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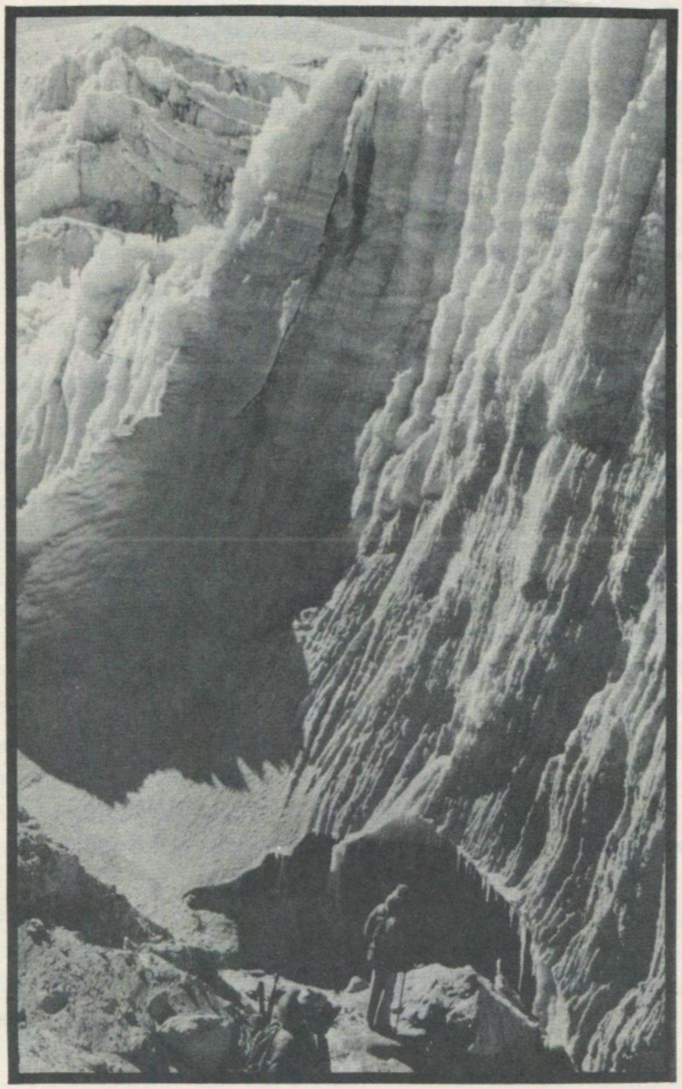

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Contents

Cover Photo: Entrance to obstruction glacier cave on the west side of the Quelccaya Ice Cap. Ice cliff is about 30 m high. Around the cave entrance, there is a resistant rim of ceiling ice protruding several cm from the cliff face. Also see Figure 3, page 17.

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BAT MANAGEMENT IN THE UNITED STATES*

A Survey of Legislative Actions, Court Decisions, and Agency Interpretations

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ABSTRACT

In 1966, Congress passed legislation which afforded native animals legal protection. This legislation has been twice revised since that time. The Endangered Species Act of 1973 provides not only animals, but, also, plants with what appears to be a reasonable degree of protection. Recent court decisions support the concept and validity of the 1973 Act.

This paper presents the results of a survey of fourteen federal departments and agencies to obtain their interpretations of the 1973 Act and, more specifically, of how bats are protected by these interpretations.

INTRODUCTION

BETWEEN THE YEARS 1600 and 1850, five American animal species vanished. In startling contrast, fifty-seven additional mammal, fish, and bird species have been forced into extinction just since the year 1850 (120 Cong. Rec. 12749 [1974]). This represents a 22-fold increase in the rate of extinction of North American species in a little more than 125 years. The basic reason for this dramatic increase is the rapid and, in some cases, uncontrolled development and advancement of our industrial and technological society (115 Cong. Rec. 6245 [1969]).

Ironically, while we have made remarkable advancements industrially and technologically and have maximized the potential and usefulness of many of our resources, we have, in effect, reduced drastically and irreversibly some of what must be considered our most precious assets as well as resources. In an attempt to counter this ongoing and potentially disastrous process, Congress passed, during the years 1969-1973, three major legislative acts designed to encompass and provide impetus to the concept of protection to any and all endangered species.

The purpose of this paper is two-fold: 1) it attempts to acquaint the reader with the development and history of these three acts, with primary focus resting on the most recent Act and subsequent evaluation of its effectiveness in recent court decisions; and 2) it specifically analyzes the impact this Act has had upon the preservation and/or eradication of bats by surveying the major federal agencies to determine if their policies and practices are, indeed, uniform and consistent both internally and externally at all levels.

* Publication of this report does not signify that the contents necessarily reflect the policies of USEPA, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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STATUTORY AND ADMINISTRATIVE PRESCRIPTIONS

Formal involvement by Congress in endangered species legislation began with the Endangered Species Preservation Act of October 15, 1966 (Public Law 89-669, 80 Stat. 926), hereinafter referred to as the "1966 Act." This law acknowledged a national responsibility to act on behalf of native species of wildlife which were threatened with extinction. It required the Secretary of the Interior to implement a comprehensive program to conserve, restore and where necessary, bolster wild populations found threatened with extinction. It also required the Secretary to determine which species were endangered and to publish this list in the *Federal Register* by scientific and common name.

An amended version, the Endangered Species Conservation Act was enacted on December 5, 1969 (Public Law 91-135, 83 Stat. 275), hereinafter referred to as the "1969 Act. This amendment to the 1966 Act expanded its scope in several significant respects:

1. It broadened coverage to include all vertebrates mollusks, and crustaceans on a world-wide basis.
2. It permitted the consideration of subspecies as well as of species.
3. It ensured that the United States would not contribute to the extinction of wildlife in other nations.
4. It protected native endangered species by making their sale or purchase unlawful.
5. It increased the funds authorized to acquire lands for the purpose of conserving, protecting, restoring, and propagating endangered species.

Although the 1969 Act laid the framework for an effective endangered species conservation program, with controls on traffic in threatened species as well as habitat preservation and restoration, it did not automatically afford native endangered species adequate protection.

President Nixon stated in his Environmental Message of February 8, 1972, that the existing law "...simply does not provide the kind of management tools needed to act early enough to save a vanishing species." (*U.S. Code Cong. and Admin. News* 2991 [1973]). A Congressional study had found "...that various species of fish, wildlife, and plants in the United States have been rendered extinct as a consequence of economic growth and development untempered by adequate concern and conservation" and that others are "...threatened with extinction" (16 U.S.C. 1531 [1975]).

The 1969 Act also did not prohibit the killing of any endangered species. The only endangered species forbidden by state or federal laws to be killed were those enumerated in the revisions of the Lacey Act of 1900 (16 U.S.C. 701 [1974]). As a result, Congress then found it necessary to improve protection for all species designated as endangered. It had also determined that "...The inadequacy of existing regulatory mechanisms" (*U.S. Code and Admin. News*, Senate Rept. 93-307, 2990 [1973]) was one of several factors, including hunting and the destruction of natural habitats, that were contributing enormously to the continuing problem of animal extinction (16 U.S.C. 1533a [4] [1975]).

After Congressional study and Presidential urging, the Endangered Species Act was passed on December 28, 1973 (Public Law 93-205, 87 Stat. 884), hereinafter referred to as the "1973 Act." It totally replaced the 1969 Act and superceded all of the 1966 Act, except for the provisions relating to the National Wildlife Refuge System.

ENDANGERED SPECIES ACT OF 1973

A major purpose of the 1973 Act is the "conservation of endangered and threatened species" (16 U.S.C. 1531 [5] [b] [1975]), and "conservation" is strictly defined as:

> "...the use of all methods and procedures which are necessary to bring any endangered or threatened species to the point at which the measures provided pursuant to this chapter (1973 Act) are no longer necessary" (16 U.S.C. 1532 [2] [1975]).

The 1973 Act empowers the Secretary of the Interior to compile and maintain separate official lists of threatened and endangered species (16 U.S.C. 1533 [a] [2] [1975]). An "endangered species" is defined as "any species which is in danger of extinction throughout all or a significant portion of its range..." (16 U.S.C. 1532 [4] [1975]). This definition is further specified by the requirement that animals may be listed as endangered "on the basis of the best scientific and commercial data available" (16 U.S.C. 1533 [1] [b] [1975]).

The term "threatened species" is defined to include "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range" (16 U.S.C. 1532 [15] [1975]). The Secretary is also empowered to issue "such regulations as he deems necessary and advisable for the conservation of such species" (16 U.S.C. 1533 [d] [1975]). The secretary may act to protect animals before they actually become endangered.

The 1973 Act also commits federal agencies to "utilize their authorities in furtherance of the purposes of this chapter by...taking such action necessary to ensure that actions authorized, funded, or carried out by them do not jeopardize the continued existence of such endangered and threatened species or result in the destruction or modification of habitat of such species which is determined by the Secretary...to be critical" (16 U.S.C. 1536 [1975]).

The Secretary of the Interior, in order to fulfill the requirements of th 1973 Act, must determine whether or not the habitat to be affected by any project might be critical to endangered species. If so, he must ensure that the actions will not harm the habitat (16 U.S.C. 1536 [1975]). This requirement imposes on federal agencies the duty of ensuring that their actions will neither jeopardize the existence of an endangered species nor modify and/or destroy the critical habitat of an endangered species. The primary responsibility for implementing this section of the 1973 Act lies with the Secretary of the Interior. Federal agencies are required to consult with and to obtain the assistance of the Secretary before any actions are taken which may affect any endangered species or its critical habitat.

The 1973 Act also specifically provides that no State law or regulation intended as a conservation measure should be construed as void. "State laws respecting the taking if an endangered or threatened species may be more restrictive than the permits or exemptions provided in this chapter (1973 Act) or in any regulation which implements this chapter (1973 Act), but not less restrictive than the prohibitions so defined" (16 U.S.C. 1535 [f] [1975]).

The 1973 Act emphasizes that "The President shall provide assistance to foreign countries and urge international cooperation in establishing programs to protect endangered species" (16 U.S.C. 1537 [a] [b] [1975]).

The 1973 Act expanded the list of prohibited activities far beyond those of the previous two Acts. In addition to prohibitions against importation (included in the 1969 Act) and prohibitions against the movement in interstate commerce of animals taken in violation of local laws (included in the Lacey Act), the 1973 Act bans "exporting, taking within the United States or its territorial seas or on the high seas, possessing or transporting any endangered species illegally taken, transporting any endangered species in interstate or foreign commerce for commercial purposes, or offering to sell or selling such animals in interstate or foreign commerce" (16 U.S.C. 1538 [a] [1] [1975]). Protection was afforded for the first time to endangered and threatened species of plants (16 U.S.C. 1538 [a] [2] [1975]).

Although Congress had recognized that hunting and the destruction of natural habitat were two major causes of extinction, the 1973 Act addressed still another cause of extinction—"overutilization for commercial, sporting, scientific, or educational purposes" (16 U.S.C. 1533 [a] [2] [1975]). Even the prohibition against "taking" addresses the overutilization issue, since "taking" is defined to include "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect" (16 U.S.C. 1532 [14] [1975]).

Finally, the 1973 Act authorized suits by private citizens seeking "to enjoin any person, including the United States and any agency or other governmental instrumentality...who is alleged to be in violation of any provision of this chapter (1973 Act) or regulation issued under the authority thereof" (16 U.S.C. 1540 [g] [1] [A] [1975]) and provided that they may obtain injunctive relief.

HABITAT PRESERVATION

As previously stated, the 1973 Act specifically mentions habitat preservation (16 U.S.C. 1536 [1975]). Habitat, as defined, consists of the spatial environment in which a species lives, including the elements of land, water, air and a geographical boundary. The critical habitat of a species may be its entire habitat or may be a portion of it if, and only if, any constituent element is essential to the normal needs or survival of that species. Critical habitat may not be restricted to the habitat necessary to maintain a minimum viable population. The following needs must be considered when determining the critical habitat of any given species:

1. Space for normal growth, movement, or territorial behavior;
2. Nutritional requirements, such as food, water, or essential minerals;
3. Sites for breeding, reproduction, or rearing of offspring;
4. Cover or shelter; or
5. Other biological, physical, or behavioral requirements (40 F.R. 17764 [1975]).

Under this concept, the destruction, disturbance, modification, curtailment, or subjection to human activity of any habitat considered critical for a given species would not conform with the 1973 Act, if such action might be expected to restrict sufficiently the numbers or distribution of that species to place said species in further jeopardy, or were to limit the potential and reasonable expansion or recovery of that species. Federal conservation actions involving critical habitats may include "the development of regulations, land and water acquisition, leasing arrangements, federal/state cooperation in implementing the 1973 Act, and other administrative research and management plans and activities (40 F.R. 17765 [1975]).

It is important to understand that there may be many kinds of actions which can be carried out within the critical habitat of a species which would not be expected to reduce its numbers or distribution, or otherwise adversely to affect that species.

DEPARTMENT OF THE INTERIOR ACTIONS

After the 1966 Act was passed, on March 11, 1967, 78 species were listed as endangered, including the Indiana Bat (*Myotis sodalis*) (32 F.R. 4001 [1967]). When the 1966 Act was replaced by the 1969 Act, another endangered species list was published. This list named 101 species, including the Indiana Bat and the Hawaiian Hoary Bat (*Lasiurus cinereus semotus*) (35 F.R. 16047-8 [1970]). Yet another list was published after the passage of the 1973 Act. This list, however, included threatened as well as endangered wildlife (41 F.R. 47180-98 [1976]). On April 28, 1976, a third species of bat was added to the ever-growing list, the Gray Bat (*Myotis grisescens*) (41 F.R. 17736-40).

In accordance with the 1973 Act, the Department of the Interior requested determination of critical habitat for 108 species, including the Hawaiian Hoary Bat and the Indiana Bat (40 F.R. 21499-501 [1975]). Critical habitat was determined for the Indiana Bat on September 24, 1976 (41 F.R. 41914-16). Appendix I lists known areas of critical habitat for the Indiana Bat.

At the time of this writing, the Department of the Interior is considering placing two additional bat species, the Ozark Big-Eared Bat (*Plecotus townsendii ingens*) and the Virginia Big-Eared Bat (*Plecotus townsendii virginianus*), on the endangered list (42 F.R. 61290-2 [1977]). Critical habitat has been proposed for one. If no adverse comments are received or reasons given during the 90-day review and comment period why these species should not be considered as endangered, the Department of the Interior will determine that they are endangered, and, as such, they will be protected by the 1973 Act. Appendix II lists the proposed critical habitat for the Virginia Big-Eared Bat.

The primary objective of the 1973 Act is "to conserve" species by providing protection and monitoring populations (16 U.S.C. 1532 [2] [1975]). The Indiana Bat, however, is one of the endangered species for which a recovery team was formed and a recovery plan prepared. This plan was approved on June 1, 1976 (*Indiana Bat Recovery Plan*, U.S. Dept of Interior, Fish and Wildlife Service, 1 June 1976, 34pp.). It states 3 objectives in assisting recovery of the Indiana Bat to where it can be removed from the endangered species list. These are:

1. To preserve critical winter habitat by restricting access to hibernacula;
2. To initiate a program of public information and education; and,
3. To monitor population levels and habitats.

The plan is proceeding according to its implementation schedule.

COURT DECISIONS

Court decisions concerning endangered species have increased in frequency in recent years. They have proven to be of major significance, in that they have embodied individual and governmental attempts to make difficult and yet practical decisions concerning the preservation of species in an increasingly technological and urbanized environment which is often heedless of nature. Since passage of the 1973 Act, several landmark federal court decisions have: 1) greatly affected application of the 1973 Act, 2) established a burden-of-proof responsibility upon those wishing to utilize the Act as a deterrent against further habitat and/or species destruction, and 3) strengthened the position of the endangered species, themselves.

Sierra Club v. Froehlke

The primary issue in *Froehlke* (392 F.Supp. 130 [8th Cir., 1975]), became whether the Army Corps of Engineers had adequately considered the fate of the Indiana Bat (*Myotis sodalis*) in its environmental impact statement regarding the construction of the Meramec Dam near St. Louis, Missouri. The Sierra Club maintained that the Army Corps of Engineers did not assess primary and secondary impacts of dam construction and its resultant flooding of certain caves known to be critical habitats of the Indiana Bat. Both the District Court and the Circuit Court of Appeals (534 F.2nd 1289 '[E.D.Mo., 1976]) ruled that the Sierra Club failed to meet its burden of proof, which was to show that the actions taken or considered by the Army Corps of Engineers had or would jeopardize the continued existence of the Indiana Bat.

National Wildlife Federation v. Coleman

In *National Wildlife Federation* (529 F.2nd 359 [5th Cir., 1976]), the issue centered upon construction of a highway through a critical habitat of the Mississippi sandhill crane (*Grus canadensis pulla*). The court ruled that, once a federal agency has had a meaningful consultation with the Secretary of the Interior concerning actions which may affect an endangered species, the final decision, of whether or not to proceed with the actions, lies with the federal agency, itself. The 1973 Act does not give the Secretary of the Interior a veto over the actions of other federal agencies, provided that the required consultations have occurred. It follows that, after consulting with the Secretary of the Interior, the federal agency involved must determine whether it has taken all necessary precautions to ensure that its actions and their subsequent impacts will not jeopardize the continued existence of an endangered species. One federal agency cannot rely on another agency's proposal to provide substitute habitat in order to satisfy its burden of ensuring the continued existence of the species irrespective of past destructive actions by others. Once the decision on whether or not to proceed is made, it is then subject to judicial review to ascertain whether "the decision was based on a consideration of the relevant factors and whether there has been a clear error of judgment" (Citizens to Preserve Overton Park. v. Volpe, 401 U.S. 402, 91 S.Ct. 814, 28 L.Ed 2nd 146 [1971]). The decision by the Circuit Court of Appeals in *National Wildlife Federation* was to enjoin the Department of Transportation from building the highway until the effects of construction on the Mississippi sandhill crane and its habitat had been adequately evaluated.

