves are significant archeological or historical sites. During the settlement of the West, lava caves were discovered and became known as places to explore, sources of ice, places to store food, and to be used for shelter.

Lava caves for thousands of years provided shelter for aboriginal man, particularly in arid lands. The caves of central and eastern Oregon are frequently found to be archeological sites. Here drifting snow collected in cave entrances and served as water sources in this nearly dry volcanic land. Camp sites of up to several acres developed around some of the caves. Smoke blackened ceilings, charcoal littered floors, pictographs and petroglyphs tell the story of early occupancy. Settlers found many artifacts: points, knives, awls, needles, obsidian and chert chips, and scrapers.

Lava tubes offer a chance to date archeological and paleontological deposits. Potassium-argon dating of a lava flow can be used to determine the maximum age of deposits. A series of deposits, in different caves and flows, can cover a span of recent history. The oldest intact lava tubes in the United States are approximately 30,000 years old.

Recent man has found many uses for lava caves. Basque shepherds in the Saddle Butte System fenced the sinks as corrals for their sheep (Larson 1977). Arnold Ice Cave, southeast of Bend, Oregon, was used as an ice source for the



Lava tubes frequently were used by aboriginal Americans such as at Fern Cave in Lavabeds National Monument in Northern California. *Nieland Photo.*

city whenever the Deschutes River failed to provide sufficient ice (Purcell 1977). Cheese Cave, Washington, for many years was used to age a local blue cheese. Nearby Meat Cave was used for meat storage and later for Christmas tree storage. Many lava tubes have served as root cellars. During the prohibition years, lava caves provided a convenient place to hide stills. Phil Brogan tells of a still in Skeleton Cave near Bend, Oregon. Malheur Cave (southeastern Oregon), with its large lake, became the gathering place for many a picnic and boating trip (lumber for boats was donated by local lumber mills). Since 1938 Malheur Cave has been the place for the annual meeting of the Masonic Order, complete with wooden bleachers and podium. During the 1960s, Derrick Cave, southeast of Bend, Oregon, was equipped with food and water as a Civil Defense Shelter and later it was the scene of experimentation for North American Aviation as part of the space program. One very common and objectionable use of lava caves is as a refuse disposal site, e.g., Garbage Cave, the Horse System near Bend, Oregon and Coyote Trap Cave in the Saddle Butte System in southeastern Oregon. These uses arose long before anyone considered lava caves' geologic and biologic resources.

There is much public sentiment towards saving our cultural and archeological sites. Specific laws protect cultural remains on public lands and thus governmental agencies are directed by law to inventory these resources and to protect them.

Use Pressure on Lava Caves

Use pressure on a cave or group of caves may partially determine the type of management which is necessary. Use pressure can be divided into three categories based on the number of visitors per year. The figures below are fairly representative of use pressure on western lava caves.

| Visitors per Month | |
|--------------------|---------------|
| Low | 0 - 30 |
| Medium | 31 - 500 |
| High | 500 and above |

Caves with low-use pressure do not require special management practices unless some special feature or hazard is present. The cave's location is best left unknown to the general public and as little attention drawn to it as possible.

Supervised Wild Caves

1. Partially Supervised.

Ape Cave, Washington, is a Forest Service cave which is left mostly unattended except on summer weekends when caver volunteers of the Oregon Grotto of the NSS greet visitors, answer questions, and provide a conservation brochure. This program, in its fourth year (1974 through 1977), has greatly reduced vandalism and trash in this highly used cave.

2. Supervised.

Lavacicle Cave, also on Deschutes National Forest land, was discovered in 1959 after a forest fire. The cave contained a magnificent display of lava stalactites and stalagmites and was described in a Portland, Oregon news article as "A hidden fairyland" (Penny 1959, p. 33). This fragile and delicate cave was soon gated and entry to the general public is with a Forest Service-designated guide only. As a result, damage to the cave has been minimized. Lavacicle Cave is well preserved and is an example of how swift, effective management can preserve the delicate features of a lava cave.

Caves Under Full Time Management

The greatest protection of lava caves is in National Monuments and at commercial caves where access is strictly regulated. Lavabeds National Monument in northern California and Craters of the Moon National Monument in central Idaho contain a number of caves which are open to the public.

Lava River Cave State Park, south of Bend, Oregon, is the most visited lava tube (200,000 people per year approximately) in the state. It has been open to the public since 1926. The state park system has constructed stairways and trails through the cave and a park at the entrance. An attendant is on duty during the summer months to watch the cave, advise visitors and to rent gasoline lanterns. No admission is charged. The cave is closed during the winter. Although visitors have trampled the sand garden (sand castle formations) at the terminal end of the cave, overall, Lava River Cave is in fairly good condition. One sees little trash or other evidence of damage.

Craters of the Moon National Monument, Idaho uses a permit system to control access into delicate caves. In the last year 55 people used this system—35 were NSS members. The forms require party size (most often ranging from 2 to 4 persons), experience, name and address of party leader. They also stipulate two sources of light and hard hats for all members of the party.

Ten thousand people visited Crystal Ice Cave in 1976. The family operated commercial cave is owned presently by Gayle, Dalles and Arthur Linscheld. The original commercial development was designed and executed by Jim Papadakas. The care to preserve the cave and its resources is exemplified by a parallel tunnelling system, with thermal windows looking into the cave. Even the lighting is designed to minimize impact upon the cave.

CONCLUSIONS

Many options are available in managing lava caves, a few of which have been discussed here. Lava caves are not just sterile dark tubes of basalt. They contain treasures that are just beginning to be discovered. Future study should be an increasing awareness of the significance of these caves and their unique values. Even though vulcanospeleology is

just beginning to come into its own, lava caves must be protected now so that future generations may enjoy their unique biota and their delicate formations. We recommend that decisions concerning lava tube management be made.

The public should be educated to appreciate and not destroy the unique features and values of lava caves.

Nonrenewable geological features should be protected.

Presently known and as yet undiscovered cavernicolous species should be protected.

Archeological and historical sites should be preserved.

The public should be prevented from harming itself in the caves.

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Wilderness Caving: What It Has Meant on Silvertip Mountain

William Steele*

ABSTRACT

Deep within the 3845-square kilometer Bob Marshall Wilderness of Montana, lies Silvertip Mountain. This remote peak contains the cave bearing Jefferson formation of Devonian aged limestone. Snowmelt runoff has caused this limestone unit to develop cave passages that total over 5 kilometers in surveyed length. The passages within Silvertip Mountain have been explored annually since an initial speleological investigation in 1972. Since caving on Silvertip began, nearly 2500 underground man-hours have been logged.

Silvertip Mountain is well within the boundaries of the Bob Marshall Wilderness, therefore giving the caverns it contains the same protection as the surface. This protection is in the form of maintenance of the pure and uncorrupted, nonmechanized quality of the land under the custodial care and administration of the United States Forest Service. Access to this remote mountain is by foot or horse over a rugged 27-kilometer trail after driving over 107 kilometers of gravel road.

It is probable that more caving areas exist within the Bob Marshall Wilderness. These will usually be remote, giving those persons intent on visiting the caves the esthetic experience of the unspoiled wilderness along with their subterranean endeavors.

The concept of wilderness areas and our need for them, is a relatively new one. It took the encroachment of civilization upon the last vestiges of wild land, for some to stand saying, "Hey, wait, why not keep some land as it was?" This happened. We have them. The establishment of wilderness areas is fairly recent history. Montana has been blessed with more protected wilderness than any of the other contiguous states.

In northwestern Montana, the Bob Marshall Wilderness Area is comprised of 3845 square kilometers (950,000 acres) of land. The Bob Marshall is the largest wilderness area yet established in the United States. For trivia's sake, this area is one and a half times the size of the European nation of Luxembourg. It does not stand alone, though, with civilization up to its boundaries. Instead, it lies nestled within a large unsettled area provided by the Flathead National Forest to the west and north, the Lewis and Clark National Forest to the east, the Scapegoat Wilderness to the southeast, the Lolo National Forest to the south and the Mission Range Primitive Area to the west.

Situated nearly in the middle of the Bob Marshall is a prominent peak, Silvertip Mountain. Silvertip stands tall at 2710 meters in elevation. It has snow fields so permanent that topographic maps indicate glaciers. The mountain is predominantly limestone, the stone sought by that oddest of sorts, the speleologist, the caver, the spelunker, who, on seeing it from a distance afar, could think of the potential for cave passages to explore and understand.

Journeys to seek out cave entrances in the immediate area around Silvertip began in 1968. At this time, the Silvertip Creek valley was visited by two individuals on a western vacation who had heard the stories of large pits seen from commercial airliners. They found some entrances, ran a survey into easily accessible Limestone Cave, which appeared on topographic maps, and published an account of their adventure in the national caving magazine, the *NSS News* (Bridge 1968). This sparked some interest, lots of rumor, but not much caving.

Three years later, Newell Campbell, a geology professor from the state of Washington, suggested to some caving friends that they walk to Silvertip Mountain to look for entrances. They trod upon the barren karst, staying high in the north cirque. They found only a small cave, christened Silvertip Col Cave, and left believing that extensive cave development did not occur there. A typical story with most mountaintop caves in the limestone of the Rockies. The following summer, a geology student who had heard of the caves of Silvertip, came up with friends hoping to find a project for a Master of Science thesis (Ayres 1975). In the 5 days they were there, they entered several cave entrances. These appeared to lead to an extensive system.

Since the initial investigative years of 1972 and 1973, over 2500 underground man-hours have been logged within Silvertip Mountain. Not all this has been waltzing down subway tunnels, to say the least. Overall, the reputation of the Silvertip caves is one of extreme ruggedness. Air temperatures in the caves are 35°F. There is rarely still air so all sorts of chill factors are calculable throughout the system. The water in the caves, converted from snow just hours before, could be walked upon if only a degree or two colder.

*National Speleological Society, P.O. Box 7672, UT Station, Austin, Texas.

By and large, the caves are predominantly vertical in nature. The development of the passages has followed a down-dipping bed of soluble limestone, some 100 meters thick. This limestone stands almost vertical near the peak, lessening in steepness as it descends in the syncline to the horizontally bedded trough below. The base of the cave system is a large trunk stream draining many branches of a dendritic pattern. This can be reached only by application of rope descent and ascent techniques, and of course, knowing the way there.

The style of caving on Silvertip has developed on an "as needed" basis. One year we ran into deep water, necessitating a return the following year with ¼-inch-thick wetsuits. We have run out of rope, having all that we had with us rigged throughout the system. We have learned much; we have also been taught many techniques that can be applied to exploration of any alpine cave system. We have surveyed over 5 kilometers of cave passages within Silvertip Mountain. The main Silvertip system stands in the top five deepest caves of the country. If we can find a subterranean way from passages known high on the mountain to those low on the mountain, it would constitute the nation's deepest cave.

What is the worth of these known cave passages? Cave biologist Andrew Grubbs investigated a number of passages this past summer for cave fauna. Except for picas, packrats and dipluria near the entrances, he pronounces the caves sterile, void of cave adapted life. They *are* quite cold. There has been no archeological evidence noted by the professional archeologists who have been part of the exploration. The passages assume the character of recreational resources which may provide unique human experiences. Once explored and surveyed in the most accurate way possible, we can go home to ponder the geological mysteries these caves offer.

Upon Silvertip Mountain there are no labeled entrances. Were you to walk upon the surface and gaze into openings, you would have no way of determining one cave from another. I quote Mike McEachern in *Alpine Karst* saying, "The ultimate goal of the surface survey is to provide a base map indicating all karst features and locating cave entrances. The surface maps provide a means of systematically exploring the karst without resorting to unsightly cairns or labels identifying cave entrances which might spoil the undisturbed natural beauty of the area and might attract uninformed visitors to the area." (McEachern 1977). We do this for two reasons. First, it is a wilderness area. It should, by definition, be void of the touch of man. Secondly, we wish to maintain the puzzle as we found it. There are numerous entrances upon the north cirque of Silvertip. A majority of them we have not even entered. One of my favorite sayings upon showing a newcomer around and being asked where such and such a cave entrance leads, is simply, "Oh, I don't know, it hasn't been looked at." This normally brings looks of astonishment. Eventually, given the accumulation of all data both subterranean and surface, we can piece together the story of how these caves have developed since the deposition of the rock, over 350 million years ago.

Silvertip caving has been a pursuit by choice. It is being done by a group of friends who enjoy exploring caves and learning about them. We invite knowledgeable acquaintances in areas such as karst geology, cave biology, hydrology, etc., to join us so we can add more information to our mounting pile.

The cave system is within the boundaries of a defined wilderness area. This affords it the same protection as that given to the surface. It is to be maintained in a preserved

state. The uncorrupted, nonmechanized character of the land is kept so by law: the Wilderness Act of 1964. The caves within this area are open for all citizens to visit if they can get themselves there, just as are the mountain peaks, deep canyons, marshy lowlands and rapid rivers. Those entering these areas must take care of themselves. As author Ed Abbey says in *Desert Solitaire*, "A venturesome minority will always be eager to set off on their own, and no obstacles should be placed in their path; let them take risks, for God's sake, let them get lost, sunburnt, stranded, drowned, eaten by bears, buried alive under avalanches—that is the right and privilege of any free American."

The lands within the Bob Marshall are administered by the United States Forest Service. Their primary interest revolves around the custodial duties of fire control, trail upkeep, and the administration of packers and guides. The Forest Service has been fully aware of our activities on Silvertip from the beginning. Our rapport with the Service, through the Spotted Bear District, has been quite open and pleasing. This practice should and will continue.

So, is there a condition on Silvertip needing additional management action? No, I would say, not presently. This same opinion applies to all of the Bob Marshall and for the Scapegoat Wilderness as well. Instead of action, I would say our approach now should be one of conscious regard. There is management going on at Silvertip. It is in its evolution and should provide a model for other remote areas.

Those of us who have been on the mountain understand and believe in what wilderness is all about. When we leave the mountain, before the first snows of September, only footprints remain on the surface and underground. We don't foresee any great surge of interest in the caves there. They *are* remote. Given a journey already to northwestern Montana, one must travel 107 kilometers of gravel road, then walk uphill for 27 kilometers. The caves can only be entered in July and August. The other 10 months provide snow-plugged entrances and extreme temperatures. These latter points provide a key to understanding the essence of Montana wilderness caving, and why there is little or no need for management concern at this time. There has been no problem. I recognize that other wilderness areas could or do have other factors. They surely stand more accessible. Only in Alaska could there be a more remote spot within the country. Each case should be looked at individually.

One thing worries me: advertisement. The Forest Service brochure on the Bob Marshall includes caving as one of the activities possible to do there. I fret that this attracts people to come on and try it. I recognize, though, that the Forest Service, since the time and thinking of Gifford Pinchot, has been dedicated to the multi-uses of their lands. I realize that this is their foundation. This principle will continue; that there are caves to be seen will be published. Well, given that, let us hope that all remains vague and ambitious cavers will go out, explore the area, and find the entrances as we did, not with locations on a map.

The theme of this year's symposium is "how to"; "how to" manage areas needing management. I stand before this assembly saying there is no need to do anything more than has been done in the Montana wilderness areas. The caves protect themselves with their remoteness, their unavailability, the shortness of the accessible season, and the amount of specialized equipment needed to enter them. These factors will not change. For all predictable future they will be remote, uncomfortable, snow bound, and technical to enter.

The handful of Americans engaged in this endeavor, to a person, have appreciated wilderness for the esthetic

experience provided by the unspoiled character of the land. They are quite pleased that the American Government, representing the public, saw fit to set these large tracts of land aside, to remain secure for future generations. There are caves there. There, no doubt, are many more mountains such as Silvertip, just as remote, just as formidable. Let us be content, with eyes open to change, that no problem will arise and cavers will be responsible to continue the precedent set in the last six years on Silvertip.

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Silvertip Mountain, Montana. Photo by Jim Chester.

Cave Resources of Grand Teton National Park

Charles Plantz*

The Teton Mountains in western Wyoming are notable for the recentness of their uplift and for the narrowness of the range compared to similarly lofty mountain ranges. The spectacular, craggy, central peaks of the range, which are the reason for the existence of the National Park, are composed of insoluble Precambrian rock. Thus, no caves are known there. At the north and south ends of the range, a lesser degree of uplift has permitted the overlying sediments to survive erosion. It is here that caves are found in the Madison and Death Canyon limestones and the Bighorn dolomite.

The southern limestone area lies mostly outside the Park boundary in the Targhee National Forest. Much visited Fossil Mountain Ice Cave and Wind Cave have long been known. More recent work has uncovered many others including Rendezvous Peak Cave, the deepest in Wyoming. Also south of the Park, stream traces have been carried out showing that some streams sinking in high elevation shelf caves pass under major ridges before resurging more than 1000 feet lower in elevation.

The majority of the northern limestone area is included within Park boundaries.

Caves occur in three areas in Grand Teton National Park:

1. The Death Canyon-Spearhead Karst Area.
2. The Wall Area.
3. The Moose Basin Divide Area.

All three areas are accessible to backpackers and horseback riders.

Caves of Wyoming lists 12 caves and pits in Area 1, near the southern boundary of the park, and 6 or 7 caves in Area 3 in the north. All are small and do not appear to need any management.

Only one cave in Area 2, Hole-In-The-Wall Cave or Wall Cave #2, is receiving significant traffic. It appears to be an immediate candidate for management. The cave is clearly visible from the nearby Park Service-designated campsite and is only a few feet above an abandoned but easily followed trail—The Old Skyline Trail. The cave is just south of the main climbing area of the Park. An informal register found inside shows a nationwide constituency suggesting climbers and backpackers.

There is about 500 feet of main passage in the cave plus 1 long and 3 short side passages. The main passage starts out about 2 ft. high and increases to about 15 to 20 ft. in height before gradually lowering until the end. The side passages are low. Parties losing all light in the cave are very likely to be able to feel their way out. There is nowhere to fall in the

cave and only one unattractive muddy lower side passage seems to be subject to flooding, possibly during the spring thaw. Thus, the cave is minimally hazardous. The primary reason for wanting it managed is to protect its formations.

Depositional speleothems are considerably less common in alpine and arctic caves than in the more familiar warmer ones. Mineral speleothems are rare in Teton caves and Hole-In-The-Wall Cave has a greater number and more interesting formations than all other Teton caves combined. There are 4 kinds of speleothems in the cave, each confined to a distinct area.

The first 100 ft. of the main passage and all of the long side passages are very well decorated with brilliant white globulites which give a blue phosphorescent afterglow upon excitation by flash bulb.

The globulite area of the cave is followed by a 20 ft. section of cave containing small but pretty helictites.

Most of the totally dark portion of the main passage has normal dripstone formations such as stalactites, stalagmites, and flowstone. This section comprises the majority of the cave.

A small room at the end of the main passage and about 20 ft. of crawlway before it, is totally covered with ice speleothems including hexagonal single crystals 3 to 4 inches across. Lowland cavers may find the ice formations the most attractive formations in the cave.

This paper was prompted as the result of formation breakage. Some of the breakage appears to be intentional. Typically, the largest stalactite in a group will be missing; broken off at the base as if collected. Larger stalagmites are similarly missing. Unintentional damage consists of flowstone apparently broken by rockfall as well as white globulite crusts that have been scraped off by people struggling through narrow parts of the long side passage.

It is not known whether damage to the cave is of recent origin. Most of all of the damage may have occurred during the thirties when the old Skyline Trail was actively used by horse parties and before souvenir collecting was frowned upon.

Plans for the cave include the installation of a sign with a conservation message. Hopefully, the sign will include something about visitors limiting their stay in the ice crystal room, since even with electric lights, the ice begins dripping in only a few minutes. After installation of the sign, Park Service personnel will monitor the cave for further attrition of the formations while considering future options.

*2242 E. Water St., Tucson, Arizona 85719.

Photography As A Cave Management Tool

Charles V. Larson*

Today no knowledgeable person disputes that caves are nonrenewable natural resources, or that cave users leave their marks on caves. Cave owners and their agents, cave managers, are vitally concerned with wear and tear on their caves. Knowing that use of a cave is desirable or inevitable, and that an irreplaceable fraction of its value will be consumed by such use, it would seem simply a matter of establishing a depreciation schedule and adjusting visitation to it, or:

$$\frac{\text{Depreciable Value}}{\text{Accounting Period}} = \text{Carrying Capacity} / \text{Accounting Period}$$

Don't you wish it were that simple!

Let us return, seriously to the above equation. First it should be acknowledged that this simple formula ignores several important factors like recoverable value (restoration), maintenance, net-beneficial alterations, etc. It is useful, however, in explaining the need for documentation of cave resources. Determination of Accounting Period is fairly straightforward; it is simply a discretionary period of time between inventories. Depreciable Value is something else!

Most cave management examples have, as a common denominator, the establishment or recognition of an acceptable level of degradation, consistent with the long range management plan. This implies that cave managers will eventually have to somehow quantify Depreciable Value. As an example, it could be the difference between the cave's value at the "beginning" (at the time of discovery or adoption of a management plan) and the value remaining when depreciation is no longer significant, regardless of the level of use. It seems inevitable that initial value be estimated and means of measuring subsequent change be devised.

As part of establishing beginning value, the cave's physical characteristics should be documented, for few managers other than owner/managers will remain at one cave for a significant fraction of its depreciable value life, to recall former conditions or to judge if the depreciation is on schedule. Especially for managers of publicly owned caves, this baseline documentation can't be completed too soon.

A large part, perhaps most, of the value of caves lies in their visual appreciation and evaluation by users. For that reason, it is convenient to divide their physical characteristics into two classes: visible and invisible (to the unaided eye); e.g., air and water quality, welfare of microorganisms, etc. What follows relates to the former. The latter is another subject.

Changes in the visible features brought about by human use fall generally into two groups; their severity in inverse proportion to the degree of care the caves receive. Changes in caves receiving little close management are apt to be abrupt, obvious, sometimes dramatic, and are usually demonstrable by the most casual documentation. On the other hand, changes resulting from use of well managed caves are likely to be subtle, slow and cumulative. Discoloration from human contact, growth of algae around lights, occasional pilferage or breakage of inconspicuous

Figure 1: The Washington Monument in Oregon Cave, central feature of Oregon Caves National Monument, as it appeared in 1974. Photo by Charlie and Jo Larson.



Figure 2: Washington Monument as it appeared in 1977. Note the accumulation of clay worms, a subtle change which would easily escape recollection. Photo by Charlie and Jo Larson.

speleothems, creeping vandalism in the form of names and initials inscribed in spite of the closest stewardship, are insidious visible changes which, as a practical matter, defy day-to-day detection and transcend an individual's recollection (Figures 1 and 2). Periodic photographic surveillance of selected cave features, in conjunction with writing and graphics, may be the only way of measuring the subtle, cumulative changes brought about by traffic in well managed caves.

All three of the commonly used methods of describing caves (writing, graphics and photography) have individual shortcomings. Writing is so subject to the writer's motivation and criteria that fact is sometimes lost and a

* President, National Speleological Society, 13402 NE Clark Road, Vancouver, Washington 98665.

comprehensive record becomes a matter of interpretation. "Joaquin" Miller, renowned Poet of the West, wrote of Oregon Cave, after having visited it in 1909, "The wondrous marble halls of Oregon lie close against the northern line of California (seven miles away), and it is not unreasonable to believe it will be found finally that they pierce entirely through the marble summits of the Siskyou mountains and have an opening on the California side." After 100 years of exploration and mapping, the cave is known to occupy a rectangular space about 1000 ft. long, 550 ft. wide and 400 ft. high.

Graphic representation of caves (maps), even those few which are accurate, are far too gross and abstract to be useful in describing local features. However, even though nearly all contemporary cave maps are crude by engineering standards, they are indispensable as a framework on which to hang written and photographic documentation.

Individual photos are limited to local features only and photography is vulnerable to careless application. Other than those handicaps, it has virtually unlimited potential as a means of describing visible, and some invisible, physical conditions. Orthodox photography could be a cave manager's most valuable tool. Properly applied it is a vivid, supremely accurate, permanent and virtually indisputable record. Its use certainly isn't limited to monitoring damage either. Other applications are training guides and future managers, selling owners on improvements, and direct income from the sale of slides to visitors. Why then, one might ask, hasn't it surpassed writing and graphics as a means of describing caves?

There are several reasons, and it would be useful to describe them for they must be overcome if a photographic program is to succeed. First, writing and mapping have been around for millennia and cave photography only two or three decades. Next, true documentary photography, akin to forensic photography, is the least abstract of the three and therefore likely to be judged the most critically. Writing is accepted as subject to the writer's motivation and criteria and in turn subjected to the reader's interpretation. Maps are totally abstract with the result that they are accepted on their merits as *maps*, and judged without reference to the original. But, shown a photo of a cave feature, the average observer (familiar with caves) tends to make a more direct comparison between subject and representation and is considerably more aware of discrepancies, especially in color. Then too, the practice of photography lacks discipline, leading to unpredictable, sometimes disastrous results. These variable results, together with an aura of amateurism created in no small measure by Eastman Kodak's "load, aim and shoot" evangelism, have tended to discredit photography as a serious, useful documentary tool. Note, however, that the foregoing circumstances are the result of attitudes, not built-in limitations.

But photos can't stand alone. For example, the 1976 progress report of the Oregon Grotto's complete survey and interpretation project of Scorpion Cave, a small but well decorated cave in northern California, relied heavily on photos which were referenced to points on a map and augmented with written observations and descriptions (Figures 3 and 4). Writing and graphics are required to complete the description of a cave and to provide identity and location for individual photos.

WHAT IS DOCUMENTARY CAVE PHOTOGRAPHY?

"To document" is most descriptive of the purpose of recording the appearance of caves on film. It is very

unfortunate that contemporary documentary photography has subverted the meaning of "documentary." Two preferred synonyms for "documentary" are "factual" and "objective." Open a popular book relating to documentary photography, however, and the scenes found will be factual, as only a camera can see facts, but not even remotely objective. There will be found photos of dust bowl refugees, headless corpses on battlefields, grotesquely emaciated children—scenes oozing with emotion. That is what documentary cave photography is not.

A perfectly objective cave photo is sometimes impossible to achieve; for example, there's no way to keep emotion out of a scene of broken or disfigured speleothems. But objectivity should be the goal.

DOCUMENTARY CAVE PHOTOGRAPHY: WHEN, WHERE AND HOW

When

Ideally, a cave's vulnerable features of consequence should be documented at the time of its discovery or when a management plan is adopted: the visible features photographed and recorded, the invisible determined, measured and recorded. Mapping can come later, for seldom does man's impact on caves change their configuration. Then periodic inventories should be made as often as necessary to monitor change and traffic, and especially at the end of meteorological cycles or when ownership or management is transferred.

Where

Ideally, every one of the cave's vulnerable features would be photographed, plus points which would reflect traffic and meteorologic or hydrologic change. Significant flora and fauna shouldn't be overlooked. That ideal has never been attained, of record, but was approached at Scorpion Cave, described previously, because the cave was small. Vulnerable features are those which experience indicates are likely to be disfigured or stolen, like attractive speleothems, or the walls at the end/s of the cave. Points which will reflect accountable wear and tear in proportion to traffic are predictable; for example, the entrance and end/s, wall-to-wall flowstone or rimstone and passage constrictions (Figures 5 and 6). Sites chosen for monitoring meteorologic or hydrologic changes should be remote, away from obvious pathways unless the effects of human presence are a factor. Flora in other than lighted commercial caves will be mostly around the entrance, but some of the things that grow around lights would bear watching. The principal value of some caves is their flora, for example Fern Dome in southeastern Oregon, which harbors an extensive fern population.

