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SYMPOSIUM ISSUE "KARST IN ALABAMA"

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Cover Photograph: The Alabama Cave Shrimp, *Palaemonias alabamae* Smalley, listed as an endangered species by the U.S. Fish and Wildlife Service, inhabits lentic subterranean waters in Madison County, Alabama, as discussed by Blackwood and Kalange in their article beginning on p. 91 of this issue. **Photo Credit**: Dave Dieter.

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SPECIAL SYMPOSIUM ISSUE

"KARST IN ALABAMA"

March 26, 1999
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CONTRIBUTED ARTICLES

Journal of the Alabama Academy of Science, Vol. 70, No. 3, July 1999.

Preliminary Report

CAVE BIOMONITORING AND WATER QUALITY ANALYSIS OF HERING CAVE MADISON COUNTY, ALABAMA

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And
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March, 1999

Presented by Nicole King and Ambika Varma to
The Alabama Academy of Science Karst Symposium
Athens State University
Athens, Alabama

INTRODUCTION

The Alabama Cave Shrimp (*Palaemonias alabamae* Smalley) is listed as an endangered species by the U.S. Fish and Wildlife Service and is known to inhabit lentic subterranean waters in the vicinity of Huntsville, Madison County, Alabama. The species was last observed in 1973 within Shelta Cave of northwest Huntsville (McGregor, O'Neil, Rheams, Moser, and Blackwood, 1997). For several years the only other known population inhabited Bobcat Cave on Redstone Arsenal in southwest Madison County. The objectives for the Alabama Cave Shrimp, as mandated by the U.S Wildlife Service, include the protection of known populations of the cave shrimp and downlisting the shrimp to threatened status. The identification of five stable reproducing populations in five discrete groundwater basins is required for reclassification (U.S. Fish and Wildlife Service, 1997). In 1991 the Geological Survey of Alabama and National Speleological Society researchers discovered a new population of the shrimp in a series of three hydrogeologically connected caves (Hering, Glover, and Brazelton Caves) located in southeastern Madison County. This discovery partly fulfills the requirements for reclassification. Due to the lack of information about the life history, range, and habitat requirements of the cave shrimp, further study is needed to protect the known cave shrimp populations. This report presents the preliminary data collected by the Environmental Field Studies class of Grissom High School on Hering and Glover caves in Horse Cove from August 1998 to March 1999.

Hering Cave Water Quality

PURPOSE

The purpose of the Horse Cove Cave Conservation Project is twofold. The first aspect of the project deals with the education of students from Grissom High School on the processes and procedures in doing scientific field research. The second aspect of the project deals with the study of the Alabama Cave Shrimp and its habitat requirements.

The education side of the project is comprised of three phases. The first phase deals with the training of students to count and identify the various cave-related species in Hering and Glover Caves. The second phase deals with the monitoring of water quality in Hering and Glover Caves as well as the Flint River above the location where Horse Cove empties into the river. The third phase involves ridge walking the back or northern part of the cove, looking for and recording geological features that might hydrologically connect to the Hering Cave system.

The primary focus of the study is the Alabama Cave Shrimp and its requirements for survival. The data collected will help delineate the habitat requirements for the cave shrimp and its interaction with other cave aquatic species. At each visit to the cave the students will observe, measure, and record changes in the environment.

PHYSIOGRAPHY AND TOPOGRAPHY

Horse Cove is located in the Jackson County Mountains District of the Cumberland Plateau section of the Appalachian Plateau physiographic province. The Jackson County Mountains district is characterized as a sub-maturely dissected plateau of high relief with mesa-like sandstone remnants above limestone lowland. In the Horse Cove area the mountains have a sandstone-cap that are generally broad and rolling with 1,000 feet of relief above the relatively flat topography in Madison County.

CAVE DESCRIPTION

Horse Cove, which is shaped like a horseshoe, is located in the southeastern section of Madison County. Keel Mountain borders all three sides of the cove with Hering Cave at the eastern end of the mountain range. Caves and springs in the back of the cove have been dye-traced to drain into the Hering Cave system (Figure 1).

The Hering Cave entrance is approximately 25 feet wide by 15 feet high with a sandy floor. The dimensions of the cave passage range from 5 - 150 feet wide. The ceiling ranges from 3 - 50 feet high. The sandy floor of the cave indicates that a high water volume flows through it during part of the year. Generally, the entire length of the cave passage is easy walking. During the winter and spring months the cave's entrance has a continuous outflow of water, which quickly disappears underground again into Glover Cave (Figure 2).

Glover Cave is approximately 300 feet downstream from Hering Cave. The large entrance, 35 feet wide by 20 feet high, connects to a large room through which the stream flows. A short walk of 75 feet into the cave leads to a skylight entrance and the first deep pool of water within the cave. Unlike Hering Cave, the floor of Glover Cave is characterized by small gravel left behind by a fast-moving stream. Deeper into the cave the gravel floor slowly changes into a sandy/muddy floor with intermittent pools. At the eastern end of the cave the walking passage becomes a large deep pool before disappearing in a sump heading west toward Brazelton Cave (Figure 3).

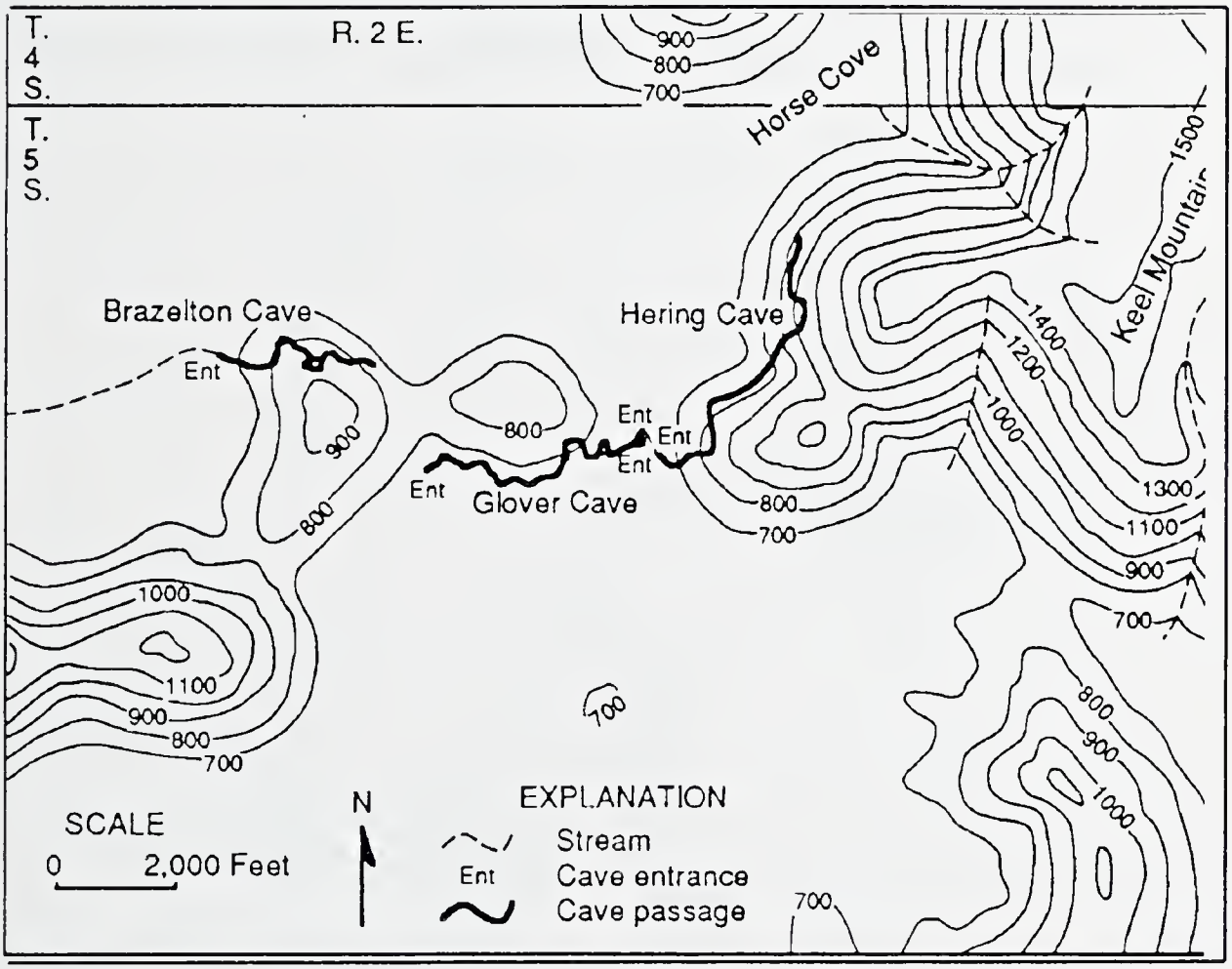

Figure 1. Overlay of Hering, Glover, and Brazelton Caves on a topographic field of Horse Cove, Madison County, Alabama.