Hiram G. Hill v. TVA

In *Hill* (549 F.2nd 1064 [6th Cir., 1977]), the Circuit Court of Appeals overruled the District Court (419 F.Supp. [E.D.Tenn., 1976]) and enjoined the Tennessee Valley Authority from completing construction of the Tellico Dam on the Little Tennessee River. The Appeals Court stated that, in its opinion, once a living species has been eradicated (in this case, the snail darter [*Percina imostoma tanasi*]), discretion loses its significance. When a project is on-going and substantial resources have been expended, the conflict between national incentives to conserve living things and the pragmatic momentum to complete the project on schedule is most inclusive. Whether the project is 50% or 90% completed is irrelevant in calculating the social and scientific costs attributable to the disappearance of a unique form of life. The on-going nature of a project does not preclude enforcement of the 1973 Act. The court ruled that a citizen suit is one method to preserve the status quo where endangered species are threatened, thereby guaranteeing the legislative or executive branches sufficient time and opportunity to analyze alternatives. Enforcement of the 1973 Act must be taken to its logical extreme.

Finally, it should be noted that the court restated that it was not authorized to override the Secretary of the Interior by arbitrarily reading species out of the endangered species list or by re-defining the boundaries of existing critical habitats on a case-by-case basis. The standard of judicial review of such rule-making is restrictive and does not permit substitution of judgment. The welfare of the snail darter and its critical habitat weighed more heavily on the Court's conscience than the write-off of millions of dollars already expended on the Tellico Dam. This decision was upheld by the United States Supreme Court (98 S.Ct. 2279 [1978]).

Defenders of Wildlife v. Andrus

In *Defenders of Wildlife*, (428 F.Supp. 167 [D.D.C., 1977]), the District Court ruled that the United States Fish and Wildlife Service must do far more than merely to avoid eliminating protected species. It must use all methods necessary to bring those species back from the brink of extinction, so that they may be removed from the endangered species list.

United States v. Capparet

In *Capparet*, (375 F.Supp. 456 [D.Nev., 1974]) the United States sought a declaratory judgment of its right to use ground water adjacent to Death Valley National Monument. The evidence established that the defendant's pumping of underground water for commercial purposes had drawn water from underground sources which supplied a pool containing the Devil's Hole pupfish (*Cyprinodon diabolis*), an endangered species, and threatened the survival of the pupfish. The defendants were enjoined so as to limit their pumping to achieve and maintain a stated daily mean water level in the pool. The significance of this decision is the importance which was attached to the protection of an endangered species, ranking it superior to property rights. The court supported the 1973 Act and the federal policy of protecting endangered species through the preservation of their natural habitat.

These decisions begin to show the basic judicial interpretation of the 1973 Act:

1. Initially, the burden of proof lies with the plaintiff and not with the federal agency responsible for the action.
2. Secondary impacts must be evaluated, in order to ensure the continued existence of an endangered species and to ensure that the critical habitat will not be modified or destroyed.
3. Social and scientific costs are more important than the financial resources which have been expended.
4. The federal government must use all suitable methods to encourage and promote the recovery of an endangered species.
5. The protection of an endangered species is more important than private property rights.

SURVEY PROCEDURE

As previously stated, the orginal intent of this study was to evaluate the responses of all Cabinet-level Departments and the relevant federal agencies to four basic questions concerning the protection and/or eradication of bats. These questions were:

1. What Federal laws, regulations, and guidelines govern your agency's actions regarding the protection and/or eradication of bats?
2. How has your agency interpreted these laws, regulations, and guidelines in formulating its internal policies?
3. What do your protection policies include: *e.g.*, cave management, cave acquisition, cave fencing (entrances), not publishing cave locations, preserving critical habitat, etc.?
4. If eradication is necessary, what methods and recommendations are followed? What chemicals are allowed and in what dosages?

As more information became available and was analyzed, it became apparent that this was a subject which could not be limited in scope merely to responses to four questions. It was, therefore, deemed necessary to provide the substantial historical background of the past and present endangered species legislation and litigation summarized in the preceding sections.

The following section provides an agency-by-agency review of existing federal policies on bats; of course, these policies are not solely confined to bats, but encompass all endangered and/or threatened species. Only comments by agencies actively involved in matters affecting bat conservation are summarized here. A list of agency contacts is contained in Appendix IV.

AGENCY RESPONSES

Department of Agriculture

The Forest Service (FS) responded to each question separately and stated that there was an umbrella of federal laws which managed and protected bats and their habitats. These laws are: The Multiple Use—Sustained Yield Act of 1960, The National Environmental Policy Act of 1969 (hereinafter referred to as "NEPA of 1969"), The Federal Insecticide, Fungicide, and Rodenticide Act of 1972 (hereinafter referred to as "FIFRA of 1972"), The Endangered Species Act of 1973 (previously referred to as "1973 Act"), The Sikes Act of 1974, and the Federal Land Policy and Management Act of 1976 (hereinafter referred to as FLPMA of 1976").

In the FS manual, Sections 2600 and 2630 reflect their policy regarding the interpretation of these laws. Section 2600, "Wildlife Management," states that the FS will aid in the enforcement of the laws of the States for the protection of fish and game. Section 2630, "Management of Wildlife and Fish Habitat," states that threatened and endangered species will receive the highest priority.

In order to protect bat habitats, the FS will either acquire the land or fence the cave entrances to restrict public entry. All possible steps to preserve critical habitats will be taken. Disclosure of these locations is generally not made, but can be specifically requested through the Freedom of Information Act. The FS has no control or eradication programs.

The Soil Conservation Service (SCS) is responsible for developing and carrying out a national soil and water conservation program in cooperation with landowners and operators, other resource groups, and federal agencies. Their survey response referenced NEPA of 1969, the 1973 Act, and Section 640.22 of the SCS Manual. This section covers rare, threatened, and endangered species of plants and animals. It sets forth background, policy responsibility, coordination, and implementation. The SCS also has published guidelines and procedures for preparing an environmental assessment for complying with NEPA of 1969 (42 F.R. 40014 [1977]).

Because the SCS is not a landowning or management agency, there are no policies for caves. If a critical habitat is encountered, the 1973 Act takes effect. The SCS does not participate in or recommend any bat eradication or control programs.

Department of Defense

The Department of Defense (DOD) has no programs for bat or cave management, no critical habitats on military lands, and no evidence of the existence of bat species in any quantity on its properties. If bat species were found, the 1973 Act would apply.

The Army Corps of Engineers stated that they did not have any bat control programs, but referred to the 1973 Act, the NEPA of 1972, the FIFRA of 1972, and the Center for Disease Control programs. Should any bats be located during the construction of a project, the Corps would coordinate with the local health officials, the Department of the Interior, the Center for Disease Control, and the Environmental Protection Agency. If bats were located within DOD buildings, they would attempt to control the bats and to bat-proof the buildings by mechanical methods.

Department of Health, Education, and Welfare

Bat programs within the Department of Health, Education, and Welfare (HEW) are the responsibilities of the Public Health Service (PHS) and the Center for Disease Control (CDC).

The PHS was created to assess and promote the highest level of health attainable for every individual and family in America and to develop international health projects, including the prevention and control of communicable diseases, such as rabies.

The CDC administers national programs for the prevention, epidemiology, and control of communicable and vector-borne diseases. It responded to the survey as follows: the CDC was registered by the Environmental Protection Agency on May 28, 1976 to release DDT for the control of bats in man-made structures, where they constitute human health hazards as potential ravies vectors. CDC has prepared a document titled, "Guidelines for the Use of DDT in the Control of Bats." This document outlines stringent criteria for the correct procedures as to requests, application, use, technique, and reports. The CDC is reluctant to release DDT for bat control because of the benefits derived from bats. Eact state has a DDT coordinator responsible for reviewing all DDT requests made in his state. The applicants must show that an abnormal rabies risk of human exposure exists and that other methods of repelling or physically excluding bats have failed before releasing DDT. The CDC will not approve any requests for the use of DDT to kill bats in caves.

Where approval is given, people spraying DDT must be licensed pest control operators familiar with the health hazards of DDT and rabies to minimize the risk of exposure. Also, it is recommended that the persons concerned with bat control be pre-immunized against rabies. Special use of DDT can also be obtained through the FIFRA of 1972, Section 18—Crisis Exemption. This section allows the Administrator of the Environmental Protection Agency to exempt (a state) if he determines that an emergency condition exists. Before he makes his decision, he must consult the U.S. Secretary of Agriculture and the Governor of the state making the request. The regulations clearly state that a responsible official must determine that there exists the possibility of an unpredictable outbreak of pests, that there is no readily available pesticide registered for the particular use to eradicate or control the pest, and that there is a critical time requirement. Within 10 days after the application to use, or after the actual use of the pesticide, the applicant must file in writing, with the Environmental Protection Agency, specific information justifying its use.

The CDC recognizes that total elimination of rabies is seldom a practicable goal and that the reduction to a normal level of risk, is a more realistic goal. The CDC will not approve programs simply to control depradating or nuisance animals.

Department of the Interior

The Bureau of Land Management (BLM) has no specific bat management plans. It is responsible for the management of wildlife habitat on public lands. Under FLMPA of 1976, the Secretary of the Department of the Interior shall prepare and maintain, on a continuing basis, an inventory of all public lands and their resources and other values, giving priority to areas of critical environmental concern. Other laws that govern BLM actions regarding bats are the 1973 Act, NEPA of 1969, the Sikes Act of 1960, the Bald Eagle Protection Act of 1940, and FIFRA of 1972.

Section 1063 of the BLM policy manual provides guidance on the protection and use of species through the enhancement and maintenance of wildlife habitat components. Section 6620 provides guidance on the preparation of habitat management plans, and Section 6840 provides guidance for the conservation of animals which are officially listed in categories that imply significant potential for extinction.

BLM requires caving permits as a means of controlling visitor use. This permit system allows BLM to restrict the number of visitors, to close the entire cave, to permit only certain portions of the cave to be used, and to restrict the size and number of parties using the cave. BLM also gates significant caves as a protection measure. These gates are designed to allow bats to pass.

If the BLM feels that bat eradication is necessary, it will contact the state wildlife agency and the U.S. Fish and Wildlife Service, and will complete an environmental assessment prior to eradication. Eradication will be accomplished by the state wildlife agency, the state public health agency, and/or the U.S. Fish and Wildlife Service.

The Bureau of Reclamation has no programs involving bats or their habitats. However, should bats be encountered, the Bureau would prevent or mitigate impacts by suitable modification or additions to the plan.

The Endangered Species Scientific Authority (ESSA) is not involved in any bat habitat or eradication programs; it is primarily concerned with international trade, including the movement of specimens for commercial, scientific, exhibition, or other reasons. There are five species of bats listed by the Convention (see Appendix III). Unless trade becomes more of a problem than at present for the survival of a bat species, ESSA probably will not be involved more extensively with bats in the future.

The Fish and Wildlife Service (FWS) has direct responsibility for bat protection and control, through the 1973 Act and the Fish and Wildlife Coordination Act of 1956. FWS has issued "Guidelines to Assist Federal Agencies in Complying with Section 7 of the 1973 Act." These guidelines are intended to furnish a broad framework within which federal agencies may prepare internal procedures to guide their activities or programs and may be used at their discretion. The working concepts mentioned in Section 7 are critical habitat, jeopardizing the continued existence, and destruction or adverse modification.

FWS has several protection policies. These policies depend on the state of the individual species or population and are dictated by a recovery plan prepared by FWS. They include cave management, land acquisition, cave fencing, preservation of critical habitat, and a moratorium on bat banding.

The FWS policy bans the use of DDT and other chemicals placed on its prohibited list. FWS recommends "bat-proofing" buildings as an alternative to DDT. Bat-proofing involves sealing the entry holes of a structure when the bats are out feeding or migrating. When a lethal toxicant is used, it may cause moribund bats to be scattered throughout a wide area, thus increasing the likelihood that people and pets may be bitten. The indiscriminate killing of bats under the guise of public health is not an acceptable practice to FWS. Bat-proofing or architectural modification is the most promising method presently available. The FWS is preparing a technical bulletin on bat management.

The National Park Service (NPS) seeks to maintain diversity and natural abundance of all wildlife species. NPS manages caves as total systems. They have management policies for animal populations, wildlife populations, threatened and endangered plants and animals, pesticide use, and caves. NPS will preserve all critical habitat areas.

Department of Transportation

The Federal Highway Administration has no specific regulations regarding bat management, but they do have a policy on the preparation of an environmental impact assessment, contained in the "Federal-Aid Highway Program Manual" Volume 7, Chapter 7, Section 2. Reference was made to the 1973 Act and, should bats be encountered, they would coordinate with the U.S. Fish and Wildlife Service.

Environmental Protection Agency

The Environmental Protection Agency (EPA) is primarily a regulatory agency. It is not directly involved in wildlife management programs and does not have any formal bat management policies. The EPA is responsible for enforcing FIFRA of 1972, which regulates the marketing of pesticides and requires that such products by registered on the basis of proven effectiveness and safety to humans, livestock, wildlife, and the environment. The regulations under FIFRA of 1972 are very specific. EPA lists the criteria for determinations of unreasonable adverse effects of pesticides. Forms of plant and animal life and viruses declard to be pests and which are injurious to health or to the environment are listed. EPA prepares guidelines for registering pesticides in the United States and lists the criteria governing exemptions under emergency conditions (see HEW response).

Currently, the EPA has only two federally registered products for bat control, a toxicant and a repellent. The Center for Disease Control (CDC) has a registration for the toxicant DDT (EPA Registration Number 36765-1) for control of bats inside of buildings. These bats must constitute a health hazard as potential rabies vectors, and the product must be used only by agencies approved by CDC and only after practical alternative methods have failed. The other federal registration is the repellent naphthalene, used for control of bats inside of buildings (EPA Reg. No. 462-19). In addition to these federal registrations, eight states (Vermont, Ohio, New Jersey, Maine, Georgia, Montana, Michigan, and North Dakota) have registered the anticoagulant toxicant chlorophacinone for use against bats inside of buildings, under the Section 24C (Special Local Needs) provision of FIFRA.

Tennessee Valley Authority

The Tennessee Valley Authority (TVA) believes that bat populations are best encouraged by avoiding attempts at management (ref: NEPA of 1969 and the 1973 Act). They recognize the ecological significance of bat populations and the importance of their protection. There are frequent consultations with U.S. Fish and Wildlife Service experts and national bat experts. TVA does not support any chemical eradication programs but, rather, places their emphasis on the protection of bat caves. TVA has worked with local grottoes (chapters) of the National Speleological Society to protect caves against vandalism and wanton destruction. TVA generally uses fencing and gating of caves as a last resort and limits the publication of the exact locations of caves to further their protection.

Council on Environmental Quality

The Council on Environmental Quality (CEQ) opposes unnecessary use of pesticides, since most eradication programs are ineffective, uneconomical, and environmentally unsound. CEQ is preparing an "Integrated Pest Management Concept" which will be available shortly.

Office of Science and Technology Policy

The Office of Science and Technology Policy (OSTP) has no regulations or guidelines regarding bat management and agreed that the use of DDT may scatter bats throughout the area, thereby increasing the likelihood that people may be bitten. OSTP also recognized that there is a serious health hazard associated with the use of long-lived, non-bio-degradible toxicants within the home. OSTP referred to the Center for Disease Control's policy and restated that a high risk must be present before releasing DDT to an applicant.

CONCLUSIONS

Responses to the questions indicate that there exist several federal policies relating to bats, all of which are basically uniform and consistent at the major levels; i.e., nationally down to the regional field offices. Ultimately, however, the Departments of Interior and of Health, Education and Welfare, and the Environmental Protection Agency have primary responsibilities for decisions made regarding bat management. Judging from the responses of these agencies, the actual eradication of bats, when they have been proven to be of potential human danger, is not a decision taken lightly. It is, in fact, one subjected to careful scrutiny, preparation, and interagency coordination.

Ironically, in our opinion, it appears that those persons on whom the actual burden of bat eradication falls seem to view the procedure, notwithstanding, with a degree of reluctance. In contrast, the man-on-the-street tends to view all bats as something conceived directly from the pages of "Dracula." The frightening scenario of the dreaded supernatural vampire fluttering whisper-soft into the night to claim yet another unsuspecting victim remains first and foremost in his mind, and countless numbers of bats, both protected and non-protected, have undoubtedly been annihilated simply through ignorance and misunderstanding.

It can be concluded, then, that a more concerted effort should be made to educate the general public about this tiny, fragile creature which is unique in the animal kingdom. Such a program would be an up-hill struggle, given the deeply ingrained cultural bias which exists, but it should be attempted.

The survey also shows that existing endangered species legislation provides a basic tempering tool—one which must be applied judiciously, yet forcefully. Such a tool will enable us to provide the necessary protection to prevent any further species extinctions and, through intelligent application, will allow all creatures to exist without perpetual threat of extinction. It would appear that through application of the 1973 Act, the courts are engaged in ecological tinkering, getting endangered species over the hurdles until management of the entire ecosystem, including habitats, can be realized.