Clearly cave managers will have to settle for something less than 100 percent coverage. Initially, to establish baseline conditions, as much of a cave should be photographed as resources, budget and volunteer labor will permit. Following the initial documentation, it would be wise to carefully select only a few monitoring points; a number for which subsequent surveillance can be assured regardless of budget cuts, loss of volunteer help or whatever. Finally, subsequent photos of the selected sites should, if possible, be made from exactly the same points as the baseline photos, using the same focal length lens.

How

Before selecting a film for documentary cave photography, some consideration should be given to reproduction. That is, what will be the form of the finished photographic

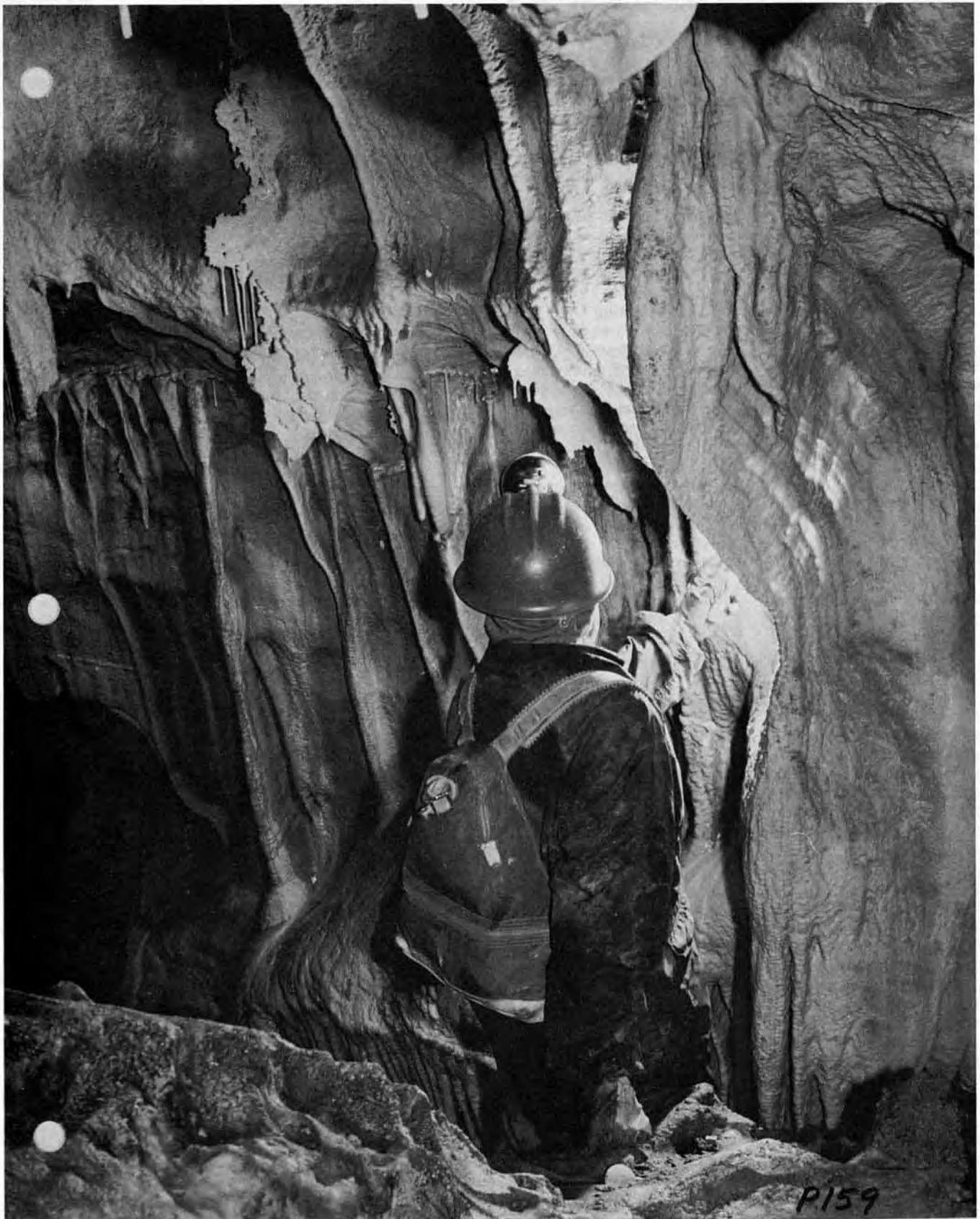


Figure 3. A black and white print mounted on a card for insertion in a ring binder, showing a selected part of Scorpion Cave, on Forest Service lands in northern California, recorded shortly after the cave's discovery. *Photo by Charlie and Jo Larson.*

SCORPION CAVE PHOTO IDENTIFICATION SHEET

This page identifies the photo on the facing page.

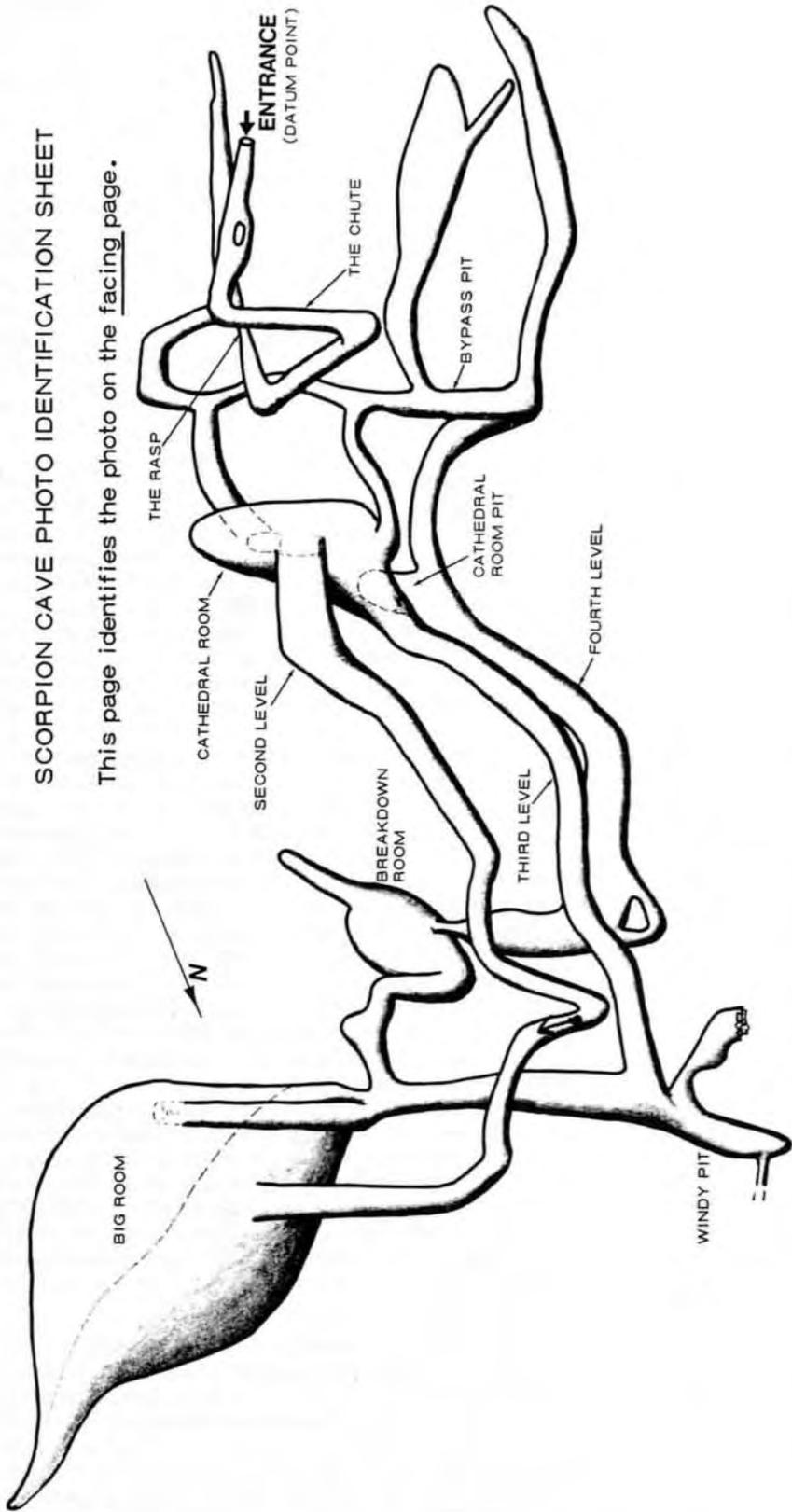


Photo identification no. P159 Date of exposure: 5-31-69

Predominant passage type (in zone of photo): Vadose

Mineralization: 80% Secondary - Draperies - Petromorphs: Quartz Boxwork - Flowstone

Meteorological data: Slight Breeze

Biota: NRO

Other observations: _____

Oregon Grotto of the
National Speleological Society

Figure 4. A companion document for Figure 3, arranged as the facing sheet in a ring binder. Photo by Charlie and Jo Larson.



Figure 5: Upper entrance to Deadhorse Cave, in southwest Washington, as it looked shortly after discovery in October, 1969. *Photo by Charlie and Jo Larson*



Figure 6: Entrance to Deadhorse Cave only three years later shows wear and tear of traffic into cave. *Photo by Charlie and Jo Larson.*

*Normally by projection.

product? Within practical limits, the choices are: color transparencies (slides), color reflection copy (color prints), monochromatic reflection copy (black and white prints) and, to a lesser extent, mechanical reproduction (halftones). The versatility of various films would also affect the choice of medium. For example, use of black and white film would obviously restrict choice, while color negative film could fulfill any or all of the above choices.

Slides: Transilluminated* color transparencies are, by several orders of magnitude, the most brilliant and realistic of all photos. The reason is simple: The best reflection copy; that is, prints or mechanicals (halftones); have a brilliancy range of about 1:50. Transilluminated transparencies, however, commonly have a brilliancy range of 1:1200. Color transparency (slide) films are available in a wide variety and are relatively inexpensive; occasionally being less expensive than black and white prints, all expenses considered. That slides are preferred for cave photos in general is easy to understand, however there are several reasons why slides are not ideal for documentary cave photography.

First, exposure of slide films is critical. A half f-stop variation, either over or under will result in a slide that is unsatisfactory for critical comparison purposes. This is not insurmountable, because several bracketing exposures could be made—film is cheap. However, if color comparison is important, slides are chancy at best, because exposure is only one of several factors influencing color balance. The initial exposure of slides consistent with a standard color reference; for example, a gray card; is very uncertain, and slide duplication entailing corrective color change is very expensive.

Next, direct comparison of small transparencies (slides) is not practical without multiple projection facilities. The human eye is marvelously adaptive and critical color comparisons can only be made side by side. Color prints for comparison can be made from slides of course, but other factors being equal, are far inferior to prints made from original color negatives. Generally speaking, except for inexpensive, commercial quality duplicates, slides do not reproduce well. They are the least desirable of all for monochromatic, mechanical reproduction (halftones) or black and white prints; the latter requiring an internegative. (Many lithographers prefer slides for full color mechanical reproduction but its astronomical cost places it outside consideration for documentary cave photos.)

Reliable processing of slides is widely available (as is unreliable processing—take care!). Color negatives, prints and slides are subject to fading with age and exposure to light but if stored and handled according to directions, all are permanent enough for foreseeable purposes. Slides are likely to suffer most from dye impermanence since they are occasionally subjected to high-intensity light when projected, so it is wise not to dwell overly long on irreplaceable originals when projecting them.

Black & White Prints: Color photos are the most realistic and, if present trends continue, soon will be generally less expensive than black and white. However, color should not be adopted for documentary cave photography before black and white is considered.

Despite improvements in color processing and permanence, the archival permanence of black and white prints hasn't been approached. Black and white prints are easily made from black and white or color negatives—not so easily from slides—using rudimentary darkroom facilities. A panchromatic print paper, difficult to work with because of its low tolerance for safelights, is normally indicated for

black and white prints from color negatives in order to properly convey human skin tones. The panchromatic paper is not required for cave photographs. As a matter of fact, the response of ordinary, orthochromatic print paper to color negatives of cave scenes is very favorable.

Black and white prints are uniformly abstract and, to a degree, tend to be judged on their merits as *pictures*, sometimes without reference to or regard for the color of the original scene. So, if it is not color change that is being monitored—often the case in lava tubes, for example—black and white photos are a good way to go. Response to color is highly objective and, if it is not a factor, its absence will make objective comparison easier.

Black and white prints are the companion of black and white films, which have the greatest exposure latitude and archival permanence of all films and are the least sensitive to adverse conditions. Finally, black and white prints from black and white negatives are the least expensive method of photographically documenting cave conditions.

Color Prints: Color prints, though they lack the brilliance of projected slides, are more realistic than black and white prints. Until recently they were inferior to black and white in two important respects: sharpness and cost. However, improved color negative films which compare with the sharpness of their black and white counterparts have been introduced, and the general popularity of color photography has forced its cost down. The result is that, in many locales, prints of a quality and consistency that permit critical analysis of physical conditions independent of color are less expensive in color than black and white. Color prints from color negatives are the optimum reference for detecting color changes of cave features for two important reasons: side by side comparison of two or more prints is easy and adjustment to a standard color reference is easily accomplished at the time the prints are made. Color comparison prints require extraordinary but not difficult techniques and, depending on locale, may entail modestly higher cost.

Color prints can be made from either negatives or slides (positives), but those made from slides are generally inferior, even if printed via internegatives. Because of the imperfection of dyes used in color photos, the color response of slides is intentionally skewed to look "right" when viewed as a positive, with the result that they do not make good prints. In the case of color negatives, color response is modified to secure better prints—there being no regard for the visual appearance of the negative. Halftones can be made from color prints but are generally inferior to those made from black and white prints. Color prints, like other color photos, will fade with age and exposure to light, but proper care of prints made from color negatives is not vital, as additional prints can be made at any time, assuming the negatives were properly cared for.

Film

Color Positive: Slides are, at the same time, the film and the finished product. Therein, perhaps, lies the greatest drawback: the value of a slide is *fixed at the time of exposure*. For some purposes this could be an advantage since it eliminates further reproductive steps, but the net effect of this limitation causes slides to be less than ideal for documentary cave photos. Generally speaking, slide films are about one half f-stop slower than color negative; one stop slower than black and white films; an important consideration in cave photography.

Color Negative: Negative films entail an extra step, creation of a positive reproduction (in principal another negative),

but therein lies their versatility and wide exposure latitude. They can be used to obtain very good color slides, though not of the resolution and grainlessness of Kodachrome slides. The cost of such slides, *if same size*, is about the same as the processing cost of a slide on slide film, but reduction or enlargement can be very expensive.

The newer color negative films have remarkable exposure latitude for ordinary subjects, nearly that of comparable black and white films, and even greater tolerance of the extremes of contrast encountered in cave photography. Whether this apparent property is a result of wider exposure latitude for cave scenes or lower threshold sensitivity has not been established.

The optimum method of monitoring color changes in cave features is use of color prints from color negatives. If such comparisons are intended, a standard color reference must be included in the scene, to be exposed at the same time by the same illumination. The handiest such reference is a standard "gray card." These inexpensive rectangles of cardboard are carefully manufactured to 18 percent reflectance and color balanced to laboratory standards. It is *very important*, for reasons of economy, that the image of the gray card in the negative or the eventual enlargement be at least 0.7 cm square (a little over 1/4 inch), to assure that the control area will overlap a color analyzer's probe diameter. The following table indicates the maximum distance that a standard gray card (measuring about 20 x 25 cm) may be from the lens and still provide an adequate control patch.

| Focal length of lens: | Maximum distance from lens of a 20 cm-square gray card |
|-----------------------|--|
| 35mm | 1.1m (3.5 ft.) |
| 50mm | 1.5m (4.9 ft.) |
| 80mm | 2.4m (7.8 ft.) |
| 100mm | 3.0m (9.7 ft.) |

The gray card could be cut to a smaller size, of course, but would then have to be closer to the lens. With a little alteration the gray card can be made into a multipurpose device. A scale can be added with ruling pen and transfer letters and self-adhesive labels can be applied on which supporting data can be written for inclusion in the scene. No better way exists for insuring that such data stays with the photo (Figure 7). The gray card should be kept clean—not an easy task in caves. No doubt it will occur to would-be users that the card could be lacquered or varnished to protect it from soil. This should not be done as such treatment would probably alter the carefully manufactured matte surface which is designed to minimize mirrorlike reflections. It is also very important that the card be illuminated by the same level and color of light that illuminates the rest of the scene. It should not be placed near colored surfaces which might reflect their color on it, thus producing a misleading control area in the negative.

Black and White Negative: Black and white films are, for ordinary photography, the most forgiving of exposure error. Their exposure latitude may be exceeded, however, by the newer color negative films, for the purpose of cave photography. Black and white films are far less vulnerable to adverse conditions both before and after exposure, are easily processed with inexpensive chemicals in rudimentary facilities and possess truly archival permanence when processed and stored properly.

Camera

Aside from the likelihood that the expedient adoption of the 35mm still camera format may be one of mankind's



Figure 7: A section of Niagara Falls in Oregon Cave, photographed in 1977 and including a gray card with date, photo serial number, compass bearing and distance from light source to subject. *Photo by Charlie and Jo Larson.*

greatest tragedies, the 35mm single-lens reflex is entirely adequate, and is recommended, for documentary cave photography. Larger formats will, all other things being equal, yield a sharper finished product, but the universal popularity and consequent availability of 35mm cameras, film, processing and projection facilities, together with their compactness, ease of operation and general acceptance make them a clear choice for long-term cave surveillance. The limited flash synchronization of focal plane shutters, found in most 35mm cameras, is no problem in the low ambient light of caves if electronic flash is used.

"Normal" lenses are recommended—around 50mm focal length for 35mm cameras—primarily for the sake of consistency. Many photographers and cameras may come and go in the course of a long-term photo program and the probability that all will have a normal lens is high. Use of wide-angle lenses is to be avoided. Wide angle treatment tends to distort features around the edges of the scene, and nearly all flash units lack the angular coverage to uniformly light a wide-angle scene. Finally, wide-angle lenses are not likely to be available as personnel and equipment changes.

Lighting

Unless adverse conditions prevent their use, electronic flash units are recommended as a light source. Though slightly "cooler" (bluish) than ideal, the color of their output is considerably more consistent than that of flashbulbs. A

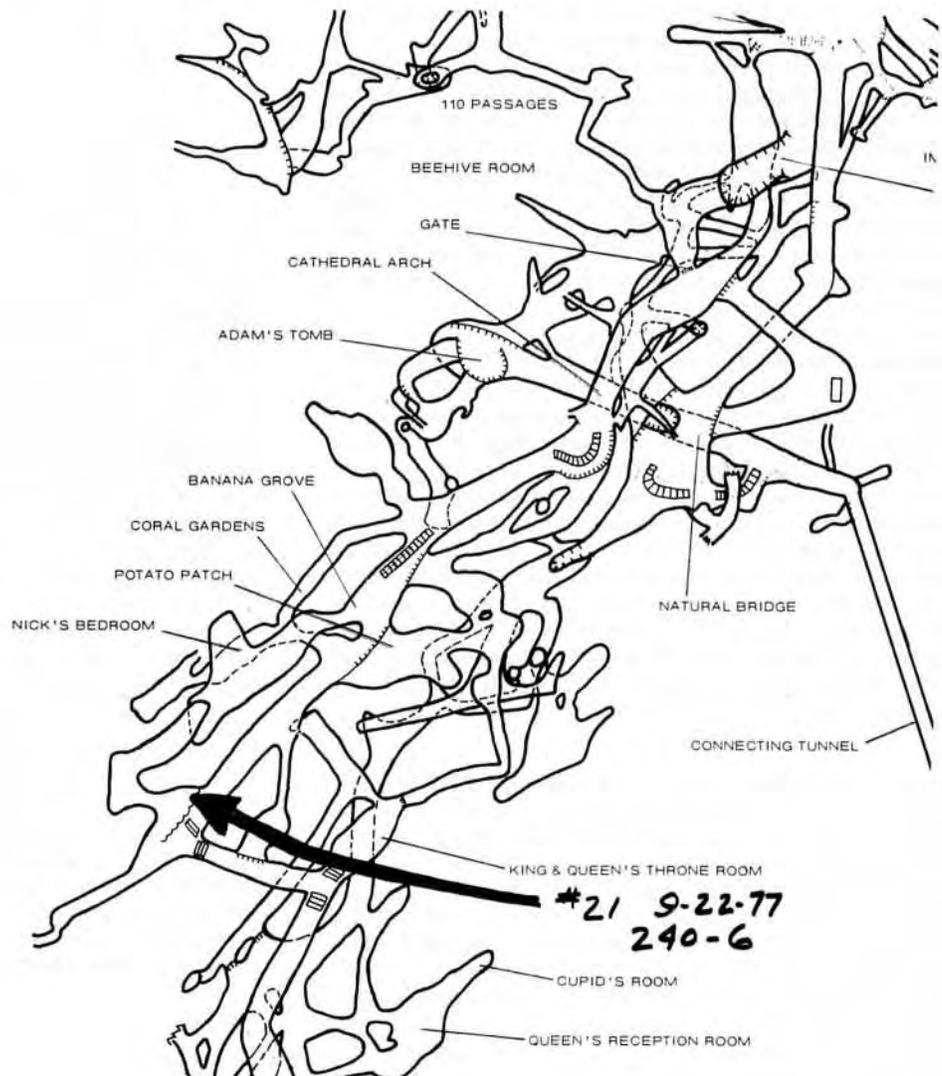


Figure 8: A companion document for figure 7; a section of the cave map with the location of the photo re-recorded thereon. *Photo by Charlie and Jo Larson.*

distinct advantage in the use of electronic units is the very short duration of their light output which, in the generally low ambient light of caves, allows hand-held exposures.

In lighted commercial caves the temptation will be strong to utilize the tungsten, fluorescent or whatever lights for photos. Such practice is not recommended if color or tone comparison is a factor. Color temperature of tungsten lights is variable, depending on voltage and fluorescents emit in an unpredictable, discontinuous spectrum.

Exposure: A piece of equipment that is guaranteed to make life easier for anyone engaged in cave photography is an electronic flash meter. These are incident light meters, unique in that they respond only to light of very short duration. Some are insensitive to ambient light; others actually integrate it. A gimmick? Absolutely not.

Guide numbers recommended by manufacturers are empirical—based on the assumption that light which might otherwise be lost will be reflected back into the scene from “average” surroundings, adding to the direct light falling on the subject. In caves the surroundings are anything but average; commonly having reflectivities ranging from near nothing up to 98 percent off some mineral oxides. Compound this range of reflectivities with the variable light output of all but the very expensive electronic flash units (\$350 and up) and it is clear that even use of a proven guide number will not assure accurate exposures. A flash meter placed in the scene gets it all together by integrating direct light from the flash unit, light reflected from the surroundings and, in some makes, the ambient light (if any).

Reflective surfaces in and near the subject affect not only the total light falling on the subject, but its color as well. This type of color shift is not predictable and together with the variable color of electronic flash units, the variable color response of camera and film, processing variables, reciprocity failures, ad infinitum, the color of the eventual photo is anybody's guess. That is why it is important to include an object of known color and reflectivity in photos to be used for recording or comparing color. A standard gray card is such a device.

Depth of field is a problem in cave photography. It is most easily alleviated by the use of smaller lens openings and for that reason small electronic flash units are not well suited. To do an adequate job of documenting cave features, without resorting to faster and consequently inferior films, a flash unit rated at 100 watt/seconds (about 15,000 BCPS) or larger is desirable. Automatic units; units which measure the light reflected from the subject and terminate the discharge when an optimum exposure is reached; are not recommended because, like recommended guide numbers, their principle of operation is based on an average subject. Cave scenes are neither average nor consistent, if an automatic unit is used for cave photography, it should be switched into the “manual” mode if so equipped.

Composition

Composition of documentary cave photos is no problem. One can approach it best by forgetting just about everything postulated about photographic composition in general. Objectivity is the object. Physical conditions are to be recorded—and nothing more.

Documentary cave photos should be like forensic photos—suitable as a basis for argument in a court of law. Anticipating litigation is not the purpose, of course, but that quality of objectivity and lack of emotional appeal that qualifies a photo as acceptable in a court is to be sought. “Creativity” is not called for, nor is inclusion of features or circumstances certain to pluck emotional strings. There's no

harm in including an occasional hand or foot but as a general rule, avoid including faces or full figures. Select photo sites and compose photos with the thought always in mind that photographers who follow you, perhaps many years later, must duplicate the view. Alignment of prominent features can help in this respect. Take the time to record bits of helpful information, like camera height, distance to subject, compass bearing and exposure data.

Finally, keep in mind that following an initial photo survey, subsequent photos will be devoted to detecting changes, so their composition and lighting should, clearly and in some detail, reveal anticipated telltale features.

Relating the Photo to the Cave

Documentary photography entails a little extra responsibility on the part of the practitioner. Just creating an objective photo is only part of the process. The photo must be unmistakably related to the cave and enough data recorded that, perhaps many years later, another person can recreate the original scene, exclusive of intervening changes in the original subject (Figure 7). A map of the cave, on which to locate photographic sites, and a companion document/s on which to record supporting data are necessities. The companion document could include a map of an entire small cave or, for maps unreadable if reduced to convenient size, only sections of the complete map (Figure 8). Note that the companion photo includes a gray card with some supporting data. It could include much more, and there is no better place for such data than in the photo itself.

RECOMMENDATIONS FOR DOCUMENTARY CAVE PHOTOGRAPHY

Photographic materials and equipment are constantly being improved, so tomorrow may be a different ballgame, but at this time the optimums in equipment, film and procedure are:

Camera: 35mm single-lens reflex or rangefinder, equipped with a normal lens (about 50mm focal length), capable of being synchronized with an electronic flash unit. A tripod will probably be required if precise alignment of cave features is important.

Light: An electronic flash unit rated at 100 watt/seconds (15,000 BCPS) or higher, with voltage stabilization if the budget will stand it, plus a flash meter.

Film: Color negative film; specifically, Kodak Vericolor II, #5025, Type S. The same film is available in sizes 120 and 220 as #6010, Type S. Black and white film is not recommended because its advantages, over color negative, are not great enough to justify the gamble that color will never be a factor in a cave's management.

Reproduction: Color proofs or small economy prints are recommended, whichever is cheapest. They are entirely adequate for most filing and reference purposes. If critical reference or comparison is indicated, larger prints in either black and white or color can be made, as well as slides if desirable.

Following the initial photo survey, which should be as comprehensive as resources will permit, select only a few sites for long-term surveillance. Continuity is more important than quantity. Inclusion of a gray card in each scene is recommended. If nothing else, it is a handy place to record supporting data. Finally, don't be stingy about recording photo data. The person who follows you probably won't be a mind reader.