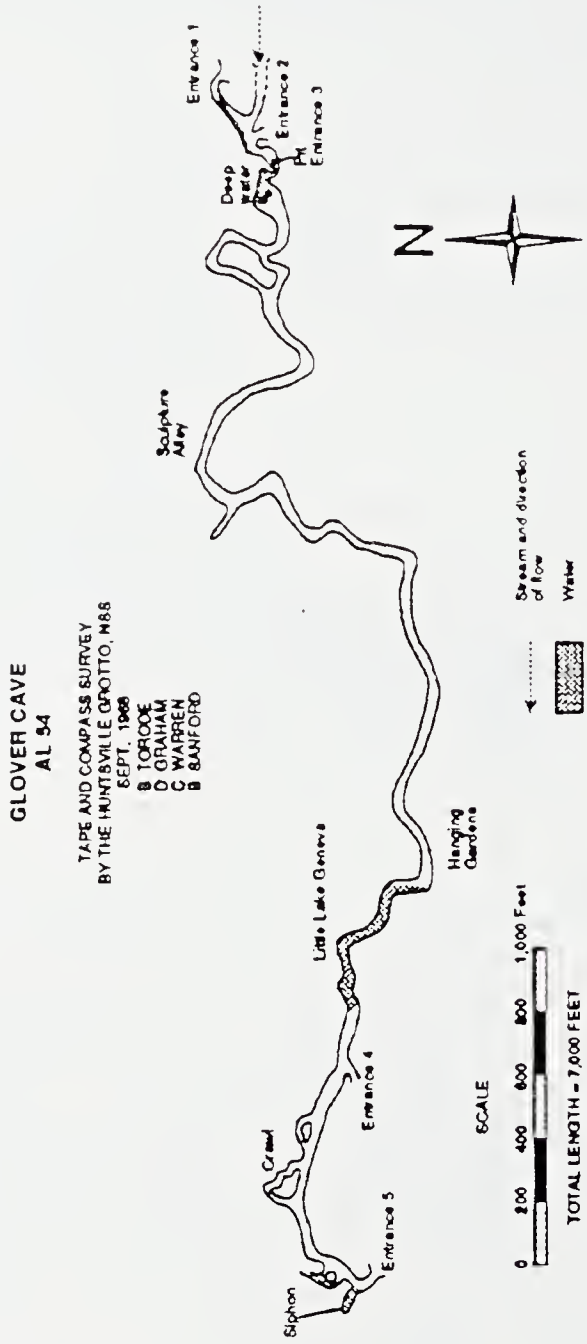

Figure 2. Tape and compass survey map of Glover Cave, Madison County, Alabama.

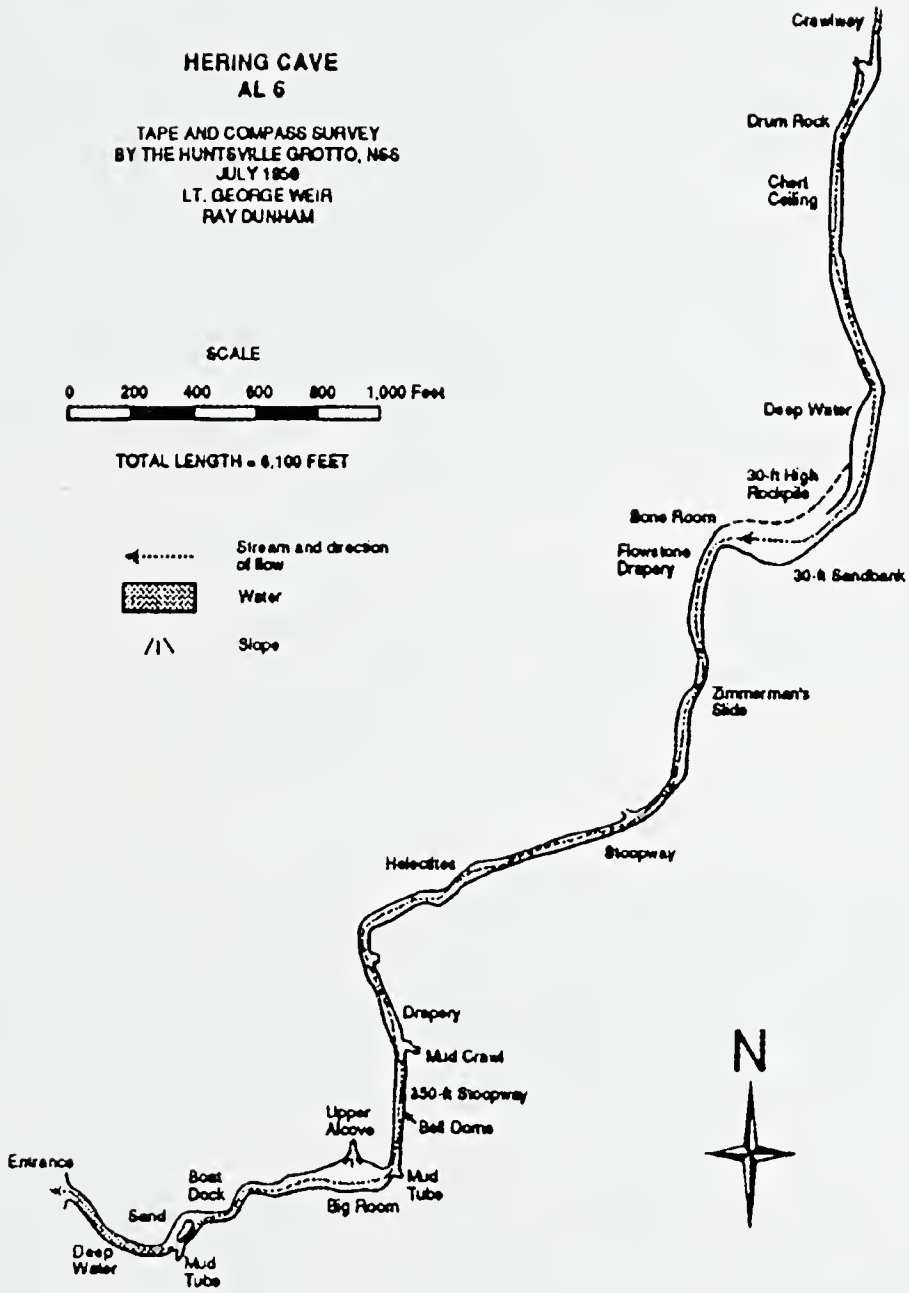

Figure 3. Tape and compass survey of Hering Cave, Madison County, Alabama.

Hering Cave Water Quality

INVESTIGATION

The students' data from Hering cave are being compared to data previously obtained from Bobcat Cave, the only other cave known to support a population of Alabama Cave Shrimp. The results are currently incomplete; final results will be available at a later date. The largest population of Alabama cave shrimp recorded at Hering Cave prior to the study consisted of four shrimp. During the fall of 1998, students counted thirty-nine cave shrimp, the largest number recorded thus far. The largest count of Alabama Cave Shrimp recorded in Bobcat Cave is fifty-one. In both caves a number of gravid females were observed. A single Alabama Cave Shrimp was found in Glover Cave, but water levels in the various pools remained high, making it difficult to detect the nearly transparent shrimp.

The following is a comparison of water quality data from Bobcat and Hering Caves.
Comparison of Hering and Bobcat Caves' Water Quality, August to December 1998
Grissom High School, Huntsville, Alabama.

	Hering Cave	Bobcat Cave
Average Specific Conductivity (μS/cm)	284	240
Average Temperature °C	14.6	15.2
Average Total Dissolved Solids	145	151

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U.S. Fish and Wildlife Service. 1997. Recovery Plan for the Alabama cave shrimp (*Palaemonias alabamae* Smalley). Atlanta, Georgia. iii p.

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ALABAMA: A SUBTERRANEAN BIODIVERSITY HOTSPOT

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ABSTRACT

The systematic study of Alabama cave fauna began in 1859 with the description of the amblyopsid fish, *Typhlichthys subterraneus*, from specimens collected in Mammoth Cave, Kentucky. However, it was not until the 1940's that a spate of activity among taxonomists resulted in the descriptions of numerous obligate cave-dwelling species (troglobites - terrestrial and stygobites - aquatic). At present 144 cave-limited species and subspecies are described from Alabama; 24 (17%) are stygobites and 120 (83%) are troglobites. Nearly 57% (83) of the Alabama species are endemic to a single county and an additional 16 (11%) are endemic to the state. The distribution of stygobites, troglobites, and single county endemics generally follows the distribution of the number of caves. A total of 3414 caves is known from 34 counties with a cluster in northeastern Alabama (especially Jackson County, with 1526 and Madison and Marshall counties each with more than 300 caves). The concentration particularly of troglobites and single county endemics in northeastern Alabama is especially striking and Jackson, Madison, and Marshall counties ranked first, second, and fourth, respectively, among all U. S. counties in the contiguous 48 states in number of troglobites. This part of the state is the single most important center of subterranean terrestrial biodiversity and subterranean endemism in the continental United States.