Many species are now endangered and, in some cases, even, extinct. This is a burden which we must bear. It is the special responsibility of our generation to ensure that this pattern does not continue into the future. Animals and plants exist harmoniously, one with another, without human intrusion. Most extinctions during the past several thousand years have been the result of human population pressure and technological development. As human dominion over the earth becomes more pervasive and more nearly absolute, we must strive ever more diligently to co-exist with nature. For, the mantle of civilization notwithstanding, we are inextricably interdependent upon the plants and animals with which we co-evolved. We cannot survive without them...a very sobering thought.

ACKNOWLEDGMENTS

Our special thanks must be expressed to Dr. Arthur Greenhall, U.S. Department of the Interior, for his invaluable assistance and consistent encouragement during preparation of this paper.

We wish to express our appreciation to those individuals who so ably refereed this paper, especially Mr. Eugene Hargrove.

APPENDIX I: Indiana Bat Critical Habitat (41 F.R. 41914-16 [1976]).

The following areas (exclusive of those settlements or man-made structures which are not necessary to the normal needs or survival of the species) are critical habitat for the Indiana Bat (*Myotis sodalis*):

Illinois	Blackball Mine, LaSalle County
Indiana	Big Wyandotte Cave, Crawford County
	Ray's Cave, Green County
Kentucky	Bat Cave, Carter County
	Coach Cave, Edmonson County
Missouri	Pilot Knob Mine, Iron County
	Bat Cave, Shannon County
	four unidentified caves in the Meramec River Basin*
Tennessee	White Oak Blowhole Cave, Blount County
West Virginia	Hellhole Cave, Pendleton County

* The names and locations of these caves *may* be available from the Division of Ecological Services, U.S. Fish and Wildlife Service (Region 6); their identifying numbers are deliberately confusing and for that reason are not given here.

APPENDIX II: (proposed) Virginia Big-Eared Bat Critical Habitat (42 F.R. 61290-92 [1977]).

Kentucky	Stillhouse Cave, Lee County
West Virginia	Cave Mountain Cave, Pendleton County
	Hellhole Cave, Pendleton County
	Hoffman School Cave, Pendleton County
	Sinnit Cave, Pendleton County
	Cave Hollow Cave, Pendleton County

APPENDIX III: International Trade In Endangered Species of Wild Fauna and Flora (42 F.R. 10462 [1977]).

The below listed species may not be imported into or exported from the United States without a valid foreign certificate of origin.

1. Horseshoe bat, *Rhinolophus euryale* (Tunisia 4-22-76)
2. Horseshoe bat, *Rhinolophus ferrumequinum* (Tunisia 4-22-76)
3. Horseshoe bat, *Rhinolophus hipposideros* (Tunisia 4-22-76)
4. Pipistrelle bat, *Pipistrellus spp.* (all species) (Tunisia 4-22-76)
5. White-lined bat, *Vampyrops lineatus* (Uruguay 7-14-76)

APPENDIX IV: Agency Contacts

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ABSTRACT OF PAPER, 1977 NSS CONVENTION, ALPENA, MICHIGAN

STRUCTURAL, PETROGRAPHIC, AND RELATIVE SOLUBILITY RELATIONSHIPS IN THE SINNETT-THORN MOUNTAIN CAVE SYSTEM, PENDLETON COUNTY, WEST VIRGINIA

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The Sinnett-Thorn Mountain cave system was formed in the lower Helderberg Group of limestones on the eastern limb of a SSW-plunging anticline. Solution passages were developed in the New Creek (Coeymans) and Keyser formations. Extensive collapse of the overlying cherty Corriganville (New Scotland) formation has been facilitated by intraformational solution.

Petrographic examination of the limestone members exposed showed that all are sparry allochemical carbonates with a ferroan calcite pore-filling cement that dissolves preferentially before adjacent, purer calcite fossils. The major cave former, the New Creek biosparrudite, has the least insoluble material and the coarsest pore-filling ferroan spar.

Different structural features have controlled primary "phreatic" passage locations at different elevations in the cave. The oldest, topmost section of the cave was formed as a maze in the New Creek limestone, below a series of vertically crushed and sheared zones in the Corriganville cherty limestone. These zones are approximately 25 cm thick and are interpreted as compressive conjugate shear fractures formed diagonally to regional folding stresses. The crushed zones and their included passages are not located at the crest of the anticline, but are slightly to the east where the bedding dip is 10° to 15° east. Subsequently, passages developed at lower elevations within areas where limestone dip varies from 15° to 40° east. These follow tensional "strike" joints in the Corriganville cherty limestone. Where the bedding dips more than 40° east, passages were not initially formed below fractures in the Corriganville cherty limestone. Fracture-controlled permeability within the New Creek and Keyser can be demonstrated, however. For example, a passage developed in the New Creek in this zone follows the intersection of two normal faults. Passages also follow the strike of a drag fold in the upper Keyser limestone.

Possible causes of this shift in the stratigraphic location of primary porosity are: (1) water, flowing in the Corriganville along open joints with dips of less than 50° west, is readily channeled along the chert beds and is not allowed to react with the underlying New Creek limestone; (2) that at bedding dips of more than 40° east, the New Creek and Keyser limestones behave in the aquifer as thick massive carbonates.

In contrast to the active role in groundwater movement played by the solutional passages and fracture permeability mentioned above, there are "passively" formed "wells" connecting different levels of the cave. These wells follow steeply dipping fracture zones that are interpreted as compressive shear fractures related to local folding stresses. The wells did not, at least initially, channelize groundwater flow. Only one other major passively formed solution void has been found. This is located in the lower southeastern part of the "Big Room," where reverse faulting has stratigraphically repeated the New Creek limestone.

VARIATIONS IN BODY COLOR AND EYE PIGMENTATION OF *Asellus brevicauda* Forbes (ISOPODA: ASELLIDAE) IN A SOUTHERN ILLINOIS CAVE STREAM

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ABSTRACT

Aquatic isopods were collected at 7 stations in and near Cave Spring Cave, Hardin Co., Illinois. ***Asellus brevicauda*** *was the most common isopod species in the immediate vicinity of Cave Spring Cave and decreased in relative abundance downstream from the cave, whereas* ***Lirceus fontinalis****, which was never observed upstream from the resurgence of the cave stream, became more abundant.* ***Asellus intermedius*** *was ubiquitous, and* ***Asellus stygius*** *was found only in the cave stream and at its resurgence.*

Of all the ***A. brevicauda*** *collected, 37% were white, 28% were normally dark, and 35% were intermediate in integumentary pigmentation. The percentage of white forms decreased downstream from the cave, while the percentage of intermediate and dark forms were usually equal at a given station. Parasitism by acanthocephalan larvae was not a factor in the reduction or loss of body pigmentation. Reduced eye pigmentation was observed in 29% of the white* ***A. brevicauda****. The variation in body color and eye pigmentation was attributed to a change in the genetic constitution of the population.*

INTRODUCTION

VARIABILITY OF the integumentary pigmentation and of the ocular structures of isopods are not common findings. Packard (1888) examined "depauperate" isopods from a well in Normal, Illinois, which possessed a range of rudimentary eyes varying in degree of distinctness. Extreme polychromatism, ranging from dark individuals to entirely white individuals, and six eye types, ranging from normal in structure and pigmentation to completely eyeless, were observed in the cave-dwelling isopod *Asellus aquaticus cavernicolus* Rac. (Kosswig and Kosswig, 1940; de Lattin, 1939). Variation in body pigment and in the number of eye facets was also observed in populations of *Asellus scrupulosus* Williams and *Asellus racovitzai racovitzai* Williams (Fleming, 1973). Mackin and Hubricht (1938) reported that specimens of *Asellus brevicauda* Forbes collected from caves in St. Clair and Monroe Counties, Illinois differed from the typical form in having "the pigmentation much reduced."

White forms of the (normally) darkly pigmented *A. brevicauda* were first observed at the resurgence of the stream in Cave Spring (Shelterville) Cave, Hardin County, Illinois, in October, 1974. A study was begun in March, 1975, to determine if there was a relationship between distance from the cave and the relative abundance of the white forms.

STUDY AREA

Two intermittent surface streams flow along the bottom and unite at the midpoint of a 3 km long and one-half km wide doline, then disappear into an unenterable subterranean passage at the western base of a low hill (Fig. 1). Water from this passage emerges on the east side of the hill, flows a few hundred meters across another doline, perforates a second hill and, finally, emerges in the floor of the Wallace Branch Valley.

A massive excavation project at the first swallow hole or diving into a 2 m deep sump near the first spring would be required for a human to enter the subterranean passage under the first hill.

Cave Spring Cave, situated under the second hill, is a joint-controlled, phreatic cave system older than the present topography and is

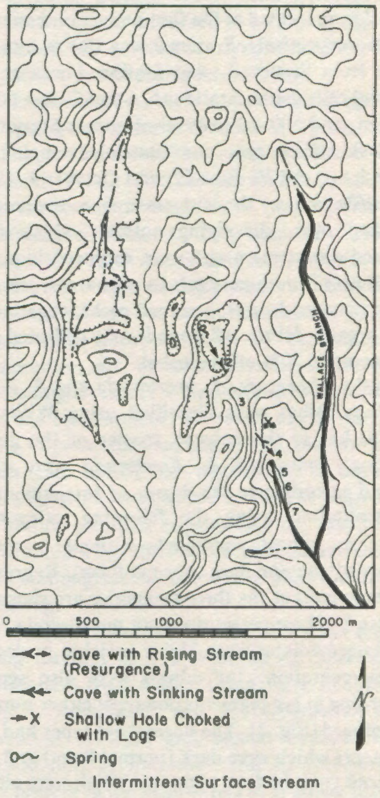

Figure 1. Map of the study area, showing the location of the sampling stations. Topography from the USGS 7.5' Shelterville, ILL.-KY. quadrangle. Contour interval = 20 ft..

undergoing modification by a vadose stream (Bretz and Harris, 1961). Deeply ponded water in the upper and lower 150 m of the cave makes it necessary either to swim or to boat into the cave. Midway along the cave, the stream plunges down an 8 m high waterfall. A sump 500 m from the upstream entrance (150 m from the downstream entrance) has prevented a portal-to-portal traverse of the cave by human explorers. A wide diversity of troglobites, troglophiles, and trogloxenes has been observed in Cave Spring Cave. The list includes the endemic troglobitic beetle *Pseudanophthalmus illinoisensis* (Barr and Peck, 1966), a new species of guanophilic pyemotid mite (author's unpublished data), and two roosts of the gray bat, *Myotis grisescens*.

The Williams brothers operate a limestone quarry at the very edge of Cave Spring Cave. They seem interested in preserving the cave and the bats. However, it is suspected that blasting operations in the quarry have caused large blocks to fall from the ceiling of the cave, and runoff from the quarry has contributed large amounts of fine limestone gravel to the stream below the cave. Access to the cave is controlled by the Williams brothers, who generally cooperate with scientific investigators and discourage recreational cavers.

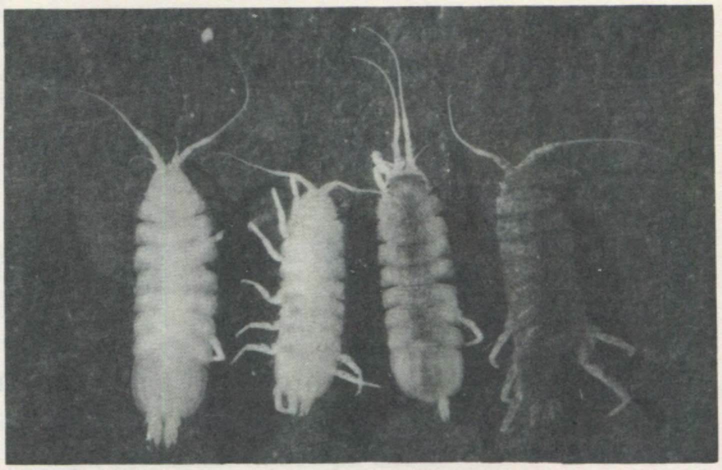

Figure 2. The three body pigmentation morphs and the two eye pigmentation types of *Asellus brevicauda*. The left isopod is typical of the white morph with reduced eye pigmentation, the next is typical of the white morph with normal eyes, the next is typical of the intermediate morph with normal eyes, and the right is typical of the dark (normal) morph with normal eyes.

METHODS

Seven sampling stations were established and numbered from the first doline (Fig. 1). Stations 1 and 2 were located at the first and second swallow holes, respectively. Station 3 was 100 m into the cave from Station 2, and Station 4 was at the second resurgence. Stations 5, 6 and 7 were 50 m, 100 m, and 500 m, respectively, from Station 4.

Each station was quantitatively sampled on March 6, April 26, June 27, and October 4, 1975. In riffle areas, the substrate was thoroughly worked over, dislodging animals which then floated downstream and were captured in a fine mesh net (7 mesh per cm). In pool areas, isopods were removed from submerged rocks, vegetation, and organic debris. All isopods were collected and preserved in 70% ethyl alcohol.

In the laboratory, *A. brevicauda* and *A. intermedius* Forbes were identified using Williams' (1970) key to the epigean species of the genus *Asellus*. Individual *A. brevicauda* were then scored according to the degree of integumentary pigmentation, using the following categories: white or almost completely without pigment; intermediate; and dark (normal form). Representative isopods of the three categories are shown in Figure 2. These categories were not discrete, and the intermediates were highly variable in degree of pigmentation. Individuals were also scored according to eye pigmentation type: either normal or reduced (Fig. 2). The normal eye types had eye pigments which were dark (normal form) and the reduced types had eye pigments which were either pink or entirely absent. The body cavities of 36 *A. brevicauda* collected at Station 2 and of all *A. brevicauda* (28 individuals) collected at Station 4 in October were examined for the presence of parasitic acanthocephalan larvae.

From these data, least-squares regression lines were calculated for the following relationships: the relative abundance of *Lirceus fontinalis* Raf. in an isopod population *vs* the natural log of the distance downstream from the cave plus one, the relative abundance of *A. brevicauda* in an isopod population *vs* the natural log of the distance plus one, and the percentage of *A. brevicauda* that were white *vs* the natural log of the distance plus one. For these relationships, a distance of 0 m was used for Station 3; 5 m was used for Station 4; and 50 m, 100 m, and 500 m were used for station 5, 6, and 7, respectively. The sample correlation coefficient, *r*, was calculated for each relationship, and a t-test was used to test the hypothesis that the variables were not linearly related (*i.e.*, $r = 0$). To test the hypothesis that the mean number of acanthocephalan larvae per isopod host was the same for the three color morphs at Station 4, an analysis of variance was performed. The 5% level of significance was used in all statistical tests.

HABITATS SAMPLED

The following descriptions of the aquatic habitats that were sampled at each of the stations were based primarily on June and October water levels. Heavy rains, which had preceded my March and April visits to the study area, raised the stream level by up to 50 cm at the epigean stations and by up to 120 cm at the cave station. During the March and April visits to the study area, water was flowing into the first swallow hole (Station 1), and isopods were collected from leaves and pieces of bark in pools and from rocks, logs, and mud and fine gravel in the stream. During the last two visits, water was not present and isopods were not observed. Station 2 was similar to Station 1, except that water was always flowing into the cave and there was not as great an accumulation of leaves and bark in the pools. The water temperature in a shallow mud-bottomed pool and in a fine-gravel riffle ranged from 13.0° C in March and April to 17.5° C in June to 9.0° C in October. Station 3, 100 m into the cave from Station 2, was upstream from both bat colonies and from the 8 m-high waterfall. It consisted of a shallow gravel riffle with large pieces of wood wedged across the passage and several small gours and one large pool on a shelf 1 m above the stream. The nearby quarrying operations have not noticeably disrupted the habitats in this portion of the cave. Because of the high water level in March, it was not possible to collect isopods in the cave during my first visit to the study area. The temperature of the stream was usually 13.0° C., but rose to 16.5° C in June.

At Station 4, isopods were collected from algae growing on rocks in the main stream channel and from leaves and rocks in a shallow slackwater pool near the spring. In June, the water temperature varied from 13.0° C in the main channel to 19.0° C in the pool. During the other three visits, temperatures in both the channel and the pool were 13.0° C.

At Station 5, isopods were found in a shallow gravel riffle and on leaves in a 50 cm deep pool. The stream had a fine gravel bottom at Station 6 and a mud bottom at Station 7. At both stations, isopods were found on logs and among leaves and tree branches which were matted together in the main stream channel. Water temperatures at the final three stations were 13.0 to 13.5° C in March and April, 19.0 to 19.5° C in June, and 14.5 to 15.0° C in October.