A Photomonitoring System for Horsethief Cave, Wyoming

David L. Stout*

ABSTRACT

A method was needed for determining damage to Horsethief Cave (Wyoming) resulting from vandalism, excessive use, and surface changes. A photomonitoring system was proposed for use in the cave. The methodology for the system was conceived and initiated in 1975. This methodology can be adapted with little difficulty for use in other caves.

The system is based on a collection of photographs taken of the same subjects from the same photo points over a period of years. Photo points were chosen to monitor fragile, attractive decorations and features, for their potential to indicate deterioration, and for use as controls free of man-caused modification. Standardization of the photographs, especially in terms of camera location and color reproduction, is a critical part of the process. The system also includes an inventory of areas not included in the photographs. A written report details any changes discovered during the inventory.

A comparison of photographs made over a period of time shows changes in passage size, color and condition of decorations, the effects of vandalism, and naturally occurring changes. A visual and written record documents changes in the cave resource. This record can be used to identify needed travel restrictions and closures of passageway, and as an aid in determining optimum levels of use.

INTRODUCTION

The Worland, Wyoming district of the Bureau of Land Management (BLM) manages more than a dozen caves. The largest of these is Horsethief Cave, located 14 miles northeast of Lovell, Wyoming. Horsethief is actually the southern section of a cave system. It is connected to Bighorn Caverns in Montana by one known passage.

Horsethief Cave is a *wild* cave. No passage modifications have been undertaken and nothing has been added to lessen hazards or make caving easier. The cave is not commercialized. To preclude unauthorized use a gate was installed near the entrance through a cooperative effort between local cavers and the BLM.

Horsethief is important regionally and possibly nationally in terms of its relatively unaltered natural state and the number of miles of known passageway (ten miles are known, more than five miles have been mapped). It has also received some nationwide exposure through the efforts of the Little Mountain Caves Conservation Task Force. Because of the reputation of the cave, it receives nearly year-round use.

The amount of use (currently about 500 visitors per year) and projected increases in use raised questions about deterioration of the cave resource. Potential problems resulting from use were identified as part of the Worland district's cave management policies. Changes in passage size and configuration, accidental damage to decorations, soil compaction in heavy use areas, and litter were sure to occur. The potential for vandalism and theft of formations existed.

Natural occurrences such as breakdown could be expected. Also, surface disturbances from uranium mining or grazing activities could conceivably have a detrimental effect on portions of the cave.

A method was needed for determining the existing condition of the cave and to document future changes and deterioration. After some study, a photomonitoring system was proposed for use in Horsethief Cave. The methodology for the system was conceived in 1975. It resulted mainly from the ideas of Ron Rothschild, who was the Worland district's outdoor recreation planner, and from Pete Uhl and Wayne Sutherland who were seasonal cave rangers. In 1976 and 1977, Roy Hayford and Pete Uhl refined the system to its present state.

Much of the first summer's work involved testing procedures and locating photo points. Each successive summer's work involves retaking the photographs made in the first year. At the same time the photographs are taken, an inventory is made by the cave rangers to document changes not recorded on film.

We feel this system has merit in determining deterioration of cave resources. Adaptation of this system for use in other caves should be fairly easy.

PURPOSE

The desired results of the photomonitoring system in Horsethief Cave are threefold. The system will provide data for use in determining optimum use levels. Damage to the cave resource resulting from excessive use, vandalism, and surface disturbance will be documented. The system will be used to identify needed travel restrictions and passage closures.

* Outdoor Recreation Planner, Bureau of Land Management, Worland District, Wyoming.

OBJECTIVES

The objectives of the system are also threefold. A visual record of resource damage will result from our efforts. Data collection procedures in the cave will be refined and standardized. A general inventory will be provided outlining changes to cave resources not included in the photomonitoring system.

METHODOLOGY

A. Equipment

The photomonitoring equipment used in Horsethief Cave is not specialized and is readily available. Any group or organization could acquire the equipment with little difficulty. The basic equipment needed is as follows:

1. An inexpensive camera, not necessarily 35mm, but of a type for which film will remain available and capable of taking "close-ups."
2. A strobe flash with an open flash mechanism to allow easy, independent firing of the flash.
3. A sturdy, collapsible, compact tripod, which can be easily stored and transported.
4. A cable shutter release, to insure vibrationfree exposures. (A vinyl-covered cable release about 40 inches long with a shutter lock mechanism is recommended.)
5. A plumb bob for centering the camera above a reference mark.
6. A 50- or 100foot measuring tape, cloth or fibreglass, for locating the camera in relation to reference marks.
7. Kodak color control patches and/or gray scale.
8. A fully damped Brunton style compass in degrees.
9. A notebook or prepared forms for posting directions about exposure, shutter speed, angle of camera, etc. (See Figure 1).

| | |
|--|------------|
| 1. LOCATION: Photo Point# _____ | Date _____ |
| 2. SUBJECT: _____ | |
| 3. CAMERA _____ FILM _____ | |
| A. LENS _____ mm, f _____ | |
| B. APERTURE | |
| #1 | #2 |
| #3 | #4 |
| C. SPEED | |
| D. LENS TO SUBJ. Dis. _____ Brng _____ Inc _____ | |
| E. Ht. of Lens _____ | |
| F. Color Chips _____ | |
| 4. LIGHTING: A. Type _____ #of Flashes _____ | |
| B. Flash to Sub: Dis. _____ Brng _____ Inc _____ | |
| C. Photo Pt to Flash: Dis _____ Brng _____ Inc _____ | |
| 5. LOCATION: To _____ Dis _____ Brng _____ Inc _____ | |
| SEE REVERSE SIDE FOR ADDITIONAL COMMENTS | |

Figure 1. Data Record Form



Figure 2. The camera and tripod are centered over the photo point marker using the plumb bob.

10. A watertight, dust-tight, shock resistant container for transporting equipment. (Surplus military ammunition boxes or oxygen bottle boxes are useful.)

B. Location of Photo Points

Permanent photo points were established in strategic locations throughout explored sections of the cave. Points were chosen for their potential to indicate deterioration and for controls free of man-caused modification. Much of the time during the first summer was devoted to inventory of the cave to determine suitable photo point locations.

As trends are identified, photo points can be culled to eliminate those providing no useful information. Additional photo points may be added as exploration progresses or as management policies change.

Once a photo point is located, it is permanently marked with a brass marker. We use pieces of 3/8" diameter brass brazing rod set into solid rock with aluminum solder. The holes for the brass plugs are drilled by hand with a hammer and drill. The plugs are small enough not to be noticed by most spelunkers. The plugs have the added advantages of being non-magnetic and rustproof. The photo point marker is tied to the nearest cave survey point by distance measurements in feet and inches and angle measurements using azimuth.

C. Camera Setup

The taking of a photograph includes recording enough data to be able to duplicate the photograph at a future date. A knowledge of cave photography is essential. The camera and tripod are centered over the photo point marker using the plumb bob (See Figure 2). After framing the picture and focusing the camera, the vertical angle and azimuth of the camera is recorded (See Figure 3). Also recorded is the height of the camera above the photo point marker.

The inclination and azimuth of the face of the strobe is recorded. When possible, the strobe location is marked with a smoke dot.

The shutter speed (bulb setting) and F-stop of each exposure must be recorded. At first, it is necessary to bracket each subject, until the optimum F-stop can be determined.

Each photograph includes a gray card in the corner of the photo, on which is written the photo point number and exposure number. The gray card (or Kodak color control patch) is later used to standardize the film processing.



Figure 3. A Brunton compass is used to determine the vertical angle and azimuth of the camera face.

A photo should be taken of the camera setup at each point, to serve as a future reference. It is also advisable to have a duplicate set of photos made for use as reference during subsequent photo sessions.

D. Film Processing

Processing of photographs is a critical step in the monitoring process. Standardization is important. The same brand of film and ASA rating should be used for all pictures. Since adequate lighting is not a problem, fast, grainy films can be avoided. A long-term supply of film should be purchased and stored because of possible changes in emulsion which might affect color reproduction. Prints are more desirable than slides due to truer color retention, ease of comparison with other photos and for convenience of storage. Having the film processed to a standard color is very important. Obviously, changes in formation color, for example, cannot be accurately recorded if the photographs are not processed to the same color standard each time. This has been our biggest problem. That is, having photographs processed to match a standard gray color chip or Kodak color control patch. A reputable local photo lab or a talented individual might solve this problem. If possible, processing should be arranged in advance. Some test photos should be submitted in advance to test color comparison. It's obviously better to spend time testing than have one year's photographs become useless because they don't correspond with the next year's photographs.

E. Analysis of Photographs

Analysis of photographs should occur as soon as all photographs for a season have been processed. Analysis should include the following steps:

1. Compare photos for constant color rendition.
2. Compare for such things as changes in the color of speleothems, breakage, removal, modification, and changes in water level.
3. Note all results, both positive and negative, by narrative in the record.
4. Identify on a cave map those sites where all observable changes have occurred.
5. Review suitability of photo points.
6. Change or retain use regulations as policy and environmental analysis dictate, based on information about deterioration of cave environment.

Analysis of our initial photographs indicated that the original photo points tended to be oriented too much toward single, attractive and fragile features. It was determined that more sites should be selected which would show trends in deterioration. Examples include crystals which may seem ordinary but will change continually over a period of time, and passage floors which are made up of light dust, small rocks, or flowstone.

Analysis confirms the notion that prints are better than slides. Also, that precision in setting up and taking photos is vital for useful data.

SUMMARY

Results of our photo monitoring system are somewhat limited by the infancy of the system. The photographs from the 1975 season are not of much use because of the trial and



Figure 4. Loss of a stalactite and a soda straw is revealed in the 1977 photo.



Figure 5. Recently broken decorations have been piled up by cavers.

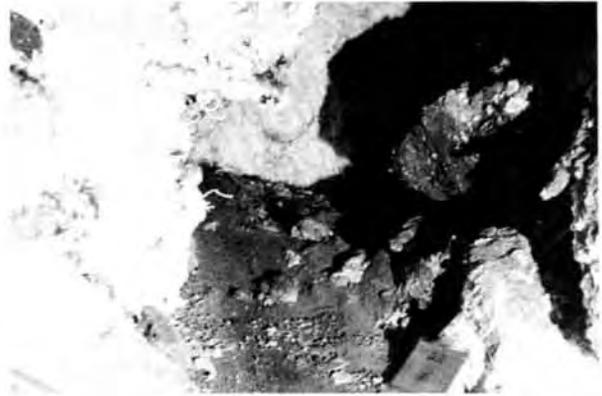


Figure 6. Comparison of 1976 and 1977 photographs shows no apparent travel in a closed passage.

error process used that year. A change from slides to prints, trouble with film processing, and failure to sufficiently bracket shots were contributing factors.

A period of five or more years may be needed before changes at some photo points will be visible in the photographs. At other photo points, however, we have already been able to detect changes (see Figures 4 and 5). We have also been able to determine that management policies with respect to passage closures and restrictions have been at least initially effective (see Figure 6).

The inventory process that accompanies the photo monitoring has provided good results in documenting major changes in the cave. The cave rangers are very familiar with the cave and are able to spot these changes.

As time progresses, we have found it is easier to do the monitoring. In 1975, it took most of the summer (three days a week, ten hours a day) to do the inventory and set a few points. In 1976, it took nine weeks (three days a week) to set the remaining points and to accomplish the photography. In 1977, it took four weeks (three days a week) to do the

photography. A total of 32 photo points have been established.

It is difficult to positively conclude at this time that the comparison of photographs indicates trends in deterioration. Based on results from our first successful year of photomonitoring, however, the system is working as planned. The system is providing information about cave deterioration. After five or ten years we hope to have enough useful data to draw conclusions upon which we can base management decisions. In the interim, the general inventory segment of the monitoring system is providing us with information. On the basis of this information, we have initiated travel restrictions (mainly trail use only) in some passages and have closed others to all but administrative travel.

We would not hesitate to recommend the use of a photomonitoring system in other caves. Once the system has been established in a cave, it should run smoothly. The data derived should be helpful in determining cave resource deterioration.

Variation in the Cave Environment and its Biological Implications

Merlin D. Tuttle and Diane E. Stevenson*

INTRODUCTION

Constancy of the cave environment has too often been assumed and emphasized. The most common generalization is that cave temperature varies only near entrances (the variable temperature zone) while the remainder of a cave is constant (the constant temperature zone), with temperature closely approximating the local mean annual surface temperature. Humidity also is often considered to be near saturation and relatively invariant. These generalizations are true in some cases. Certainly, the cave environment is buffered in relation to the outside environment. Overall temporal and spatial variation of temperature and humidity among and within caves, however, is far greater than is generally suspected, and even a small amount of such variation can have great impact on cave faunas (Jegla and Poulson, 1969; Juberthie and Delay, 1973; Delay, 1974; Juberthie, 1975; Poulson, 1975; Tuttle, 1975, 1976; Wilson, 1975; Peck, 1976).

Although literature demonstrating considerable variation exists, it is scattered, often in foreign or little-known publications, and sometimes is authored by laymen who publish only once on the subject. Consequently, few individuals, even among biospeleologists, are adequately aware of much of the available literature and its biological implications. Another source of confusion has been the fact that many authors, while presenting a thorough discussion of one or more variation-producing factors, still have opened or concluded with general statements about the constancy of the cave environment.

Despite the confusion, in the existing literature a variety of factors—such as number, size, and position of entrances, passage size, contour and slope, overall cave volume, distance of greatest volume from entrances, amount and seasonal timing of entry of surface water, air flow, and the annual range of outside temperature—have been noted to strongly influence cave temperature and humidity (see Halliday, 1954; Moore and Nicholas, 1964; Plummer, 1964; Cropley, 1965; Geiger, 1965; Peters, 1965; Vandel, 1965; Conn, 1966; Barr, 1968; Daan and Wichers, 1968).

This paper integrates current knowledge of the cave environment with particular emphasis on air flow and temperature; it presents some of our data on the subject, and discusses the importance of such information to biological research and cave management. We believe that familiarity with factors influencing cave environments can be highly useful in biospeleology and cave management, both for the generation of hypotheses and predictions in ecological and distributional studies and for predicting the biological uniqueness and potential of any given cave under investigation.

METHODS

From 1960 to 1975 the senior author visited several hundred caves, primarily in Alabama, Florida, Tennessee, and Virginia, and recorded temperatures at hundreds of winter and summer roosts of the gray bat (*Myotis grisescens*). Temperature and humidity readings were recorded using a Bendix Psychron motor-driven psychrometer. Since gray bats prefer caves that provide the greatest possible deviations from mean annual surface temperatures, the caves visited during these bat studies provided examples of strikingly different structures and temperature regimes. Many other caves, not used by gray bats, provided additional comparisons.

From the winter of 1975-76 through the winter of 1976-77 a more detailed study of cave temperature was conducted. Thousands of temperature measurements were made in 25 caves and mines from Wisconsin to Florida, in an effort to test the predictions generated incidental to the previous bat studies. A quick, accurate temperature measuring device was essential, and a Bailey Thermalert, Model TH-2 digital readout thermometer with a 1-mm diameter thermister probe was used initially. Testing in controlled water baths at temperatures of 0-30°C demonstrated precision of $\pm 0.1^\circ\text{C}$. However, accuracy under field conditions varied with the temperature of the instrument itself, forcing one to carry it beneath one's coveralls and to repeatedly recalibrate against a laboratory-tested Wesco mercury thermometer. Though readings could be made in only a few seconds, accuracy with the Thermalert in the field was only $\pm 0.3^\circ\text{C}$.

Accuracy was greatly improved with the purchase of an IMC Digital Thermometer, Model 2100 (produced by IMC Instruments, Inc., Glendale, Wis.), with a range of -40° to $+250^\circ\text{F}$. This thermometer proved far more suitable for use in caves. It weighed only about 500 gms. (including batteries), was extremely sturdy, provided accuracy and precision of $\pm 0.1^\circ\text{F}$, and continued such reliability over an instrument temperature range of 0 to 110°F . Using a sensor probe 2.2 mm in diameter, this instrument had a response time of 3 seconds in liquids, 30 seconds or less in air, and from 45 seconds to several minutes (depending on density of solid) for surfaces. Most air and wall temperatures reported in this paper were taken with this instrument.

Although the data are not presented here, gross daily and seasonal temperature variation was recorded in five cases using Weksler maximum/minimum thermometers, and 24-hour comparisons between inside and outside temperatures were made using Bacharach Tempscribe recording thermometers, in order to verify our findings. Mean annual surface temperatures (MAST) were obtained from U.S. Department of Commerce (1975a-c) publications. A steel tape or, for the longest distances, a Model 100 Optical Tapemeasure (produced by Ranging Inc., Rochester, N.Y.) were used for cave measurements.

Data from only a few representative caves in the study could be included here, but the omitted observations agree well with those selected for discussion.

* Vertebrate Division, Milwaukee Public Museum, Milwaukee, Wisconsin 53233

FACTORS THAT INFLUENCE CAVE TEMPERATURE

Conduction from Cave Walls

If one surface of a very large limestone block were exposed to a seasonal cycle of temperature, "it may be predicted that its interior temperature would remain very close to [mean annual surface temperature (MAST)] within a very few feet of its surface." A time lag in temperature adjustment of approximately 7 days for every foot of depth produces this constancy (Cropley 1965). Cropley described as Zone III an area of a cave where isolation from outside conditions is such that "no temperature variations occur except those that are initiated by the conduction of heat from the surface through the cave roof." Although this is the characteristic of the constant temperature cave of popular legend, he found no instance of a "true Zone III location," but concluded that relatively isolated rooms "are sufficiently common that the legend is perpetuated." The main effect of cave wall conduction will be seen to be the tendency to gradually return differing air or water temperatures to mean annual surface temperature—the more isolated from outside influences an area is (whether by distance or physical barriers) the more nearly its temperature will approximate MAST.

Geographic Location

Vandel (1965) listed geographical location and altitude as important factors affecting cave temperature; their major influence is on the range and mean of the annual surface temperature and on standard barometric pressure. Since the amount of variation from mean annual surface temperature that can be achieved in any given cave is directly proportional to the annual range of surface temperature (see discussion below), caves in tropical regions would be expected to exhibit only the slightest deviations from MAST. To a lesser extent, fluctuations also should be reduced in caves on islands, peninsulas, or even in coastal areas. Within a given area, cave entrances on north versus south slopes, those at different elevations, and those on exposed surfaces versus in deep, protected valleys or sinks will face different means and ranges of surface temperature, which often result in detectable differences in internal temperatures.

Another geographic factor is the nature of the geological structure present; caves of certain configurations may exist primarily in certain areas. Barr (1961:13) documented the existence of strong geographic tendencies in the distribution of caves of "essentially horizontal" versus "steeply or moderately inclined beds." Such structural tendencies would be expected to be reflected in geographic trends in cave temperature and humidity. This in turn may have important zoogeographic implications.

Water Circulation

In order for internal temperatures to vary above or below mean annual surface temperature, a cave must have a route of communication with the temperature fluctuations of the outside atmosphere. With cave wall conduction exerting only infinitesimal effect extremely short distances from the surface, the two main routes of communication are circulation of air and water. Water is most likely to cause deviations from mean annual surface temperatures when it enters directly from the surface in seasons when surface

temperatures deviate farthest from the mean annual temperature (Cropley, 1965) or, in rare instances, when it enters from thermal springs (Geiger, 1965). Flooding, as noted by Barr (1968), can produce sudden and pronounced temperature changes and can play a vital role in triggering reproduction of aquatic troglobites (Poulson and Smith, 1969; Jegla and Poulson, 1970). The "disrupting" influence of outside water will, of course, last only until it has flowed a distance sufficient to allow it to reach thermal equilibrium with the cave walls.

Air Circulation

Although exceptions do occur, the impact of air circulation in caves is generally far greater than that of water, if for no other reason than the fact that whereas most known caves have some air circulation (those isolated by water sumps being an exception), a much smaller proportion have major water circulation. The four main causes of air circulation affecting cave temperature (see Plummer, 1964) will be discussed. It will be seen that the magnitude and type of impact of all air flow types is overwhelmingly determined by the structure (passage configuration) of the cave itself.

Barometric pressure.—Atmospheric (or barometric) pressure frequently has been cited as a primary factor influencing within-cave air movement and temperature fluctuation. Although other factors such as solar-induced atmospheric tides can produce slight pressure changes (Encyclopedia Britannica, 1975), the relatively greatest fluctuations in barometric pressure at any given altitude are directly the result of temperature changes (Moore and Nicholas, 1964).

At one location pressure changes can, of course, occur that are due to temperature changes (and the resulting winds) at another distant location, as in the case of changes preceding storm fronts. It is only these *non-temperature-associated* pressure changes that can be discussed meaningfully as *barometric pressure influences* on cave climate. Changes in the outside air temperature obviously will be accompanied by changes in barometric pressure, since the latter is determined by the weight of air (colder = heavier). In this paper, however, references to barometric pressure effects will refer only to the *non-temperature-associated* changes; temperature-associated pressure changes will be considered synonymous with temperature fluctuation.

At certain times, as noted by Porter (1974), "All caves should exhibit an airflow into the entrance when the outside atmospheric pressure rises, and should emit air when the pressure falls." Nevertheless, the overall impact of this circulation appears to be relatively minor (Moore and Nicholas, 1964; Plummer, 1964), especially when compared to that of thermal convection. Its effect certainly is more gradual, transitory, and of less magnitude. Apparently rare cases exist where caves, such as Wind and Jewel Caves in South Dakota, have extremely large volumes and generate significant winds through barometric pressure interactions alone (Conn, 1966). Even in these caves, however, internal temperatures probably are affected little, compared to the amount that would occur if thermal convection were directly involved.

Surface wind—Surface winds carried into or through caves by their own force may be of some importance in certain instances (Plummer, 1964; Geiger, 1965), but most examples are limited to a cave with a short simple tunnel between its two or more entrances, or to a relatively shallow cave with a large entrance. Plummer (1964) discussed the flow of surface

winds through caves with entrances a *large* distance apart, but points out that in such cases the "motion is not properly 'caused' by the surface winds." He contends that "both the cave and surface winds result from the same difference in barometric pressure between the locations of the entrances." This effect would be most likely to occur in a cave shaped like a nearly level tunnel.

Resonance—Schmidt (1959), Eckler (1965), Peters (1965), Moore and Nicholas (1964), Plummer (1964), Porter (1974), Russell (1974) and others have discussed this potential cause of cave "breathing" through a single entrance. The oscillation of air has been attributed to movement of outside air across the entrance, creating resonance similar to that which "produces a sound when a person blows across the mouth of a coke bottle." (Cave 3 of Fig. 1 is of the "jug" shape postulated as suitable for resonance.) Schmidt (see Barr, 1968) also suspected that such resonator effects could explain air flow oscillations in passages at the bottom of

large "elevator shaft" types of passages; he hypothesized that "vertical air columns of considerable height" in the tall passages could produce effects similar to surface winds.

Although we have not attempted to investigate this phenomenon in any detail, we doubt that the above explanations are of more than rare importance. We have observed both regular and irregular breathing cycles in caves of a variety of structures, and note that oscillations are most likely to occur when outside temperature is fluctuating around or is close to inside temperature. Furthermore, such oscillations often persist in the absence of outside wind. When marked outside temperature changes are occurring, as during a storm (for an example, see Eckler, 1965), breathing easily can be explained by thermal convection; Peters (1965) has discussed differing cave structures and how they might cause patterns of breathing.

Moore and Nicholas (1964) have pointed out that the now famous Breathing Cave in Virginia is itself probably a multiple-entrance cave dominated by air currents caused by

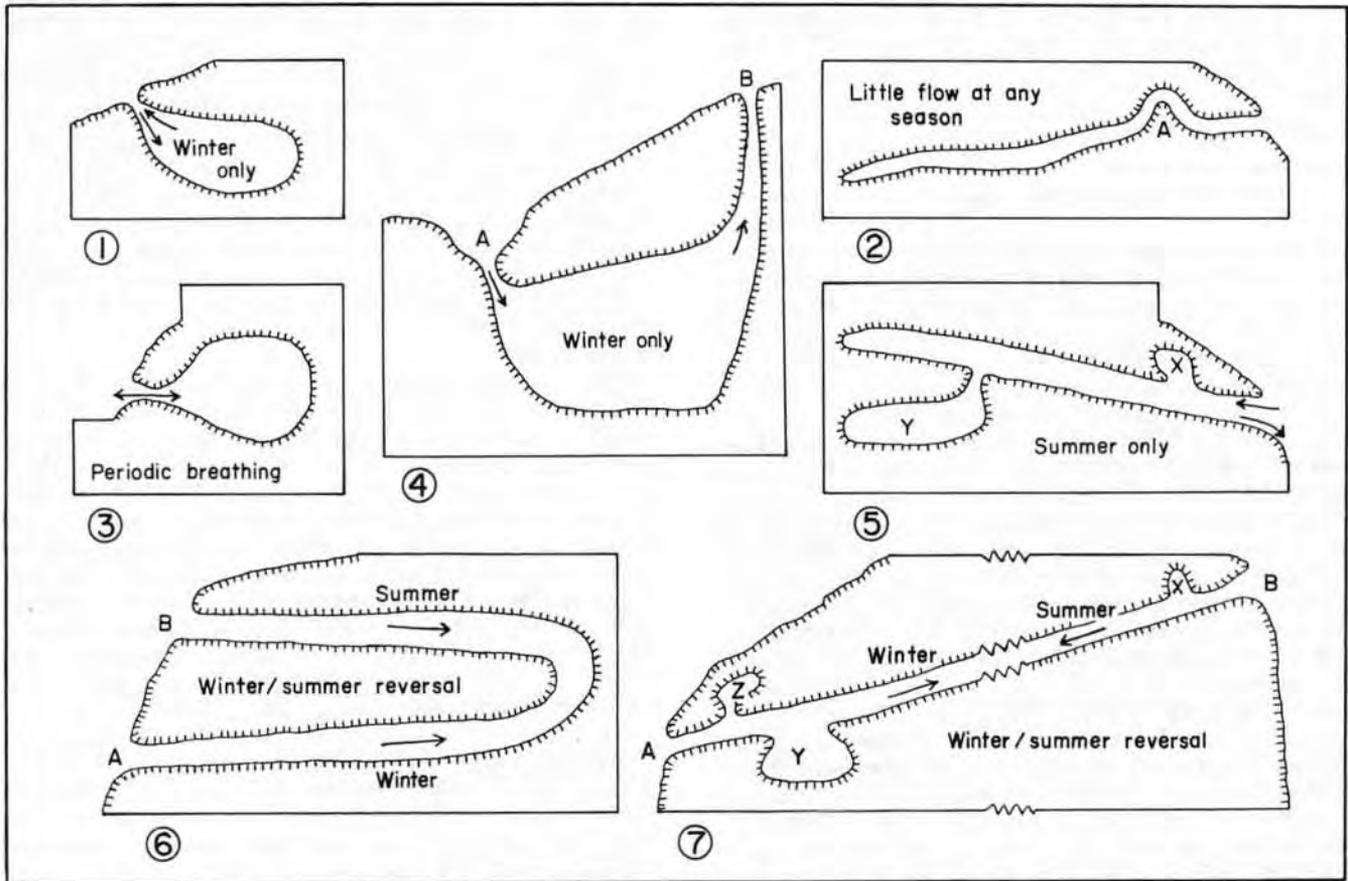


Figure 1. Simplified cave structures. Air flow indicated as occurring in "winter" will generally occur when outside temperature is below mean annual surface temperature (MAST); flow marked "summer" will occur when outside temperature is above MAST. *Type 1*: Breathes (as indicated by arrows) in winter; stores cold air in summer. *Type 2*: Undulation at A acts as dam inhibiting air flow; temperature relatively constant beyond dam. *Type 3*: "Jug" shape often postulated to exhibit resonance; may have pulsing in and out air movement, especially when outside air deviates from MAST. See text for alternate explanation for the oscillation of air. *Type 4*: Strong air circulation from A to B in winter; stores cold air in summer. *Type 5*: The reverse of *Type 1*; warm air enters along ceiling in summer while air cooled by cave walls flows out along floor. No flow in winter. X is a warm air trap, Y stays a relatively constant temperature. *Type 6*: Strong air flow from A to B in winter; equally strong air flow in opposite direction in summer. *Type 7*: Same as *Type 6*, with a warm air trap (X), cold air trap (Y), and an area of relatively constant temperature (Z). Distance between and elevational displacement of the entrances are critical factors in the air flow direction in these two cave types; the flow of air (cooled relative to outside temperatures by the cave walls) down in summer must be strong in order to overcome the tendency for warm outside air to rise into A. Similarly, in winter the "negative pressure" created by air (now warmer than outside air due to the MAST effect of the cave walls) rising out of B must be strong enough to pull cold air up into A.

thermal convection. They point to internal complexity of structure as the probable source of breathing and discount the idea that the air flow oscillations are caused by outside wind blowing past its entrance. An alternative explanation (using thermal convection as opposed to resonance) will be proposed to explain air flow oscillations in caves of Type 3 (Figure 1) in the section, "Cave Structure and Volume."