INTRODUCTION

Northern Alabama is one of the great cave regions of the United States, and with neighboring northwestern Georgia and southeastern Tennessee, forms the TAG area, known for its many long and deep caves. Alabama caves are found in three major settings: Mississippian and some Ordovician carbonates of the interior plateau of northern Alabama; Orodvician and some Mississippian carbonates of the folded Appalachians in northeastern Alabama, and Cenozoic carbonates of southern Alabama. Some caves are also developed in Paleozoic marbles of the Slate Belt in eastern Alabama. Jackson and Marshall Counties of northeastern Alabama extend across both the interior plateau and folded Appalachian carbonate sections, and contain a multitude of caves and a variety of cave types. Madison and Limestone counties of northern Alabama consist almost entirely of limestone and contain a number of caves and cave types. The large number and great variety of caves in northern Alabama has produced a multitude of subterranean environments for organisms.

The first obligate cave organism known from an Alabama cave was the eyeless fish *Typhlichthys subterraneus,* described by Girard in 1859 from specimens collected in Mammoth Cave, Kentucky. In his 1888 compendium of cave biology, Alpheus S. Packard made no mention of Alabama caves or cave fauna, with the exception of Nickajack Cave, whose entrance is in Tennessee but extends into Jackson County, Alabama. The systematic study of Alabama cave fauna really began in earnest in the 1940's and 1950's (Fig. 1) under the encouragement of Walter B. Jones, Alabama state geologist. Among taxonomists active at that time were Orlando Park and J. Manson Valentine, who between them described 24 obligate cave-dwelling (troglobitic) beetles. Activity continued to rise in the 1960's with 30 new species descriptions. After a decline in species descriptions in the 1970's and 1980's, taxonomic activity increased in the 1990's with 35 species and subspecies described, many of them pseudoscorpions named by William Muchmore. Stewart B. Peck (1989, 1995) summarized information on Alabama troglobites and these papers are the indispensible references about Alabama cave fauna. Unfortunately, no similar summary is available for stygobites (obligate cave-dwelling aquatic species). The most thorough ecological study of an Alabama cave is that of John E. Cooper in Shelta Cave in Marshall County. He focused on the stygobitic fauna, especially the 3 syntopic crayfish species in the cave (Cooper 1975).

METHODS AND MATERIALS

A list of stygobites and troglobites by county was assembled as a part of a larger study of the cave fauna of North America (Culver *et al.* 2000). Lists were prepared from taxonomic descriptions, published fauna lists, and the files of biologists working in Alabama caves. An accompanying list of the number of caves by county was provided by Tom Moss of the Alabama Cave Survey. Maps were generated using MapView ™, and data analysis was done with EXCEL ™. A complete list of species, county distributions, and conservation status for all U.S. stygobites and troglobites can be found on the world-wide web at *www.karstwaters.org/kwidata.htm.*

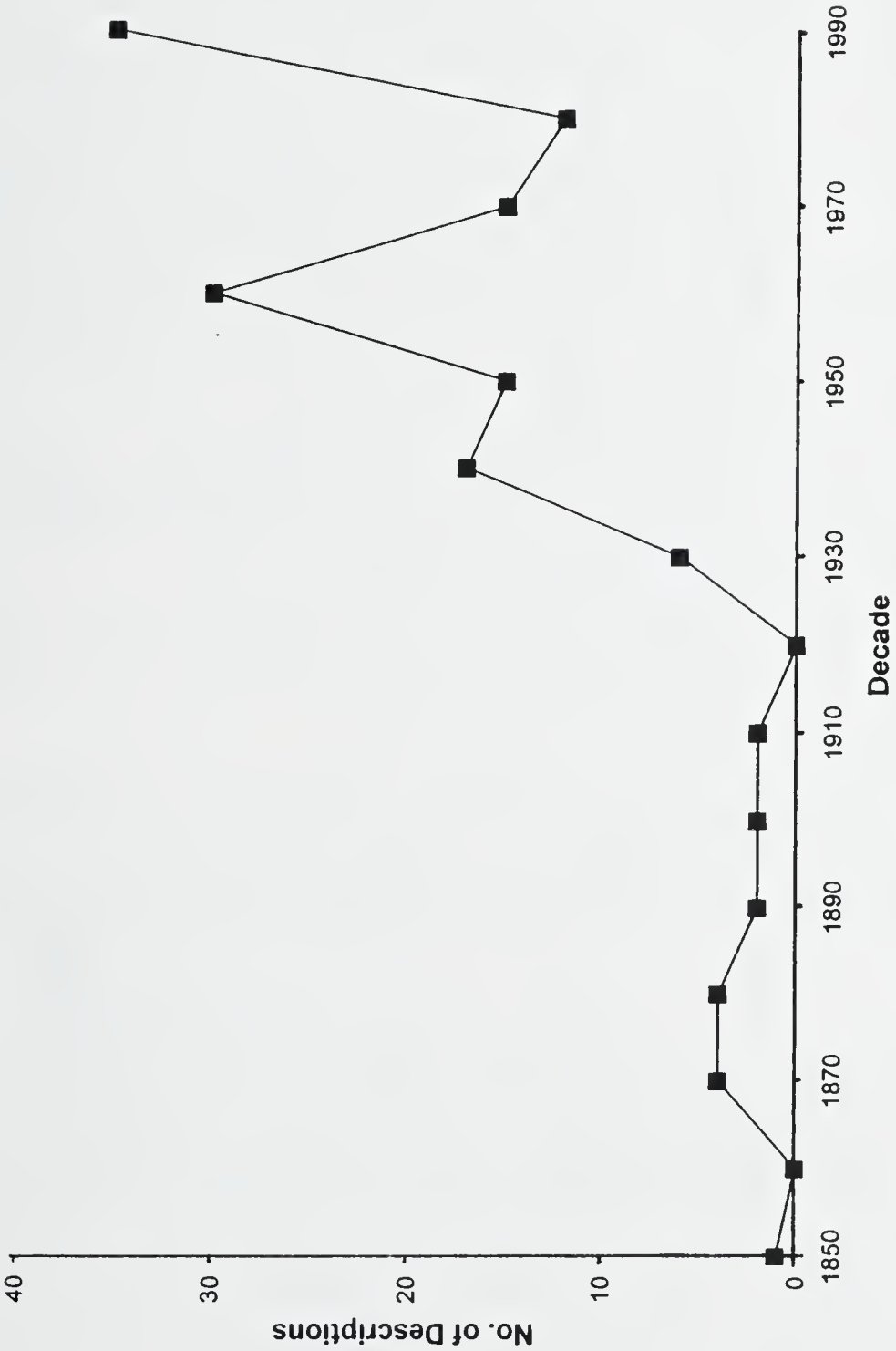


Figure 1. Graph of the rate of description of stygobites and troglobites found in Alabama caves, by decade.

RESULTS

A total of 144 stygobites and troglobites are known from Alabama caves (Table 1). Only Texas, with 186 species and Tennessee, with 168 species have more species than Alabama. Of the 144 species, 24 (17%) are stygobites, the rest troglobites. In the 48 contiguous United States, the percentage of stygobites is higher—31% of the 973 described species (Culver *et al.* 2000). Nearly 57% (83) of the Alabama species are endemic to a single county, and another 16 (11%) are endemic to Alabama. Equivalent figures for the 48 contiguous states are 61% and 22% (Culver *et al.* 2000).

Two Alabama stygobites are not included in the summary in Table 1—the amphipod *Stygobromus alabamensis* (Stout) and the isopod *Caecidotea alabamensis* Stafford. Both of these species are primarily in non-cave subsurface habitats—the interstitial. Interstitial habitats, including wells and seeps, the particular habitat where the above two species were found has been little studied in the United States, with about 50 described species. By way of contrast, in Europe the number of stygobitic interstitial species rivals the number of stygobitic cave species (Botosaneanu 1986).

Groups with high diversity in Alabama caves include crayfishes (6 species), *Ptomaphagus* beetles (13 species), pselaphid beetles (17 species in 6 genera), and pseudoscorpions (41 species in 6 genera assigned to 2 families). Groups with comparatively low diversity compared to other cave regions in the U.S. are amphipods (5 species in 2 genera), isopods (3 species in 2 genera), and mites (no species).