RESULTS

The data in Table 1 indicate that *A. brevicauda* was the most common species of isopod in the immediate vicinity of the cave (Stations 2 to 4) but decreased in relative abundance downstream, where *L. fontinalis* became more abundant. *L. fontinalis* was never observed upstream from Cave Spring Cave. The relationship of the relative

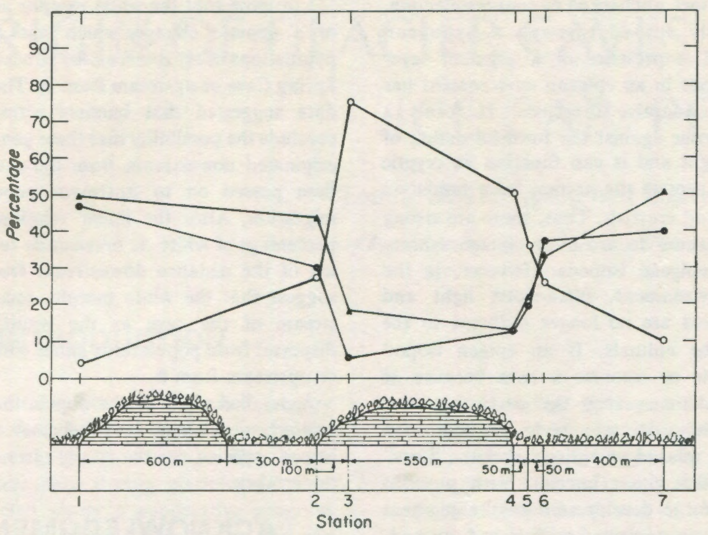

Figure 3. Percentages, at each station, of the three body pigmentation morphs of *Asellus brevicauda*. Black dots represent percentages of dark morphs, black triangles represent percentages of intermediate morphs, and circles represent percentages of white morphs. A diagrammatic cross-section through the study area is depicted beneath the graph; vertical exaggeration is 10 X.

TABLE 1. Percentages, by species, of the total numbers of isopods collected at each station. Numbers of isopods collected are in parentheses.

Species	Station Number						
	1 (94)	2 (243)	3 (132)	4 (119)	5 (174)	6 (192)	7 (100)
Asellus brevicauda	48	90	89	40	43	49	20
Asellus stygius	0	0	3	2	0	0	0
Asellus intermedius	52	10	8	24	9	9	10
Lirceus fontinalis	0	0	0	34	48	42	70

TABLE 2. Parasite burden of the three color morphs of *A. brevicauda* collected in October 1975 at stations 2 and 4.

Station	Pigmentation category	Number of isopods examined	% of isopods infected	Mean number of acanthocephalan larvae per isopod
2	White	12	0	0
	Intermediate	12	0	0
	Dark	12	0	0
4	White	12	50	0.750
	Intermediate	8	50	0.625
	Dark	8	50	0.625

abundance of *L. fontinalis* in the isopod population at each station downstream from the cave (Y) and the distance of the station from the cave in meters (X) was $Y = 5.93 + 9.93[\ln(X + 1)]$ with $r = 0.9506$. The relationship of the relative abundance of *A. brevicauda* in the isopod population (Y) and distance from the cave (X) was $Y = 76.95 - 8.96[\ln(X + 1)]$ with $r = -0.8386$. The variables in the *L. fontinalis* relationship were linearly related ($t = 5.93$, $df = 3$, $p<0.01$), while the variables in the *A. brevicauda* relationship were not significantly related ($t = 2.67$, $df = 3$, $p<0.10$). *A. stygius* (Packard) was numerically never a significant component of the isopod population at Stations 3 or 4. *A. intermedius* was found at all stations, was most common upstream, and was the predominant isopod species at Station 1.

The highest percentage of white *A. brevicauda* at one station was 75% and occurred in the cave (Fig. 3). At the first swallow hole (Station 1), only 4% of the *A. brevicauda* were white, while at the second swallow hole (Station 2), 27% were white. At the second spring (Station 4), 52% were white, and at 50 m, 100 m, and 500 m downstream from this spring, 36%, 26%, and 10%, respectively, were white. Downstream from the cave, the relationship between the percentage of white *A. brevicauda* at a station (Y) and the distance from the cave in meters (X) was $Y = 73.45 - 10.17[\ln(X + 1)]$ with $r = -0.9960$. A significant linear relationship between the variables was observed ($t = 19.31$, $df = 3$, $p<0.01$). Over the whole study area, 37% of the *A. brevicauda* were white, 35% were intermediate, and 28% were dark (normal form). Approximately equal numbers of the intermediate and dark forms were present at each station.

Of the total number of *A. brevicauda* at all stations, 11% had reduced eyes; the eyes were either pink in pigmentation or entirely absent. All the intermediate and dark forms had normal eyes, while 29% of all white forms had reduced eyes.

None of the body cavities of 12 white, 12 intermediate, and 12 dark *A. brevicauda* collected at Station 2 in October contained parasitic acanthocephalan larvae (Table 2), while 50% of the body cavities in each pigmentation category of the 12 white, 8 intermediate, and 8 dark *A. brevicauda* collected at Station 4 in October contained larvae. The mean number of larvae per isopod host at Station 4 was 0.75 in the white forms and 0.625 in both the intermediate and dark forms. No significant differences at the 5% level of significance was found among the means of the number of larvae carried by the three pigmentation forms ($F_{(2,25)} = 1.218$, $p>0.05$).

DISCUSSION

The Cave Spring Cave area provides an excellent natural laboratory for studying the population and community dynamics of the four sympatric isopod species found there.

A. brevicauda is usually associated with springs and spring-fed streams (Williams, 1970); occasionally it is found in caves (Mackin and Hubricht, 1938). The success of this species in cave environments suggests a preadaption for subterranean habitats. The data in Table 1 indicate that *A. brevicauda* is most abundant in and near the cave and decreases in abundance downstream from the cave. Homeostatic mechanisms with narrow limits of tolerance to temperature, pH, or other physical or chemical factors might restrict *A. brevicauda* to a buffered, cave-like environment. However, nearly one-half of the isopods collected at the first swallow hole, which can hardly be considered a buffered environment, were *A. brevicauda*. The isopods at this station probably migrate into the cave under the first hill when the intermittent surface stream is dry and migrate out of the cave when the stream is flowing.

L. fontinalis was never found above the second spring (Station 4) and replaced *A. brevicauda* downstream from Cave Spring Cave (Table 1). Only *A. brevicauda* and *A. intermedius* were present at the first and second swallow holes whereas only *L. fontinalis* and *A. intermedius* were present in the headwaters of Wallace Branch Creek (author's unpublished data). Only 4% of the isopods collected at Station 3 were *A. stygius*, which was commonly found in similar areas in other caves. This troglobite was easily found in other areas of Cave Spring Cave, especially downstream from the two bat colonies. The submerged surfaces of large rocks there were covered with a black, carbon-like substance. I estimate that *A. stygius* reached a density of 4000 isopods per m^2 of rock surface in these areas.

Competitive interactions might explain the observed distributions of the four isopod species in the study area. Culver (1970) presented evidence of changes in microhabitat distributions of isopods and amphipods caused by the presence of other species: *Gammarus minus* excludes *Stygonectes emarginatus* and *Asellus holsingeri* from riffles. In the cave streams which Culver studied, competition was for space to avoid the current rather than for food. More data are needed to conclusively demonstrate that, when *A. brevicauda* is in its optimum habitat, it can exclude *L. fontinalis* in epigean streams and *A. stygius* in cave streams. Each of the various habitats at the stations should be quantitatively sampled for isopods and amphipods to obtain sufficient data to make inferences about the competitive interactions of the species.

The integumentary pigments of the asellids belong to a class of ommochromes similar to xanthommatin (Needham and Brunet, 1957). Baldwin and Beatty (1941) demonstrated that the presence or absence of light does not affect the pigmentation of the European epigean *A. aquaticus* and assert that the variable degree of paleness observed in populations of *A. aquaticus cavernicolus* cannot be due to the lack of light, because all the animals would be affected to the same degree. By analogous reasoning, I assume that if light or diet were the sole factor in the reduction and loss of integumentary pigmentation, then this phenomenon would be much more common in other spring and cave populations of *A. brevicauda.*

In a population of *A. intermedius* from central Illinois, Seidenberg (1973) observed that individuals infected with an acanthocephalan parasite were decidedly lighter than uninfected individuals. However, at Cave Spring Cave, there were no significant differences in the mean acanthocephalan parasite load among the white, intermediate, and dark morphs at the resurgence of the stream in Cave Spring Cave (Station 4). None of the isopods sampled at the second swallow hole (Station 2) contained acanthocephalan larvae. The absence of acanthocephalan larvae upstream from the cave was attributed to the absence of the parasite's definitive host, usually an aquatic vertebrate, and the presence of barriers within Cave Spring Cave, such as the 8 m-high waterfall, which prevented the upstream migration of infected isopods. The parasitism data suggested that the cave served as a partial barrier to isopod migration and allowed gene flow from upstream populations to downstream populations, but not the reverse.

Kosswig and Kosswig (1940) observed that at least five gene loci are involved in pigment production in *A. aquaticus cavernicolus*. They believed that color had a neutral survival value in a cave environment and that a "loss" mutation at any of the five loci, unchecked by counterselection, will gradually spread through a hypogean population. The presence of a pigment layer covering isopods in an epigean environment has at least two adaptive functions. It forms a protective barrier against the harmful action of ultra-violet light and it can function as cryptic coloration to protect the animal from predators such as fish and crayfish. Thus, there are strong selective pressures to maintain integumentary pigments in epigean isopods. However, in the hypogean environment, ultra-violet light and visual predators are no longer a threat to the survival of the animals. If an epigen isopod species is able to colonize a cave because of preadaptive changes, then the strong selective pressures which maintain body pigments are either greatly relaxed or entirely absent. "Loss" mutations which either interfere with pigment production or the development of the pigment layer are no longer selected against but, instead, are maintained and spread through the cave population by the combined effects of mutation pressure and random genetic drift. According to this model, a loss of visual pigments might also be predicted to occur within hypogean populations. However, visual pigments, which are also ommochromes, are thought to be more stable than integumentary pigments (Vandel, 1965). The results of my study support this hypothesis, since 37% of all *A. brevicauda* were white, but only 11% had reduced or absent eye pigmentation.

I propose that the white morphs are the result of a genetic change which has occurred in populations of *A. brevicauda*, either within Cave Spring Cave or upstream from it. The parasitism data suggested that barriers within the cave preclude the possibility that these genetic changes originated downstream from the cave and were then passed on to upstream populations via migration. Also, the linear relationship of the percentage of white *A. brevicauda* to the natural log of the distance downstream from the cave suggest that the white morphs occurred downstream of the cave as the result of passive dispersal from populations either within the cave or upstream from it.

A detailed study of the population dynamics, ecology, physiology, and behavior of the four isopod species in the study area should be undertaken.

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I thank the proprietors of the Williams Stone Quarry for permission to visit the cave, and Thom Fehrmann, Steve Beckman, and David Osterbur for assistance in collecting isopods. Dr. Larry M. Page assisted with the identification of the isopod species. Dr. Thomas L. Poulson and Dr. William W.M. Steiner criticized an earlier draft of this manuscript. Mrs. Alice Prickett prepared the illustrations. Finally, I owe Dr. Lewis J. Stannard the deepest appreciation for his continued interest and encouragement.

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ORIGIN OF GLACIER CAVES IN THE QUELCCAYA ICE CAP, PERU*

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ABSTRACT

The 5645 m-high Quelccaya Ice Cap of the Cordillera Oriental contains both obstruction- and crevasse-type glacier caves in several outlet glaciers. Reconnaissance observations on the obstruction caves, produced by deformation of ice around obstructions in the bed of the glacier, indicate that two distinct forms occur: (1) single passages parallel to the ice-flow direction with a bedrock protuberance or boulder at the head, and (2) single passages perpendicular to ice flow and formed in the lee of bedrock ledges. The crevasse-type caves form from crevasse-wall collapse and roofing by snow and firn; they may occur at all angles to glacier flow. Speleothems observed in the caves include stalactities, stalagmites, columns, and cave coral; cave ceilings are usually fluted or striated.

* Contribution No. 338 of the Institute of Polar Studies, The Ohio State University, Columbus, Ohio 43210.

INTRODUCTION

IN JULY 1974, 1976 and 1977, and January 1977, the first author observed several types of glacier caves in the Quelccaya Ice Cap, south central Andes, Peru during glaciological field work conducted under a cooperative program between the Institute of Polar Studies and the Peruvian Institute of Geology and Mining. The main objective of this research project is the development of a paleoclimatic record for an equatorial glacier (Thompson and Dansgaard, 1975), in a fashion similar to that previously accomplished for Greenland and for Antarctica

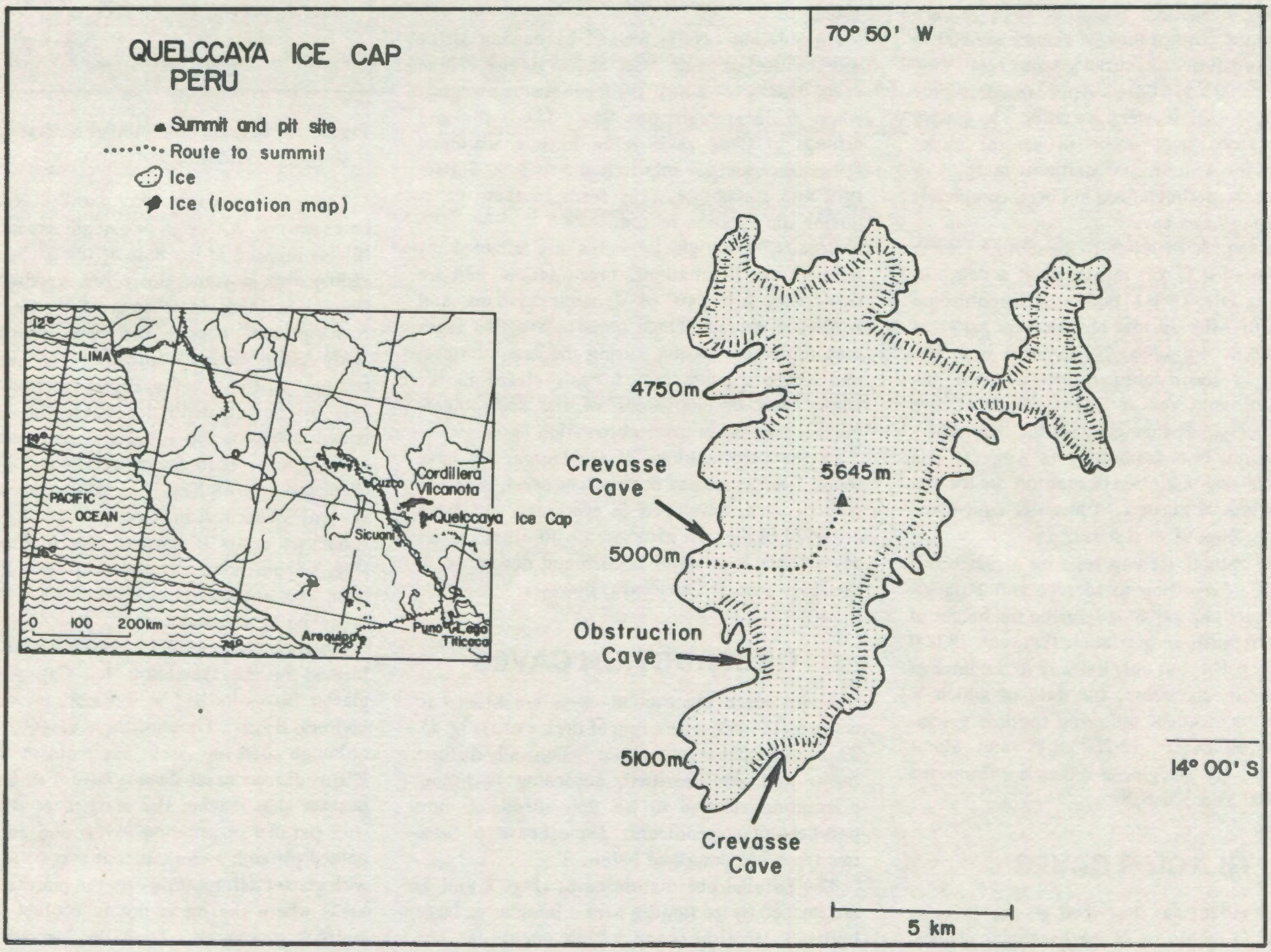

Figure 1. Map of Quelccaya Ice Cap, showing locations of some of the glacier caves.

(Dansgaard, *et al.*, 1969, 1971; Johnsen, *et al.*, 1972; Thompson, *et al.*, 1975; Thompson, 1975, 1977). Field work during these expeditions concentrated on establishing and maintaining an automatic recording meteorological station, snow pit studies, and ice coring for later particle, isotope, and β activity studies in the laboratory. A network of ablation and accumulation stakes was also established, to record changes in the glacier surface. The glacial history of the area has been studied by Mercer *et al.* (1975) and by Mercer and Palacios (1977). Hastenrath (1977, 1978) has reported on the meteorology and heat budget of the ice cap. Glaciospeleological field investigations have included observations on morphology, temperature, and speleothems; preliminary results have been reported by Thompson and McKenzie (1977).

THE QUELCCAYA ICE CAP

The Quelccaya Ice Cap (13°50'S, 70°50'W) is located in the Cordillera Oriental, 105 km east of Sicuani, Peru (Fig. 1). Except for small glaciers in New Guinea and on the Stanley Plateau in the Ruwenizori Range, Uganda, the Quelccaya Ice Cap is the only ice cap within the tropics. The ice cap covers an area of 70 km^2 and has four ice domes, the highest of which is 5645 m. Ice tongues on the eastern margin extend to 4900 m but, on the western side, outlet glaciers reach only to between 5000 and 5100 m. Approximately 90% of the margin exhibits steep ice cliffs. The glacier caves described here occur in several outlet glaciers on the western and southern margins of the ice cap; the perimeter has not been completely explored for glacier caves.

The ice cap is believed to be temperate. A temperature of 0°C was measured at a depth of 15 m during July, 1976 (Thompson, unpublished data). In July, the diurnal temperature range at the Summit is +6°C to -14°C; there is a 3°C difference in mean temperature between the winter and summer seasons. Most of the precipitation occurs during the southern summer; the dry season lasts from May to August. The mean annual accumulation of snow on the ice cap since 1969 is 2.08 m, or 1.14 m water equivalent (Thompson, unpublished data).