Thermal convection—The impact of thermal convection on air movement in and out of caves (and therefore on cave temperatures) is well known; thermal convection is generally believed to be the most important factor in determining the direction and amount of air exchange with the surface (Halliday, 1954; Plummer, 1964; Geiger, 1965; Peters, 1965; Daan and Wichers, 1968; Porter, 1974; Russell, 1974). The principle of thermal convection in caves is that air escapes (rises) through an upper entrance (or through the top of a single entrance) when it is warmer than the outside air. Conversely, air will escape through a lower entrance (or through the bottom of a single entrance) when it is cooler than the outside air. The greater the inside-to-outside temperature gradient, the faster the rate of air movement; flow ceases when the temperatures are the same. (This equilibrium condition theoretically should be reached when the outside temperature equals mean annual surface temperature for the area. Different cave types may deviate so markedly from MAST, however, that this equilibrium point may be shifted at times.) Caves can exhibit such air flow seasonally, on a daily cycle, or in response to passage of weather fronts. Direction and timing (and to a certain extent, rate) of flow will be determined by the structure of the particular cave.

Cave Structure and Volume

Figure 1 presents several simplified examples of how air circulation works in caves of different structure. Although the number of entrances (including cracks too small for human passage) is an important variable of air circulation, the elevational difference between multiple entrances is of primary importance for thermal convection-induced temperature variation, as noted by Halliday (1954), Plummer (1964), Geiger (1965), Porter (1974) and others. Negative pressure (as described by Peters, 1965, and Daan and Wichers, 1968) can create powerful *chimney* effects in caves with entrances at different elevations (Figure 1, Types 4, 6 and 7). Halliday also pointed out that other factors, such as irregular, tortuous passages or narrow entrances, "will act as baffles to air currents." We have noted that vertical undulations are especially effective natural dams against the free flow of convection currents (see Figure 1, Type 2).

The location of a cave's greatest volume relative to its entrance(s) is also of great importance. Distance of a cave's greatest volume from the entrance(s) has been shown to be of importance in determining depth and pattern of air movement in and out of caves where movement is the result of changes in barometric pressure (Conn, 1966). Elevational displacement of cave volume from an entrance(s), however, is perhaps the most important single factor affecting cave temperature (see Figure 1, Types 1, 4, 5, 6 and 7). As noted by Geiger (1965) "if a cave slopes downward from the entrance, cold air flows downward inside it and is no longer affected by warmer and lighter air. Caves of this type are called sack caves and act as cold reservoirs. . . The opposite thermal effect is obtained when a cave slopes upward from its single entrance." Caves with their greatest volume above the entrance can act as warm air traps; cooled air sinks out as warm air rises in. These considerations also apply to cave

chambers or passages that extend above or below passages with air flow, as illustrated in Figure 1, Types 5 and 7.

Small passages, in addition to acting as baffles, also dampen temperature fluctuations through their increased cave-wall-surface-to-volume ratio—the tendency of the walls to return air to mean annual surface temperature will have maximum effect. Halliday's (1954) study of ice caves demonstrated not only the importance of having the volume below the lowest entrance but also the necessity of large volume for cold air storage. Halliday, in discussing classical examples of limestone ice caves, repeatedly noted the presence of very large volume. He mentioned room sizes of 100 feet by 30 feet, 200 feet by 50 feet, and 300 feet by 50 feet, and described another as "one immense room of ballroom proportions."

Thermal convection and the distribution of a cave's volume in relation to its entrance also could provide an alternate explanation of *breathing* (air flow oscillations) in caves of Type 3, Figure 1. With its volume approximately equally distributed above and below the entrance, such a cave could be expected to have warm summer air entering along the entrance ceiling, with cooled air spilling out along the bottom of the entrance. The reverse flow pattern would occur in winter. If the entrance were sufficiently constricted, however, *breathing* could be predicted to occur. There no longer would be room for air to move simultaneously in opposite directions; density differentials should lead to a pulsing action. At some point, further increases in entrance passage length and constriction should almost completely inhibit exchange of inside and outside air in caves of this type.

INTERACTION OF CAVE STRUCTURE AND AIR FLOW

The following examples of specific caves (see Figures 2 and 3) were taken from our studies in the southeastern United States and will illustrate the extent and nature of cave structure/air flow interactions. Cave names and locations are withheld because most of the caves discussed contain populations of endangered bats or other cavernicolous faunas. This information will be provided, on request, to those documenting *bona fide* need.

Seasonally Reversing Air Flow

Cave number 1 of Figure 2 is an excellent example of Type 6/7, Figure 1. Due to its relatively simple shape, large passage diameter, and 43-meter elevational difference between entrances, air flow is direct and rapid. We have observed a strong (unmeasured, although probably sometimes exceeding 15 KPH) flow of air exiting the lower entrance and entering the upper on hot summer days, with the reverse being true on cold days in winter. Temperatures at the entrances in February (Figure 2) show the effect of the cold air entering the low entrance, and warmed air exiting the upper one. Local residents and the cave's former owner report complete or nearly complete cessation of air flow, either in or out of either entrance, when the surface temperature is approximately 60°F (15.6°C). Air flow cessation would be expected in this general temperature range due to its proximity to mean annual surface temperature (15.7°).

As a consequence of its strong, seasonally reversing air flow, this cave shows the greatest annual range of temperature of any of the hundreds of caves observed in this study. Note the extremes of deviation from MAST at locations H and D in July and February (outside

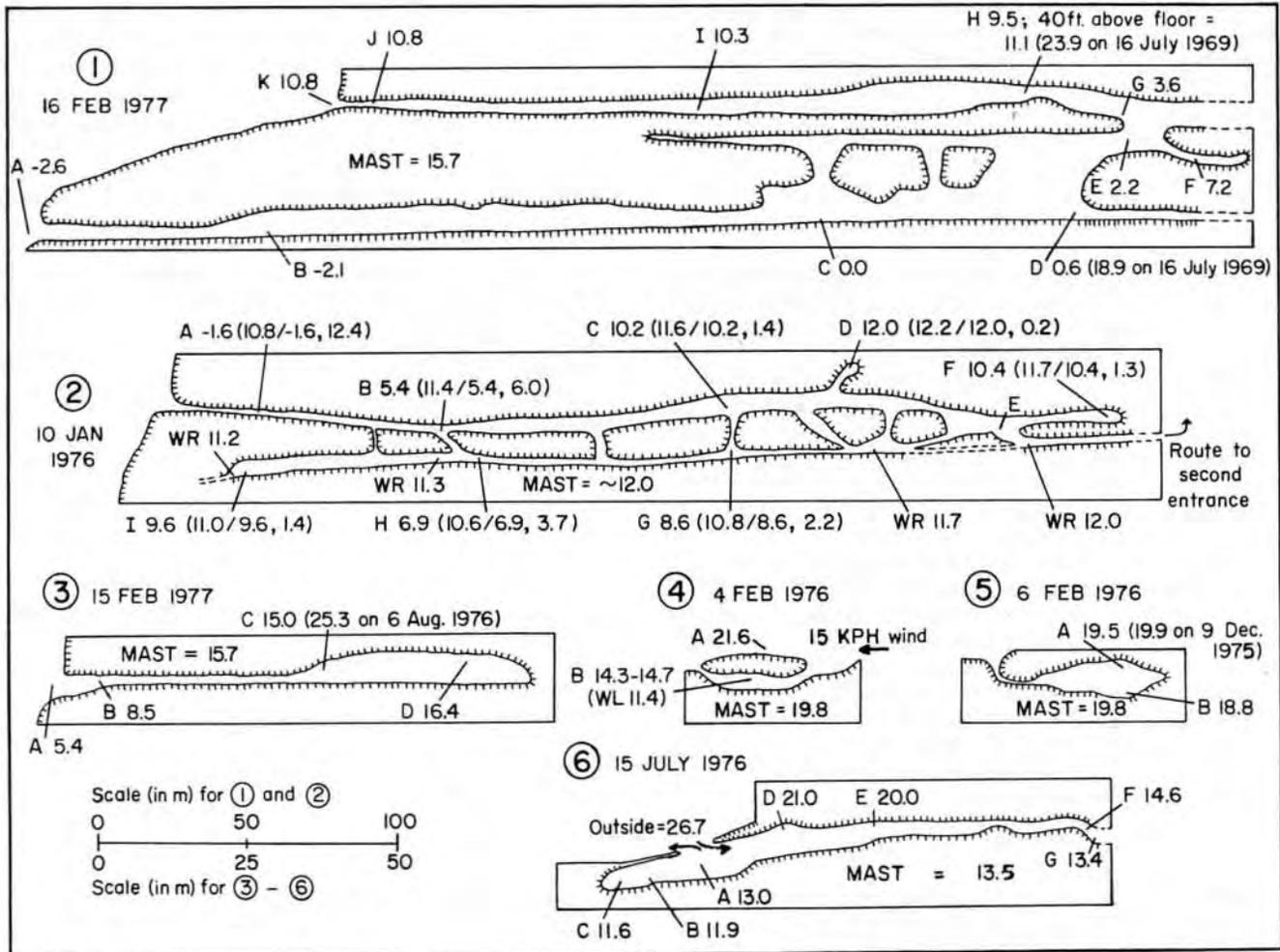


Figure 2. Six southeastern caves and temperatures (in °C) at some sites for the date indicated near the cave number. Temperatures on additional dates may be given in parentheses. MAST = mean annual surface temperature, WL = wall temperature, WT = water temperature. For cave 2 the range of temperatures from January through August is given in parentheses (maximum/minimum; number of degrees in the range). Streams flow from right to left through the lower levels of caves 1 and 2.

temperatures approximately 34°C and -3°C respectively). Certainly a temperature of 0.6°C 350 m inside an Alabama cave requires exceptionally strong circulation of outside air. This reading, and the high summer temperature at H, are all the more surprising since the cave passages slope in the "wrong" way: down from K between J and I, and up from A to D. Both readings are attributable to the dramatic impact of the negative pressure created by air exiting such a large cave—in summer cool air pours out of the bottom entrance in such a quantity that warm air is "sucked" in the upper entrance and down the slope. In winter the reverse occurs, when warm (relative to outside) air escaping through the upper entrance creates a partial vacuum which "sucks" cold air into the lower entrance and deep into the cave. Lower outside temperatures in January undoubtedly produced below-freezing temperatures as far in as site D.

Cave number 2 of Figure 2 is a nearly horizontal, two-level tube which, according to Barr (1961), ends at point F. Mean annual surface temperature is probably 12°C or slightly below; temperature recording stations within 70 km on opposite sides from the cave have MASTs of 12.4 and 13.4°C, but the cave is at a higher elevation than either station. This cave is a good example of how knowledge of

cave temperature variation can lead to prediction of undiscovered sections. Our observations of a seasonally reversing air flow (into the known entrance in winter and out of it in summer) strongly point toward the existence of a second, previously unsuspected entrance. Furthermore, the direction of flow requires that the second entrance be higher in elevation than the one known, making this cave an example of Type 7, Figure 1. The tell-tale air flow is quite strong in the stream passage beyond point E, indicating that this passage leads toward the undiscovered entrance. Further evidence of a second entrance can be seen in the relative fluctuations of air and wall temperature in the cave, to be discussed later.

Given postulation of this second entrance, the pattern of temperatures observed within the cave are what would be expected. Location A shows the lowest January reading and the greatest January to August fluctuation, with B, H, and G following in decreasing order. This follows the flow pattern of cool dense air from the entrance, and the entire lower cave level is a cold air trap. It is not as cold as might be expected; cold air settles into this low area, but it is warmed by the stream which pools there before disappearing in a sump. Note the cooling effect of the lower cave on the

stream, which enters the known cave (near E) at 12.0°C and progressively cools to 11.2°C at I. C is little affected by air from either entrance; it is too high relative to the known entrance to be cooled in winter, and too distant from the other to be greatly warmed in summer. Warm summer air being drawn into the upper entrance evidently has been cooled approximately to MAST by the time it reaches the known cave. D is an example of a relatively constant-temperature room such as Z, cave type 7, Figure 1. Distance from the warm air (upper) entrance, plus small volume, prevent it from being a warm air trap. Temperatures at F are slightly lower than the presumed MAST, indicating that it is probably nearer to the known cooling entrance than to the undiscovered upper one; its overall temperature stability, however, is indicative of its isolation from both entrances.

The above two caves illustrate the impact of seasonally reversing air flow in multientrance, multilevel caves. Cave number 6 of Figure 2 illustrates a more subtle example of seasonally reversing air flow. Its moderately large, sloping entrance, simple structure, and the distribution of volume both above and below entrance level allow year-round air flow through the single entrance. When outside temperature rises above internal cave temperature, cool air spills out the bottom of the entrance. The "negative pressure" so created enhances movement of warm air through the upper part of the entrance into the upper sections of the cave. The size of the entrance is sufficient to allow the two opposing streams of air to pass simultaneously, and they are easily detected by an observer. In winter the relatively warmer cave air will rise through the entrance, being replaced by denser, colder air from outside (air flow arrows would reverse directions). In this type of cave, relative velocities of flow, summer versus winter, depend on the amount of volume above versus below the entrance.

It is important to note that the two ends of the cave will have their major circulation at different times. The lower end will have greatest air flow in winter, and be a cold air trap in summer; the upper end will have greatest air flow in summer and act as a warm air trap in winter. Periods of temperature stability (deviating from MAST in opposite directions within the same cave) will be much longer and more predictable in this cave than in caves 1 or 2 of Figure 2. The range of temperatures between points C (below MAST) and D (well above MAST), and their relationship to MAST and the outside temperature illustrate the difference between the two "trap" areas. The narrow, undulating passage creates a relatively stable MAST regime beyond F. On the day of observation there was no detectable air flow at B and C despite the rapid movement of air above. The outward moving flow of air along the ground outside (1.5 m below the point registering 26.7°) was 18.4°C.

Nonreversing Air Flow

Cave number 3 of Figure 2 illustrates the impact of having all of the cave volume above entrance level. Its air flow pattern is like that of Type 5, Figure 1, although its elevational rise is only slight. The room containing C and D is a warm air trap, as demonstrated by an August temperature considerably in excess of MAST. Despite strong winds which buffet the entrance from across a large reservoir, the large entrance size (2 m high by 11 m wide), the cave length of only 76 m, a direct, relatively unobstructed path from the entrance to the innermost volume, and its relatively small total volume, this cave does not become cold in winter; the warm air is trapped and very little flow occurs. Even at the end of a record cold winter in

1977, location D remained slightly above the local MAST. If there were a strong upward slope between points B and D and/or if the volume from C to D were greater in an upward direction, this cave's winter temperature would be even higher. Nevertheless, its annual average is well above that expected based on MAST.

Some of the most remarkable thermal gradients known to occur in caves are found in those which have "sack" structures similar to that illustrated in type 4 (Figure 1). A cave located in eastern Tennessee (see Figure 3), where the MAST is approximately 14°C illustrates this. Entrance A, just above the rim of a large sinkhole, slopes upward into the main chamber; entrance C, located 11 m below the rim in the bottom of the same sink, slopes down into the cave. Entrance B, slightly below C, opens directly into the main chamber. In summer, cooled air from the upper portion of the chamber spills out into the sink, which acts as a large dam. Consequently, on 18 July 1976, when the outside temperature at the rim of the sink (site 1) was 23.6°C, the temperature near the bottom of the sink (site 2), outside entrance C, was 14.0°C (approximately MAST). A thermal range of 6.7 (site 3) to 23.5°C (site 4) existed in the main chamber (35 m tall, 54 m long and 12 to 20 m wide). A mild negative pressure created by the escape of cold air probably aids in drawing warm summer air in through A and B; the temperature at the very top of the room may have been even warmer than that recorded at site 4. Though slight air flow is possible in summer, the cave's only strong air flow is limited to periods of cold winter weather. Multiple entrances and its greater overall volume above the highest entrance and below the lowest one, allows this cave to function as a more efficient cold and warm air trap than cave 6, Figure 2.

Data from a second cave of very similar structure illustrate an annual temperature cycle in such a cave (Figure 4). Again, there is an elevational increase (roughly 35 m) from the bottom of the cave's main, large room to the cave's upper entrance. In this cave the main entrance room is 46 m long, 18 m wide and 15 m high, with several major passages extending out to the sides and downward. A single large canyon passage approximately 25 m tall and 1.5-2 m wide connects the lower cave to an upper room that is approximately 27 m long, 18 m wide and 4 m high. The upper room exits to the surface at a level about 1 m below its upper end through an entrance less than 1 m in diameter. The larger lower room is entered through either of two

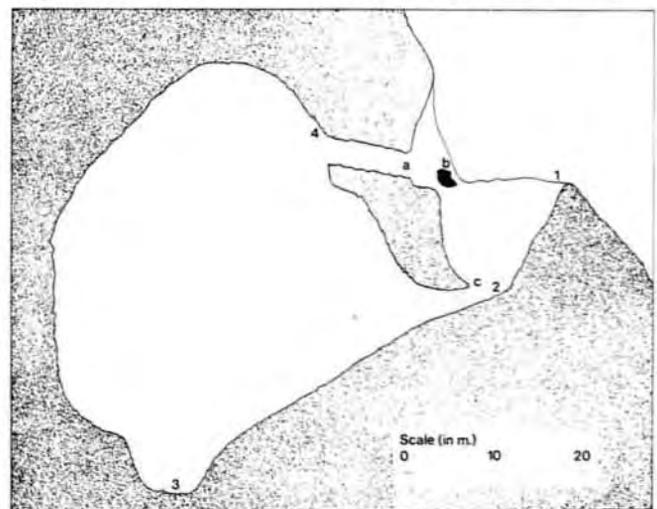


Figure 3. Cross section of an eastern Tennessee cave which acts as both a cold and warm air trap. Air circulation is greatest in winter.

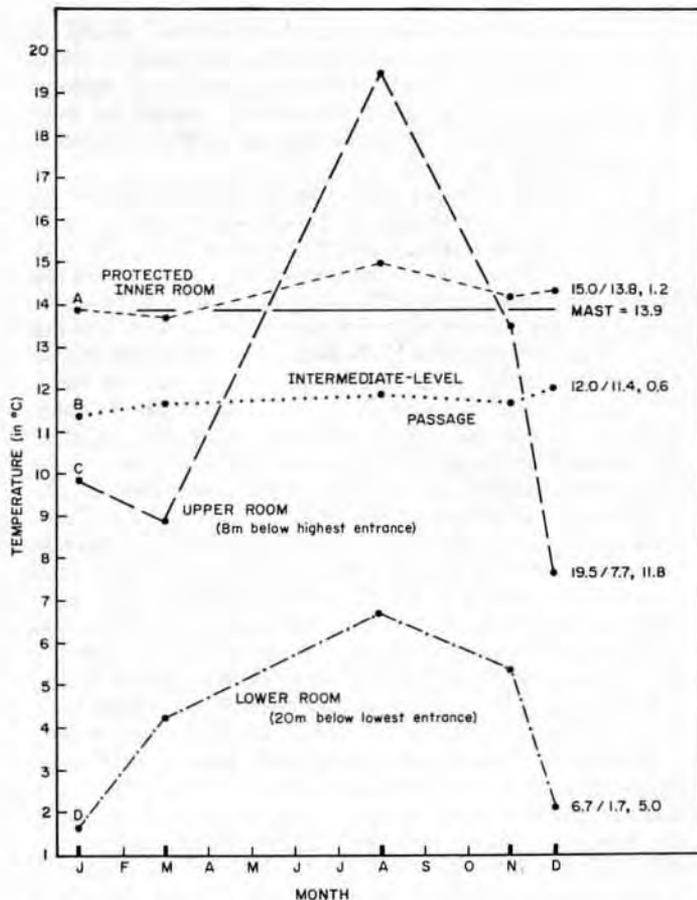


Figure 4. Air temperatures (maximum/minimum, number of degrees in the range) at four sites in a northeastern Tennessee cave on 18 November 1975, and 13 January, 9 March, 1 August and 20 December 1976. The cave is similar to Type 4, Fig. 1, with the addition of a warm air trap near entrance B. MAST = mean annual surface temperature.

entrances near the upper end of its ceiling, both of which average about 1 m wide by 2 m high. Though this cave is more complex than the last, it serves as another good example of the fourth type shown in Figure 1.

The record of air temperature from location A (Figure 4) in this cave is from a deep, inner room, protected from air flow by a very narrow irregular passage and several vertical turns that act as ideal dams (as in Figure 1, example 2) against flow of either warm or cool air. As expected, air temperature there closely approximates MAST and shows an annual fluctuation of only 1.1°C. Even this small fluctuation is thought to have been caused by the occasional use of the room as a roosting place for several thousand bats. Location B was in a major side passage roughly half way between upper and lower levels of the cave. Here air temperature varied by only 0.6°C, despite relatively free circulation of air, but constantly was below MAST. Site C was located in the uppermost room 18 m from the upper entrance. At this location small amounts of cold air "leaked" in, lowering temperatures in winter, while slight summer loss of cool air from the lower entrances created sufficient negative pressure to draw warm outside air down into the room, resulting in a nearly 12°C annual fluctuation. The temperature record for site D, located near the bottom of the main, lower room, 40 m from the lower entrances, shows

an annual fluctuation of 5°C with the annual high temperature still 7.3°C below that expected based on MAST. Its large volume below the lowest entrance makes this main room an exceptionally efficient cold trap.

As in the previous example, the lower entrances were surrounded by a deep sinkhole which reduced loss of cold air. Summer air movement was slow enough that it was detected only at the small upper entrance. During cold winter weather a strong flow of cold air enters the lower entrances, while relatively warm air exits through the single upper entrance.

Air Flow Prevention

As previously discussed, lack of elevational differences between multiple entrances, small entrance size (particularly in single-entrance caves), and natural dams can reduce or nearly eliminate air circulation. When these characteristics are present, singly or in combination, the result generally will be caves or sections of caves with the relatively constant temperatures of popular legend.

Cave 5 (Figure 2) provides a very simple example of the impact of a small entrance. The entrance passage into this cave includes a 5 meter-long horizontal section that is only ¼ m in height and 1.5 m wide. With an enlarged entrance, this cave would be of type 1 (Figure 1) and would fall well below MAST in winter, yet due to its restrictive entrance size and shape, its average air temperature on 6 February 1976 was less than a degree below MAST. The 18.8°C temperature near the lowest point in the cave may have reflected the impact of cold surface water flowing into the sinkhole entrance during winter rains. A prominent factor in reducing air exchange with the outside in this cave is the cross-sectional shape of the entry passage. If the passage were simply turned 90°, placing its greatest width in a vertical plane, this cave's annual temperature fluctuation likely would increase considerably. Warm and cool air could then exit and enter simultaneously.

Surface Wind

Cave 4 (Figure 2) of this study illustrates the relative ineffectiveness of surface wind, even on a tunnel-like cave only 17 m long with two entrances (4.9 m wide by 1.4 m high and 3.5 m wide by 0.8 m high). Although a 15 KPH surface wind was blowing in the same direction as the cave passage, the air temperature in this cave at 1700 on 6 February 1976 was more than 7° below the outside temperature and approximately 5°C below MAST. Despite this cave's small size, simple shape, relatively large entrances, and its directional orientation, the surface wind had only moderate impact; slight directional air flow along the cave ceiling in the expected direction was noted, and the 3° difference between air and wall temperature demonstrated that a relatively rapid rise in air temperature had occurred during the day. This cave and cave 3 (Figure 2) demonstrate that surface winds probably have little effect on any but the smallest and simplest caves.

EFFECT OF WATER ON CAVE TEMPERATURE

A central Tennessee cave with a single vertical entrance (6 m deep and 4 m in diameter; located in the bottom of a shaded, 8-m-deep sinkhole) provides an excellent example of the potential impact of surface water on cave temperature. A 100-m section of passage below the entrance averages 11 m wide and 3 m tall and would be expected to have an

average air temperature below the mean annual surface temperature of 14°C. Even if air circulation were poor, a cave below such a single sinkhole entrance should not exceed MAST. However, on 30 July 1976 we found that the air temperature 90 m inside the described large passage was 21.1°C, some 7°C above MAST. This could be accounted for only by the presence of a large stream flowing through the main passage below the cave entrance. Though the stream clearly fluctuates in size, at the time of our visit it averaged 7 m wide, 0.25 m deep, and was flowing rapidly.

At its point of entry, the water temperature was 21.3°C (0.2°C warmer than the air 2 m above), but 90 m downstream it already had lost 0.1°C to the surrounding cave. Cave air at that point (nearly directly below the entrance) was 20.3°C. Approximately 100 m farther downstream the air temperature was 19.4°C. At this point an upper level passage, averaging about 2 m in diameter, slopes very slightly upward and continues for at least 100 m, and probably much farther. Air temperatures near the ceiling 25 and 75 m into this side passage were 17.2 and 15.3°C, respectively. At 95 m, just past the first downward dip in the passage, the air temperature near the floor was 14.3°C, approximating the expected temperature based on MAST. Clearly, the high temperature of this cave's stream had measurable impact on the cave's air temperature, even at a considerable distance beyond the main stream passage. Due to the structure of the cave's single entrance, it is very unlikely that warm air entered from outside.