A total of 3414 caves have been reported from 34 counties. Their distribution is shown in Figure 2A. The concentration in northeastern Alabama, especially Jackson County, with 1526— is twice the number reported for any other county in the U.S. Madison and Marshall counties each have more than 300 reported caves.

The distribution of stygobites (Fig 2B), troglobites (Fig. 2C), and single county endemics (Fig. 2D) generally follows the distribution of number of caves. In a simple least-squares linear regression model, variance in cave number for counties with at least one cave accounts for over 70% of the variance in the number of stygobites, troglobites, and single county endemics (Table 2). The concentration of troglobites and single county endemics in northeastern Alabama is especially striking (Figs. 2C and 2D).

DISCUSSION

By any measure, Alabama is an important center and by most measures the most important center of subterranean biodiversity in North America. Nearly 18% (120) of troglobites, 14% (83) of single county endemics, and 8% (24) of stygobites known from the 48 contiguous states are known from Alabama. Jackson, Madison, and Marshall counties ranked first, second, and fourth, respectively, among all U.S. counties in the contiguous 48 states in number of troglobites. Northeast Alabama is the single most important center of subterranean terrestrial biodiversity in the continental United States. The same three counties ranked first, second, and sixth among all counties in the contiguous 48 states in the number of single county subterranean endemics. As is the case with troglobites, northeast Alabama

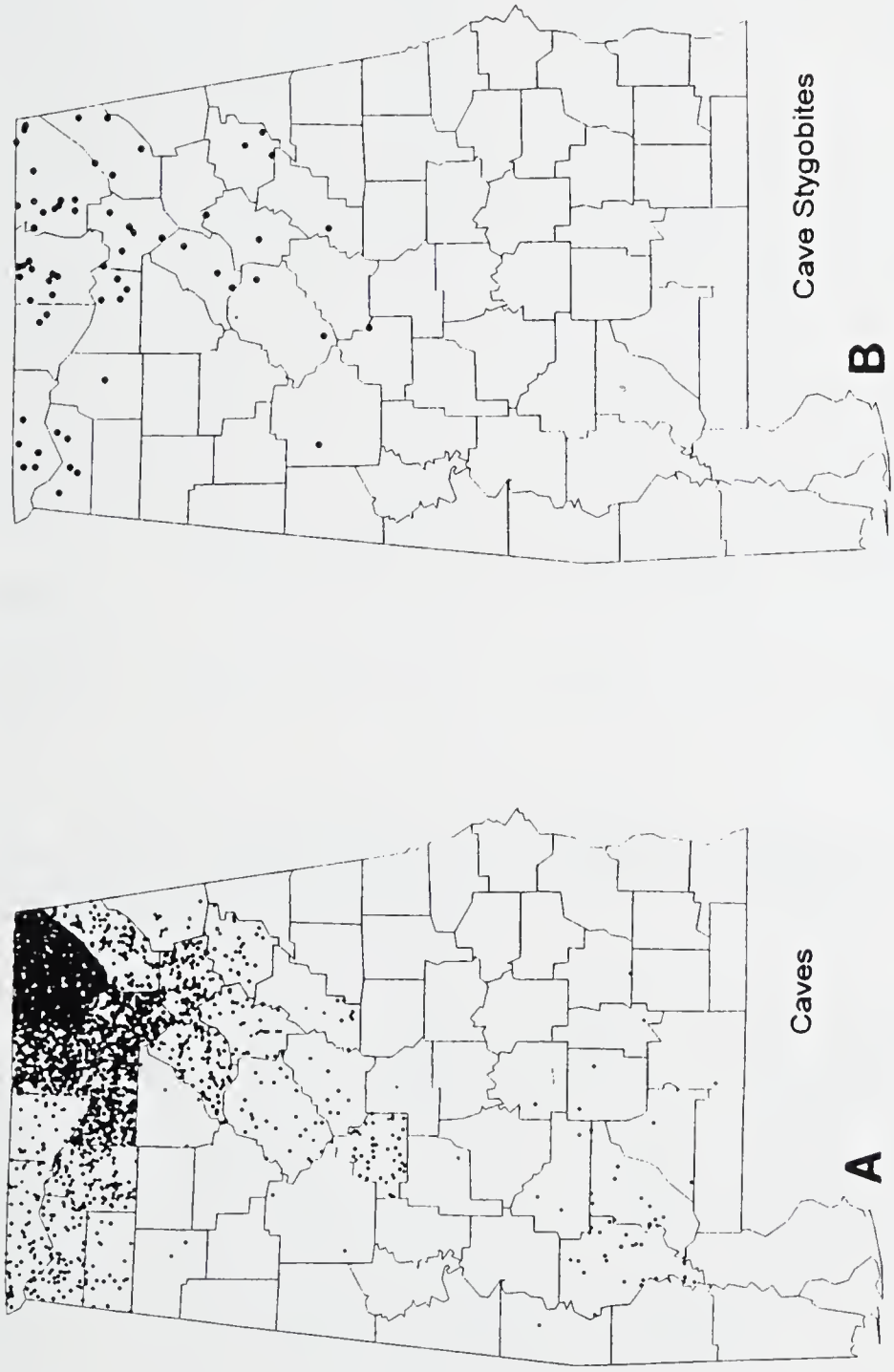
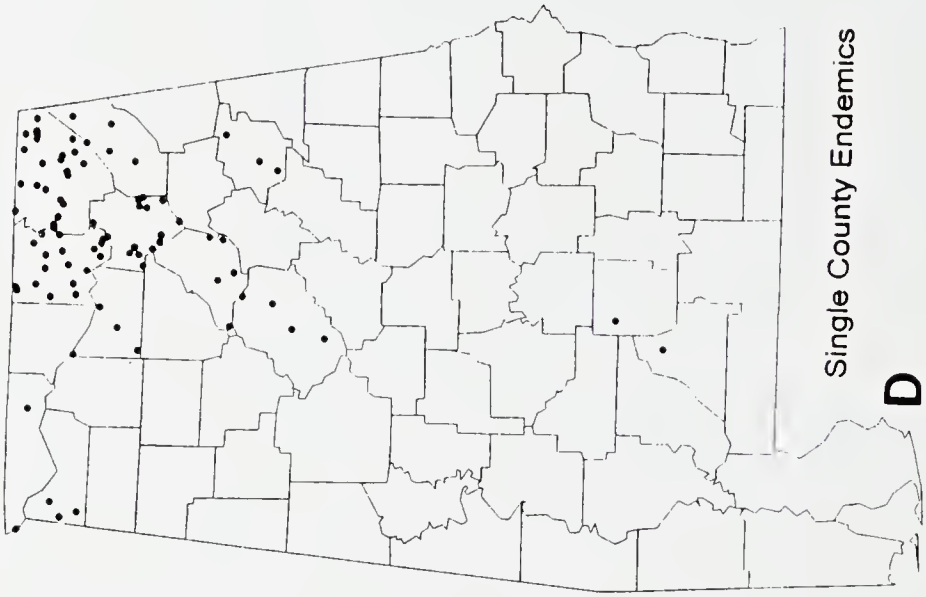


Figure 2. Distribution maps of caves (A), stygobites(B), troglobites (C), and single county endemics (D) by county. Position of dot within a county is random, and does not indicate the location of the cave or organism.



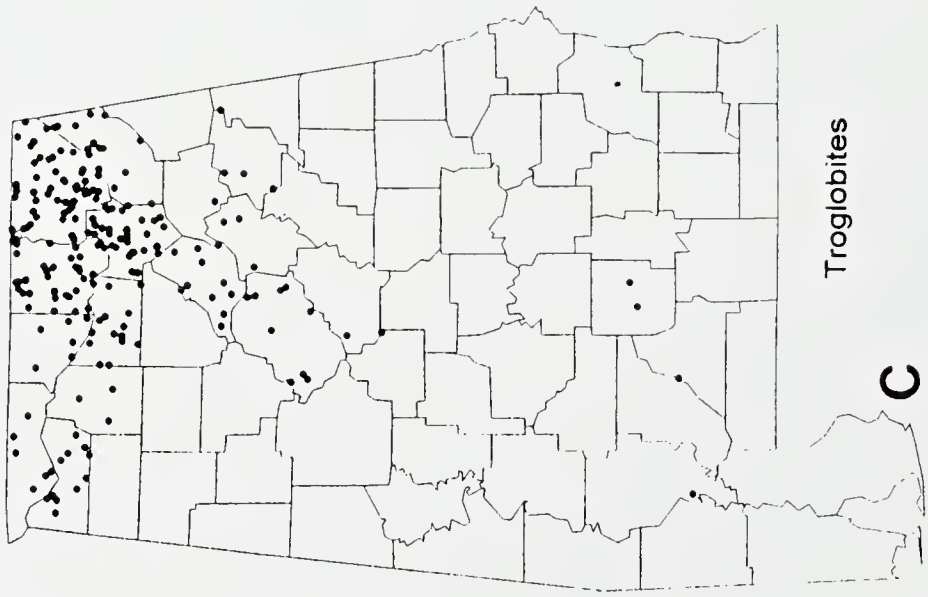


Figure 2 cont'd

Table 1. Obligate cave-dwelling species, genera, families, and orders for the ten classes and phyla represented in Alabama caves.