The 200 m-thick ice cap rests on a plateau of welded tuff. According to Mercer and Palacios (1977), the ice cap expanded during the height of the late Wisconsinan glaciation (between 28,000 and 14,000 B.P.), but only halfway to the limit of the maximum glaciation, the date of which is unknown. Readvances following the last glaciation occurred before 12,250 B.P. and about 11,000 B.P.; the Neoglacial advance culminated between 600 and 300 B.P.

GLACIER CAVES

Halliday (1976) has described glacier caves as caves formed within or at the base of a glacier. Such caves have been known for over a century; however, only within the last few decades has much attention been paid to them by glaciologists in their attempts to understand basal processes of glacier flow and by speleologists searching for new types of caves and speleothems. Developments in glaciospeleology—"a limitless new branch of speleology"—have been reviewed by Halliday and Anderson (1970) and more recently by Halliday (1976).

Peterson and McKenzie (1968) described an Alaskan glacier cave that had formed by the flow of ice around a bedrock protuberance and indicated that there was a second category of glacier cave formed by the ablative action of meltwater streams. In 1970, McKenzie re-defined these two types of glacier caves as obstruction caves and ablation caves. An obstruction cave is formed by interruption of the ice flow at the base of a glacier. A bedrock high or boulder in the ground moraine could initiate the formation of a cave that, in many cases, could lack an entrance for most of the year because of accumulated snow. The size of an obstruction cave depends on the rate of closure of the cave relative to the velocity of the ice. Obstruction caves usually have fluted or striated ceilings developed in a till/ice mixture carried at the base of the glacier. Speleothems may include sublimation crystals, hair ice, and till curls (Peterson and McKenzie, 1968).

An ablation cave is formed by moving air or water within or at the base of the glacier. These caves usually form near the terminus or margins, where meltwater streams flow. The walls and ceilings of these caves often have a scalloped appearance and are relatively debris-free. Stalactites and stalagmites may form in these caves during the ablation season.

Because most glacier caves are affected by temperature fluctuations, precipitation, and ice flow, they are part of dynamic systems and subject to change. Thus, some obstruction caves may undergo ablation during the late summer, and ablation caves may become closed in the winter and develop some of the speleothems normally found in drier obstruction caves.

In the investigations at Quelccaya, we have found two varieties of obstruction caves. Another type of cave, developed in crevasses, has been observed in the past associated with other glacier caves. They have never been found developed to the stage seen at Quelccaya, however.

OBSTRUCTION CAVES

About seven obstruction caves are known to occur on the western margin of the ice cap (Fig. 1). These caves occur in two morphologically distinct forms and are classified, according to tunnel orientation relative to ice flow direction, into parallel and perpendicular. Typical caves of these two types are described below.

The parallel obstruction caves (Fig. 2 and 3) are formed by ice flowing over a boulder or large bedrock protuberance which occurs at the upglacier end of the cave. The largest cave observed was at an elevation of 5100 m; it was 21 m long and had an opening 3 m wide and 2 m high. This cave showed little evidence of closure, having approximately the same dimensions at the point of origin—in this case a large boulder (Fig. 4)—as at the entrance. A 22 m long half-cave wall on the side of the glacier (Fig. 5) suggests that the cave was much longer in the past. The ceilings of this and other parallel obstruction caves often extend a few centimeters beyond the ice cliff as a 4 cm-thick ridge (Fig. 3). Because this glacier has very little basal debris where these resistant rims occur, it is thought that the rims may owe their stability to a different ice fabric developed by deformation at the base of the glacier.

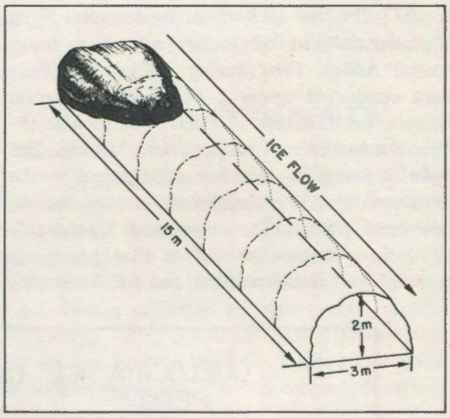

Figure 2. Diagram of a parallel obstruction cave, showing boulder at end.

Speleothems within the parallel obstruction caves are few. Although one might expect to see a till/ice mixture at the base of the glacier, this is visible only in some caves and is seldom more than 15 cm thick. In other caves, the till/ice layer is not present, because the ice is moving over a fairly clean bedrock surface. The walls and ceilings of these caves show a fluted surface (Fig. 6); the flute depth depends on the size of the irregularities in the subglacial surface, but no flutes deeper than 5 cm were seen. Till curls (Peterson and McKenzie, 1968) were present in several obstruction caves (Fig. 7). A few stalactites occur at the entrance to these caves (Fig. 6), but none was observed more than 2 m from the entrance unless the cave had been breached by a crevasse.

Obstruction caves of the perpendicular type are formed in the Quelccaya Ice Cap where the glacier leaves its bed as it passes over resistant bedrock ledges. Three of these caves were seen, although there no doubt are more in the area. Perpendicular caves do not have a single, direct passage that reaches the margin, as is the case with parallel obstruction caves, and entrance is gained through a crevasse that may be associated with glacier deformation over the plateau lip or in areas where the ice is not in contact with the bedrock downstream from the bedrock ledges. The caves ranged in length from 5 to 30 m and up to 4 m in height. Average dimensions of these

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VOLUME 40, 1978

CONTENTS

Dear Reader,

This is the first "annual index" ever published by *The NSS Bulletin* (volumes 1 through 20 were indexed in a general way by George F. Jackson—see vol. 20). It required about 125 hours of work by three people and cost about $688 to typeset and print. The money spent on this index would have paid for one medium-long paper, instead. Before we publish another index, we'd like you to tell us whether or not it would be worth the effort. If you like an index but find fault with this one, explain....

The NSS BULLETIN

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Volume 40 (1978)*

* Compiled by James Hedges, extensively edited by Frank Howarth and Nancy Howarth.

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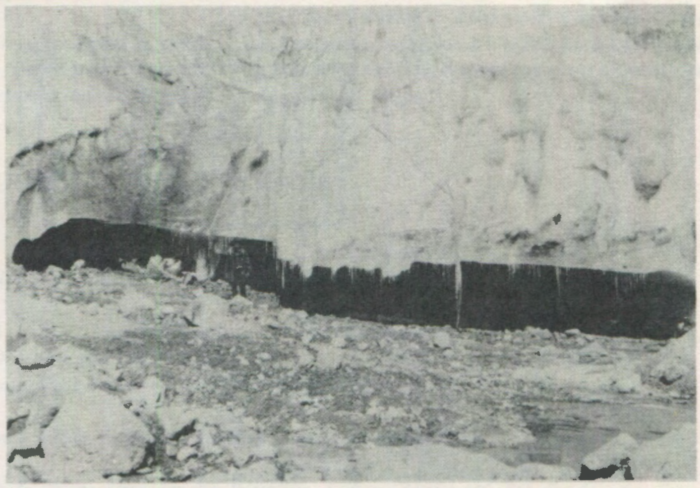
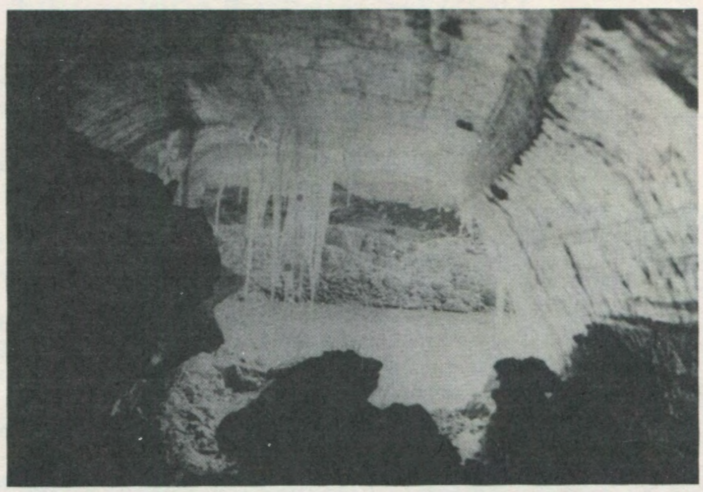


Figure 3. (above) Entrance to obstruction glacier cave on the west side of the Quelccaya Ice Cap. Ice cliff is about 30 m high. Around the cave entrance, there is a resistant rim of ceiling ice protruding several cm from the cliff face.

Figure 4. (top right) Three-meter wide boulder at the head of a 21 m-long obstruction tunnel of the parallel type.

Figure 5. (center right) Entrance to an obstruction cave extending 21 m under ice cap from far left. The 22 m-long half-tunnel shown here has been exposed by retreat of the ice cliff.

Figure 6. (bottom right) View out of a parallel obstruction cave. The cave ceiling is fluted and striated; the absence of scallops indicates minimal ablation. Ice stalactites form by refreezing of meltwater from the cliff face.



caves are indicated in the schematic diagrams (Figs. 8a and 8b). Figure 9 shows the interior of one of these caves, which contains stalactites, tilted stalactites, and deformed columns. The cave floor has a pebbly surface analogous to cave coral.

The ceilings of these caves are fluted, and the stalactites are associated with fractures in the ice ceiling.

CREVASSE CAVES

Crevasse caves have been investigated on the west and south margins of the ice cap (see Fig. 1). These caves measure more than 50 m in length, range between a fraction of a meter to 5 m in width, and have ceilings up to 20 m in height (Fig. 10). The crevasse caves form along areas of tensile stress in the ice and, also, on the slopes

Figure 7. (top left) Base of glacier in obstruction cave showing 5-cm thick debris/ice layer and a 15-cm high till curl. Glacier flow is from right to left.

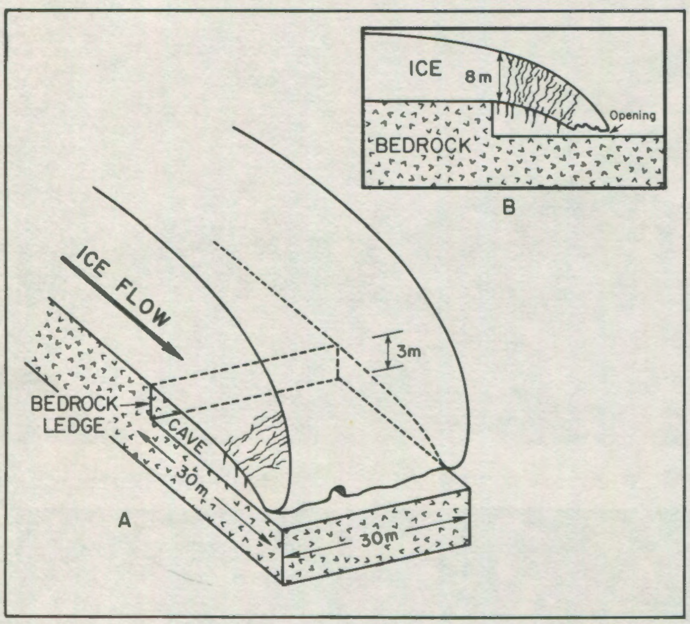


Figure 8. (center left) Diagrams of a perpendicular obstruction cave: (a) perpendicular cave showing bedrock ledge, (b) lateral view of perpendicular obstruction cave.

Figure 9. (bottom left) Perpendicular obstruction cave with deformed stalactites formed by meltwater penetrating from the glacier surface through fractures in the ceiling. Ice in the form of cave coral floors the cave.

Figure 11. (below) Entrance to crevasse cave on west side of Quelccaya Ice Cap. Snow and firn form ceiling. Ice speleothems often occur within these caves.

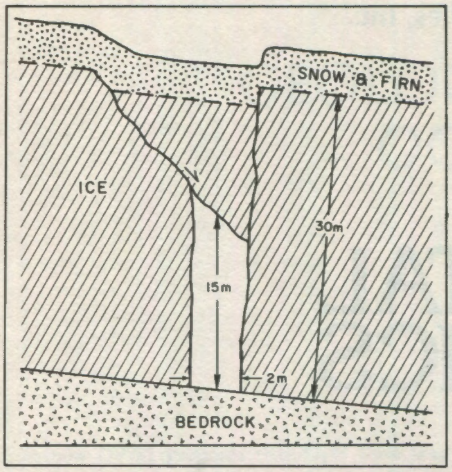


Figure 10. Diagram of a crevasse cave. The ceiling of the cave is formed by a collapsed crevasse wall covered by snow and firn.

below bedrock ledges over which the glacier has "calved," producing accumulations of large jumbled blocks on the slopes below. The ceilings of the crevasse caves are formed by snow and firn accumulation, partial crevasse filling by ice which has slumped from the crevasse wall, or a combination of these processes (Fig. 11). These caves contain stalactites and flowstone which build outward, perpendicular to the crevasse wall, and, in come cases, partition the crevasse cave. Although these caves receive meltwater from the surface and, in places, are open to the surface, only a small upper portion of any cave shows a scalloped surface indicating ablation. Floors of the caves often contain stalagmites and cave coral.

SUMMARY AND CONCLUSIONS

Two forms of obstruction-type glacier caves have been identified on the basis of tunnel orientation relative to ice-flow direction. Speleothems include (1) stalactites, (2) stalagmites, (3) columns, (4) cave coral, and (5) till curls. These cave features apparently persist throughout the year, as the caves do not pass through an ablation phase.

A further type of cave, formed by the roofing óf a crevasse, has been defined. Although crevasse passages have been associated with other types of glacier caves, in the Quelccaya Ice Cap they are well-developed and distinctive forms that warrant a separate category in the classification of glacier caves.

Speleothems in the crevasse cave were primarily flowstone, stalactites and stalagmites. Scalloped surfaces were uncommon, suggesting little ablation of the walls of these caves.

Future work will include (1) observations on cave temperatures and changes in speleothems, (2) determination of glacier bed-flow rates, and (3) ice-fabric studies of the basal glacier ice. Further exploration of the ice-cap margin should reveal additional caves of each type, which would assist in developing a more complete understanding of their origin.

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Davis, D.G. (1979)—Geology and Speleogenesis of Ogle Cave: Discussion: *NSS Bulletin* 41: 21-22.

GEOLOGY AND SPELEOGENESIS OF OGLE CAVE: DISCUSSION

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Jagnow (1978) proposes that Ogle Cave was developed by water, acidified by pyrite oxidation, descending from the pyrite-rich Yates sandstone. He also attributes other Guadalupe caves to this mechanism. Former directions of water movement in Guadalupe caves must of necessity be inferred from more or less indirect evidence, since flow rates were generally too slow to leave such directional indicators as scallops and ripple marks. Jagnow cites only one cave, Queen of the Guadalupes, in which evidence for descending flow appears convincing. This cave, however, is a simple 200-ft pit series, apparently either vadose-originated or vadose-altered, and is very atypical of the area. Other major Guadalupe caves contain substantial evidence of solution by *ascending* water, an alternative which has been neglected in published work on these caves.

If the normal mode of Guadalupe cave solution had been by descending water acidified in the Yates, cave features should be observed which, in fact, are absent or rare. For the simplest likely case—phreatic solution with base level above the Yates—solution should have been most intense immediately below the Yates, nearest the acid source. However, few notable solution cavities are known at that level (the best example being the main corridor of Cottonwood Cave), and carbonates adjoining the Yates show no more intense solution effects than do strata hundreds of feet below. In the alternative case—solution with base level below the Yates, the acidic water would have traversed a zone of aeration in its descent from the Yates to the zone of horizontal flow at base level. This would have produced a vadose solution channel or shaft (domepit) below each input point. However, except for Queen of the Guadalupes—a special case which, as Jagnow points out, lies beneath an exceptional concentration of oxidized pyrite—few if any such shafts are known in the Guadalupes. In fact, the rarity of vadose solution features is one of the most striking differences between the Guadalupe cave province and most others.

Guadalupe caves, as a group, contain other features which are difficult to explain by descending-water solution. A number of these caves are characterized by relatively broad horizontal passages or rooms underlain by phreatically-enlarged vertical fissures or descending tubular conduits which lack "drains" at their bottoms. These pits are commonly explorable for 200 ft to more than 500 ft below base-level passages. Caves of this type include Hell Below, Sentinel, Pink Dragon, Virgin, Three Fingers, Madonna, and Carlsbad. Others may exist unrecognized, because the horizontal element of the pattern has been eroded away or the vertical element hidden by breakdown or secondary deposits. In a slow-flow phreatic regime, such deep vertical passages should not, as a rule, be expected to result from solution initiated from above, since deep circulation along the joints will be inhibited by sedimentation. Water rising under pressure from below is not subject to this constraint. This is the most obvious explanation of the frequent occurrence of deep phreatic pits, another extraordinary trait which, together with the rarity of vadose shafts, strikingly differentiates the Guadalupe cave province from others in which cave-forming water has actually been observed descending from above.

The morphology of Ogle Cave, itself, is ambiguous and could fit either a descending-water or an ascending-water model. However, Carlsbad Cavern is a very inviting candidate for an ascending-water origin, as follows: Water from an underlying aquifer rose by way of the Bottomless Pit and followed a sinuously ascending route, through a proto-Big Room and up the Main Corridor, to a base-level outlet above the present entrance level. With successive drops in base level, new horizontal levels were developed at the air/water interface in adjustment to progressively lower outlets, at the Bat Cave, Guadalupe Room, Big Room, Left Hand Tunnel, and finally Lower Cave levels. The Main Corridor and Bottomless Pit, which are anomalous in the descending-water model, are integral feeder conduits in the ascending-water model. The developmental sequence of horizontal base-level passages is the same in either model.