While working in caves of northwest Florida in winter, we repeatedly observed not only the impact of cold surface water, but also that of deep pools of subterranean water. Two caves less than 5 km apart illustrate these temperature differences. On 3 February 1976 the first cave was approximately half-full of surface water from winter rains, and the water temperature was 11.4°C. Air temperature 1.5 m above the water ranged from 11.3 to 12.4°C. The second cave, visited 5 February 1976, sloped sharply downward from its 2-m entrance and had an easily detected flow of cold air along its floor, with warm air exiting along the ceiling. Despite these characteristics (which favored entrapment and storage of cold air) its air temperature 28 m inside and 1.5 m above a pool of water roughly 30 m long, 12 m wide and more than 12 m deep ranged from 16.6 to 17.8°C. The water was of subterranean origin, and its temperature was 19.9°C, only 0.1°C above the MAST reported by a nearby weather station.

RELATIONSHIP BETWEEN AIR AND WALL TEMPERATURE

Wherever air in a cave is isolated from the external atmosphere it should come into thermal equilibrium with surrounding cave walls. As already noted, the locations of such protected places are highly predictable, as are the locations of probable large differentials between air and wall temperatures. The magnitude of difference in air and wall temperature provides a test of one's assumptions regarding constancy of temperature for any given location: areas of assumed constant temperature should show consistent equilibrium of air and wall temperatures. (It should be remembered, however, that even areas of great fluctuation may frequently exhibit air/wall temperature equilibrium, for example, during sustained periods of minimal air flow.)

Air/wall temperature differences should be greatest near cave entrances where air enters. Near such "sucking" entrances, air temperature should average above wall temperature in summer, while it should average below wall

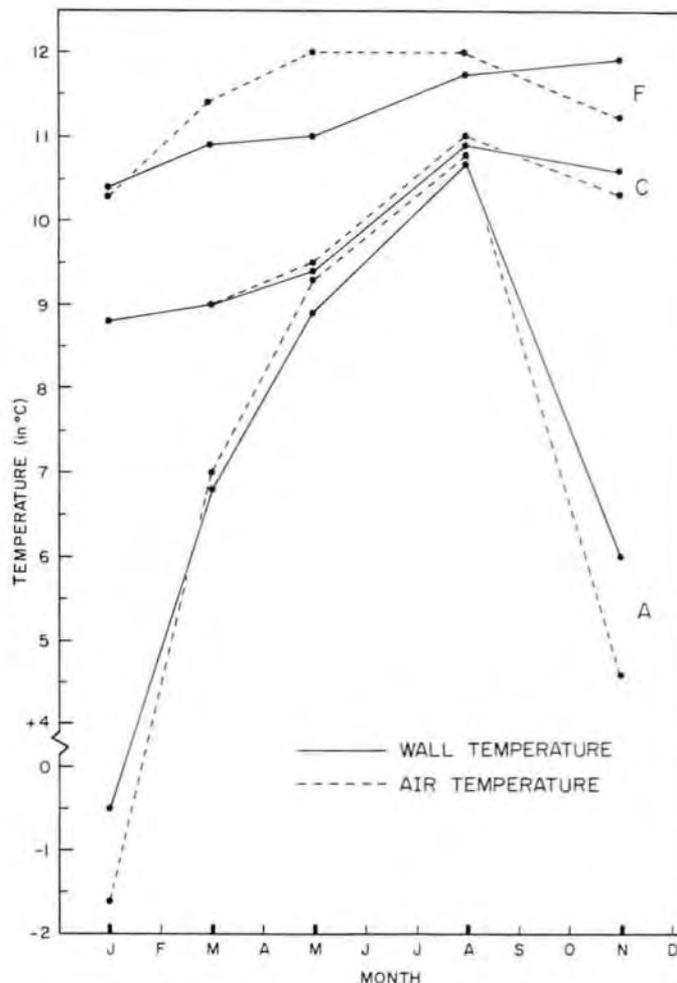


Figure 5. Air and wall temperatures through a seasonal cycle at 3 sites in cave number 2, Fig. 2. Dates of the measurements are 15 November 1975, and 10 January, 6 March, 16 May and 18 August 1976.

temperature in winter. However, these expected differences will decrease with distance of air flow through a cave, so that even rapidly moving air exiting through distant entrances may have reached equilibrium with surrounding walls.

Accordingly, analysis of air/wall temperature differences (Figure 5) in cave 2 of Figure 2 provided additional evidence in favor of the existence of a second, unknown entrance, as noted previously. Near the known entrance (site A), which "sucked" air in winter, the greatest differences between air and wall temperatures occurred in November and January (air temperature below wall temperature). Differences were very small in March, May, and August (with air slightly higher than wall in temperature, and both still below MAST), when the entrance was "blowing." The reverse was true at site F near the end of the known cave, on the way to the undiscovered entrance; the greatest difference occurred in May (air higher than wall temperature), and the least in January. Clearly, "warm" air was passing this location during the spring on its way from the undiscovered to the known entrance. The relative slowness of wall temperature response to air temperature fluctuations is pointed out by the August-November and January-March readings at sites A and F where air temperature drops below wall temperature with the beginning of cold weather, and rises above wall temperature in spring. Finally, site C, which is

relatively isolated from either entrance and from air flow (as noted previously), exhibits the expected minimal air/wall temperature difference.

When comparing differences in air and wall temperatures it is important to remember that, regardless of season, both the amount and direction of air flow will be determined by the amount and direction of differences between inside and outside temperature. These differences may fluctuate widely, not only as a result of the passage of storm fronts, but also on a daily basis, due to night-day changes. Although we visited the respective locations of temperature measurement in cave 2 at approximately the same time of day each visit (to maximize comparability of readings among visits), we recorded several day-to-day and within-day fluctuations between air and wall temperatures at location A in order to illustrate the potential extent of such fluctuations.

On 28 December 1976 the air temperature in front of the known entrance was $+8.6^{\circ}\text{C}$ at 1145 hr and -2.8°C at 2250. At 1200 the air temperature at location A was fluctuating from 5.8 to 6.1°C , and the wall temperature was 3.9°C . (Unfortunately no temperatures were recorded at location A at 2250.) Clearly, outside temperatures during the previous night had fallen well below freezing, and the cave walls, cooled by that incoming night air, were now being warmed but were still cooling incoming air to below the higher daytime temperature.

The reverse situation is well illustrated by data from the following exceptionally cold day. At 1250 on 29 December 1976 the outside temperature was -6.1°C , and at 1935 the temperature had fallen to -8.2°C . Inside the cave at 1300 the air temperature at location A was fluctuating from -3.3 to -2.9°C , and the wall temperature was 0.8°C . At 1925 the air temperature at this site had continued to fall, varying from -4.7 to -4.5°C , and the wall temperature was -1.4°C . On this day continually falling outside temperature prevented the situation recorded on the previous day when inflowing air was warming the cave walls. On the second day incoming air ranged 2.1 to 3.3°C lower than wall temperature, as opposed to 1.9 to 2.2°C above wall temperature on the previous day. The first day's data are undoubtedly more representative of average daily cycles.

These data probably can explain the contradiction between our findings and those of several previous authors who claimed that wall temperatures in caves are normally about 1°C lower than that of adjacent air masses (Twente, 1955; Nieuwenhoven, 1956; Hall, 1962; McNab, 1974). These researchers limited their investigations to winter studies of hibernating bats. Bats normally hibernate in caves whose structures act as cold air traps, and such caves tend to take in more and colder outside air at night than during the warmer days. By mid- or late morning, when researchers generally arrive at their caves, air flow often has slowed considerably and may have stopped altogether. Nevertheless, the last air drawn in was probably considerably warmer than the coldest night air, leading to the observation that air temperatures are generally higher than those of adjacent walls.

RELATIONSHIP BETWEEN AIR MOVEMENT, TEMPERATURE, AND HUMIDITY

A thorough study of cave humidity and the subtle interrelationships between humidity and the many factors that may bear upon it is far beyond the scope of our research. We did, however, make sporadic comparisons among humidity, temperature, and air movement in 10 of the caves investigated. Substrate type, ground moisture,

and the presence of streams or standing water all contribute to basic cave humidity levels. Superimposed upon these basic factors, rates of air flow, nearness to a "sucking" entrance and the humidity and temperature of air entering from outside compared to existing cave conditions were found to be of importance in determining daily and seasonal patterns of humidity.

Regardless of season or temperature of the inflowing air, relative humidity was lowest near the entrance where outside air entered. A gradient of increasing relative humidity existed between the places of entry and exit of the flow. Further, in caves with seasonally reversing air flow, passages that have low relative humidity at one season may have high relative humidity at another. These patterns are illustrated by our recordings from cave 2 (Figure 2). On 10 January 1976 when air movement was past locations A, B, H, G, and E, in that order, sample relative humidities were as follows: B—49 percent; halfway between H and G—82 percent; halfway between G and E—86 percent; halfway between E and D (upper cave: air flow nearly nonexistent)—98 percent. The movement of outside air through the cave clearly affected relative humidity levels along its route. On 16 May, when the direction of air flow had reversed (passing from E to D, C, B, and A), the relative humidity halfway between E and D had dropped as expected (to 88 percent). No other measurements were taken on that visit.

Strong air flow has been considered by some to be closely associated with low humidity throughout a cave (Vandel, 1965; Barr, 1968). Although it is true that air flow often can be a desiccating influence, particularly near "sucking" entrances in winter, ground moisture or areas of water can increase relative humidity of even strongly flowing air to near saturation as it passes through the cave. For example, despite the fact that troglomorphic trechine beetles are limited to areas where the relative humidity is 98 percent or above (Barr, 1959), a number of individuals of three species have been observed feeding in a "wind tunnel" in a Kentucky cave where the air flow exceeded 40 m per minute (Barr, 1968). Barr seemed puzzled by this apparent contradiction, but we suspect that the contradiction was only apparent—as we have pointed out, rapidly moving air in caves is not necessarily dry. One of us (Tuttle) once made a similar observation of trechine beetles in a "wind tunnel" in a Kentucky cave; the relative humidity was 98 percent, despite the strong air flow.

In reference to the relationship between the total volume of air flow through a cave system and the cave's humidity, it also is important to note that air flow rates will vary greatly in different sections of the cave even along the main route of flow. For example, in a single passage, diameter and shape may vary dramatically, so that a given volume of air flow through the area would be rapid and potentially very influential on humidity in a narrow section while remaining virtually undetectable in a very large area. Within the parameters discussed in this section, however, our limited data indicate that overall patterns and timing of relative humidity changes are largely correlated with, and dependent upon, predictable daily and seasonal patterns of air flow.

Finally, although it is usually relative humidity which is reported in the literature, it is important for cave biologists to keep in mind the distinction between this measurement and absolute humidity (mass of water vapor present in a unit volume of atmosphere). In some instances the two measurements follow the same relationship from site to site. This is the case for the cave 2 example above—absolute humidities (in the same site order, in g/m^3) on 10 January were 2.6, 7.5, 8.0 and 9.9. The 16 May absolute humidity had

dropped to 8.8. In other cases, high relative humidities at low temperatures actually may be more potentially desiccating than lower relative humidities at higher temperatures, due to the lesser amount of water vapor present in the air in the former case. For example, in the cave discussed in Figure 4 the relative humidity at location C on 10 January 1976 was 99 percent. On 1 August 1976 it was only 92 percent. Although the August relative humidity was lower, absolute humidity was nearly two times higher—15.5 g/m³ in August versus 8.4 g/m³ in January. In a similar cave (Figure 3) the relative humidity on 18 July 1976 was only 70 percent in the path of incoming air (site 4), while it was 100 percent at the floor of the same room (site 3) and 99 percent just inside entrance C (where air exited very slowly). These relative humidities follow the pattern discussed in the paragraph above but, due to the great temperature gradient in the room, absolute humidities (14.1, 7.6 and 8.8g/m³ respectively) are totally reversed in relationship among sites. Temperature of the air, due to its effect on absolute humidity, must be included in the list of factors considered in evaluating the impact of a cave's humidity regime on its faunas.

BIOLOGICAL IMPLICATIONS

Humidity is a very important environmental parameter for many terrestrial cavernicolous animals (Barr, 1959, 1961, 1967; Vandel, 1965). Cold dry air entering a cave in winter, as it warms inside, certainly can be a desiccating influence to organisms in that area. In particular, respiratory water loss for an animal with a body temperature warmer than the air will be more severe the greater the temperature difference. It is important to note, however, that besides the large-scale factors influencing humidity (discussed in the previous section), a number of other considerations influence the effect of given levels of air flow and humidity on organisms. The size of the boundary layer associated with a particular organism's coupling with its environment is proportional to the size of the organism and the roughness of the substrate on which the animal rests, as well as to the wind speed (see Juberthie, 1969, for a cave study of microclimate). Substrate moisture in many situations, then, may be of more importance to small arthropods than air moisture. In other words, in addition to the fact that flowing air in a cave is not always dry, different organisms in a particular area of cave in fact may be exposed to very different environments—low air humidity (relative or absolute) may have little effect on a small terrestrial arthropod on a rough, moist floor compared with its effect on a bat.

Air flow, despite its potential for lowering humidity, should not be assumed to be entirely bad for most or even any cave organisms. It may be of considerable importance as a directional cue for some cave animals. Trechine beetles are reported to be highly sensitive to air flow (see Barr, 1968), and two species of cave crickets (*Ceuthophilus conicaudus* and *Hadenoecus subterraneus*) are believed to use air currents in their orientation to and from cave entrances (Reichle *et al.*, 1965; Campbell, 1976; Levy, 1976). Additionally, air flow and associated patterns of temperature and humidity are as predictable in many caves as are many other cues that are used by surface animals. Many cavernicolous animals are thought to be extremely sensitive to even slight changes in air flow, temperature, and humidity (Barr, 1959, 1961, 1964, 1967; Vandel, 1965), and the role of air flow as a seasonal or daily cue may be of major importance in some caves.

Beyond the cue effects of air movement and temperature,

temperature directly affects a variety of troglonexes (animals that live in caves but cannot complete their life cycles without leaving caves). Bats will be discussed in detail later. Our casual observations indicate that cold caves which harbor hibernating bats often additionally serve as hibernating sites for a variety of otherwise surface arthropods (e.g. culicine mosquitoes and the noctuid moth *Scoliopteryx libatrix*) that were not often found in warmer caves. On the other hand, these same cold caves rarely contained amphibians, such as *Eurycea lucifuga* and *Plethodon glutinosus* (even when relative humidity remained high), which often were abundant in other caves nearby. Even if the major effects of air movement and temperature were limited to determining the within and among cave distributions of such troglonexes as bats and cave crickets, they ultimately could exert strong indirect effects on troglotic (animals that are so highly specialized that they cannot live outside of caves) and troglophilic (animals that often live their entire lives underground but also can live in moist places under rocks or logs on the surface) cave animals that depend on these animals as primary sources of energy.

Dependable food sources in a cave environment are of vital consequence to its fauna; whether they be guano from bats and crickets, entrance litter, or detritus from floods, supplies vary seasonally (Barr, 1967). Strong selective pressure must exist for the development of responses to such available cues as changes in water temperature, pH and oxygenation (for aquatic animals), air flow, temperature and humidity (for terrestrial animals), and flooding. In fact, initial studies indicate that many troglotes, both terrestrial and aquatic, use seasonal flooding to time peaks of reproduction (see Barr, 1968; Poulson and Smith, 1969; Juberthie, 1975, among others).

Clearly, the potential impact of the above environmental factors in determining species survival and distribution is great and the problems complex. We make no pretense of understanding more than the potential importance of these variables. It is important, however, to note the extent to which the environment of the cave depends on its exchange of air and water with the outside. Hopefully, our discussion of cave structure and the causes and predictability of daily and seasonal patterns of air flow, temperature, and humidity will act as a stimulus for much further investigation of these potentially important environmental parameters.

Temperature Constraints on Cave Bats

For most bats, and especially for cave dwelling species, the selection of appropriate roosting temperatures is of critical importance (Harmata, 1973). Twente (1955) noted that it was vital for bats to choose roosts with temperatures appropriate to the desired metabolic processes: warm for digestion and growth in the summer, and cool for torpor in the fall and winter, with the exact optimum temperatures varying somewhat among species. McManus (1974) found that hibernating *Myotis lucifugus* in a New Jersey mine "demonstrated a clear preference for temperatures near 2°C," the temperature at which Hock (1951) found the species' oxygen consumption to be lowest. Harmata (1969) demonstrated that *Rhinolophus hipposideros* could select "the proper temperature of hibernation" with accuracy as near as 0.8°C.

Whatever the mechanism of selection, microspatial distribution preferences and movements along temperature gradients also have been demonstrated in summer roosts of

many species, with clustering playing a role in behavioral temperature regulation then as well as in winter (Licht and Leitner, 1967; Harmata, 1969, 1973; Tuttle, 1975; Trune and Slobodchikoff, 1976, among others). A number of authors have noted the high metabolic cost of the wrong ambient temperature for bats (Hock, 1951; Herreid, 1963; Stones, 1965; Davis, 1970; McManus, 1974).

For cave dwelling species, caves with roosts of appropriate temperatures are limited in number. At extremely high latitudes caves may be too cold for use at any time. At somewhat lower latitudes, where MAST ranges 2 to 12°C, caves often provide appropriate hibernating quarters but are normally too cold to permit summer use. In areas of intermediate latitudes (MAST 12 to 20°C), most caves are too warm in winter and too cold in summer, and few are used by bats in any season. At lower latitudes nearer the equator, increasingly warm caves are ideal for maternity use but unsuitable for hibernation (Dwyer, 1971).

Throughout most of the cavernous areas of the United States, caves are of the intermediate type with regard to temperature. Consequently, although bats may be able to utilize them in spring or fall when their temperatures may be acceptable (Harmata, 1973), most U.S. caves are unsuitable for bat use for summer nurseries or winter hibernacula. Thus, those species that use caves are often severely roost limited. (The problem is compounded for species which use caves in summer, since the cave must have not only appropriate temperatures available but also must be close enough to proper feeding habitat.) Distribution of caves of appropriate temperature, then, likely plays an important role in the determination of many distributional boundaries (McNab, 1974; Humphrey, 1975).

For example, although numerous caves and mines exist in Utah, Twente (1960) concluded that virtually all were of inappropriate structure to provide temperature ranges essential to bat hibernation. He did not find a single suitable cave or mine among more than 500 examined. Additionally, the endangered gray bat (*Myotis grisescens*), a species which uses caves year-round, appears to be limited in its north-south distribution primarily by the absence of warm caves for rearing young in the north and by a lack of cold hibernating sites in southern caves (Tuttle, 1975, 1976). Few caves anywhere within its range provide roosts of appropriate temperature, and even in Alabama, where gray bats probably were once most abundant, this species is not known to have ever occupied more than 2.4 percent of the area's 1635 known caves in summer or 0.1 percent in winter (Tuttle, in press). This is despite the fact that this species is behaviorally able to reduce thermoregulatory costs during summer by clustering together in large numbers in ceiling domes or in restricted passages where heat can be trapped (Tuttle, 1975), thereby utilizing otherwise marginal caves.

Since most U.S. caves are in the intermediate, unusable range of temperature, cave bats generally are forced to select the very few caves that have structures permitting them to deviate well above MAST (for summer use) or below (for winter use). Structures of caves chosen for winter hibernation are easily predictable. Except at high latitudes or elevations, they almost invariably fall into categories 1, 4, 6 or 7 (Figure 1). Of these, Type 4 is by far the best. Without a cold air trap, Type 6 does not provide adequate stability. A midwinter period of outside warmth could prove highly detrimental to bats (many of which cannot go out to feed) hibernating in a simple cave of this type. A small, simple cave of Type 1 could prove equally unsatisfactory in an unusually cold winter. Accordingly, among the eight largest

bat hibernating caves known in the Southeast, five are of Type 4 and three are Type 7. All of these occupied caves are large and have structural complexity adequate to provide temperatures ranging from near freezing to 12 to 15°C.

Summer maternity roosts usually are restricted to heat traps, especially in caves of Type 6 (if a trap exists) and 5 and 7 (where the rooms marked "X" probably would be best). *Myotis grisescens*, despite its ability to heat summer roosts by aggregating in large colonies, still prefers caves of these types; one of the largest maternity colonies ever known existed in Cave 3 (Figure 2), a Type 5 cave. Although few observations of summer cave colonies of *Plecotus rafinesquii* have been made, the several maternity colonies observed by us in southeastern caves each numbered fewer than 200 individuals. Such small colonies lack the ability to heat roosts of marginally low temperature, and as might have been expected, each was located in a heat trap of the kind illustrated by Xs in Types 5 and 7 (Figure 1). Temperatures in these roosts were all between 21° and 25°C, although MAST ranged only 14° to 16°C. Other examples could be presented, but it is sufficient to point out that bats must either abandon caves during the maternity period, seek exceptionally efficient heat traps near cave entrances, or heat their cave roosts by clustering together in very large numbers on domed ceilings (a strategy for which any benefit must be balanced against the cost of increased intraspecific competition for food). Successful growth and survival of young gray bats depend on the success of one of the last two strategies (Tuttle, 1975).

Finally, the ideal bat cave is generally one which offers a large thermal range. Ability to move among temperature zones within a cave can allow bats to control embryonic development (thereby synchronizing parturition time—Racey, 1969; Dwyer and Harris, 1972), to achieve deeper torpor when stressed by inclement weather during summer or when fat acquisition becomes important in late summer, or to adjust to temperature fluctuations throughout a season or between years. Obviously, structural and elevational complexity and increased cave size generally will contribute to this desired thermal range. Tall canyon passages often provide especially suitable temperature gradients for winter hibernation.

It is rare for any one cave to provide sufficient thermal complexity for year-round occupation; seasonal migration between caves is usually necessary for bats which use caves year-round (see Tuttle, 1976). Two caves discussed in this paper, however, are important to bats both in winter and summer. The cave (discussed in the section on Non-reversing Air Flow) from which the readings in Figure 4 were taken houses one of the largest winter populations of *Myotis grisescens* known, as well as a sizeable summer bachelor colony of the species. The hibernation roosts are in areas of the cave which are protected from freezing but are well ventilated by cool winter air; the summer roosts are in warm areas much higher in the cave.

The second such cave, Cave 1 of Figure 2, contains the largest summer colony of *Myotis grisescens* known. The main roost, located in the dome-like area around H, is warmed by the summer air sucked in from entrance K by the strong air circulation discussed previously, and by the body heat of the colony of 128,000 bats (formerly more than 250,000). In winter, the appendix-like area (F), due to its configuration and location, traps and stores air of low temperature, providing a hibernation roost of relatively constant temperature for a number of bat species, including *M. grisescens* and *M. sodalis*.

MANAGEMENT IMPLICATIONS

Choosing Caves for Protection

Clearly, knowledge of cave structure and its relation to temperature and humidity is of potentially great importance in predicting species distributions within and among caves, and in determining the relative merits of any given cave for protection. Data on such factors as number, size, shape and location of entrances, internal passage size, contour and slope, distribution and amount of volume relative to cave entrances, and source and amount of water flow (if any), can be used to predict and/or verify the probable seasonal temperature and humidity regime of a cave.

Given the limitations of resources, time and manpower, it often is important to establish criteria for recognition of caves of special or unique merit. Obviously no single structural type can be singled out for exclusive protection, since each cave type presents a potentially different setting for the evolution of different faunas and survival strategies. In fact, a wide variety of cave types should be protected. For example, caves that are good for bat hibernation may not be good for some terrestrial cavernicoles, and vice versa. Frequently the object of cave protection is centered around one or two endangered species. In such situations it is vital to ascertain not only the species' temperature, humidity, and other microhabitat requirements, but also its food requirements and sources when relevant, in order to guarantee that all important parameters are adequate.

For bats, when food supply availability and other external variables are equal, caves of greatest structural and therefore thermal complexity generally are best. Nevertheless, in the case of maternity colonies, where warmth is of primary concern, even simple caves (for example cave 3, Figure 2) may be of great importance. Also, in the case of endangered bats, their present usage of a cave often is not a reliable indicator of its suitability for use. The best caves often have been heavily disturbed and now contain very few bats. On the other hand, other nearby caves, of very marginally suitable temperature but less disturbed, may contain more bats. In many cases the most important cave, in terms of the species' longterm survival, is the one that presently has few bats.

A good example is illustrated in Figure 3. As a result of this cave's popularity with local cavers, it has not housed major bat populations for perhaps as long as 50 or more years. Although no bats were present at the time of our visit, scattered recent droppings indicated that some bats continue to visit the cold area at night in the summer and probably in the fall. If the cave were protected, it could potentially become an important bat hibernating site, as it undoubtedly once was prior to disturbance. In addition to its cold trap characteristics, which make it suitable for hibernation, there is evidence (in the form of feces) in the warmest area which indicates that some bats continue to attempt to use the area as a summer roost. Similarities with known roosts suggest that the species involved may be *Plecotus rafinesquii*. In this case as in many others, then, the cave's structure and resulting environment can tell more about its importance to bat populations than does its present degree of usage. This is almost certain to be true for caves valuable to other animals as well.

Means of Protecting Caves

Knowledge of factors affecting cave environments also is of great importance in determining the proper means of cave protection. In a number of instances, improper gating of

caves has reduced or destroyed the bat populations intended for protection, either through reducing free access by the bats or reducing the air flow necessary for maintenance of appropriate temperature and humidity (Mohr, 1972; Tuttle, 1977). Creation of additional entrances also can have disastrous results. Specific recommendations for cave protection through gating or fencing are provided by Tuttle (1977). In brief, structures which in any way alter air flow should be avoided. Any structure which blocks an entrance can affect not only air flow, but also the supply of food (in the form of entrance debris) for those cavernicoles requiring within-cave sources. In general, it is sound policy to simply avoid tampering directly with an entrance unless absolutely necessary.

It is of interest to note that alterations in temperature and humidity can have negative effects not only on cave life, but also on cave formations by altering development. Furthermore, protection or destruction of one species may influence the survival of a whole group of other species; for example, protection of a summer bat colony protects the whole guano ecosystem which may be present. Another vital factor for the public and individuals responsible for caves to be aware of is that even actions outside of caves can have great impact inside; in particular, smoke from fires built in or near an entrance can be drawn into a cave, as McCavit (1975) noted. At the very least, unnecessary disturbance is the result; at the worst, whole populations of bats and perhaps other animals may be killed.

Hopefully, this discussion of the factors influencing cave environments and our examples will prove useful to those who deal with caves in a scientific, managerial, or recreational capacity. It is apparent that, at times, lack of understanding of the many complexities involved has impeded the progress of both research and protection of faunas. Improved understanding of these factors, combined with increased knowledge of cavernicolous species habitat requirements, should provide guidelines for utilization and/or protection of valuable cave resources.

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Visual Characteristics of Caves: An Informational Perspective

Dr. Thomas J. Gallagher*
Humboldt State University
Arcata, CA

ABSTRACT

The visual characteristics of caves attract the serious caver but are problematic for most of the general public. An explanation of this phenomenon is suggested by contrasting the surface landscape to the cave environment with the use of an informational model of visual preference. Caves, in general, are found to be extremely high in the "promise of information" and extremely low in "legibility," substantially the opposite of most surface landscapes. Preference patterns of different types of cave users are discussed. Inventory of caves as to specific visual qualities is proposed to help establish management goals consistent with human visual interests.