Phylum or Class	Orders	Families	Genera	Species
Turbellaria	1	2	2	2
Oligochaeta	1	1	1	1
Mollusca	2	3	3	4
Arachnida	3	10	16	52
Crustacea	4	6	10	17
Diplopoda	3	4	5	8
"Apterygota"	2	4	5	13
Insecta	2	4	10	44
Osteichthyes	1	1	2	2
Amphibia	1	1	1	1
TOTAL	20	36	55	144

Table 2. Linear least-squares regression of number of caves in a county with three dependent variables: number of stygobites, number of troglobites, and number of single county endemics. Only counties with at least one cave were included in the analysis.

Dependent Variable	Slope	S.E.	Intercept	S.E.	R^2 (adjusted)	$F_{1,32}$
Stygobites	0.010***	0.001	0.88**	0.30	0.74	93.51
Troglobites	0.039***	0.004	2.31*	1.00	0.74	120.7
Endemics	0.018***	0.002	0.68	0.50	0.76	105.8

* $p<.05$

** $p<.01$

*** $p<.001$

is the single most important center of subterranean endemism in the continental United States.

One particular cave—Shelta Cave in Huntsville—is worth special notice. Among individual caves and springs, only Mammoth Cave in Kentucky and San Marcos Spring in Texas surpass Shelta Cave in number of stygobites and troglobites (Culver and Sket 2000). With 24 species (12 stygobites and 12 troglobites), Shelta Cave ranks in the top 15 caves and springs worldwide in number of species of stygobites and troglobites (Culver and Sket 2000). Shelta Cave is owned and managed by the National Speleological Society.

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ENDANGERED AND THREATENED SPECIES OF NORTH ALABAMA KARSTLANDS

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The U.S. Fish and Wildlife Service (Service) is the federal agency responsible for listing and recovery of endangered and threatened species. In Alabama there are seven federally listed karst species. A karst species is a plant or animal that is dependent upon caves, sinkholes, groundwater, springs or seeps for its habitat.

There are two endangered karst mammals in Alabama. Using caves for protection and shelter, the gray bat (*Myotis grisescens*) and the Indiana bat (*Myotis sodalis*) have specific habitat needs which change with the season. During the winter, both bat species can be found hibernating in Alabama, with gray bats using nine caves and Indiana bats using seven caves. Only warm caves are used as summer maternity sites by gray bats; in Alabama, seven caves are presently used and several other caves historically used. Some Alabama caves are also used as roost sites for non-breeding adults and during migration. Overall, endangered cave bats in Alabama are doing fine. Recently, cavers found two new cave sites being used by gray and Indiana bats in Bankhead National Forest.

Bats are important to the cave ecosystem because of their droppings (guano), which is a key link in the cave food chain. Many aquatic cave species rely directly or indirectly on guano dropped or washed into cave streams. In Alabama there are five endangered or threatened aquatic karst species - one cave fish, three spring fishes, and one cave shrimp.

The endangered Alabama cave shrimp (*Palaemonias alabamae,* Smalley) is a tiny (up to 35 millimeters in length), colorless, appearing translucent-white, decapod crustacean. It was first found in Shelta Cave underneath the city of Huntsville, Alabama in 1958 and 15 years later it was then observed in a Redstone Arsenal cave. But by the late 1970's the shrimp could no longer be found in Shelta Cave. It is not known why the cave shrimp was extirpated from Shelta Cave, but many suspect groundwater contamination, possibly from termite insecticides. Presently, the Alabama cave shrimp is found in four caves in Madison County, Alabama. Additional cave shrimp, perhaps a new species, have been recently found in Colbert County.

The Alabama cavefish (*Speoplatyrhinus poulsoni*), one of the rarest of all cave fish, is found in only one cave in Lauderdale County, Alabama. This small, pinkish-white fish has an elongated and flattened head, no eyes, no pelvic fins, and has sensory papillae along its head

and sides. The highest number of Alabama cavefish ever recorded is only 10-12 fish in one visit. This fish is difficult to census since its cave habitat is complex and difficult for humans to access and it periodically floods making it impassable. In 1997, the Key Cave National Wildlife Refuge was established to help protect the endemic cavefish - this cave is also an important maternity site for endangered gray bats.

The watercress darter (*Etheostoma nuchale*), an endangered species, naturally inhabits three springs (Glenn, Thomas, and Roebuck) of the Black Warrior River watershed, Jefferson County, Alabama. The darter was successfully transplanted to another Jefferson County spring. This darter requires dense aquatic vegetation growing in cooler, deeper, spring backwaters. Seven acres of Thomas' Spring are protected as the Watercress Darter National Wildlife Refuge. The Service is investigating the purchase of additional darter habitat.

Found only in Alabama, the threatened pygmy sculpin (*Cottus pygmaeus*) inhabits Coldwater Spring and its adjacent spring run in Calhoun County. The City of Anniston, uses Coldwater Spring as their main water supply but they are required to leave at least 3 cubic feet per second spring flow to maintain the sculpin's habitat.

The last Alabama fish species associated with karst, is the threatened slackwater darter (*Etheostoma boschungi*). This darter is found in five tributary streams to the south bend of the Tennessee River flowing along the Alabama and Tennessee border. The slackwater darter requires two distinct habitats; nonbreeding habitat of slow flowing streams and breeding habitat of spring seepage waters.

A karst-related plant, the threatened American Hart's-tongue fern, (*Phyllitis scolopendrium*), has evergreen, strap-shaped fronds growing in a cluster from its short underground rhizome. This plant is found in Alabama, Tennessee, Michigan, New York, and Canada. Alabama has two populations of this fern; a healthy population is growing on ledges around a limestone pit cave in Morgan County and another small population is growing by a sinkhole at Fern Cave National Wildlife Refuge in Jackson County. The plant grows in deep shade on dolomitic limestone which is high in magnesium, and requires cool, humid, moist habitat conditions.

FIVE EXTINCTION FACTORS FACING KARST SPECIES

There are five human-related factors threatening the survival of all karst species. The five factors are: (1) habitat loss, (2) non-point source pollution, (3) illegal killing or collecting, (4) competition, and (5) predation. The first two factors are considered to be the leading causes for localized extirpation of many karst species.

In karstlands, changes in land use impacts life not only above ground but also under the ground. The habitat, or home, of karst species are fragile and can easily be destroyed or damaged by many human activities. Caves and sinkholes can be permanently filled in with

cement, rocks, soil, and debris or can be inundated with water from impoundments and reservoirs. Over pumping of groundwater lowers the water table and can dry up springs and seeps. Cattle grazing and trampling destroys sensitive spring habitat. Logging of forest trees crushes imperiled plants, reduces or eliminates shade and detritus (food source), alters hydrology, and causes non-point source pollution in the form of siltation and sedimentation. Quarry mining, road building, suburban and urban development all harm and often permanently destroy karst features.

The water quality of springs, seepages, and groundwater can become polluted and unsuitable for aquatic species. Chemicals spilled or poured directly into sinkholes (point source pollution) does harm aquatic karst species, but the more serious, long-term threat is groundwater degradation and contamination from non-point source pollution (NPSP).

Some sources of NPSP contaminating Alabama's groundwater include sedimentation from construction and timber harvest; fertilizers, herbicides and pesticides from lawns, golf courses, farmlands; human waste from leaking septic tank systems and sewage waste systems; animal waste from animal feed lots; leachate from landfills; leaking underground gas and oil storage tanks; and storm water runoff.

The third extinction factor is the illegal killing or collecting of karst species. In Alabama endangered cave bats have been directly and indirectly killed by humans. Endangered karst plants and aquatic cave species have been taken by hobbyists for collections and aquariums, respectively.

Competition for food resources and predation are natural events but humans can alter the natural balance of these last two factors. For example, the introduction of grass carp into the endangered watercress darter's habitat changes the natural aquatic environment. The removal of dense vegetation by the carp decreases the amount of food, breeding substrate, and cover (protection from predators) available to the darter.

For all karst-related species, habitat loss and habitat degradation, including declining groundwater quality, are the main reasons leading to population declines and extirpation. To reduce the extinction risk of our unique karst plants and animals, we must conserve and protect not only the karst feature itself but also the surrounding groundwater recharge area. **Endangered means there is still time, extinction is forever**.