If my hypothesis is correct, Carlsbad and most other Guadalupe caves were developed on the upwelling limbs of deeply curving flow paths of the pattern described as "bathyphreatic" by Ford (1977). Evidence for recent ascending flow from the Capitan limestone in the subsurface on the east side of the Delaware Basin is given by Moore (1959), who noted that salt has been leached from a narrow band directly above the Capitan. In the western part of the Capitan complex, now exhumed and drained, the cave patterns just described are consistent with the assumption of similar ascending flow at an earlier time. The earliest source area could have been Guadalupe Mountains National Park, which now contains the highest terrain and was therefore likely to have been the first area to be elevated above regional base level. If this was the recharge area, it could explain the observed fact that the highest part of the Guadalupes seems to have the smallest caves. Recharge is usually more diffuse than discharge; moreover, if sulfuric acid solution is involved, recharge water may flow a relatively long distance before reaching maximal acidity, since the acid is not developed in the soil. (If soil chemistry was not the basis for cavern solution in the Guadalupes, this could also account for the rarity of surface karst forms other than small-scale rills; however, surface karst may be subdued there merely because mechanical weathering is dominant over solutional weathering in dry climates.)

In regard to the sulfuric acid solution mechanism, Jagnow states (p. 14) that to his knowledge, this mechanism "has not previously been proposed for the origin of the caves in the Guadalupe Mountains." It was, in fact, proposed for the Guadalupe caves in unpublished form as early as 1971 in a paper sent to Carlsbad Caverns National Park by Stephen Egemeier and was examined further in his Ph.D dissertation. The dissertation was based primarily on the thermal Kane Caves of Wyoming, but discussed Guadalupe caves as well (Egemeier, 1973, pp. 69-72). The work of J. Michael Queen (1973) on large-scale replacement of carbonate by gypsum could also be taken as indicative of sulfuric acid solution in Guadalupe caves; however, Queen himself has recently proposed a replacement process involving the mixing of gypsum-saturated brine with fresh water, in which sulfuric acid is not invoked (Palmer, Palmer, and Queen, 1978).

Jagnow is correct, in my opinion, in accepting the sulfuric acid reaction as a major solution reaction in Guadalupe cave development; but, if most solution was by ascending water, the Yates pyrite cannot have been the primary sulfide source. An alternative sulfide source, a more mobile and probably larger source, is the oil and natural gas deposits widespread in the Carlsbad area. Hinds and Cunningham (1970) state that hydrogen sulfide, associated by hydrocarbons, is "commonly found in formation waters throughout most of Eddy County." If, as is likely, this situation prevailed in the Tertiary and early Pleistocene groundwater of the proto-Guadalupe mountains, sulfuric acid could have been formed simply by oxidation of H_2S. The chemistry of this process, in which free sulfur may appear as an intermediate product, was discussed by Egemeier (1973, pp. 39-40). The observed presence of sulfur in Cottonwood Cave (Davis, 1973) is at least consistent with this reaction. Sulfur in disseminated form should be sought in any analyses of Guadalupe cave gypsum deposits.

The Guadalupe caves show some heretofore unexplained peculiarities which may be understandable, at least in part, as phenomena of sulfuric acid solution. The caves tend to be unpredictably located with respect to surface features, and are often characterized by broad but short passages which terminate abruptly. Such blind passage terminations were considered by Egemeier (1973) to be typical of the sulfuric acid mechanism. These terminations result from the fact that oxygen is required to convert sulfide to sulfuric acid. Major solution is not continuous along the entire path of groundwater flow, but begins suddenly at points where anaerobic sulfide-bearing water becomes oxygenated. (Similar discontinuities of solution may be caused by mixture corrosion in the carbonic-acid mechanism, but oxygenation is more fundamental in sulfuric acid solution than mixture corrosion is in carbonic acid solution.)

There are substantial regional differences in the patterns resulting from H_2S-related cavern solution. In Egemeier's interpretation of the Wyoming caves, major cavern enlargement took place only where ascending, sulfide-bearing water from deeply buried synclines had risen to base level and come in contact with air, permitting sulfuric acid attack to replace limestone by solid gypsum which, in turn, was dissolved by free-surface streams, forming horizontal galleries at or above the water table. He called this process "replacement-solution." Some of the widest Guadalupe chambers, such as the Big Room of Carlsbad Cavern and the Cavernacle in Virgin Cave, show undercuts in the ceilings which seem to indicate similar solution at a horizontal air/water interface when the rooms were partly flooded. In the Guadalupes, however, sulfide-charged water must also have been mixed with flows of oxygenated surface water penetrating deep into the phreatic zone in places, to account for the enlargement of ascending conduits. In such phreatic cases, the term "replacement-solution" may not be appropriate, because undersaturation with $CaSO_4$ may prevent gypsum from passing through a solid phase. The complex Guadalupe cave morphology probably reflects more varied sources of oxygenation and slower flow rates than in Wyoming. Characteristics of cave development via H_2S are the subject of a forthcoming paper by R. Mark Maslyn (1978).

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REVIEW—*Middle American Cave-Crickets and Allies. I. The group Phoberopodes, with a Review of the Phallic Structures of the Ceuthophilinae.* (*Orthoptera Saltatoria : Ensifera : Rhaphidophoridae*), T.H. Hubbell. Rome, Accademia Nazionale dei Lincei, Quaderno 171, pp. 275-324 (Subterranean Fauna of Mexico, Part III).

This is part of a valuable series being produced under Italian sponsorship on the cave faunas of Mexico, with contributions by many specialists. The paper is important for the cave cricket systematist, because it outlines an advance in understanding of the phallic structures of the Ceuthophilinae, a tribe of crickets which are so important a component of North American cave faunas. The new group Phoberopodes (Pristoceuthophilini) is established for *Phoberopous* S. and P., with two species, one new, and *Hypsobadistes*, n. gen., with three species, all new. Two of the species of *Hypsobadistes* are cave-inhabitants with extraordinarily long, slender appendages and are believed to be obligate trogloxenes. The group is confined to the highlands of Guatemala and Estado Chiapas of Mexico, a region which has served as a major center for the evolution of so many animal groups.

I find the paper to be most valuable to the general cave biologist in its discussion of the crickets' origin, differentiation, and relationships. This section presents a synopsis of historical geological events which is one of the best I have encountered for understanding the biotic history of the region. A model is thus given which should be seminal in shaping interpretations of the histories of other terrestrial arthropods in cave and karst regions of nuclear Middle America.

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Bassham, Elbert (1978) Traverse blunders and their detection: *NSS Bulletin* 41: 23-26

TRAVERSE BLUNDERS AND THEIR DETECTION

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ABSTRACT

This technique reveals the existence of blunders, whether the blunder is likely to be vertical or horizontal, and its probable location and magnitude. Small random errors probably will keep parallel lines from being exactly parallel and the intersections of the normals from falling at exactly the same points. However, if the random errors are sufficiently small and the blunders sufficiently large, this technique is very effective. The number of points in the traverse is not limited, nor does it matter if the traverse crosses itself (as in a figure eight).

INTRODUCTION*

IT CAN BE unconditionally stated that *no measurement is exact* (except, possibly, for counting). Every measurement contains errors, and errors may be classified in three ways:

Natural Errors. These are caused by variations in wind, temperature, humidity, refraction, gravity, and magnetic declination. These can usually be compensated for by applying correction factors.

Instrument Errors. These result from any imperfections in the construction or adjustment of instruments, and from the movement of individual parts. These can usually be reduced by double centering methods.

Personal Errors. These arise from the limitations of the human senses of sight, touch, and hearing.

Included in personal errors are ***mistakes***, which are caused by a misunderstanding of the problem, by carelessness, or by poor judgement. It is very difficult to detect small mistakes, because they merge with errors. Large mistakes are often referred to as *blunders*.

Blunders are gross errors committed by the instrument man, tape man, or note man such as transposing figures (67.1 for 76.1), reading upside down (89 for 68), mis-hearing numbers (two-nine for two-one), sighting the wrong point on a foresight or backsight, or turning an angle from the wrong backsight with a theodolite or transit. There are many ways to commit a blunder, and surveyors must always take precautions to eliminate them.

Once the data goes to the data processor, the search for blunders begins. Occasionally, after the data is calculated and plotted, comparison with the sketch will identify the location of a blunder. However, if it cannot be detected by comparison with the sketch, other methods must be used. Too often a complete resurvey is called for or the traverse is warped to force a closure.

*A preliminary version of this paper appeared in *The Texas Surveyor* 20(5): 4-6, 1975, entitled "Traverse Error Analysis."

DOUBLE BLUNDERS

There exists a method of identifying the probable location of single blunders, but this author recently discovered a way of identifying the probable locations and magnitudes of some double blunders, also. This method requires a closed traverse, *i.e.*, a traverse that forms a complete loop or polygon, where each leg of the traverse has a measured azimuth and distance. In the case of a theodolite or transit survey, each point must have a turned angle and each leg must have a measured distance.

To identify the existance of a blunder in a closed traverse, determine the coördinates (latitude, departure, and elevation) of each point along the traverse, including the closing point. If measurements could be exact, the beginning point and closing point would have the same coördinates. Since no measurement is without errors, these coördinates will not be the same. Sample computations are shown in Table 1. The closure vector is defined to be the vector with magnitude equal to the calculated distance from the closing point coördinates to the beginning point coördinates. Its direction is from the closing point to the beginning point. The magnitude of the closing vector is calculated by:

$$\text{Magnitude} = \sqrt{(\text{diff. in lat.})^2 + (\text{diff. in dep.})^2 + (\text{diff. in elev.})^2}.$$

Let $P = \frac{\text{total of survey distances}}{\text{magnitude of closure vector}}$. The precision of the survey is then expressed as 1:*P*. In a brunton and tape survey, if *P* is smaller than, say, 200, the existence of one or more blunders can be assumed. In a theodolite or transit survey, this criterion may range from 5000 to 20000, depending on survey conditions, equipment, and techniques. In other words, when the precision drops below a certain level, it becomes clear that the misclosure must be attributed to blunders rather than to random or accidental errors. Discussions of survey errors are provided by Schwinge (1962), Schmidt and Schelleng (1970), and Rutherford and Amundson (1974).

VERTICAL BLUNDERS

To identify a vertical blunder, consider the difference of elevation of the beginning point and closing point. If the difference is small compared to the magnitude of the closure vector, then the blunder is probably a horizontal blunder. If it is large, then the blunder is probably in a vertical angle or in a distance along a steeply inclined leg of the traverse.

Table 1. Sample Closure Computations.

From	To	Vert. angle	Slope dist.	Az.	Vert. dist.	Horiz. dist.	Lat.	Dep.	Elev.
	A						100	100	0
A	B	- 14°	75.5	85°	- 18.27	73.26	106.38	172.98	- 18.27
B	C	- 51°	25.1	250°	- 19.50	15.80	100.98	158.14	- 37.77
C	D	- 42°	36.4	81°	- 24.36	27.05	105.21	184.85	- 62.13
D	E	- 4°	96.1	269°	- 6.70	95.87	103.54	89.00	- 68.83
E	A	+73°	64.75	97°	+61.92	18.93	101.23	107.79	- 6.91

ΔLat.	1.23	Closure vector magnitude	10.49
ΔDep.	7.79	Closure vector azimuth	261.0°
ΔElev.	-6.91		

To identify the probable location of a vertical blunder, a plot of the traverse is needed. This plot should be a profile view (latitude against elevation or departure against elevation, preferably along the major trend). Now, plot the closure vector (extended) and its perpendicular bisector, hereafter called the *normal* (Fig. 1). This closure vector and its normal give important clues about the location of the blunder.

Compare the closure vector to each leg of the traverse. If a leg is found to be parallel or nearly parallel to the closure vector, then this leg is a possible location for a distance blunder of magnitude approximately equal to the magnitude of the closure vector and direction opposite to that of the closure vector.

Now, compare the normal to each leg of the traverse. If a leg is found to be parallel or nearly parallel to the normal, this leg is a possible location for a vertical angle blunder of magnitude approximately equal to the arctangent of the magnitude of the closure vector divided by the length of this leg.

It is possible that vertical blunders may be indicated at more than one place. While this analysis does not positively identify the location of the blunders, it does identify probable locations. This permits a surveyor returning to find the blunders to check these probable locations first, thereby drastically reducing the amount of resurvey needed.

Note that if more than one vertical blunder has been made, this analysis fails and the entire traverse must be resurveyed.

HORIZONTAL BLUNDERS

If the blunder is not a vertical blunder, plot the plan view (latitude against departure). Now, plot the closure vector and its normal (Fig. 2). This closure vector and its normal give important clues about the location of the blunder.

Compare the closure vector to each leg of the traverse. If it is parallel or nearly parallel to a leg, that leg is a possible location for a distance blunder approximately equal in magnitude to the closure vector and in direction opposite to that of the closure vector.

Now, compare the normal to each leg of the traverse. If it is parallel or nearly parallel to a leg, that leg is a possible location of an azimuth (bearing) blunder approximately equal to the arctangent of the magnitude of the closure vector divided by the length of this leg.

It is possible that horizontal blunders may be indicated at more than one place. While this analysis does not positively identify the location of the blunders, it does identify probable locations. This permits a surveyor returning to find the blunders to check these probable locations first, thereby drastically reducing the amount of resurvey needed.

Note that if more than one horizontal blunder has been made in an azimuth (bearing) and distance traverse, this analysis fails and the entire traverse must be resurveyed.

HORIZONTAL BLUNDERS IN A THEODOLITE TRAVERSE

In a theodolite (transit) survey, instead of measuring azimuth (bearing) to determine direction, an angle is turned between a backsight and a foresight. It may be a right or a left angle, an inside or outside angle, or a deflection right or left. A vertical blunder is still analysed as described above, but a horizontal blunder is handled in a different way and can yield much more information.

In a traverse where all angles are turned and all distances are measured, any of the points may be considered a starting point. Processing the data for this type of survey includes calculating a closing point for each point of the traverse. This is done by choosing a starting point and calculating coördinates around the traverse to the closing point in the usual way. Then, use the angle turned at this closing point and the next distance (same as the first distance) to calculate a closing point at the next point. This process is continued completely around the traverse for the second time, producing a closing point for each point of the traverse. In Table 2, a measured inside angle for each traverse point and a measured distance for each leg are used. By computing around the traverse twice, a double set of coördinates is obtained for each point. The traverse and normals are plotted in Figure 4. Double points are not shown, due to the scale of the drawing. It is recommended that a computer be used for the computations and plot, so that adequate precision may be obtained for meaningful results.

Plot the traverse, the closure vector, and its normal at *each* point. These closure vectors and their normals give important clues to the locations of blunders.

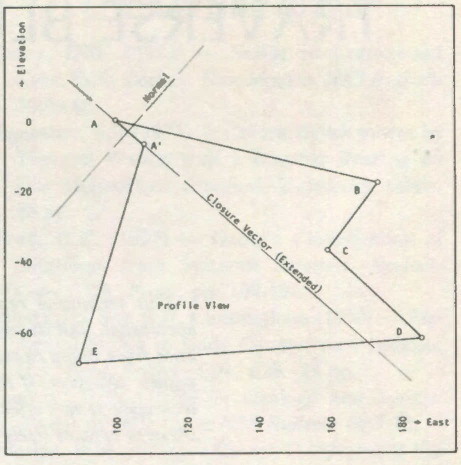

Figure 1. Closure vector A-A' is parallel to traverse leg C-D, indicating a possible distance blunder in leg C-D of magnitude $\overline{A\text{-}A'}$. The normal is parallel to traverse leg B-C, indicating a possible vertical angle blunder in leg B-C of magnitude arctan $\left(\frac{A\text{-}A'}{B\text{-}C}\right)$.

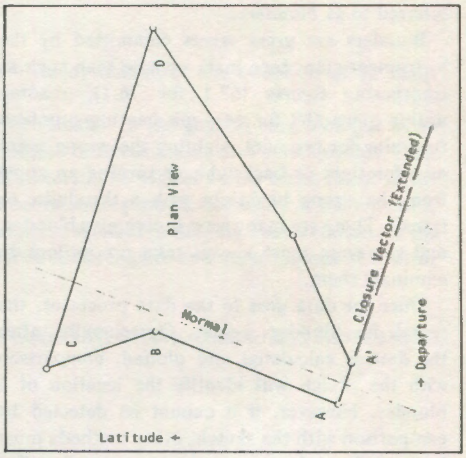

Figure 2. Closure vector A-A' is parallel to traverse leg C-D, indicating a possible distance blunder in leg C-D of magnitude $\overline{A\text{-}A'}$. The normal is parallel to traverse leg A-B, indicating a possible azimuth blunder in leg A-B of approximate magnitude arctangent $\frac{A\text{-}A'}{A\text{-}B}$

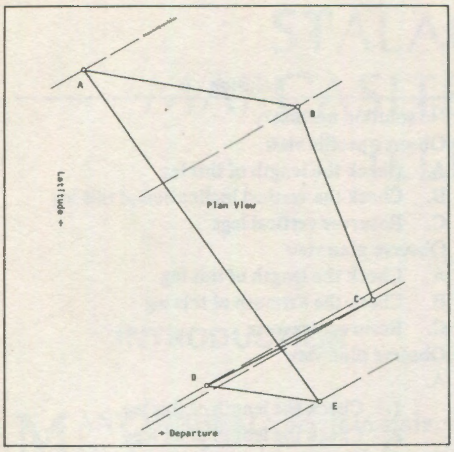

Figure 3. Dashed lines show parallel closure vectors (extended) indicating a distance blunder. Leg C-D is the most probable location of the blunder, because it is the leg most nearly parallel.