Caves, quite literally, are dark and mysterious. For many people they are threatening, to be approached with caution, adequate light, and a guide. For others, specifically National Speleological Society members and other serious cavers, the same quality of caves that repels many, is found attractive and interesting. This phenomenon can be understood through examination of the visual characteristics of the cave environment and the relation of these visual characteristics to people. That response to caves is primarily visual in origin follows from the substantial human dependence on vision for environmental knowledge. Recent research by Kaplan and Wendt (1972) and Gallagher (1977) has demonstrated that people respond to landscapes largely on the basis of visual informational characteristics. That is, a person's preference for a scene can be predicted by analysis of the scene's informational characteristics. An awareness of the viewer's past experience is also used to determine which specific characteristics will be relevant.

The theoretical model that links people, preference, and visual information has been developed by Kaplan (1972, 1973, 1975). This model, which is the first to offer a rational explanation of esthetic values, proposes that the successful evolution of the human species has occurred in large part because of the human capacity to know the environment well. Much of this knowledge, it is proposed, is gathered by highly evolved eyes and processed by an equally capable brain; one that is interested in knowing and making sense of the environment. People, it is proposed, enjoy landscapes that satisfy the interests of this information processing system. It is not surprising, if we view people as active information processors, to find preference for landscapes that are understandable or promise new information.

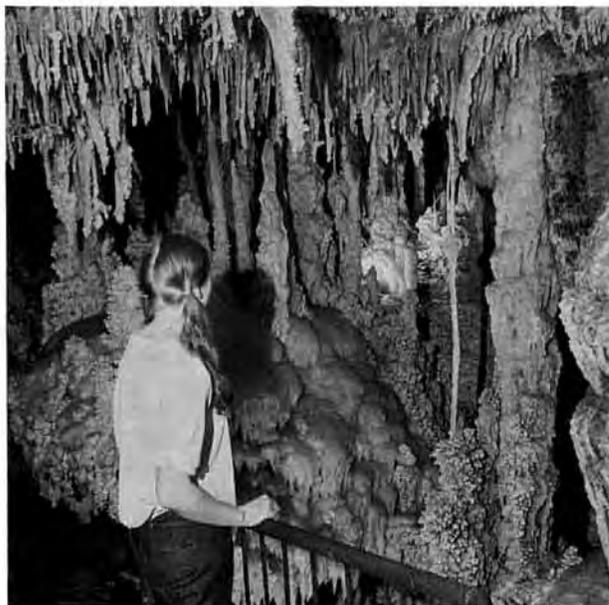
A scene that is understandable is said to be legible; it can easily be *read*. In the legible landscape there is a sense of safety and certainty, factors which attract visitors not highly knowledgeable or experienced in that particular landscape. For those visitors with a substantial *lore* in that landscape there is little concern for safety and certainty, and hence, little relation of preference to legibility. Four landscape characteristics, which are very common to most modern landscape development, have been found to relate to legibility.

1. Open space—the provision of open space provides important sight lines, as well as running room.

2. Fine texture—ground surfaces that are fine textured, such as lawn, provide additional ability to identify "what is out there."
3. Order—arrangement of landscape features in harmony with an understandable principal, such as a symmetrical pattern. Landmarks also help order the landscape by providing reference points.
4. Edge—the separation of the landscape into distinct zones, such as brush and lawn or water and land, with an abrupt edge.

Each legibility characteristic helps the viewer gain knowledge of the environment, and a sense of safety, rapidly.

The *promise of information* has also been shown to be an excellent predictor of preference, but for a different group of people. Those viewers that are not safety oriented because they already know the environment well through past experience have a strong preference for landscapes that promise a great deal of information. Viewers with legibility concerns are found to be disinterested in this factor. The following characteristics are associated with the promise of information:



Caverns of Sonora. Photo by Charlie and Jo Larson.

* Humboldt State University, Arcata, California.

1. Complexity—the provision of a diversity of things to look at requiring additional time to view.
2. Mystery—the arrangement of the landscape so that the viewer must change viewpoints to see more, and is encouraged to do so by glimpses or other indicators of more to come.

These characteristics are not as common to modern landscaping as the legibility group, being more typical of natural landscapes and overgrown gardens.

It should be noted again that different types of people prefer the two types of landscapes. Safety oriented people relate to the legibility group, while more secure people relate to the promise of information. It can be expected that any single person's preference will start with legibility, then advance to the promise of information as security and knowledge are achieved and curiosity becomes the dominant motivating force. Such a pattern of interest would guarantee early man adequate knowledge for safety's sake, and yet provide the mechanism for increasing knowledge by searching out new places.

If caves are examined in light of these groups of predictors, we find that they are definitely not legible, and that they promise an extreme amount of information.

Open space. Few caverns of adequate size exist to provide the sense of space that people require on the surface. When such large cave spaces do exist they are extremely difficult to light. Most cave spaces are claustrophobic to the majority of the population, and the smaller passages serious cavers frequent are completely outside of the experience or interests of the general public.

Fine texture. At issue here is the ability to see the ground plain clearly enough so as to recognize potential adversities. This factor is almost nonexistent in caves (except those caves in movies) because of the absence of a distinct floor. The ground surface of caves is typically extremely coarse textured and offers little ability to visually predict what lies ahead.

Order. The extreme irregularity in both horizontal and vertical dimensions, the erratic nature of walls and floor, the litter of ceiling breakdown, the lack of an overview caused by limited lighting, all work to make most caves highly disordered by surface landscape standards. Some large cave formations that develop regular patterns, such as flowstone, provide temporary relief to the disorder. Caves with major visual features that serve as landmarks help provide a sense of order.

It should be noted that a sense of order can be developed through knowledge of cave and speleothem formation processes. Knowledge of such processes, when provided by a guide or a visitor center display, assist the visitor in making sense out of what they see, and thus can help them move toward an interest in complexity and mystery, the more rewarding experience of the two.

Edge. The distinction of regions by a defined edge also has few opportunities to be expressed in a cave. On land and in developed landscapes they are quite common due to human interaction with the land. In a cave the presence of distinct zones and defined edges is limited; gourd or rimstone dams are perhaps the best example.

From this evaluation it is easily seen that caves are not the place the general public goes for frequent visits. Preference for large rooms with ordered speleothems and adequate lighting can be easily related to the legibility characteristics presented. Caves are, however, as rich with the promise of information as they are depleted of legibility.

Complexity. Caves are often diverse far beyond most surface landscapes. There may be a vast number of things to look at, and with head lamps they are necessarily viewed

incrementally. Places that on the surface could be viewed quickly therefore require a great deal of time in a cave. Headlamps, by lighting only a portion of the cave at one time, force the caver to mentally develop a total picture of the cave. Such a picture requires effort; a challenge the secure caver enjoys.

Mystery. The hallmark of the cave experience is the sense of mystery. The cave draws the visitor by changes in direction and by darkness ever farther through passages, offering new discoveries whenever a change of position is made. For the curious, the cave is an excellent source of satisfaction; the ultimate terrestrial wilderness challenging the discoverer.

Most caves can be viewed as sources of promised information and illegibility. The general public is far more likely to visit a commercial cave, where alterations such as lighting and walkways have been made, than to visit a wild cave. Furthermore, commercial caves offer guides and a crowd of people that can help one feel more secure than in a wild cave. Conversely, the serious, experienced caver would be unlikely to find a great deal of continued satisfaction in a cave altered to suit the public.

The informational approach to visual preference of surface landscapes offers a new perspective on the interests of the cave visitor, and hence, has value to the cave manager. It would appear extremely valuable for the cave manager to understand the informational characteristics of their caves so that goals and objectives can be set to fit them. It seems highly undesirable to designate a cave for general use if it is far too complex, mysterious, and illegible for them to appreciate. Encouragement of public use of a difficult cave can easily lead to accidents and other negative experiences for most visitors. Introducing this type of concern into management goals, and, thus, into the inventory process, can help match visitor interests and capabilities to a specific type of cave. Inventory techniques that measure informational landscape variables have been conducted on a limited basis for both research and management purposes. Development of measurement techniques for caves could occur rapidly given agency interest. Understanding the visual interests of cave users, and understanding the visual quality of caves, provides the cave manager with an additional opportunity to meet and overcome cave management problems.

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CAVE RADIATION HEALTH SEMINAR

Robert T. Beckman*

(Introduced by Keith Yarborough of NPS)

Yarborough:

This evening we have a presentation by Bob Beckman of the Mining Enforcement and Safety Administration, Denver Technical Support Center. He is going to describe for us the health hazards that are involved in continuous exposure to radon gas and especially the breakdown products of radon daughters in underground atmospheres such as in mines or in caves. Be aware that the atmospheres in caves are usually a lot less radioactive, in airborne alpha radiation. At any rate, in mines, forced air ventilation is used to depress the airborne alpha radiation levels, whereas in caves this is unnatural and unacceptable because of the adverse impact which such ventilation would have on caves' microclimates, biota and formations. We have good documentation of that type of effect from a microclimate study that was done in the early 70's at Carlsbad Caverns. This involved the elevator shaft which was not sealed before July 1972. Air escaping up the shaft caused significant drying of the cave, despite its great size.

Bob is going to discuss the cave radiation health hazard. Then I would like to elicit from you thoughts about possible cave radiation health standards. (A summary of the comments was not available.)

... The standards for radiation health are just a part of the overall spectrum of cave hazards which I personally feel are a subset of the even greater spectrum of cave management considerations. These, I feel, necessitate a larger scope of cave management consideration for National Park Service and all others of the caving community... Bob Beckman is going to discuss the very real cave radiation health hazard involved—given that it is very subtle and that it takes a long period of continuous exposure to this radiation in order to develop lung disease, even lung cancer. Nevertheless, it is a very real and, ultimately, a very deadly type of caving hazard. It doesn't splat you quite as flat as a rock falling on you, but it can kill you all the same.

Beckman:

The radiation health hazard present in many cave systems is a result of the migration of radioactive Radon-222 (Rn-222), formed by the radioactive decay of Radium-226

(Ra-226) present in the country rock, through the interstices of the country rock into the cave openings. This Rn-222 decays with a half-life of 3.8 days and forms Radium A (Po-218), RaB (Pb-214), RaC (Bi-214), and RaC' (Po-214) as short-lived daughters. The daughters will reach equilibrium with the radon in the cave air in about 3 hours. Any person entering this atmosphere containing Rn-222 mixed with the short-lived daughters will breathe this mixture and a portion of the daughters will be retained in the lungs. The daughters retained in the lungs continue the decay process and deliver a substantial amount of alpha energy to the lung tissue. Excessive exposure to these radon daughters causes a significantly higher lung cancer rate.

Dr. Geno Saccomanno, Pathologist, St. Mary's Hospital, Grand Junction, Colorado, has developed a sputum cytology method for evaluation of sputum samples taken from persons exposed to chemical carcinogens and radon daughters. This technique involves the collection of a sputum sample, the concentration of sputum cells, the fixing of those cells on a slide, and subsequent microscopic analysis of these cells. On the basis of this microscopic analysis, the degeneration of lung cells in the sputum can be classified and the progress of the radiation injury followed sequentially. Prolonged radiation injury generally progresses in the following sequence:

- Normal Cytology
- Mild Atypia
- Moderate Atypia
- Marked Atypia
- Carcinoma In Situ
- Invasive Carcinoma

Of course, each subsequent class indicates more degeneration than the class before it, but the analysis requires a trained observer. Dr. Saccomanno feels that once a person has reached the Marked Atypia stage, then that person will develop lung cancer, even if taken from the hazardous atmosphere. However, if the person is removed from the atmosphere before he reaches Marked Atypia, then he can recover.

Cigarette smoking seems to have a synergistic or enhancing effect on the damage caused from the alpha radiation given off by the radon daughters in the lungs. For this reason, persons exposed to radon daughters should not smoke, especially in the presence of radon daughters.

*Mining Enforcement and Safety Administration, Denver Technical Support Center, Radiation Branch.

Airborne Alpha Radiation in Natural Caves Administered by the National Park Service

Keith A. Yarborough*

Preliminary work on this program of research and monitoring for cave management purposes by the National Park Service (NPS) was reported at the 1976 National Cave Management Symposium (NCMS). The dual objectives are: to protect employee health and to determine the interrelationship between airflow and alpha radiation levels in caves as well as diurnal and seasonal variations in these. Because the 1977 Symposium focuses so intensively on cave management considerations, the more detailed scientific findings of this program will not be reported here. A detailed summary is now being prepared and will be completed in January 1978. This will cover the results of all work on this investigation and will be reported at the "Natural Radiation Environment III" meeting to be held in Houston, Texas in late April 1978.

At the 1976 NCMS, credit was given to two early "pioneers" of cave radiation work, Messrs. Richard Breisch and Jo Bob Trout, who reported in the late 1960s and mid-1970s. I have learned recently of other work done in 1962 through 1964 in several caves in Alabama by some other pioneer workers. Tom Aley has sent me copies of their papers. Louise and Bill Varnedoe, Verne Reckmeyer, and others did this work, the results of which check closely with the findings summarized by me here and at the 1976 NCMS. Bill Varnedoe wrote a letter to the editor of the *NSS NEWS* which appeared in its September 1977 issue and from which Tom Aley made contact with Bill. Their work describes cyclic airflows and alpha radiation changes as well as seasonal variations in these; the effects of wet and dry cave conditions on the radiation—the wetter conditions and/or greater airflows produced increased alpha radiation; and gamma radiation measurements. As far as I know, with one exception of a measurement made in a New York cave in 1954 (reported to me by Rich Breisch but done by S. T. Harris) this work of the earlier 1960s is the first such reported. It should be credited as such.

In summary then, working hypothesis put forward last year have been tested, verified to a great extent, but modified somewhat by additional findings. These are now stated as follows:

1. For all caves having minimal manmade disturbances to natural airflow patterns, the airborne alpha radiation increases in the summer and decreases in the winter in those caves in which the primary cause of airflow is produced by temperature induced density (gravity flow) gradients.
2. For all undisturbed caves in which the primary cause of airflows is due to temperature gradients, two general types of cave configurations have been identified in

order to relate natural cave airflows and resulting airborne alpha radiation levels:

Type I: "Upside-down" (USD) caves which go "up into" the earth.

Type II: "Right-side-up" (RSU) caves which go "down into" the earth.

These two hypotheses, and two unique cave alpha radiation/airflow exceptions which have been observed, are based on data from the field investigations; generalized and organized using Newton's Second Law for the Conservation of Linear Momentum (written here per unit volume of fluid flowing and neglecting relativistic effects):

$$\Sigma \vec{F} = \frac{d(p\vec{v})}{dt} = p\vec{a}$$

Where this is a *vector* equation, signified by the arrows:

1. $\Sigma \vec{F}$ represents the *vector summed* major force types which act on the fluid flowing. These are:
 - (a) the pressure force (\vec{P}) produced by atmospheric pressure gradients between the inside and the outside of the cave.
 - (b) the gravity force (\vec{G}) produced by temperature gradients between the inside and the outside of the cave.

Both pressure and temperature affect the density of the air, by the gas laws. Thus:

(Note: In this generalization, Drag

forces, (\vec{D}) are small because the airflow velocities and densities are usually small. Therefore, \vec{D} has been neglected for first approximations.)

2. p = density of the air (i.e.—mass per unit volume of air).
3. \vec{a} = acceleration induced in the fluid mass by the *vector sum* of the forces acting on it. (The product, $p\vec{a}$, is the "inertial force" of the fluid which *reacts* to the sum of the acting forces.
4. The derivative, $\frac{d(p\vec{v})}{dt}$ is the time rate of change of the momentum, $p\vec{v}$. (In fluid mechanics this derivative is expanded into the "substantial" or total acceleration which is composed of the local (temporal) and the con-

* Physical Scientist and Project Coordinator, Southwest Regional Office, National Park Service, Santa Fe, N.M.

vective acceleration; the latter being velocity changes in space regardless of time and the former being velocity changes in space regardless of time and the former being velocity changes in time regardless of space. These subdivisions are *not* considered here as it is the *total* acceleration of the air which is important at this point in the analysis).

Thus, the two force types interact to produce the airflow:

$$\vec{P} \leftrightarrow \vec{G}_T = p\vec{a}$$

In most natural caves investigated (both RSU and USD) the temperature gradients produce the *primary* force type by creating density differences between the inside and outside of the caves. Air then moves either into (incast flow) or out of (outcast flow) under the action of gravity. Pressure affects the air density as well as producing gradients which can cause airflows which may augment or resist the main temperature produced airflow. Exceptions are Wind Cave and Jewel Cave in South Dakota. Here the *main* force type is atmospheric pressure. Though this force type also acts at all other caves, it is secondary to the gravity force. However, at Wind and Jewel, airflows are induced *primarily* by alternating high and low pressure systems which pass through the area, as well as the location of the caves and the overall position of the Black Hills in which they are located with respect to the overall winter and summer meteorological patterns and atmospheric wave systems. Temperature (density) gradient—gravity produced flows do act, but here they are secondary to the atmospheric pressure effects. The pressure can also affect air density. Mainly, however, the passage of a high pressure system seems to "charge" the caves with higher pressure, incast air. It also decreased emanations of radon gas in the caves. This air is then released when a low pressure system enters the area following the high. The pressure gradient produces outcast airflows. Also, the reduced pressure which subsequently occurs in the caves enhances the emanation of the radon gas from the rocks and formations of the cave.

Another, less significant exception is Timpanogos Cave which has a "straight through" configuration. Its alpha radiation levels are low (less than 0.10 WL) in general, with slight increases during the summer over those of the winter. It is a small cave system situated high on a canyon wall with its main passage parallel to the canyon's axis. Both up and down canyon winds flush the cave regularly. Doors at each end of the tour route do not preclude this air movement since there are other, larger natural openings for continuous venting. This venting keeps the radiation in the cave low.

Another exception which has been observed is New Cave near Carlsbad Caverns. As Dr. Ahlstrand reports at this symposium, the radiation levels there remain about constant (at 0.20 to 0.25 WL) throughout the year, with only minor fluctuations seasonally. The reason is not clear in terms of interrelated airflows. Perhaps there is subtle air movement which has not been detected. New Cave is of the RSU type of configuration, but may have other openings for venting. No strong air movements have been observed near its main natural entrance.

Therefore, except for these anomalies, both of the two general configurations experience airborne alpha increases in the summer, compared to the winter but for opposite reasons. In *USD* caves the radiation levels increase in summer because the *airflow does occur* in a strong way, but in *RSU* caves it appears that the radiation levels *also*

increase in summer, but because the air tends to stagnate (except for weather fronts passages which may induce some airflows). How can this seeming paradox be explained?

The explanation comes from considering *how* the air tends to flow in each general cave configuration type: USD *versus* RSU. In the USD type, the airflow process is cyclic and unsteady, in general (except as perturbed by weather systems inducing pressure changes and thus, pressure produced airflows superimposed on the cave's general gravity airflows). However, in winter these cyclic flows are of short duration and occur only near the cave's entrance(s). In winter, although air may sink into USD caves upslope, it takes it a long time; *i.e.*, perhaps several days of cyclic actions, which may be interrupted by cloudy weather; to carry this air to the entrance(s). Thus, the airflows mobilize *small total amounts* of Rn per unit of time in winter and move these to the toured areas where the measurements are made. Therefore, even if in radioactive equilibrium, per unit volume, the *concentration* (*i.e.*, radiation per unit volume of air in pCi/l) levels are less. However, in summer, air moves from the cave extremities more quickly; moving *greater total quantities* of radiation (per unit time) in shorter time periods to the toured areas. Hence, the *concentrations* measured there are *higher* in summer than in winter due to high air velocities.

On the other hand, the RSU cave types have more sustained and steadier airflows *in winter* because then the colder more dense *outside* air sinks into the cave, displacing its comparatively warmer, less dense air and flushing out the radiation. This process continues in a long-term fashion so that the winter radiation levels are lower than in summer. Indeed, the airflow in RSU caves can be greater at night than in the daytime since the outside air temperature is lower at night. In summer, the reverse of this process occurs, and the cave air, being comparatively colder and denser than the outside air, tends to stagnate. Hence, the radiation levels can build up and become higher than in winter. Of course, as in the USD caves, the effects of passing weather fronts can perturbate a RSU cave and produce airflows in summer which overcome the stagnation to some extent. In winter, these can augment the gravity flows and depress the radiation levels further. Indeed, it can be speculated that the fluctuations on long-term plots might be the superposition of pressure produced airflow/radiation level oscillations on the long-term gravity airflow/radiation situation.

To the discerning, an RSU cave seen from below appears to be USD, and *vice versa*. Therefore, it is not unreasonable to expect some caves in both general types of cave configurations to be double-ended. A situation of this kind has been found to exist in Cumberland Gap Historic Park. Dr. Jim Quinlan has shown that Cudjo's Cave, the main entrances of which lie on one side of a ridge line at an elevation of about 1550 feet MSL, is connected by water flow passages with Indian Cave, which lies on the other side of and up the ridge line with an entrance elevation of about 1850 feet MSL. Airflows can also pass between the cave systems. (It also seems that three other caves, Skylight, Big and Little Saltpeper, which also lie across and up the ridge from Cudjo's Cave with entrance elevations of about 1820, 1970 and 1800 feet MSL, respectively, connect with Cudjo's.)

Table I presents data which show that, in summer, air can sink down into the RSU caves, Skylight and Indian, and flow out of the USD cave, Cudjo's. The radiation levels are low in the RSU caves and higher in the USD cave. A transition with almost equivalent radiation levels occurs during the spring when little airflow develops at either end of this cave

Table I
Seasonal Comparison of Airflows and Radiation Levels
at Cudjo's and Indian Caves

| Date | Radiation, in W.L. | | Airflow | |
|---------|--------------------|--------|-----------------------|-------------------------------|
| | Cudjo's | Indian | Cudjo's | Indian |
| 8-02-77 | 0.38 | 0.12 | outcast | somewhat incast |
| 6-24-77 | 0.44 | 0.54 | slightly outcast | slightly incast to none |
| 3-25-77 | 0.05 | 1.31 | very slightly outcast | very slightly incast to none |
| 1-22-77 | 0.03 | 1.01 | very slightly incast | none to very slightly outcast |

system. In the winter, the modest reversal of airflow produces a reversal of radiation levels.

Indian cave has a small entrance with an overhanging lip which causes an interesting and unique situation which I have seen in only one other cave—nearby Skylight. This lip greatly modifies the possibility of airflows in or out of Indian and produces a very sharp transition from outside air conditions to true cave air of constant temperature and humidity. This occurs within 15 to 20 feet of the entrance, at most. During the bitter winter weather of January 1977, cave radiation monitors entering Indian Cave went from sub-zero cold to the stable cave temperature of about 53°F in this short distance.

Skylight has a lip located about 100 feet in from its entrance. This cave has a very large mouth similar to a shelter overhang and another "skylight" opening above the main entrance. Hence it is well ventilated. In the spring and summer the radiation levels both in front and behind the lip are low, and about the same, but in winter a startling difference occurs. In all seasons the "sealing" lip tends to create a true cave air situation behind it while the outer area of the open cave is very nearly like surface air. Table 2 shows comparative data.

Table 2
Seasonal Comparison of Radiation Levels on Each
Side of Sealing Lip at Skylight Cave

| Date | Outside Lip, WL | Behind Lip, WL | Entrance, WL | Entrance Airflow |
|---------|-----------------|----------------|--------------|--|
| 8-02-77 | 0.011 | 0.010 | 0.005 | incast at ceiling, outcast along floor |
| 6-25-77 | 0.002 | 0.002 | 0.002 | incast at ceiling, outcast along floor |
| 5-08-77 | 0.005 | 0.038 | 0.005 | None |
| 3-26-77 | — | 0.580 | — | None |
| 3-27-77 | 0.010 | 0.720 | — | None |
| 1-23-77 | 0.034 | 0.176 | 0.031 | None |

Dr. Merlin Tuttle's fine paper given at this symposium discusses the temperature/density gradient (gravity) type of airflows in caves. His findings are similar to those found in the NPS investigation. Thus, the importance of the effects of natural airflows on cave radiation must always be emphasized along with radiation measurements because the basic rule of thumb is that increased radiation occurs when cave air stagnates but decreased radiation occurs in the immediate vicinity of noticeably moving cave air, in general. It seems generally true that airflow decreases airborne radiation while stagnation increases it. Any seeming paradoxes result from how the air moves through a cave system with respect to time and space. Airflows are controlled by the interaction of atmospheric pressure gradients and temperature induced density (gravity) gradients as the major force types.

NPS has the most extensive radiation data on its two largest cave systems. Dr. Gary Ahlstrand, Research Ecologist for Carlsbad Caverns and Guadalupe Mountains National Parks, discussed at this symposium the results of two years of radiation monitoring at Carlsbad and shows long-term plots of radiation level parameters and meteorological variables vs. chronological time. The NPS administered cave area which consistently has measured the highest airborne alpha radiations is Mammoth Cave in Kentucky. Messrs. Joe McGown, Danny Close and Bobby Carson have done all of this very fine work, guided by Mr. Jay Cable and Superintendent Amos Hawkins. They deserve great credit for their efforts on this project.

Table 3 summarizes generalized findings for the first full year of observation from May 1976 through April 1977. The natural airflow in this immense cave system has been modified by one elevator shaft, several constructed access entrances and certain operational practices. The most important of these latter is the placement of sheet metal covers over the gateway at the large natural, "Historic" entrance to the cave. This is done in mid to late October each year. These are removed in mid to late March, annually. This interrupts the natural airflow regime for Mammoth which is generally a USD type cave system: strongly outcast airflows during the summer with some cyclic, diurnal variations with concomitant alpha radiation fluctuations which reverse in winter to have strongly incast airflows at the Historic Entrance. (Mammoth's stable temperature is about 54°F.) General evaluation of overall flow patterns has been made for the major seasonal temperature gradient situations: (1) when the outside average air temperature exceeds that of the cave's 54°F, and (2) when the outside average air temperature was less than 54°F. This evaluation shows a general outflow for temperature gradient situation (2). However, the placement of the covers each fall causes the radiation levels to surge upward immediately. A peak is reached in about a day with a lowering of general radiation following that; probably due to equilibration of the cave system to this interruption of the natural airflow and the establishment of incast flows of lesser extent through other, though less effective entrances. Tests of alternately putting up the covers, then removing them on a weekly cycle for each position, done in mid-October 1977, show alternating upward and downward shifts in the cave's general alpha radiation levels.