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CAVES AND SPRINGS OF NORTH ALABAMA IN SOCIAL CONTEXT

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ABSTRACT

The Tennessee Valley Region of north Alabama is an especially rich source of information about the historical importance of caves and springs. As they dispersed westward, early settlers used caves as shelter, and built homes and established communities beside springs. Caves were a source of guano used as fertilizer and saltpeter used in manufacture of gunpowder. Purported therapeutic properties of spring water established reputations for several celebrated and once-flourishing resorts. Today, springs and caves are no less important to north Alabama residents, especially as they present opportunities for outdoor recreation, and as they provide habitat for sensitive species. In this article, the author explores the uses made of north Alabama caves and springs from the early 1800's to the present.

INTRODUCTION

Among Alabama's abundant natural resources are two often overlooked or taken for granted karst features–its many caves and springs. As an aside to my interest in the distribution and ecology of cave and spring dwelling fishes, I became interested in the historical and social importance of caves and springs to individuals and communities. The scope of this examination of the subject is limited to north Alabama's Tennessee Valley, encompassing nine counties. Four of these counties claim nearly three-fourths of the state's 2,700 caves: Jackson-44%; Madison-12%; Morgan-10%; Marshall-7% (Woodward, 1988). There are several hundred springs in the same region. Results of this limited investigation suggest the entire state to be a rich source of information about the historical and social importance of caves and springs.

ROLE IN EARLY SETTLEMENT

Madison County

As they dispersed into the Mississippi Territory, early settlers built their homes beside springs, and in some cases used caves as shelter. Jones (1969) describes the early settlement of what is now Madison County.

"John Ditto had come to what is now Huntsville in Madison County as early as 1802 and had built a shack beside the spring [Big Spring]; soon after, however, he removed to Ditto Landing [on the Tennessee River] and established a ferry. Samuel Davis came to the spring

prior to Hunt, and started the foundation of a cabin, but left it uncompleted. Accompanied by David Bean, upon reaching the spring [in 1805], Hunt and Bean found the work left by Davis, and finished the cabin. Bean went back to Tennessee; Hunt stayed. When Davis returned and found Hunt occupying the cabin he had started, he removed to and settled in New Market."

"In 1803 or 1804, Isaac Criner, his uncle, Joseph, and cousin Stephen McBroom explored the northern part of what is now Madison County in the vicinity of modern day New Market. Returning to this area during the spring of 1805, they began their homes... For his cabin, Isaac selected a spot near a spring on Mountain Fork [now known as Cress Well], from which flowed a stream of water as large as that from the spring near which [John] Hunt had settled."

The town of New Market and city of Huntsville, then, owe their locations to springs. John Hunt doubtless had learned the spring's location and came from east Tennessee with the express purpose of finding and settling near it (Taylor, 1976). Early settlers of the area sent word to former neighbors and friends of the beauty of the country now Madison County, the fertility of the soil, and of the spring's abundant supply of water (Betts, 1916). By the time Madison County was created by the Mississippi Territorial Legislature on December 13, 1808, there were 300 persons living in the squatter village then generally known as "Hunt's Spring" (Fisk, 1997). At the land sales in August, 1809, held in Nashville, Tennessee, the nearest Federal Land Office, there was sharp competition for the quarter section encompassing the big spring. Leroy Pope, the "father of Huntsville," had to pay $23.50 per acre for the prize; adjoining parcels brought only from two to four dollars per acre (Taylor, 1976).

Jones (1969) also informs that the spring now called Kelly (Indian) Spring drew the first settlers to that section of Madison County. A deed of sale for land adjacent to the spring, dated prior to 1820, refers to the spring as "Prices Big Spring." Jones indicates the settlement around the spring to have broken up around 1845 because of repeated outbreaks of malaria.

Limestone County

Dunnavant (1993) provides the following account of early settlement of Athens in Limestone County, indicating the importance of a spring to establishing that community.

"Jim Craig and his family are reported to have come in 1803 to the Big Spring that later would become the site of Athens. Chickasaw Indians apparently made the Craig family less than welcome, and they left. Samuel Robertson and his family came to the spring in 1808 and established a trading post. Robert Beaty and John D. Carriel began selling lots in their town of Athens, laid out around the Big Spring near Robertson's trading post, on May 8, 1818."

Limestone County was created by act of the Alabama Territorial Legislature on February 6, 1818. On November 17, 1818, the Legislature passed an act providing that an election be held to select five commissioners who were to be empowered to fix a seat of justice for Limestone County: Athens, Cambridge, and English's Spring contested for the location of the county seat (Walker, 1973). In context of this article, it is relevant to note that each community contesting for the county seat was settled near a large spring: Athens' Big Spring; a spring just west of present day Cambridge Lane; and English's Spring (known today as

Pryor Spring) just north of present day Calhoun Community College. By act of the Legislature on December 3, 1819, Athens was declared the county seat.

Colbert County

The following account of early settlement of Tuscumbia in Colbert County follows closely that of Leftwich (1965) and indicates the importance of a spring to establish that community.

Within the bounds of present day Colbert County were five towns vying for superiority, including Cold Water (now known as Tuscumbia) and, six miles up the Tennessee River, Bainbridge. The commissioners of Bainbridge presented claims of that location in glowing terms and, in regard to water, advertised the following: "...no town in the western country can boast a better supply...along the eastern margin there are upwards of twenty springs."

Of the five towns, only Tuscumbia has survived to the present. Situated on site of the Indian village Oka Kapassa (Ococoposa, The Tennessee Valley Historical Society, 1974) meaning in the Choctaw-Cherokee dialect, Cold Water, that town had some real advantages over its rivals, first among them being a large spring, which furnished an abundant supply of water. Michael Dickson, the first known white resident of Cold Water, built his log cabin on land that included the spring. The land was purchased from the Indian Chief Tuscumbia for $5 and two pole axes. Incorporated under the name of Cold Spring December 20, 1820, on June 14, 1821 the legislature changed the name to Big Spring, and on December 31, 1822, changed the name again, this time to Tuscumbia.

Mashall County

A story handed down from generation to generation has Isom Wright living in what is now called Cathedral Caverns in Marshall County (Anonymous, 1952). Isom was one of 5 brothers who arrived in the Mississippi Territory around 1800 and settled in Kennamer Cove. Four of the brothers returned to Kentucky whence they came; Isom remained, and was discovered several years later by two of the bothers and relatives who returned to the Cove to be living in the cave, assisted by local Indians.

Jackson County

The following account of early settlement of Jackson County follows closely that of Hollis (1962), and indicates the importance of a cave to establish that settlement.

Sauty Cave was one of the first settlements in the part of the Mississippi Territory that ultimately became Alabama's Jackson County. Tradition has it that Indians often camped in the opening to the cave, perhaps leading to its discovery by white settlers. The earliest actual record of settlement at Sauty Cave (also known as "Sauta" Cave) is a document located in the Madison County courthouse that details an 1813 claim by mine operator Colonel William Robinson against employee Argyle Taylor "...for taking four hundred weight of saltpetre with force and arms from the plaintiff". (Jones, 1935; Hollis, 1962). For use in manufacture of gunpowder, saltpeter had been mined from the cave before and during the War of 1812. By act of the State legislature December 13, 1818, Jackson County was created and Sauty Cave was designated the seat of government.

MINING OPERATIONS IN NORTH ALABAMA CAVES

About the turn of the 19th century, it was discovered that many north Alabama caves contained deposits of saltpeter, a basic ingredient of gunpowder. Apparently, many fewer caves contained substantial deposits of bat guano, used by farmers as fertilizer. Ultimately, development of more economical methods for nitrate production eliminated the need both for saltpeter and bat guano.

Guano

An anonymously written article entitled "The Mastodon Cave," dated March 11, 1875, and published in the North Alabamian, a Tuscumbia newspaper, carries the report that "...Harvey Donegan, and some others, have bought the guano or bat manure in this cave, and will soon commence getting it out. It is said to be fully equal to Peruvian guano, and sells readily at forty dollars per ton." (Anonymous, 1875). Talucah Cave in Morgan County also once was mined for bat guano for use as fertilizer (Anonymous, 1956).