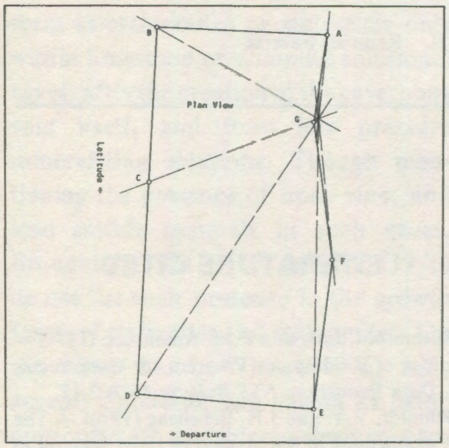

Figure 4. Dashed lines show normals intersecting near point G, indicating a probable angle blunder at point G.

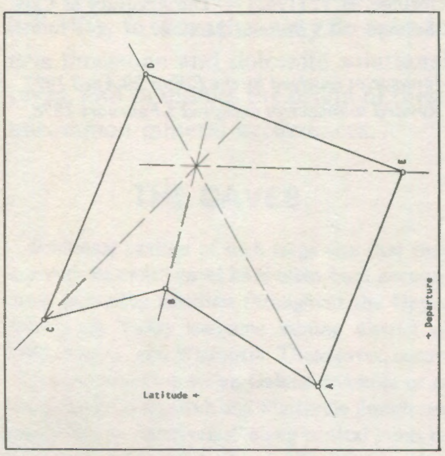

Figure 5. Dashed lines show normals intersecting on a line between points a A and D, nearer point D. This indicates probable angle blunders at these points, with the largest blunder at point D.

PARALLEL CLOSURE VECTORS

Observe the closure vectors. If they are all parallel, then the blunder is a distance blunder (Fig. 3). Compare the closure vectors to each leg of the traverse. If a leg is found to be parallel or nearly parallel to these closure vectors, that leg is a possible location of a distance blunder of magnitude approximately equal to that of the closure vector at any point.

Note that if no leg is found to be parallel or nearly parallel to the closure vector, then two or more distance blunders have been made and the analysis fails. Each distance of the traverse must be measured again.

NON-PARALLEL CLOSURE VECTORS

If the closure vectors are not parallel, their normals will all intersect at a point. The closure vectors and the location of the intersection point of the normals give important clues about the location of possible blunders.

NORMALS INTERSECT AT A TRAVERSE POINT

If the intersection point of the normals falls at or near a point of the traverse, an angle blunder was probably made at this point (Fig. 4). Its magnitude will be approximately equal to the arctangent of the magnitude of the closure vector at any one of the points divided by the length of the normal from this point to the intersection point of the normals.

NORMALS INTERSECT BETWEEN TWO TRAVERSE POINTS

If the intersection point of the normals falls on a line joining two traverse points, then a possible double blunder consisting of two angle blunders was made at these traverse points (Fig. 5). The magnitude of the blunders cannot be predicted, but the traverse point nearest the intersection point of the normals will be the point with the large angular blunder.

DISTANCE AND ANGLE BLUNDER

If the intersection point of the normals does not fall at or near one of the traverse points, then a possible double blunder consisting of a distance blunder and an angle blunder was made (Fig. 6). Compare each closure vector with each traverse leg. If a closure vector is found to be parallel or nearly parallel to a traverse leg, this traverse leg has a possible distance blunder, and the traverse point projecting this parallel closure vector has a possible angle blunder. The magnitudes of the blunders cannot be predicted.

It is possible that blunders may be indicated at several places, especially in the case of double blunders (Fig. 6). While this analysis does not positively identify the location of the blunders, it does identify probable locations, allowing the surveyor returning to find the blunders to check these probable locations first, and drastically reduce the amount of resurvey needed.

Note that if there are more than two blunders in a theodolite (transit) and distance traverse, the analysis fails and the entire traverse must be resurveyed.

Table 2. Latitude and departure calculated for Figure 4.

Point	Inside Angle	Azimuth	Distance	Latitude	Departure
A	—	180°	1000	10000.0000	10000.0000
B	90°	90°	1000	9000.0000	10000.0000
C	180°	90°	1347.88	9000.0000	11000.0000
D	93°15'	363°15'	1223.08	9000.0000	12347.8800
E	86°99'30"	269°15'30"	982.2	10221.1129	12417.2198
F	68°53'	258°08'30"	905	10208.3991	11435.1021
G	188°31'14"	266°39'44"	549.87	10022.4284	10549.4160
A'	92°20'16"	179°	1000	990.4137	10000.4788
B'	90°	89°	1000	8990.5660	10017.9312
C'	180°	89°	1347.88	9008.0184	11017.7789
D'	93°15'	2°15'	1223.08	9031.5421	12365.4536
E'	86°00'30"	268°15'30"	982.2	10253.6792	12413.4715
F'	168°53'	257°08'30"	905	10223.8271	11431.7253
G'	—	—	—	10022.4273	10549.4197

Table 3. Traverse blunders and their detection.

Situation	Analysis	Solution
1. Precision within limitations	1. No analysis necessary	1. No solution necessary
2. Closure vector near vertical	2. Vertical blunder	2. Observe profile view
A. Closure vector parallel to a traverse leg	A. Distance blunder in this leg	A. Check the length of this leg
B. Normal parallel to a traverse leg	B. Vertical angle blunder in this leg	B. Check the vertical inclination of this leg
C. Not A or B	C. Two or more blunders	C. Resurvey vertical legs
3. Brunton survey	3.	3. Observe plan view
A. Closure vector parallel to a traverse leg	A. Distance blunder in this leg	A. Check the length of this leg
B. Normal parallel to a traverse leg	B. Azimuth angle blunder in this leg	B. Check the azimuth of this leg
C. Not A or B	C. Two or more blunders	C. Resurvey traverse
4. Theodolite survey	4.	4. Observe plan view
A. Closure vectors all parallel	A. Distance blunder	A.
1. Parallel to a traverse leg	1. In this leg	1. Check the length of this leg
2. Not parallel to a leg	2. In more than one leg	2. Check the length of all legs
B. Normals intersect at a traverse point	B. Angle blunder at this point	B. Check the angle at this point
C. Normals intersect at a point on a straight line between two traverse points	C. Double blunder. Angle blunder at each of the traverse points	C. Check the angles at these points
D. Normals intersect at a point not near one of the traverse points and a closure vector at one of the traverse points is parallel to a traverse leg	D. Double blunder. This leg has a distance blunder and this traverse point has an angle blunder	D. Check the length of this leg and check the angle at this point
E. Not A, B, C or D	E. Three or more blunders	E. Resurvey traverse

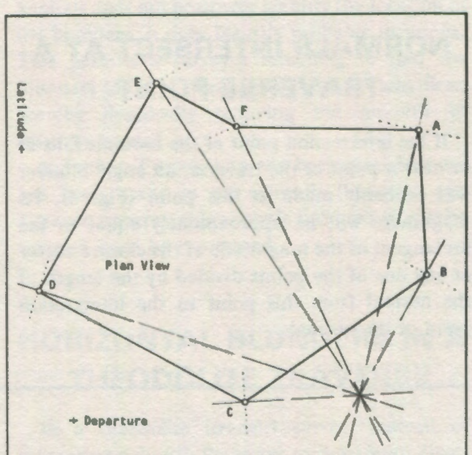

Figure 6. Dashed lines show intersecting normals; dotted lines show closure vectors (extended). The closure vector at B is parallel to legs E-F and C-D, indicating a possible angle blunder at B and a distance blunder in leg E-F or C-D. Also, that the closure vector at F parallels leg B-C suggests a possible angle blunder at E and a distance blunder in leg B-C.

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STALACTITES AND HELICTITES OF MARCASITE, GALENA, AND SPHALERITE IN ILLINOIS AND WISCONSIN

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ABSTRACT

Iron, lead, and zinc sulfide minerals (marcasite, galena, and sphalerite, respectively) existed as stalactites and helictites in caves encountered during mining activities in the Upper Mississippi Valley lead-zinc mining district of Illinois and Wisconsin. The larger specimens that grew upwards from the floors of the mineralized caves have been called stalagmites; they are more properly called stalactites, because of their central feeder canals and mode of growth. Although rare, these should be included in lists of cave minerals and their growth forms.

INTRODUCTION

MANY MINERALS occur in stalactitic and stalagmitic growth forms. Hicks (1950) listed over 60, but many of these are from deposits in non-carbonate rocks. Broughton (1971) published a more restrictive list of 24 minerals that form as stalagmites or stalactites only within limestone or dolomite solutional caves, after the creation of the cavernous void itself, and from low pressure mineralizing solutions. Though mentioning the presence of iron, zinc, and lead sulfide minerals in such caves, Broughton (1971, 1977) and Hill (1976) do not list their presence in the growth forms of stalactites and stalagmites. On the other hand, White (1976) fully accepts sphalerite and galena as being appropriately considered proper cave minerals. The purpose of this note is to report the occurrence of iron, lead, and zinc sulfide minerals as stalactites and helictites, to show that they do exist in true limestone and dolomite solutional caves, and to discuss the origin of these uncommon mineral occurrences.

THE CAVES

Solutional cavities of such large size that they can truly be called caves have often been encountered in mining activities throughout the Upper Mississippi Valley lead-zinc mining district of Iowa, Illinois, and Wisconsin. These caves, occurring in middle Ordovician Galena dolomite or in the underlying Decorah and Platteville limestones may be either "gash veins" along vertical joints or "flat and pitch" cavities formed by collapse after the solution of underlying limestones (Bretz, 1938; Bradbury, 1959; Brown and Whitlow, 1960; Cox, 1914; Howard, 1960b; Heyl, *et al.*, 1959).

There is no consensus as to whether these caves were formed before or during the process of mineralization, but most of these authors accept the idea of pre-mineralization cave openings. Howard (1960b) further suggests artesian groundwater as important to the initial formation of the gash veins as well as of the flat and pitches. At least some of the caves near the water table have been enlarged after mineralization through the oxidation of their sulfide ores and the formation of sulfuric acid (Morehouse, 1968).

THE SULFIDE MINERALS

The caves contained a variety of minerals, and some of these supported an active mining industry. The principal ores were galena (lead sulfide, PbS) and sphalerite (zinc sulfide, ZnS). The next most common sulfide minerals, marcasite and pyrite (iron sulfide, FeS_2) are of little commercial value in the district. Many papers mentioning the iron sulfide mineral in the stalactites call it "pyrite." X-ray analysis of the specimens available to me reveals them to be composed entirely of marcasite, with no trace of pyrite. Details of the mineral occurrences are given in Heyl, *et al.* (1959).

SULFIDE MINERAL SPELEOTHEMS

It is well known that the sulfide mineral ores deposited in caves often formed large crystal masses (Bradbury, 1959; Brown and Whitlow, 1960; Heyl, *et al.*, 1959). It seems to be less well known that these minerals also occurred in the growth forms of stalactites and helictites, even though many occurrences are now known.

The most remarkable deposit of sulfide mineral stalactites was discovered in the Marsden (later called the Black Jack) Mine, some 5 mi south of Galena, in Jo Daviess County, Illinois. At the time of discovery, they were little valued except as curiosities, and most were destroyed for their metal content. The few surviving specimens are now in scattered museum collections.

The cave containing these speleothems was discovered in 1854, when Stephen Marsden cleaned out a spring. For 12 hours afterward, the waters issuing from the sulfide-mineral-laden cave behind the spring flowed black. After drifting 20 ft along the spring crevice, a cave 20 to 30 ft in diameter was encountered (Cox, 1914). This cave, in turn, led to a flat and pitch ore deposit including a second cave, this one 18 ft wide, 75 ft long, and 18 to 24 in. high. Other, smaller, caves occurred on the flat and in the pitches.

Chamberlin (1882) described this cave and its speleothems as follows:

> "It is from such geodic caves, particularly those occurring on the flats, that the beautiful specimens, for which this mine is renowned, are derived.
> Both stalactites and stalagmites of the ores are found in them, not only those of a single mineral, as pyrite or calcite, but composite accretions. One form consists of an irregular reticulated core of galena, surrounded by from one to three inches of blende sphalerite, in radiant crystallization, coated on the exterior with pyrite, sparsely studded with small modified crystals of galena. In other cases the core contains calcite as well as galena.
> These stalactites sometimes attain a diameter of six inches, and a length of as great as the height of the cavern will permit; in fact they sometimes form columns stretching entirely across the opening. Stalagmites, *bearing galena on their summits*, are said to have been found here".

Chamberlin did not actually see the cave and its formations *in situ*, but wrote about and illustrated them from specimens or from the descriptions of others. As will be seen, the question as to whether or not the speleothems descended from the cave ceiling is important, but is not directly answered by Chamberlin.

While the Marsden (Black Jack) Mine contained the most notable occurrence of metallic sulfide stalactites, they also were discovered elsewhere in the lead-zinc mining district in Illinois (Bain, 1905; 1906, p. 86-87) and in Wisconsin (Behre, Scott, and Banfield, 1937; Heyl, *et al.*, 1959; George, 1925). Only Heyl, *et al.* note carefully that the speleothems pointed upwards and that they did not hang vertically from the cave ceilings. The only reference I have found to such speleothems in other parts of the world is that of Salvadori and Zuffardi (1964) on marcasite stalactites in Sardinia.

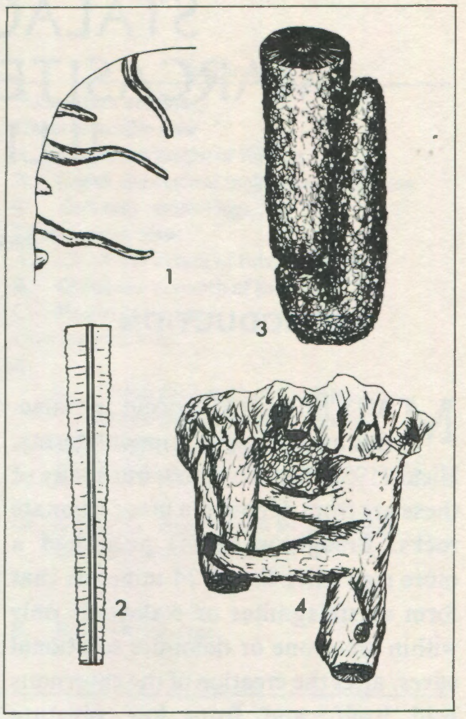
These sulfide mineral speleothems existed in a variety of shapes and sizes (Howard, 1960a). The simplest are curved or curling tubes several cm long with a central canal, composed of marcasite or pyrite and projecting like helictites or "staghorns" in all directions from the roof and walls of the cavities in which they occur (George, 1925) (Fig. 1).

A second form is that of straight stalactites of marcasite or pyrite with a central tube, composed of crystals radiating outward from the central canal (figs. 2, 5, 6, 8). They often are one-half to one cm in diameter, with a smooth or rough outside surface, and may be steeply conical, tapering nearly to a point, or may be pencil-like. Some of these may have sharp bends and turns, like the above helictitic forms (figs. 3, 4). When these have been observed *in situ*, they seem always to project upwards from the floor of the cavity (Agnew, *et al.*, pp. 87 and 132) without any corresponding growths on the ceiling above them.

The last sort are massive, shaped like large stalactites or columns, and are composed of sphalerite, marcasite, and/or galena. They are 5 cm or more in diameter and are composed of coarsely radiating crystals. Some of these still have the central tube, which may be as much as or even more than 2 cm in diameter, but in others the tube has been plugged with pyrite or galena (figs. 9, 10).

Specimens of the above, mostly from the Marsden Mine, are in the collections of the Peabody Museum, Yale University; the Geology Museum, Harvard University; the U.S. Geological Survey, Reston, Virginia; the Wisconsin School of Mines, Platteville; and the Author.

Where more than one mineral occurs in a speleothem, they were deposited in a regular paragenetic sequence (Agnew, *et al.*, pp. 97, 162) which started with pyrite and/or marcasite, proceeded to sphalerite, and ended with galena, although some overlapping did occur as the composition of the ore solution changed during deposition. Thus, the maximum quantity of galena was deposited after the time of maximum deposition of sphalerite, but the galena was accompanied by much marcasite and its deposition ended before that of marcasite.



Figures 1-4. Increasing size and complexity of marcasite speleothems. **Figure 1.** Helictite-like curling tubes of marcasite (pyrite?), several cm long, found 20 to 30 m below the water table in mines in Wisconsin. **Figure 2.** Longitudinal section of linear marcasite stalactite, about 8 cm long, showing tapering form, central canal, and construction of radiating crystals. **Figure 3.** Marcasite stalactite, about 7 cm long, composed of radiating crystals, with a central canal, showing two periods of growth, separated by a constriction. A notable feature is the 180° change in direction of growth. **Figure 4.** Complex group of marcasite stalactites, about 10 cm long, on a sphalerite groundmass, with helictite-like projections. Figure 1 from Howard (1960a), after George (1925). Figures 2-4 of specimens from Black Jack Mine, from Howard (1960a), after Chamberlin (1882).