In general, the overall, man-affected situation at Mammoth Cave produces a buildup of radiation levels during the winter compared to the summer when the levels are somewhat lower. It can be speculated that, without the interruption of the natural airflows and the seasonal variations in them, this huge USD cave system probably would

Table 3
General Alpha Radiation Monthly Summary Levels
Months → Radiation Levels, WL, for Mammoth Cave

| Tour Route | May 1976 | | June 1976 | | July 1976 | | Aug. 1976 | | Sept. 1976 | | Oct. 1976 | | Nov. 1976 | | Dec. 1976 | | Jan. 1977 | | Feb. 1977 | | Mar. 1977+ | | April 1977 | | Annual Averages | | | | |
|--------------------|-----------|------|-----------|------|-----------|------|-----------|------|------------|------|------------|-------|-----------|------|-----------|------|-----------|------|-----------|------|------------|------|------------|-----------|-----------------|-----------|-----------|--------------|------|
| | Range | Ave. | Range | Ave. | Range | Ave. | Range | Ave. | Range | Ave. | Range | Ave. | Range | Ave. | Range | Ave. | Range | Ave. | Range | Ave. | Range | Ave. | Range | Ave. | Range | Ave. | Range | Overall Ave. | |
| Scenic (Half-day) | 0.58-0.68 | 0.64 | 0.37-0.61 | 0.48 | 0.38-0.51 | 0.43 | 0.45-0.70 | 0.59 | 0.60-0.74 | 0.67 | 0.59-1.12* | 0.80 | 0.70-0.87 | 0.78 | 0.61-0.70 | 0.66 | 0.58-0.58 | 0.75 | 0.58-0.58 | 0.66 | 0.58-0.58 | 0.72 | 0.65 | 0.47-0.64 | 0.56 | 0.32-0.63 | 0.47 | 0.52-0.72 | 0.62 |
| Frozen Niagara | 0.28-0.61 | 0.50 | 0.28-0.51 | 0.38 | 0.32-0.55 | 0.40 | 0.33-0.43 | 0.39 | 0.38-0.70 | 0.50 | 0.38-0.92* | 0.60 | 0.47-0.68 | 0.61 | 0.46-0.71 | 0.54 | 0.49-0.49 | 0.69 | 0.59-0.59 | 0.55 | 0.59-0.59 | 0.67 | 0.63 | 0.36-0.56 | 0.46 | 0.29-0.68 | 0.44 | 0.39-0.64 | 0.50 |
| Wild Cave | 0.25-0.62 | 0.44 | 0.34-0.40 | 0.36 | 0.38-0.50 | 0.44 | 0.33-0.55 | 0.44 | 0.50-0.71 | 0.59 | 0.62-0.92* | 0.74 | 0.65-0.76 | 0.70 | 0.58-0.62 | 0.59 | 0.53-0.53 | 0.64 | 0.59-0.59 | 0.58 | 0.51-0.51 | 0.58 | 0.54 | 0.34-0.77 | 0.58 | 0.30-0.47 | 0.36 | 0.44-0.63 | 0.53 |
| Lantern | 0.64-0.99 | 0.85 | 0.70-0.89 | 0.82 | 0.75-0.91 | 0.82 | 1.09-0.90 | 0.99 | 0.56-1.03 | 0.80 | 0.12-1.13* | 0.65 | — | 0.99 | — | — | — | — | 0.84 | — | — | — | — | — | — | 0.25-0.71 | 0.47 | 0.64-0.92 | 0.79 |
| Echo River | — | — | — | — | — | 0.42 | — | — | — | — | 1.51-2.02* | 1.77 | 0.82-1.13 | 0.97 | 0.81-0.96 | 0.89 | 0.52-0.52 | 0.77 | 0.67 | 0.67 | 0.68-1.00 | 0.80 | 0.80 | 0.40-0.88 | 0.70 | 0.16-0.97 | 0.48 | 0.67-1.02 | 0.84 |
| Historic | 0.45-0.75 | 0.57 | 0.48-0.73 | 0.58 | 0.60-1.08 | 0.80 | 0.68-0.88 | 0.78 | 0.42-1.00 | 0.79 | 0.37-1.29* | 0.65 | 0.72-1.07 | 0.90 | 0.76-0.81 | 0.79 | 0.62-0.66 | 0.64 | 0.64 | 1.03 | 0.64-1.03 | 0.84 | 0.84 | 0.53-0.87 | 0.73 | 0.31-0.59 | 0.46 | 0.55-0.89 | 0.71 |
| Snowball Lunchroom | 0.48-0.68 | 0.59 | 0.26-0.52 | 0.40 | 0.34-0.68 | 0.49 | 0.35-0.73 | 0.52 | 0.53-0.62 | 0.58 | 0.59-1.89* | 0.94 | 0.48-1.47 | 0.77 | 0.42-1.16 | 0.79 | 0.89-1.25 | 1.10 | 1.10 | 1.10 | 0.48-1.10 | 0.70 | 0.68 | 0.41-0.68 | 0.53 | 0.27-1.09 | 0.56 | 0.46-0.99 | 0.66 |
| Great Onyx Cave | — | — | 0.63-0.84 | 0.71 | 0.68-0.94 | 0.80 | 0.64-0.95 | 0.81 | — | — | — | 1.12* | — | — | — | — | — | — | 0.67 | — | — | 0.76 | — | — | — | — | 0.74-1.22 | 0.81-0.91 | 0.85 |

+ Natural entrance gate covers taken down: March 27, 1977

* Natural entrance gate covers put up: late October 1976

Table 4
Comparison of Summer Radiation Levels at Mammoth Cave ("Unaltered" Airflows)

| Tour | No. of Samples | Average W.L. July 1977 | Average W.L. July 1976 | % Change | Average W.L. Sept. 1977 | Average W.L. Sept. 1976 | % Change |
|------------------------|----------------|------------------------|------------------------|----------|-------------------------|-------------------------|----------|
| Historic Tour | 33 | 0.68 | 0.80 | -15.0 | 0.88 | 0.79 | +10.0 |
| Half Day Tour (Scenic) | 44 | 0.44 | 0.43 | + 2.3 | 0.59 | 0.67 | -12.0 |
| Lantern Tour | 35 | 0.93 | 0.82 | +12.0 | 0.96 | 0.80 | +17.0 |
| Wild Cave Tour | 28 | 0.46 | 0.44 | + 4.3 | 0.50 | 0.59 | -15.0 |
| White's Cave | 7 | 1.63 | 1.23 | +24.5 | — | — | — |
| Snowball Room | 6 | 0.49 | 0.49 | 0.0 | 0.53 | 0.58 | -09.0 |
| Great Onyx Tour | 12 | 0.72 | 0.80 | -10.0 | — | — | — |
| Frozen Niagara Tour | 6 | 0.36 | 0.40 | -10.0 | 0.45 | 0.50 | -10.0 |

respond to temperature/density gradient (gravity) airflows in an overall way similar to smaller USD caves such as Lehman in eastern Nevada and Crystal in Sequoia, California. Oregon Cave, also of the USD type, has a man-made exit tunnel which has greatly modified the natural airflow patterns and serves to depress the radiation levels, especially in the summer, below what otherwise might occur. We therefore must be very careful in our management practices in caves. Though desirable decreases in airborne alpha radiation may occur, great and undesirable alteration of cave microclimate can also take place. Table 4 compares some summer 1976 and 1977 data—a time of year when basically unaltered "airflow" is occurring at Mammoth and when other USD caves, having little alteration in natural airflow patterns, experience high radiation levels. Table 5 also indicates that on occasion the thoron-daughter levels exceed 0.10 WL and must be accounted for in the calculation of employee alpha radiation exposure amounts. No other NPS caves investigated have ever had more than a few hundredths WL., never exceeding 0.10 WL.

Due to careful management efforts at Mammoth by which personnel were shifted from work in the cave to surface activities, none exceeded 4.0 WLM exposure during the first year's monitoring from May 1976 through April 1977. The maximum exposure for this 12-month period for all of the tour guide personnel was 3.056 WLM. This individual also had carried out the monitoring measurements on an interim basis for four months during the summer of 1976. The maximum annual exposure among maintenance workers was 3.447 WLM. These exposures were achieved by rotating personnel to surface activities during the year. Table 5 shows the shift in general radiation level which occurs (from first week of May 1977 data) when the thoron-daughter level exceeds 0.10 WL and a correction must be made.

Table 5
Effect of Thoron-Daughter Radiation on Overall Alpha Radiation Levels at Mammoth Cave

| Tour Route | Average Level Without T-D's, W.L. | Average Level With T-D's, W.L. |
|-------------------|-----------------------------------|--------------------------------|
| Historic | 0.69 | 0.82 |
| Scenic (Half Day) | 0.73 | 0.83 |
| Wild Cave | 0.57 | 0.68 |
| Lantern | 0.43 | 0.53 |

Thoron produced alpha radiation is much more hazardous than that from radon. At radioactive equilibrium 100 pCi/1 of radon produces 1.0 WL radiation, but only 8 pCi/1 of thoron is needed to give 1.0 WL.

Very little alpha radiation has ever been found in lava tube caves or volcanic areas. These results agree with those of other investigators. Nor has much alpha radiation been found in thermally active areas which are open to free surface air movements; e.g. Lassen, Yellowstone, Hot Springs, Arkansas. However, at Hot Springs the radiation levels are high in *enclosed*, unventilated water collection reservoirs. Also, at Yellowstone's Mammoth Hot Springs, old, inactive fissures, which may interconnect over a considerable distance in the sort of RSU (at higher elevations) USD (at lower elevations) configuration described above for Cudjo's and Indian caves at Cumberland Gap, have significant alpha radiation levels, especially in the summer.

The presence of considerable levels of alpha radiation can be used to indicate the existence of extensive though, as yet, unknown additional cave system networks, as long as the natural airflow patterns have not been distributed. Thus, at

Round Spring Cave in Ozark Riverway, Missouri, I predicted that the "left-hand" passage which leads off to the southwest from the tee-shaped entry passage and "Junction Room" should connect with a more extensive system—at least by airflow passageways. This was subsequently confirmed by a very knowledgeable local caver, Mr. Rimbach (of Meramec Cavern fame). He indicated that another large cave system does adjoin the southwest passage of Round Spring through which only air can move, but people can shout between. Therefore, I predict that Lehman Caves is much more extensive, as Crystal Cave in Sequoia, California should also be.

These are some of the more salient scientific findings. The remainder of this paper will deal with those aspects of the NPS cave radiation investigation which are most pertinent and timely for cave resource management. The Radon Ranger has been replicated during the past year so that now there are trained and equipped alpha radiation monitors at all NPS caves at which tours are given.

The overall NPS program has evolved into two sequential phases:

1. The research phase to develop a full year's data base on radiation levels at all other NPS *toured* caves, besides Carlsbad and Mammoth, beginning in January 1977; and
2. The long-term management and health/radiation observation phase after January 1978. This latter phase will begin with the drafting of *interim* radiation health standards for NPS administered caves.

The assistance and cooperation of all interested sectors of the caving community is urgently sought in doing this. This is vital so that *cave* oriented standards be prepared. Help from other agencies, NSS, CRF and NCA members is sought, in particular. The draft standards will be circulated for comment *before* they are placed into even an interim format. The long-term phase of the NPS Cave Radiation Program will then proceed to determine what, if any, health impacts are experienced by NPS cave employees by relating routinely monitored radiation levels with annual sputum cytology exams and other health parameters. This will continue over a period of many years. To expedite this extended phase a computerized data base for centralized control is being prepared during the latter part of the research phase.

Considerations of the possible cave radiation health hazard are a just part of any evaluation of overall caving hazards, as was stated in my 1976 NCMS paper. Furthermore, description of caving hazards as they vary among different caves is just one part of the broad spectrum of inventory and planning concepts which must constitute a complete cave management approach.

To focus on possible cave radiation health standards, the NCA recently engaged Mr. Tom Aley, Director of the Ozark Underground Laboratory near Protom, Missouri, to conduct a mailed questionnaire survey among personnel and managers of commercial caves, on a voluntary basis. NPS personnel were also queried in this survey. The preliminary results of this survey had been relayed to me by a private communication from Tom. The gist of these findings seems to be that most "seasonal" employees seem to be mainly students who work only an overall average total of about 16 months underground and 20 months in cave air environments. While permanent employees may work for many years, they tend to spend less and less time underground as their management work requires more and more time. However, they may still be exposed to cave air environments if it is used in cave buildings. With very few

exceptions, cave personnel worked only at one cave. None had been involved in mining. About one-third smoke, but not underground.

Steve Knutson published an article in the August 1977 issue of *NSS News* about the possible health implications to cavers of airborne alpha radiation. Tom Aley and others, including myself, have written in about this. In my paper on the NPS Cave Radiation Program presented at the 1976 NCMS a listing was given of the most important radiation health standards derived from uranium mining which cavers *might* consider for interpretation and *possible* cave management application. However, it is imperative that any such standards be developed *specifically* for the *management of caves, not mines*. NPS was advised of this at an interagency meeting held in early November 1976. At that time, EPA representatives pointed out the following:

"The President's Reorganization Plan #3 of 1970 terminated the Federal Radiation Council had transferred its functions and statutory responsibilities to the Administrator of the Environmental Protection Agency. At the time of this transfer, the Federal Radiation Council was considering the advisability of having Federal agencies implement the 4 CWLM limit for underground uranium miners tentatively proposed by the FRC in 1969. These discussions continued under EPA auspices and in May of 1971, the EPA Administrator affirmed the 4 CWLM limitation. Following public comments, this Federal Guidance was reaffirmed on July 9, 1971, 36 FR 12921.

"This Federal Guidance applied only to underground uranium miners. Moreover, the guidance was based on a consideration of the expected impact on the health of miners (based on the information available by 1971), technical feasibility, and the costs of reducing radon levels in underground uranium mines; as well as the national need for uranium ore.

"As might be expected, application of the annual 4 CWLM limit to occupational groups other than underground uranium miners has occurred. However, this has been without explicit consideration of the risk-benefit and cost balance in other industries. Specifically, the NRC has promulgated regulations limiting occupational exposures to 4 CWLM per year in the uranium milling industry, MESA has extended the 4 CWLM limit to all underground mining, and EPA in June of this year made similar *interim* recommendations for occupational exposures in the Carlsbad Caverns, 41 FR 22409. In that *Federal Register* Notice, the Agency noted that these interim regulations were limited to the Carlsbad Caverns and asked for public comment on the advisability of applying the same recommendations to other caves and caverns open to the public.

"We have received no public comments on the Interim Recommendations. While such feedback would be helpful, the Agency recognizes its obligation to consider the larger problem. It is by no means clear that Federal Guidance established on the basis of a particular set of industrial conditions at a given time is generally applicable to other occupational exposures where the costs and feasibility of their control may be quite different as well as the benefits of the activity itself.

"In addition, the health impact from radon daughter exposures is somewhat clearer now than when the guidance for uranium miners was formulated. It is apparent that the risks were not overestimated and

that the general trend of information on radon daughter induced lung carcinogenesis indicates the risks may be somewhat greater than anticipated in 1970. Therefore, the Environmental Protection Agency believes that appropriate limits for caves and caverns open to the public should be considered *de novo*, independent of existing Federal Guidance for underground uranium miners."

NPS agrees with the viewpoint expressed in the last sentence of the EPA statement and has shaped its Cave Radiation Program accordingly in order to obtain information for cave management. Furthermore, NPS is committed to protecting the natural integrity of the caves which it administers and will not use any artificial means of reducing cave radiation levels such as forced air ventilation, bulkheading and battening which some people in MESA, OSHA and NIOSH have recommended. Nor does NPS believe that radiation health standards less stringent than those for uranium mines cannot necessarily be used in cave management. Both OSHA and NIOSH have advised that they cannot, but NPS is seeking evidence to support any standards which may be drafted for interim use in caves while the long-term effort to collect epidemiological data for cave personnel is carried out. Certainly, medical research has shown that prolonged and continuous exposure to airborne alpha radiation, *from whatever source*, can induce lung disease—even lung cancer—in humans and in experimental animals. NIOSH has advised that rotation of personnel to surface work activities and the substitution of others in order to break up continuous periods of exposure and also to reduce total accumulated exposure amounts is not a safe procedure because it exposes a greater number of people to the radiation/health risk, although the degree of risk for each individual is probably decreased. There are different degrees of resistance which vary among individuals, as Bob Beckman pointed out in his talk. Rotation of personnel has been used for years in the uranium mining industry without NIOSH or OSHA changing the practice.

What might the radiation health standards for cave management entail? A number of aspects must be addressed:

1. How are the exposures obtained; i.e.—continuously or intermittently and what is the total exposure amount in WLM (both radiation level, in WL, and length of exposure time must be determined to give total exposure).
2. The total exposure to be permitted in a 12 month period, and the use of personnel rotation to remain under this limit.
3. Whether cave tour guides can also be permitted to go caving, in view of the annual exposure limit.
4. The frequency of monitoring as determined by the radiation levels and then seasonal variations. EPA has advised that a "sliding" scale can be used: as the levels increase, more frequent monitoring is needed, and conversely. Obviously, no cave area need be routinely monitored unless it is occupied. But how often must it be visited to be considered "occupied"? Also, if the radiation level in WL exceeds a certain value, then exposure records for employees and/or cavers should be kept. But what level should this be? The work of Dr. Ahlstrand and his associates at Carlsbad Caverns for two years shows that the magnitude and seasonal variation of radiation levels appear to be quite similar each year. Therefore, a shifting scale could be estab-

lished after a cave had been "calibrated." But this may not hold true for all caves, nor will it be possible to expend the effort to so "calibrate" a cave by making the extensive and expensive measurements over a long time period which are needed.

5. For epidemiological evaluation purposes, an initial complete physical exam, including sputum cytology, followed by an annual sputum cytology exam seems desirable.
6. If the *average* radiation level (in WL) exceeds a certain value, an area in a cave—or all of it "occupied"—should be closed and no entry permitted. What should this level be? How can it be determined when entry might again be possible?
7. The use of artificial ventilation and/or other nonnatural means to reduce the radiation levels compared with possible adverse impacts on the cave's microclimate, biota, formations, etc. There are important implications in this about the effects of such actions on rare and endangered cave biota, especially fauna and the applicability of NEPA, court actions, the preparation of Environmental Impact Statement, etc.
8. Smoking by cavers and in caves.
9. The radiation due to both radon and thoron gases must be measured in caves. Usually, thoron daughter levels in caves are very low—thankfully. However, Reckmeyer, the Varnedoes, *et al.* reported gas ratios of thoron:radon:actinon in an Alabama cave in 1963 and 1964 to be 10:2:0.01. NPS measurements show that during the summer of 1977 on several occasions the thoron daughter levels at Mammoth Cave exceeded 0.10 WL. For this situation, an adjustment in the radon daughter and the total WL then becomes necessary.
10. Employees and the general public should be advised of the radiation health hazard—as well as *all* the hazards involved in caving. But what is the best means to use? This has been done for NPS employees at each toured cave, with good written handout materials used at Carlsbad, Wind and Jewel Caves and discussions held at others. A draft handout for visitors has not as yet been finalized.
11. Measurements of free ions, of the percent concentration of each radon daughter in the total radiation level, of cave air quality as to dust particles per unit volume, meteorological and airflow conditions, and of radon gas concentrations are all needed to fully describe a cave's radiation situation. It should be noted that the extremely clean air in caves; often only a few hundred condensation nuclei per cc.; may pose an added radiation health hazard not found in mines or other less clean underground atmospheres. The radon and/or thoron daughter particles are *ionized* solids immediately after being produced by the radioactive decay of the two gases. Being electrostatically charged, they tend to attach to solid surfaces or perhaps water droplets. In clean cave air, having fewer condensation nuclei, this plateout probably is less. Therefore, there can be more "free" (unattached) daughter particles in the cave air which can attach to a caver's lung tissues when inhaled. Such electrostatic attachment precludes these particles from being exhaled, and gives the lung tissue a more sustained alpha energy dosage than occurs from a daughter particle which has plated out on a dust particle in the cave air. Such attached daughter particles tend to be exhaled—between 60 and 75 percent are expelled within one or two breaths.
12. Cave air should not be used to ventilate (either heat or

cool) or otherwise air condition surface buildings where employees spend considerable periods of time. (NPS data from March 1976 at Mammoth Cave showed 0.5 to 0.6 WL in the Administration Building which was ventilated year-round by cave air. This practice was stopped in late April 1976. It has been prohibited at all NPS cave areas since then.)

However, if natural airflows in a cave are obstructed by man-placed covers or shields, it may be advisable to remove them in order to restore natural conditions which may also reduce radiation levels (as at Mammoth Cave).

The obvious implication of this is that all groups involved in caving and/or cave management should make their views known—both in a larger-scaled, general sense as well as on the subject of cave radiation health standards. Please share your ideas around. To contact the Radon Ranger (Keith A. Yarborough), either call (505) 988-6412 (FTS 8-476-1412) or write to him at Southwest Regional Office, National Park Service, P.O. Box 728, Santa Fe, New Mexico 87501.

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Alpha Radiation Project at Carlsbad Caverns: Two Years and Still Counting

Gary M. Ahlstrand, Research Ecologist and Patricia L. Fry, Park Technician*

Initial public disclosure was made in 1975 at the National Cave Management Symposium held in Albuquerque, New Mexico that the presence of radon and its radioactive decay products had been detected in Carlsbad Caverns (Van Cleave 1976). At the symposium held in Mountain View, Arkansas, the evolution of the problem at Carlsbad Caverns was described and steps being taken to better understand the problem were reported (Ahlstrand 1977). Results from a two-year-long alpha radiation study at Carlsbad Caverns National Park are presented in this paper.

The noble gas radon is one of the isotopes formed during the natural radioactive decay of uranium to lead. As the inert radon decays, successive "daughters" of polonium, lead, and bismuth are formed. Some of these isotopes are energetic alpha emitters. Fear that inhalation of these radon daughters over extended periods of time might lead to health problems prompted the current study at Carlsbad Caverns.

METHODS

Underground portions of Carlsbad Caverns National Park viewed by visitors and staffed with National Park Service (NPS) employees were sampled regularly to determine radon daughter concentrations. Four zones were designated within Carlsbad Caverns and one at New Cave. The four zones at Carlsbad Caverns were: the Main Corridor, the Scenic Rooms, the Big Room, and the Lunch/Pump Room. In collecting the samples, a known volume of air was drawn through a fiberglass filter. Consecutive five minute walking samples were taken along an established route through each zone. Ten walking samples were used to sample the four zones at Carlsbad Caverns, while at New Cave, three or four samples were required. Radon daughter levels were determined using an alpha scintillation counter to measure the alpha activity of daughter products trapped on the filter. Daughters of radon 222 were sampled according to procedures given by Budnitz (1974). Daughters of radon 220 (thoron) were determined using methods described by Rock (1975).

Atmospheric concentrations of radon daughters are reported in terms of the working level (wl). The working level is sometimes described as the latent alpha energy inherent in a liter of air containing 100 pCi each of polonium 218, lead 214, bismuth 214, and polonium 214, but a more precise definition is any combination of radon daughters in one liter of air that will ultimately release 1.3×10^5 MeV of alpha energy during decay to lead 210.

Radon concentrations in the Pump Room at Carlsbad Caverns were measured and recorded hourly from May 1976 to May 1977 with a monitoring system loaned to the park by the Denver Mining Research Center, U.S. Bureau of Mines. The main components of this system consisted of a

scintillation type detector, and controlled airflow and data acquisition systems. Using these instruments, radon was measured by drawing air at a constant rate through a filter and the detector. Pulses produced in the detector by alpha particles from the decay of radon and its daughters were then amplified, counted, and logged by the data acquisition system.

Temperature extremes were recorded daily from a maximum-minimum thermometer housed in a weather instrument shelter placed approximately 150 m from the Natural Entrance to Carlsbad Caverns. Atmospheric pressure was monitored with a recording barograph placed next to the radon monitoring system in the Pump Room.

Employees in the cave were required to record daily the time spent in each zone. Each employee's exposure was calculated and recorded in working level months (wlm) using data from their time records and the weekly mean radon daughter concentrations for each zone. One working level month is defined as the exposure received by breathing air at one working level concentration for four and one-third weeks of 40 hours each. In addition to individual total cumulative exposure records, running twelve-month cumulative exposure records were maintained for each NPS employee.

RESULTS AND DISCUSSION

Data for the first year of monitoring radon daughter products in regularly visited portions of Carlsbad Caverns are summarized in Figure 1. The levels vary seasonally and approximate a plot of daily temperature minima for the portion of the curve below about 13°C. A similar pattern was observed during the second year of the study (Fig. 2).

Temperatures within the cave range between 11 to 20° C, but are relatively constant for any given portion of the cave throughout the year. Virtually all of the cave lies below the known entrances. Obviously, exchange of cave and outside air occurs through these openings. As daily outside temperature minima become higher than the cave air temperature, the overlying, less dense air lends stability to the cave air. Air exchange possibly takes place through unknown openings at lower, warmer levels of the cave as long as the overlying air temperature remains below the cave air temperature.

Ranges of radon daughter average concentrations in the four zones of the cave during the first year were: Main Corridor, 0.06-0.45 wl; Scenic Rooms, 0.08 to 0.55 wl; Big Room, 0.10 to 0.53 wl; and the Lunch/Pump Room, 0.07 to 0.51 wl. For the second year of the study the ranges were: Main Corridor, 0.40 to 0.46 wl; Scenic Rooms, 0.06 to 0.45 wl; Big Room, 0.06 to 0.46 wl; and the Lunch/Pump Room, 0.06 to 0.46 wl.

Relative radon daughter levels for the zones were lowest in the Main Corridor during the cool season, but were frequently the highest of any zone during the warm season.

*Carlsbad Caverns and Guadalupe Mountains National Parks
3225 National Parks Highway, Carlsbad, New Mexico 88220.

All of the known natural openings are adjacent the Main Corridor portion of the cave and the relative values detected are predictable based on observed ventilation patterns due to thermal convection. Of the regularly sampled zones, the Big Room had the highest radon daughter levels consistently throughout the year. The Big Room is the most distant from a natural opening of the zones regularly sampled.

Representative values for radon daughter concentrations in some non-developed portions of Carlsbad Caverns are listed in Table 1. The greatest radon daughter concentration sampled in the cave during the two year period was 1.03 wI and occurred in an area of the Lower Cave portion. The highest levels of radon daughters sampled in Carlsbad Caverns were usually found in this part of the cave.

As would be expected, radon concentrations in the cave exhibit the same seasonal pattern in relation to temperature as do its daughter products (Fig. 3). Air exchange rates between cave and outside air tend to increase with decreasing temperatures, causing dilution of radon concentrations in the cave.

In addition to large scale seasonal variations, radon levels in the cave often undergo marked daily fluctuations in response to atmospheric pressure changes (Fig. 4). Radon concentrations rise in response to low pressure systems, while high pressure systems cause the emanation of radon to be reduced. A high pressure system in combination with a drop of the outside temperature below that of the cave can produce a marked reduction in radon levels.