Saltpeter

During the 1800's, gunpowder was made of purified saltpeter or niter, charcoal, and sulfur, the niter being much the larger portion of gunpowder material (Rains, 1861). Saltpeter was mined from Sauty Cave before the War of 1812 and, until discovered and destroyed by northern forces in April, 1862, saltpeter mined from the cave contributed to the southern effort during the Civil War (Anonymous, 1956; Hollis, 1962). Several other north Alabama caves reputedly were mined for saltpeter during the Civil War, including the cave now recognized by the name Cathedral Caverns, also in Jackson County. Apparently, this cave was not suited to this purpose: today, there are only hints of saltpeter mining activity - one small pit, and tally marks on the cave wall (Varnedoe, 1994). Then known as Mastodon Cave, Keeton Cave in Lauderdale County probably was mined for saltpeter during the War of 1812, and almost certainly during the Civil War (Varnedoe, 1980). A considerable amount of saltpeter was mined from a cave "...on the Cole place..." near present-day Gurley in Madison County (Taylor, 1976). Apparently, local citizens used the saltpeter to make gunpowder. However, there is tradition that, under pretense of mining saltpeter "...a gang of rogues and counterfeiters...carried out their...operations in the saltpetre cave." (Taylor, 1976).

MINERAL SPRINGS RESORTS

The medicinal properties of spring water established the reputations of several celebrated and once-flourishing resorts in north Alabama. The famous and well to do sipped and sometimes bathed in the mineral waters that early physicians prescribed as a restorative and cure. Such resorts were located in Madison County (Monte Sano Hotel), Limestone County (Moore's White Sulphur Springs; Pettusville Springs; Wooley Springs), Lauderdale County (Bailey Springs), Lawrence County (Lignon Springs), Morgan County (Valhermoso Springs; McClanahan Springs), and DeKalb County (White Sulphur Springs).

An Ellis and Company advertisement dated June 1, 1888 (Leftwich Brothers and Curtis, 1888) invites one's attention to Bailey Springs, a "Resort for Health and Pleasure," and touts Bailey Springs Water as a curative.

"For fifty years these waters have had unparallel (sic) success in the cureed (sic) of Dropsies, Scrofulous Affections, Dyspepsia in all its forms, Chronic Skin Diseases, and diseases peculiar to women. In all affections of the urinary organs it is superior to any other water in America. Its patronage is from every State in the Union. It has customers in Mexico, Canada and New Brunswick. It has achieved its reputation by merit and not by advertising. Its beneficiaries send it patronage by their personal recommendations. Many invalids come to be healed at Bailey who had never heard of it till some friend, who had been cured of some similar disease, insisted upon its trial."

"No drug known to the science of medicine is so certain or so beneficial in its action on the kidneys as the ROCK SPRING WATER of Bailey Springs, Ala. It's action is eliminative. It enters directly into the blood, purifies it of all poisonous material, and carries the disturbing elements out of the system through the proper channel for their ejection – the kidneys. Thus the germs of scrofula are washed from affected structures, and to diseased parts a new vigor and chemical nourishment are supplied that insure recovery. In dyspepsia the water gives new energy to the digestive function, and removes from the blood the vicious products of the previously imperfect process. AS A UTERINE TONIC and RESOLVENT it has no equal. Its efficiency in removing dropsical effusions is simply wonderful. Its power as a NERVE SEDATIVE is shown not only by its tranquilizing and sleep producing effect, but by its efficacy in relieving HAY FEVER and SPASMODIC ASTHMA, especially when used directly from the springs."

Bailey Springs water was sold by Ellis and Company in cases of twelve three-quart bottles ($7.50), in five-gallon demijohns encased in wood ($3.25), and in ten ($5.00) and twenty ($8.50) gallon kegs. Noting that "The glass packages are the best," a case of bottles could be refilled for $4.25; demijohns could be refilled for $2.00 (Leftwich Brothers and Curtis, 1888).

WATER SUPPLY

The importance of springs to turn-of-the-century landowners may be appreciated by considering an advertisement for "...a few pieces of property..." listed by Leftwich Brothers and Curtis (1888). Of 24 parcels advertised for sale and located in the Tennessee Valley, 9 were described to contain a "...good spring...", "...good springs...", or to be "...well watered by springs." One parcel featured "...numerous springs of pure freestone water;" another featured "...a spring with water-power to run 25 or 30 horse-power machinery..."

The importance of springs as a source of water supply for emerging north Alabama communities is, perhaps, self-evident. One tangible way to appreciate that importance, however, is to consider place names associated with government functions. For example, 1879 Tax Precincts in Limestone County included Milhouse Springs, Good Springs, Collier's Springs, Edmonson's Springs, Wooley Springs, and Sand Springs (Smith, 1989), and Limestone County post offices, long since abolished, once included those at White Sulphur

Springs, Good Springs, Blowing Spring, Pleasant Spring, Sand Spring, and Wooley Springs (Walker, 1973). DeKalb County post offices no longer in service included those located at Duck Springs (1850-1866), Head Spring (1854-1866), and Sulphur Springs (1885-1918). Suffice it to say, it appears that many communities across north Alabama developed a centrally located spring as a primary water source.

Because many turn-of-the century homes and businesses were constructed of wood, fires caused frequent and heavy damage, sometimes devastating blocks at a time. To combat such destruction, the same springs that provided water for everyday use also provided water for use to fight fire.

Madison County

Fisk (1997) describes the development of Huntsville's Big Spring, the nucleus for the south's first public water works: The spring was "...awkwardly located for furnishing water to businesses and residences situated on lots in the area of town above spring level. Even worse, its downhill location prevented the quick transportation of water to the scene of a fire..."

"As early as 1816, a fund had been established to purchase a fire engine. By what system water was to be raised from the spring to fill the engine at town level was not at that time revealed, and the fund did not accumulate very fast. Obviously, it would take a real conflagration to persuade the populace to view the threat of fire seriously. Such...happened on August 5, 1821...when a new theater building burned less than a month before its first scheduled performance."

"Funds were raised, a fire engine (hand pumper) purchased, and a volunteer fire company organized. The matter of getting water to fill the engine was solved by Hunter Peel, then county Engineer, who proposed to dam the flow from Big Spring to furnish power for operating a hydraulic pump. The pump would raise spring water up the bluff through a piping system that then would lead underground to a reservoir beside the courthouse. The piping system was to be constructed of hollowed [cedar] logs with ironbound joints. The arrangement would serve not only to provide water for the fire engine, but also to supply water to businesses and homes."

Limestone County

According to Walker (1973), "In 1893, almost the entire east side of the square at Athens was destroyed by fire. Perhaps because of this tragedy (two young men died horribly in the holocaust) and the property loss inflicted by the fire, the town determined to install a water works. The pumping equipment, reservoir and storage tank were installed in 1897 at the spring [Big Spring] on the corner of Market and Beaty streets." (Walker, 1973). The same year, a water tank was erected beside the Limestone County Courthouse, and three miles of water mains were installed to serve 3,333 residents (Dunnavant, 1994).

RECREATION

During my research, I have noted many references to picnics being enjoyed in close

proximity to north Alabama caves and springs, and a great many references to exploration of caves which, for "cavers," constitutes both recreation and sport. Certainly, caves and springs figured importantly in leisure time activities in the past, and they continue to be important sources of public enjoyment today.

In north Alabama, several outstanding municipal parks are developed around large springs: Athens' Big Spring Park, Tuscumbia's Spring Park, and Huntsville's Big Spring International and Brahan Spring parks.

Located in the center of Huntsville, Big Spring long has been favored as a spot for social and recreational activity. Today, the spring is part of Big Spring International Park, a focal point of Huntsville's downtown. "Warm days find families toting bags of bread and popcorn to the park to feed ducks and fish. Throughout the year, the park is a popular spot for runners and walkers, courting couples, and those looking for a serene setting for reading and studying." (Joiner, 1993). The Park also is location for the annual Panoply arts festival each spring and Big Spring Jam each Fall.

A few miles away, Brahan Spring also has been developed to meet the city's recreational needs. The lake formed by Brahan Spring is open for fishing, for use by remote control miniature powerboat enthusiasts, and for boating, skiing, or jet skiing (Anonymous, 1984).

North Alabama caves, too, have been developed as public attractions. In the late 1800's, visitors to Huntsville's Shelta Caverns (now recognized by the name Shelta Cave) enjoyed dances, dinners, and boat excursions on an underground lake. A Mr. Fuller from Ohio, purchased the property in the 1890's and proceeded to develop it for the public. The caverns were lighted by electricity, trails were opened up, boats were put on the underground lake, and a large dancing pavilion was erected where a band furnished music for dancing (Record, 1951).

Not yet open to the general public, the Alabama Department of Conservation and Natural Resources State Parks Division purchased a Marshall County cave site in 1987, thereby establishing Cathedral Caverns State Park. To date, some $5,000,000 has been spent to develop the 460 acre Park, site of a magnificent underground, historically, and archaeologically significant cavern that is listed on the national register of natural landmarks. A recent study suggests that as many as 250,000 people annually will visit the caverns once it is reopened (Nichols, 1997). First developed by Jay Gurley in the 1950's, ownership of the cave changed hands twice before it was purchased by the state. In 1995, the cave had a role in the movie "Tom and Huck," based on the Mark twain classic "Huckleberry Finn." (Brewer, 1996).