ORIGIN OF THE SPELEOTHEMS

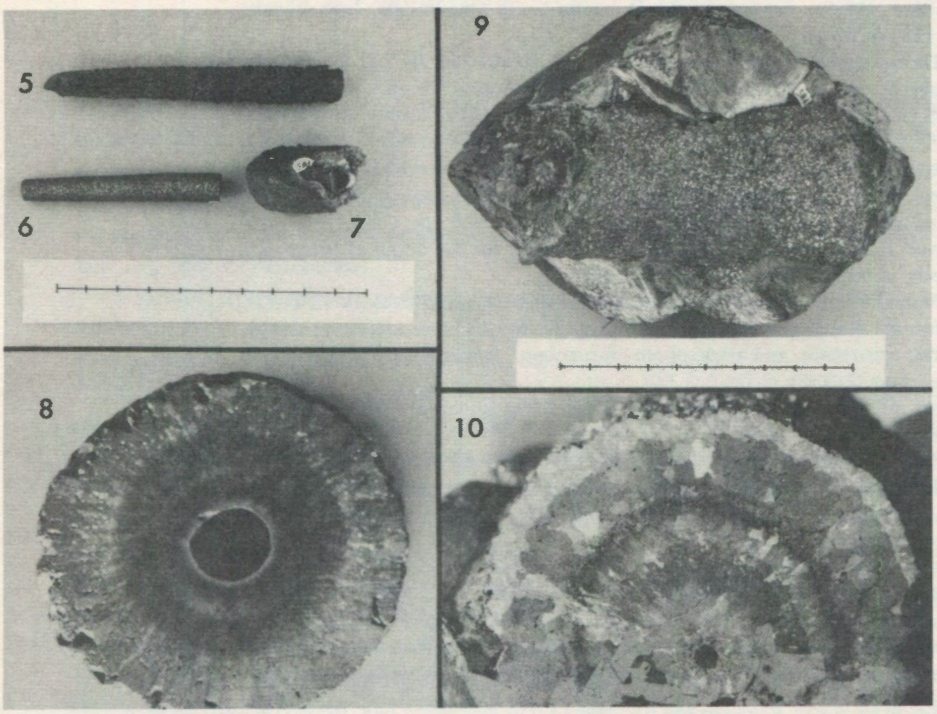
The source of the mineralizing solutions and the sulfide ores of the district is a controversial subject. The various ideas are fully reviewed by Agnew, *et al.* (1959, p. 146), but also see Zuffardi (1976). The ores may have resulted from secondary concentration and supergene deposition from descending meteoric waters (Cox, 1914; Zuffardi, 1976) or from warm, ascending, saline solutions. Most investigators now favor the latter hypothesis (Bradbury, 1959; Banaszak, 1975; Heyl, Landis, and Zartman, 1974; D.E. White, 1974). In either case, such minerals must have formed under the water table and could not have been deposited from water dripping into an air-filled void.

The mode of deposition of the speleothems is the most interesting aspect of their presence. The exact chemical circumstances of sulfide mineral deposition is not known, but any theory of ore deposition must also be able to account for the central canals, radiating crystals, and generally upward orientation of the speleothems. Most of the speleothems have been called stalactites, because of their long, slender shapes. However, as already indicated, the important point is that there is no precise historical record to indicate that any of these were pendant from the ceilings of the caves. Where precise information does exist, it always indicates that the speleothems were projecting vertically or nearly upward from the floors of the voids.

Sulfide mineral deposition may occur under a number of circumstances when the ore fluid is cooled, diluted, neutralized, or encounters a reducing agent. The most likely sequence of events (Bahnaszek, 1975) begins with lower-density, metal-rich chloride brines, low in sulfide content, ascending into the carbonate host rocks. There, they dissolved carbonate until equilibrium was attained. Metallic sulfides, under normal circumstances, were then deposited *slowly* on the cave boundaries as the ore solutions were reduced, diluted, cooled, or became more acidic. The result was geode-like voids lined with crystals of sulfide minerals.

I suggest, in contrast, that the stalactites and helictites were formed at points in these voids where were *localized* the sources of the agent responsible for precipitation of the minerals. This process occurred more rapidly than was possible through the simple but slow process of cooling of the ore fluids. These points of deposition were orifices or pores through which the precipitating gas or fluid entered the ore-fluid filled cavities.

The direction of flow of the precipitating agent was upwards, the direction in which the speleothems grew. This would necessitate the entry of a gas or fluid that was less dense than that already in the cave. Although the idea is largely rejected, a gaseous reducing agent could have been H_2S or methane, either of which might have been produced by oxidation of the large quantities of organic matter in the carbon rich "oil rock" or other beds of the underlying Decorah or Platteville formations. If the precipitating agent had been a rising fluid, it need only have had the effect of changing the pH, temperature, or concentration of the ore fluids in order to have caused precipitation.



Figures 5-10. Sulfide mineral stalactites from Black Jack Mine, Illinois; in author's collection. **Figures 5 and 6.** Simple marcasite stalactites with central canal and composed of coarse and radiating crystals. **Figure 7.** False "stalactite" composed of sphalerite on an elongated galena crystal core, without a central canal. **Figure 8.** Cross section of marcasite stalactite (same as in Fig. 6), showing crystal structure and central canal; specimen is 9 mm across. **Figure 9.** Massive stalactitic column, with sphaleritic core, intergrown with large galena crystals, covered with a 3 mm thick coating of marcasite (which has fallen off most of the large galena crystals on the backside of the specimen). **Figure 10.** Section of same specimen as in Figure 9, showing central canal and radiating crystals of sphalerite in concentric rings. Galena is intergrown with the sphalerite below the central canal. The outer and lighter semicircle is the coating of marcasite. Radius of the column is 3 cm. Scale lines for figs. 5-7 and 9 are in centimeters.

As the sulfide minerals were deposited around the orifice, the point of entry of the precipitating agent would grow upward into the cavity as a mineral tube. The developing tube served as the site of outward growth of the minerals radiating out from the sides of the tube. Since the base of the tube was available for the longest time, the crystals would have grown most from the base and in proportionately decreasing lengths higher up the lengthening tube. The upward-growing speleothem thus came to acquire the (generally) uniformly tapering stalactitic form. The last-deposited minerals (calcite, galena, and marcasite) plugged the canals of some of the speleothems in the terminal phase of their growth.

It is evident that a semantic problem occurs here, which turns around the criteria used in the definitions of "stalagmite" and "stalactite." While stalagmites grow upward, they do so by the sub-aerial deposition of laminae of material which is dripped onto them, and they never have a central canal.

Stalactites, on the other hand, are incipiently formed around an orifice or pore, their tips may be fed by central canals, and they show in cross section crystals radiating outward from the central canals. I suggest that these aspects of the origin of speleothems are more important than is the direction in whcih they point and that, thus, the sulfide minerals from the Marsden and other mines can be called "stalactitic", even though they developed in an upward direction.

The larger speleothems were formed with a vertical axis when the ascending flow of the precipitating agent was fairly abundant. Stalactites with central tubes over 2 cm in diameter suggest upward flowing jets of ore depositing agents (Heyl, *et al.*, 1959, p. 158). Speleothems with axes off the vertical (the helictites) probably were formed when the flow of the precipitating agent was slight, and forces such as crystal orientation overcame those of hydraulics, just as in the sub-aerial deposition of calcite or aragonite helictites. Constrictions and variations in diameter and growth direction of a single speleothem were caused by variations in the volume or composition of the flow of the precipitating agent.

In conclusion, it should be realized that the phenomenon reported here resulted from unusual conditions and events and does not suggest anything other than a rare (but notable) event.

ACKNOWLEDGEMENTS

Many people have aided and accompanied me in my study and exploration of the Upper Mississippi Valley Lead-Zinc District, especially Dr. Alan D. Howard. Paul Herbert, Jack Gill, R.T. Shannon, Ross Marsden, Marie Marsden, and F.J. Donohue, all of Galena, Illinois, provided information on the geology and human history of mining in the region. Tom Simkin, Curator, Division of Petrology and Volcanology, National Museum of Natural History, Washington, D.C. permitted study of sulfide mineral stalactites in the collection under his care, especially specimens R865-1, 47726, R17311, B3745, R478, and R865. Drs. G. Y. Chao and D. H. Watkinson (Carleton University) helped in obtaining X-ray identification of the marcasite and in making sections of the specimens, respectively.

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REVIEW—*The systematics and biology of the cave-crickets of the North American tribe Hadenoecini (Orthoptera Saltatoria : Ensifera : Rhaphidophoridae : Dolicopodinae)*, **T.H. Hubbell and R.M. Norton. Ann Arbor, University of Michigan Museum of Zoology, Miscellaneous Publication 156, 124 pp., 5 plates.**

Cave-crickets are the most conspicuous components of the cave faunas of North America. The genus *Ceuthophilus* is the most widespread and perhaps the most often seen, but is less cave-associated than the subject of this paper, the Hadenoecine crickets. The latter are restricted to the eastern United States and are composed of two genera: *Euhadenoecus* gen. nov. contains four species, of which three are new. *Hadenoecus* Scudder contains five species, of which four are new. While two species of *Euhadenoecus* are forest dwellers, all the other members of the tribe are obligate cavernicoles that reproduce only in caves and emerge from them at night to feed.

Parts I and II of this study, by T.H. Hubbell, describe the tribe, the genera, and species (including parthenogenetic populations) and discusss their distribution, phylogeny, and evolutionary history. I found Part II to be most interesting and exciting because of the story it presents of the evolutionary development of the taxa and of the biogeographic hypotheses, which may have some general application to other components of North American terrestrial cave faunas. Part III, by R.M. Norton, treats the life history, behavior, and ecology of the two best-known species, *H. subterraneus* of the Mammoth Cave Region and *H. cumberlandicus* of the Cumberland Plateau region of eastern Kentucky.

The whole paper should serve as a model for all future works dealing with the evolutionary and ecological development of our terrestrial cave faunas. Since these crickets are so important in sustaining many other components of terrestrial cave communities through their mediation of organic input into cave ecosystems, it is a pleasure to see that much of their story has finally been made known, although some problems yet remain to be solved. In short, this is required reading for all students of cave faunal evolution.

I hope Dr. Hubbell will now perform the same service in bringing to a completion his studies on the taxonomy and evolution of the southeastern cave *Ceuthophilus*.

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INFORMATION FOR CONTRIBUTORS TO *THE NSS BULLETIN*

Papers discussing any aspect of speleology are considered for publication in *The NSS Bulletin*. We particularly welcome articles describing important caves and cave areas, on the history of caves and of speleology, on problems and techniques of cave conservation, and critical reviews of current literature, in addition to papers on the more traditional subjects of cave geology, geography, anthropology, fauna, and ecology. The material presented must be original and of lasting interest. Authors should demonstrate the significance of their work to speleological theory and should elucidate the historical antecedents of their interpretations by reference to appropriate literature. Presentations consisting of raw data, only, will not be accepted.

A narrative style of writing is preferred. Fine prose is terse yet free from lacunae, sparkles without dazzling, and achieves splendor without ostentation. Data and interpretations blend effortlessly along a logical continuum so that the reader, having read, neither knows nor cares how many pages he may have turned while following the author's exposition.

As written language must communicate through time as well as across space, neologisms should be introduced only if needed to express new concepts or to record new percepts. Standard usage, therefore, is required of all authors. For general style, refer to papers in this *Bulletin* and to the following handbooks: "Suggestions to Authors" (U. S. Geological Survey), "Style Manual for Biological Journals" (American Institute of Biological Sciences, Washington, D. C.), and "A Manual of Style" (The University of Chicago Press).

Articles on earth sciences (including pseudokarst), life sciences, conservation, social science (including history), and exploration should be sent directly to the appropriate specialist on the Board of Editors (see masthead); articles not clearly falling into any of those categories may be sent to the Managing Editor. Potential contributors, especially those not professional scientists or writers, are invited to consult with the editors for guidance or aid in the presentation of their material.

Two double-spaced, typewritten copies of each manuscript, including all illustrations, are required. Manuscripts should not exceed about 10,000 words in length (approximately 40 pages of typescript), although this limit may be waived when a paper has unusual merit. Photographs must be sharp, high in contrast, and printed on glossy paper. All line drawings should be neatly rendered in "india" ink or its equivalent; the smallest lettering must be at least 2 mm high after reduction. Typed lettering is not satisfactory. Captions will be set in type and added in proof. The dimensions of original drawings and of cropped photographs should be made some multiple of the length and width of a column or of a page, when possible, in order to avoid problems with the layout. In case of doubt regarding length or illustrations, consult with the editors.

Abstracts are required of all papers; these must be brief and must summarize the author's discoveries and conclusions, not merely tell what he did. Captions are required for all illustrations. All unusual symbols must be defined. Authors should give their institutional affiliation (if any) and address exactly as they are to appear in print. Direct quotations from non-English language sources should be given in the original languages, with English translations (if desired) in footnotes. References to the literature must be by author and date, with specific pages where desirable. Literature cited must be listed in an end bibliography, with entries arranged alphabetically by the author's surname, typed in the format employed in this *Bulletin*. References must contain all information necessary for locating them, with titles and journal names completely spelled out in their original language and including all diacritical marks. Inclusive page numbers of articles and the total number of pages of books must be given. All persons to whom "personal communications" are attributed should be named in the bibliography and a current address provided for each.

Contributed papers will be refereed by one or more authorities in the appropriate specialty and will be edited for style before publication. After being refereed and again after being edited, papers will be returned to the authors for inspection and for any revisions which may be necessary. Please enclose a self-addressed, stamped envelope for the return of your manuscript.

By act of the Board of Governors of the NSS (#81-277, dated 8-12-74), a charge of not less than $25 per printed page will be levied against the author's institution or other funding agency after a paper has been refereed, edited, and accepted for publication. Payment will not be expected of scholars whose research was not sponsored or whose budgets do not include money earmarked to subsidize publication. In no event, will the ability to pay page charges be discussed until after final acceptance of a manuscript.

Reprints may be ordered when galleys are returned by the authors to the Managing Editor; these will be supplied at cost.

Summary: (1) data and/or interpretations must be original; (2) use a narrative style of writing; (3) follow standard English usage; (4) do not exceed 10,000 words (40 double-spaced pages of typescript) without receiving permission from the Managing Editor in advance) (5) submit two complete copies, including abstracts and all illustrations; (6) enclose a self-addressed, stamped envelope for the return of your manuscript.

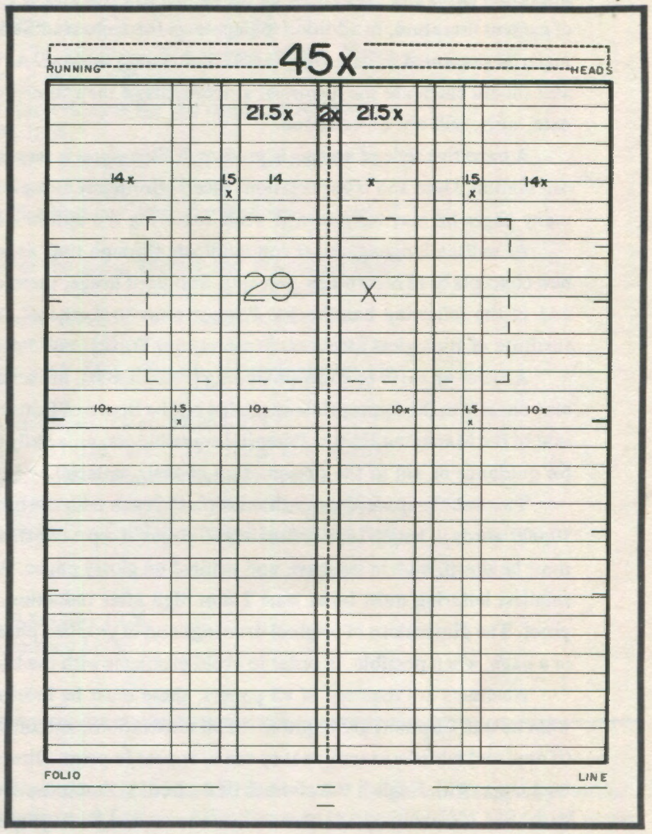
TECHNICAL NOTE

The NSS BULLETIN is trying a new layout in this and the previous issues. It follows accepted rules of best design, but may appear unconventional because editors of scientific journals rarely have time to do the necessary planning. If there be no great outcry, the revised layout will become the standard. Readers' comments are invited.

Previous layouts have allowed but two column widths—half a page or a full page. The new layout, 45 picas wide, can be divided into three 14-pica columns (14 [1.5] 14 [1.5] 14 = 45) or four 10-pica columns (10 [1.5] 10 [2] 10 [1.5] 10 = 45), as well as into two 21.5-pica columns (21.5 [2] 21.5 = 45) or one full-width 45-pica column. This provides twice as many standard sizes for illustrations and much greater flexibility in placing illustrations on the page, as well as wider latitude in matching type to subject matter. The optimum justified line of type contains between 40 and 60 characters; 14 picas of 8-point Times New Roman contain 47 characters.

The basic, triple-column layout used for most articles lends itself readily to a typographic grid of thirds (9 grid units). Illustrations and other visually dominant matter are placed within grid units or on grid-line intersections. Large illustrations may, of course, occupy several grid units. In four-column work, the grid becomes one of 16ths and in two-column work, quarters.

Research has shown that traditional, serif-roman types are slightly easier to read than gothic or san-serif roman. Although some readers have suggested changing to a "modern" type, it does not seem advisable to do so. *JH*



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