Table 1. Radon daughter levels in non-developed portions of Carlsbad Caverns.

| Location | Date | Conc. (wI) |
|------------------------------|-----------|------------|
| Bat Cave | 5 Nov 75 | 0.15 |
| Music Room | 30 Sep 76 | 0.28 |
| Guadalupe Room | 6 Nov 75 | 0.28 |
| New Mexico Room | 5 Nov 75 | 0.47 |
| New Mexico Room | 25 Jan 76 | 0.36 |
| New Mexico Room | 9 Jun 77 | 0.26 |
| Mystery Room | 5 Nov 75 | 0.33 |
| Mystery Room | 29 Dec 75 | 0.07 |
| Lower Cave | 5 Aug 75 | 0.46 |
| Lower Cave | 5 Aug 75 | 0.46 |
| Lower Cave | 24 Nov 75 | 0.17 |
| Lower Cave | 10 Sep 76 | 0.71 |
| Lower Cave | 12 Jun 77 | 0.48 |
| Naturalist Room, entrance | 22 Oct 75 | 1.03 |
| Naturalist Room, entrance | 26 Apr 76 | 0.65 |
| Naturalist Room, entrance | 9 Sep 76 | 0.87 |
| Naturalist Room, entrance | 29 Apr 77 | 0.53 |
| Left Hand Tunnel | 5 Aug 75 | 0.37 |
| Left Hand Tunnel | 23 Oct 75 | 0.51 |
| Left Hand Tunnel, left fork | 23 Oct 75 | 0.38 |
| Left Hand Tunnel | 6 Nov 75 | 0.32 |
| Left Hand Tunnel, right fork | 14 Oct 76 | 0.15 |
| Lake of the Clouds | 5 Aug 75 | 0.38 |
| Lake of the Clouds | 6 Nov 75 | 0.25 |
| Lake of the Clouds | 9 Jan 77 | 0.27 |

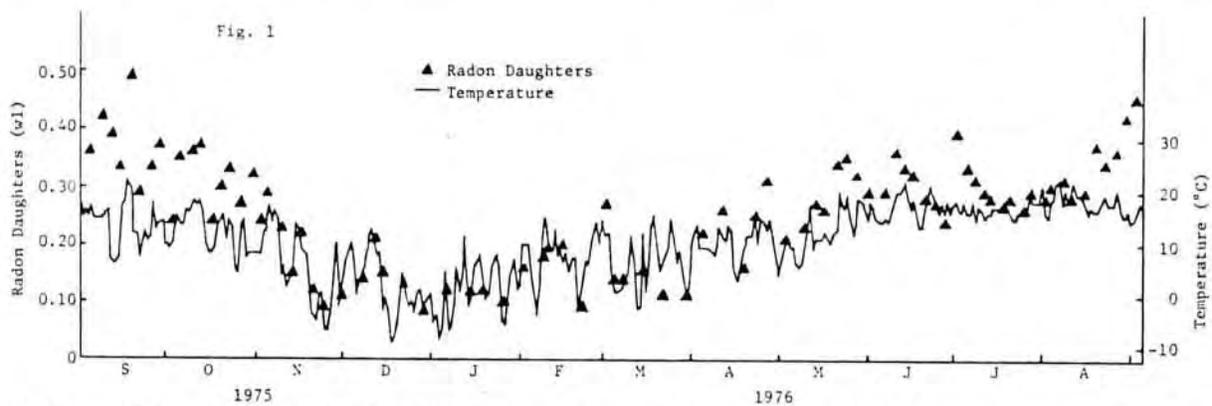


Figure 1. Seasonal fluctuation of radon daughter levels in developed portions of Carlsbad Caverns in relation to daily outside temperature minima at the park during the first year of study. Each level depicted represents the mean of ten samples required to monitor visited portions of the cave.

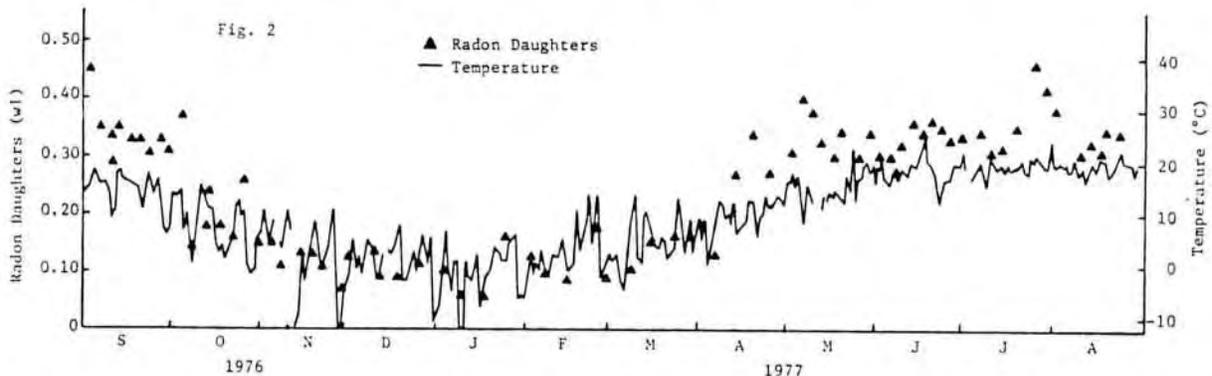


Figure 2. Seasonal fluctuation of radon daughter levels in developed portions of Carlsbad Caverns in relation to daily outside temperature minima at the park during the second year of the study. Each level depicted represents the mean of ten samples required to monitor visited portions of the cave.

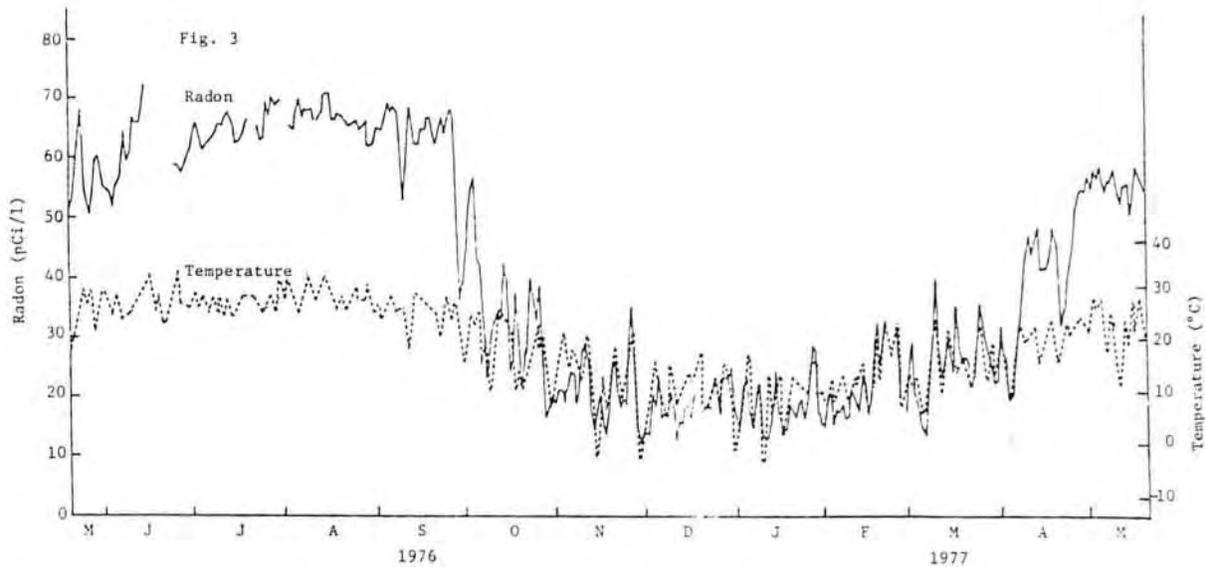


Figure 3. Radon concentrations in the Pump Room area of Carlsbad Caverns in relation to daily outside temperature minima at the park. Radon is reported as the average of daily maximum and minimum concentration.

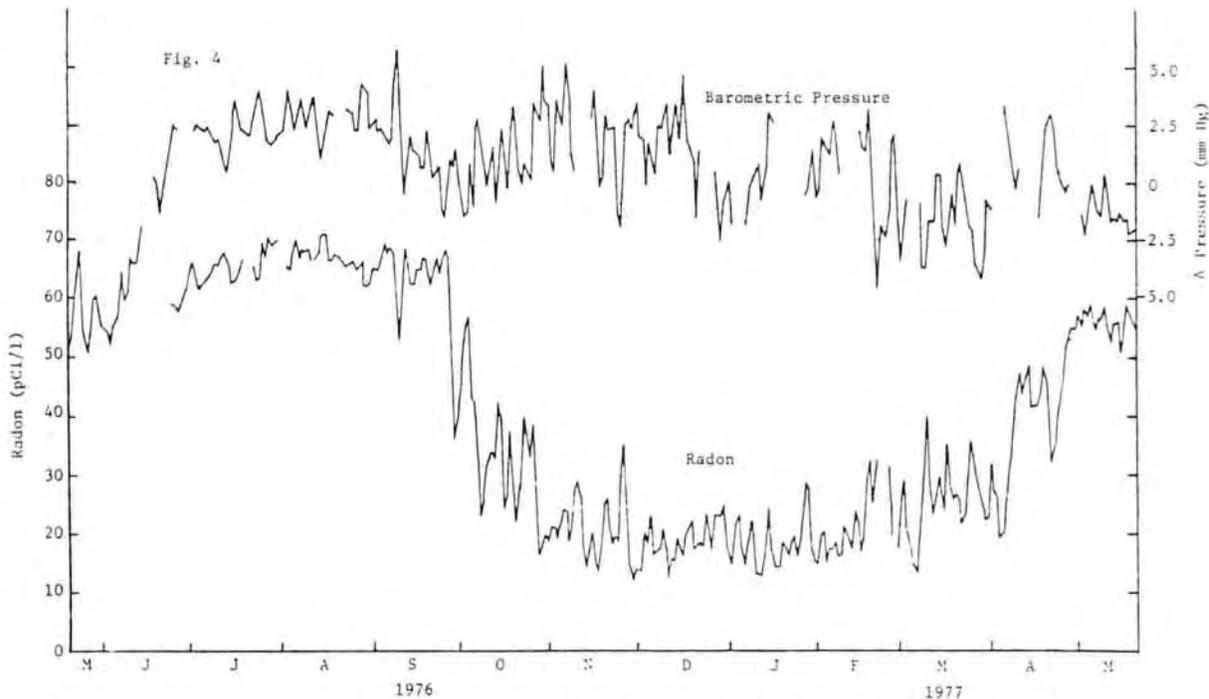


Figure 4. Radon concentrations in the Pump Room area of Carlsbad Caverns in relation to changes in barometric pressure. Radon and barometric pressure are reported as daily averages of maximum and minimum values.

Transient equilibrium between radon and its daughters can be established in approximately three hours in a closed system. Beckman (personal communication) has measured growth curves of the daughter isotopes of radon in dynamic systems. In either type system, the radon daughter to radon concentration coefficient increases as the age of the radon containing air increases until equilibrium is attained. Concentrations of radon and its daughters in Carlsbad Caverns (Fig. 5) show patterns which are inversely related to cave air exchange rates. However, the data present an

apparent enigma, for the coefficients calculated for the cool season equal or exceed those for the warm season. One would expect the opposite to occur.

Comparison of average radon daughter concentrations in Carlsbad Caverns on an annual basis for the two year period shows that the same general curve was formed during both years of the study (Fig. 6). Radon daughter concentration averages for the cave during the first year of the study ranged from 0.08 w/l in December 1975 to 0.49 w/l in September 1975. The range observed in the second year was

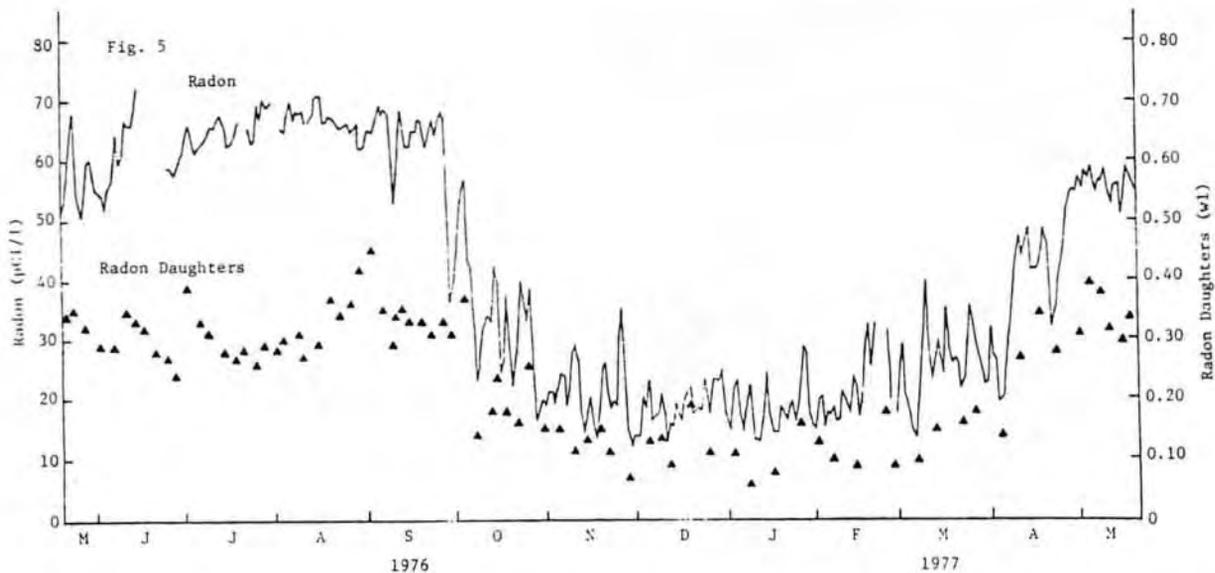


Figure 5. Comparison of radon concentrations with radon daughter levels in the Pump Room area of Carlsbad Caverns. Radon is reported as daily average of maximum and minimum concentration.

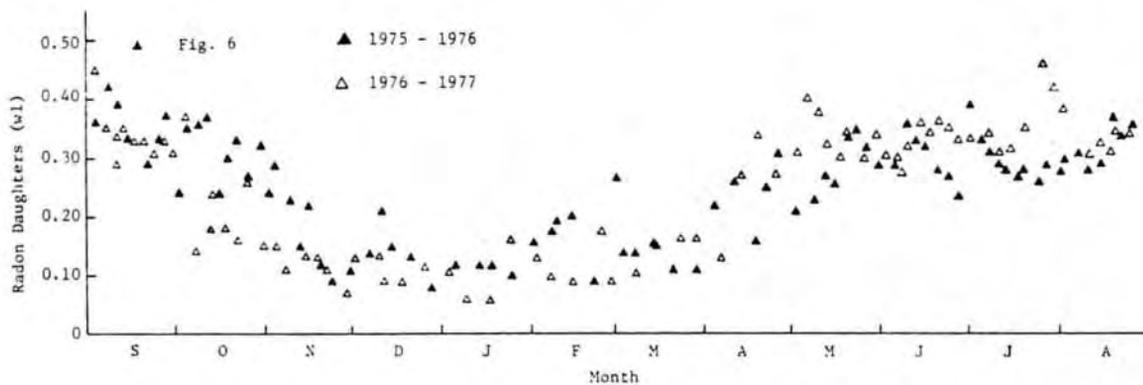


Figure 6. Annual comparison of average radon daughter levels in developed portions of Carlsbad Caverns. Each level represented is the mean of ten samples required to monitor visited portions of the cave on a sampling day.

from 0.06 wl in January 1977 to 0.46 in July 1977.

A similar comparison of the radon daughter concentrations in New Cave show little or no seasonal variation of the levels for this cave (Fig. 7). Radon daughter levels ranged between 0.17 to 0.40 wl during the first year of the study and between 0.12 to 0.28 wl during the second year. Annual means for the cave were 0.23 ± 0.05 wl and 0.22 ± 0.04 wl for the first and second years respectively. Due to closure of New Cave during the winter of 1975 to 1976, routine sampling in the cave was interrupted for a four month period.

Averages of radon daughter levels sampled in other caves at the park are listed in Table 2. Note the extreme variation in levels at Spider Cave over a six week span.

Thoron daughter levels ranged from 0.0 to 0.11 wl over the two year period in Carlsbad Caverns. Seldom, however, did these levels exceed 0.04 wl.

Running twelve month cumulative exposures for NPS employees at Carlsbad Caverns were all less than 2 wlm. All

Table 2. Radon daughter levels in backcountry caves at Carlsbad Caverns National Park.

| Cave | Date | Average Conc. (wl) |
|----------------|-----------|--------------------|
| Chimney | 6 Oct 76 | 0.80 |
| Christmas Tree | 29 Jun 77 | 0.07 |
| Helen's | 6 Oct 76 | 0.14 |
| Lechuguilla | 8 Sep 76 | 0.04 |
| Musk Ox | 6 May 76 | 0.10 |
| Mystery Light* | 15 Sep 76 | 0.28 |
| Ogle | 23 Nov 76 | 0.01 |
| Spider | 3 Aug 77 | 1.30 |
| Spider | 26 Aug 77 | 0.37 |
| Spider | 13 Sep 77 | 0.52 |

*Cave in Guadalupe Mountains National Park

employees have been advised of the apparent increased health hazard associated with individuals who combine tobacco smoking with exposure to alpha radiation. Employees are urged to wear respirators if for any reason they must enter any of the higher level areas in non-developed portions of the cave or backcountry caves.

Data from this study suggest that it should be quite possible to write a program for predicting average radon

daughter levels for any given day from inputs consisting of date, minimum temperature, and barometric pressure once the shape of the radon daughter concentration curve for a cave has been determined. The accuracy attained with such a program should be comparable with that obtained using current monitoring techniques. In the meantime, two years have elapsed and we continue to count the alpha activity in Carlsbad Caverns.

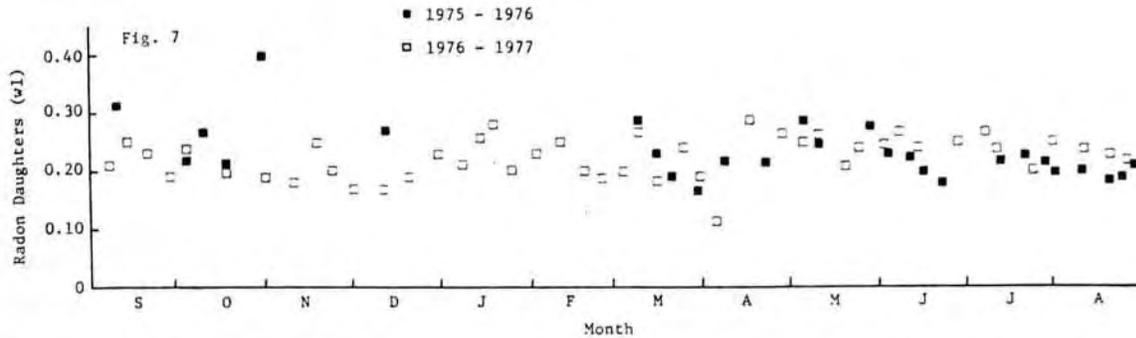


Figure 7. Annual comparison of average radon daughter levels in New Cave. Each level represented is the mean of all samples taken that day along the regularly visited route through the cave.

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Participants List

1977 National Cave Management Symposium

Gary M. Ahlstrand (National Park Service)
3003 Ocotillo Canyon Drive
Carlsbad, NM 88220

Tim & Diane Anderson (Shasta Caverns)
P.O. Box 801
O'Brien, CA 96070

Robert T. Beckman
MESA
P.O. Box 25367, DFC.
Denver, CO 80225

Michael Beer (National Speleological Society)
3825 Fifth Ave. S.
Great Falls, MT 59405

Ellen Benedict (National Speleological Society)
8106 S.E. Carlton
Portland, OR 97206

Earl Biffle (Spelean Research Association)
26 Lake Road
Fenton, MO 63026

Karen Bischoff
Cave Management Services
P.O. Box 733
Gold River, B.C. VOP 1G0
Canada

James A. Blaisdell
National Park Service
P.O. Box 128
Klamath Falls, OR 97601

Catherine Blean
National Outdoor Leadership School
Box AA
Lander, Wyoming 82520

Robert Bogart
Mark Twain Cave
3303 Sunnyside
Hannibal, MO 63401

Paul G. Boos
Bureau of Land Management
450 Valley View Dr.
Richfield, Utah 84701

John Brady
St. Louis District
Corps of Engineers, Rm. 853
210 N. 12th St.
St. Louis, MO 63101

H. Gassaway Brown (United States Forest Service)
10504 Woodland Ave. S.E.
Albuquerque, NM 87112

Jim & Mary Alice Chester (National Speleological Society)
410 E. Aspen
Bozeman, MT 59715

Alexia Cochrane (National Speleological Society, AMCS)
Tin Cup Road
Darby, MT

David & Ann Cordero
c/o Nea Cordero
1742 N. Mariposa
Los Angeles, CA 90027

Dave Cowan (National Speleological Society)
5313 North Ave.
Carmichael, CA 95608

Vincent Crowston ("Buzz") (Parks, Canada)
Box 2351
Revelstoke, B.C. V0E 2S0
Canada

Donald A. Dayton, Superintendent
Carlsbad Caverns & Guadalupe Mtns.
3225 National Parks Hwy.
Carlsbad, NM 88220

Rochelle Devereau (National Speleological Society)
40548 Mohawk River Rd.
Marcola, OR 97454

Jerry Dick
Rt. 2, Box 659 D
Laramie, WY 82070

Nancy Dorset (National Speleological Society)
P.O. Box 704
Morgantown, WV 26505

William R. Elliott
1012 Country Club Road
Georgetown, TX 78626

John Erdmann (Bureau of Land Management)
3427 Dover Rd.
Cheyenne, WY 82001

Wayne B. Erickson
Bureau of Land Management
P.O. Box 1828
Cheyenne, WY 82001

Stephen & Evelyn Fairchild
Moaning/Boyden Caves
Box 78
Vallecito, CA 95251

Cynthia Fiack
Rt. 1 Box 384
Glenn, CA 95943

Milford Fletcher (National Park Service)
Box 728 (Country Club Gardens)
Santa Fe, NM 87501

Fredrick A. Flint
Spotted Bear Ranger Station
Hungry Horse, MT 59919

Scott Forssell
Roswell District Office, BLM
Box 1397
Roswell, NM 88201

Larry W. Frederick
Wind Cave National Park
Hot Springs, S.D. 57747

Dr. Tom Gallagher (Humboldt University)
1423 L Street
Eureka, CA 95501

Gandalf (National Speleological Society)
c/o Glenda Dawson
426 Rita
Corpus Christi, TX 78412

Stephanie Gilbert
Lewis & Clark Caverns
P.O. Box 10024
Three Forks, MT 59752

Jim Goodbar (Cave Research Foundation)
7161 Green Tree
Dallas, TX 75214

Mark Grady (deceased)

Andy G. Grubbs (Association of Mexican Cave Studies)
1304 Bob Harrison
Austin, TX 78702

Gene Hargrove (National Speleological Society)
6270 Famous Ave.
St. Louis, MO 63139

Harry & Clara Heidemann (National
Caves Association)
Route 3, Box 515
Natural Bridge Caverns, TX 78218

Jack Hess (University of Nevada)
4582 Maryland Pkwy.
Las Vegas, NV 89109

Allan Hinds (United States Forest
Service)
1104 W. Edwards
Carlsbad, N.M. 88220

George N. Huppert
Coordinator of Environmental Studies
U. of Northern Colorado
Greeley, CO 80639

Roger Inman
Bureau of Land Management
Box 119
Worland, WY 82401

Jean Jancewicz (National Speleological
Society)
1307½ Kirkwood
Austin, TX 78722

Ronal Kerbo
Carlsbad Caverns National Park
3225 National Parks Hwy.
Carlsbad, NM 88220

Tom Koualicky
Forest Service, Northern Region
Missoula, MT 59801

Charlie & Jo Larson (National Speleo-
logical Society)
13402 NE Clark Rd.
Vancouver, WA 98665

Barbara Martin
2219 St. Laurent Blvd.
Ottawa, Ont. K1G 1B1

Paul P. Martin II
Phillip's Resource Area
Bureau of Land Management
Malta, MT

Robert Martin (National Speleological
Society)
338 Bridge Place
West Sacramento, CA 95691

Mike McEachern (National Speleological
Society)
1404 Kirkwood Rd.
Austin, TX 78722

William Mixon (National Speleological
Society)
5035 N.S. Drexel Blvd.
Chicago, ILL 60615

Jim & Libby Nieland (National Speleo-
logical Society)
Box 9, St. Helens Ranger Station
Cougar, WA 98616

Eugene Regan (National Speleological
Society)
Box 1166
Dillon, MT 59725

John L. Schippleck
Lehman Caves National Monument
Baker, NV 89311

Charles A. Plantz
2242 E. Water St.
Tucson, AZ 85719

Bob Reeves
United States Forest Service
Box I
Mtn. View, Arkansas 72560

Eugene Regan (National Speleological
Society)
Box 1166
Dillon, MT 59725

Doug Rhodes (Adobe Press)
515 Isleta Blvd. SW
Albuquerque, NM 87105

Rick Rigg
169 E. 25th
Idaho Falls, ID 83401

Allen Robinson (National Outdoor Leader-
ship School)
Box AA
Lander, WY 82520

Katherine Rohde (National Park Service)
Drawer T
Carlsbad, NM 88220

Rollie Saylor
United States Forest Service
Bldg. #1 Fort Missoula
Missoula, MT 59801

John L. Schippleck
Lehman Caves National Monument
Baker, NV 89311

David & Bonnie Seesholtz (United States
Forest Service)
Rt. 1 Box 366
Amboy, WA 98601

Floyd W. Sharrock
USDA - Forest Service
Federal Building
Missoula, MT 59807

Ralph E. Squire (National Speleological
Society)
2931 Tully Rd.
Hughson, CA 95326

William Steele (Association of Mexican
Cave Studies)
Box 7672 UT Station
Austin, TX 78712

Diane Stevenson
929 N. Astor #2606
Milwaukee, WI 53202

Stitt, Robert (National Speleological
Society)
1417 Ninth Ave. W
Seattle, WA 98119

David Stout
P.O. Box 119
Bureau of Land Management
Worland, WY 82401

Wayne Sutherland
Box 1118
Buffalo, WY 82834

Martin D. Timmerville (Army Corps of
Engineers)
134 Mary St.
Sullivan, MO 63080

Jerry L. Trout (United States Forest
Service)
1312 Chico
Carlsbad, NM 88220

Merlin Tuttle (Milwaukee Museum)
929 N. Astor #2606
Milwaukee, WI 53202

Peter J. Uhl (National Speleological
Society)
P.O. Box 244
Laramie, WY 82070

Michael J. Van Note
c/o Seely Lake Ranger Station
Seely Lake, MT 59868

Dave Walker (Klamath Mountain Conser-
vation Task Force)
3860 W. Mercer Way
Mercer Is., WA 98040

Clark W. Whitehead
Bureau of Land Management
Drawer 1160
Lewistown, MT 59457

Phil Whitfield
British Columbia Parks Branch
521 West Ines St.
Nelson, B.C. V1L 3J2
Canada

John G. Woods
Mt. Revelstoke & Glacier National Parks
Box 599
Revelstoke, B.C. V0E 2S0
Canada

Keith A. Yarborough
P.O. Box 728
Div. of Natural Resources
N.P.S. - SW Regional Office
Santa Fe, NM 87501

Gaylord C. Yost
U.S. Forest Service R-9
633 W. Wisconsin Ave.
Milwaukee, WI 53203

Ron Zuber (National Speleological
Society)
Dept. of Horticulture & Forestry
North Dakota State University
Fargo, ND 58102