No longer open to the public, in the 1890's, Manitou Cave in DeKalb County once was a location for candlelit dances (Unpingco, 1969). According to Robert B. Thomas (The DeKalb Legend, 1974), for many years the Manitou Cave area was used as a picnic ground: "From the fairly level ground near the spring, wooded steps had been built up to the Fort Payne and Eastern Railroad. These steps were originally for tourists who rode up on the train and walked down these steps to the cave entrance where guides conducted tours through the cave. Inside the cave were wooden bridges. Points of interest, such as the hay stack, the drum rock, the ball room, etc. were noted." The only operating "pay" or "show" cave in north Alabama is Sequoyah Caverns in DeKalb County, a "wet" cave. Picnics and dances also once

were held at Hughes Cave in Morgan County (Morgan County Genealogical Society, 1995).

HABITAT FOR SENSITIVE SPECIES

The Southern cavefish (*Typhlichthys subterraneus)*, a state protected species, is found in many caves scattered throughout the Tennessee Valley region of north Alabama. During their investigation of 84 caves located in southern Madison, western Jackson, eastern Morgan, and northern Marshall counties, McGregor *et al* (1997) observed Southern cavefish in 14 caves. The Tuscumbia darter (*Etheostoma tuscumbia)*, also a state protected species, populates springs located in the Tennessee Valley region of Madison, Limestone, Lauderdale, Colbert, Lawrence and Morgan counties. Key Cave (Lauderdale County; Key Cave National Wildlife Refuge), Cave Spring (Morgan County; Wheeler National Wildlife Refuge), and Indian Cave (Limestone County) provide habitat for the gray bat (*Myotis grisescens*), a federally listed endangered and state protected species.

Madison County

Historically, Madison County's Shelta Cave was known to possess one of the most diverse and abundant cave assemblages known (Hobbs and Bagley, 1989). Since the mid-1970's, however, the fauna has dramatically declined ostensibly due to disappearance of once abundant bats, guano from which provided energy that powered the system (Lee, 1987), from water quality degradation, or a combination of these and/or other factors (McGregor *et al*, 1997). Located in northwest Huntsville, Shelta Cave is the type locality for the Alabama cave shrimp (*Palaemonias alabamae*), a federally listed endangered and state protected species. The shrimp was first collected from Shelta Cave in 1958, and last reported from that cave in 1973 (Cooper and Cooper, 1974). The shrimp was found in Bobcat Cave on the United States Army's Redstone Arsenal in southwest Madison County in 1973 (Cooper and Cooper, 1974). In 1991, Geological Survey of Alabama and National Speleological Society researchers discovered a new population of the shrimp in a series of three hydrologically connected caves (Herring, Glover, and Brazelton caves), each located in southeastern Madison County (McGregor *et al*, 1997).

Jackson County

The Sauta Cave system in Jackson County provides habitat for the world's largest colony of Tennessee cave salamander (*Gyrinophilus palleucas*), a state protected species. Gray bats (*Myotis grisescens*) inhabit the Sauta Cave system. Gray bats and Indiana bats *(Myotis sodalis*) hibernate in Fern Cave. To provide protection for these federally listed endangered and state protected bat species and their critical habitat, the FWS has acquired land encompassing each cave. Established in 1978, Blowing Wind Cave National Wildlife Refuge is located seven miles west of Scottsboro; established in 1981, Fern Cave National Wildlife Refuge is located twenty miles west of Scottsboro and two miles north of Paint Rock.

Lauderdale County

Key Cave, located five mile southwest of Florence on the northern shore of Pickwick

Lake in Lauderdale County, is the type locality for the Alabama cavefish (*Speoplatyrhinos paulsoni)*, an Alabama endemic. To provide protection for the only known habitat of this federally listed endangered and state protected species, land encompassing the cave was acquired by the FWS in 1997, and is managed as Key Cave National Wildlife Refuge.

Limestone County

Distribution of the Spring pygmy sunfish (*Elassoma alabamae*) appears to be restricted to springs and spring-influenced stream habitat in Limestone County (Mayden, 1993; Jandebeur, 1998). Currently, the FWS or the State of Alabama does not protect this species.

MISCELLANEA

Over time, caves and springs in north Alabama have been used in many ways. What follows are brief accounts of other uses for north Alabama caves and springs gleaned from newspaper articles and local histories.

Distillery

It has been reported that, before the Civil War (Garrett (1964), a government-owned distillery was operated at a large, free-flowing spring in Waterloo, Lauderdale County. The spring was located on property owned by Miss Ruby Boatman. As reported by Dendy (Tennessee Valley Historical Society, 1979) "The farmer brought in his corn, apples, and peaches and had them made into whiskey and brandy. He gave part of his finished product as a 'toll' for the work."

Fallout Shelter

Anticipating a "Cold War" nuclear attack, Sauty Cave in Jackson County once was prepared as a fallout shelter by members of the Alabama National Guard, Company B, 151st Engineer Battalion (Hollis, 1962).

Fish Hatchery/Fish Farm

Clark Spring in Decatur, Morgan County, once was the water source for a privately owned and operated fish hatchery. The extent of development of the hatchery (ponds covered approximately a one-quarter square mile area) may be appreciated by inspecting the 1963 United States Geological Survey 7.5 Minute Series (Topographic) map for the Decatur Quadrangle. The area now is developed as Decatur's Wilson-Morgan Park.

Madison County's Kelly (Indian) Spring is the water source for six fishponds. According to Thompson Kelly, Jr. (pers. comm.), for about two years in the mid-1960's the two ponds closest to the spring were used as "catch-out" ponds for trout; the other four ponds were used to raise catfish.

Hideout

According to Unpingco (1969), Molly's Cave near Somerville, Morgan County, is named for an escaped slave who sought refuge there. Murrel's Cave near Margerum, Colbert County

is reputed to have provided a hiding place for John A. Murrel and his gang (Unpingco, 1969). Murrel is reported by Walker (1973) to have led a "...gang of outlaws and cut-throats who, as land pirates, preyed on travelers on the Natchez Trace..." Gentry (1962) fixes the last days of Murrel's operation about 1833. According to an anonymously written article (1952), "Stephen Silas (Babe) Wright of Swearingen... says that his father told him about some men who lived in... [Cathedral Caverns] during the Civil War-draft dodgers and army deserters who hid out there."

Military Encampment

On his way to Horseshoe Bend, in 1814 Andrew Jackson reportedly camped at a big spring in northeast Ft. Payne, DeKalb County (DeKalb County Legend, 1978). According to Garrett (1964), during the Civil War Federal troops often were encamped around McFarland Spring at Florence in Lauderdale County. Also in Florence, a large spring called "Succatainia" in Indian language, meaning "Sweetwater," is located on Sweetwater Plantation (Tennessee Valley Historical Society, 1962). As told by McDonald (Tennessee Valley Historical Society, 1974), "War years were rough at Sweetwater. The big spring at the rear of the home made an ideal campsite, and both armies used it as Lauderdale County changed hands time and again when the tide of war washed to and fro." In a report on exploration of a cave at Bird's Spring (now known as Byrd Spring), on property then owned by S. W. Harris, Esquire, an anonymous author (1888) speculates that a skeleton discovered near the main entrance "...possibly [is] that of a soldier. During the late unpleasantness both armies alternately camped on the Harris property." The author also is aware of a location in Limestone County marked by Camp Spring, reputed to have been an encampment for Civil War soldiers. When the Spanish American War began, the Huntsville Chamber of Commerce secured an encampment for the city named Fort Wheeler. According to Chapman (1932), "On Trinity Sunday, 1898, its [Huntsville's] streets and yards were swarming with soldiers. Regiments were scattered all round the city: the Fifth Ohio and Fifth Cavalry regulars were at Brahan Spring."

Navigation

As early as 1816, Dr. Thomas Fearn and other promoters urged that the natural runoff from Huntsville's Big Spring be utilized to connect the spring with the Tennessee River at Triana (Fisk, 1997). This would allow cotton bales to be barged to the river on flatboats rather than to be hauled overland on wagons (Ryan, 1979). The improved waterway was the goal of the Indian Creek Navigation Company. Fearn's Canal, as it came to be known, opened in 1828 and operated profitably from the collection of tolls until about 1845 (Ryan, 1979), at which time backwash from the Tennessee River in flood clogged the canal's exit with silt (Fisk, 1997), and the canal was abandoned.

Refrigeration

As they dispersed westward, early settlers built their homes beside springs, and used caves and springs for milk houses and cool storage (Unpingco, 1969). Commenting on rural life in DeKalb County in 1900, The DeKalb Legend (1978) observes, "A spring was a very

important part of most of the first farms. Large wooded boxes, constructed with holes in each end for the water to run through and with shelves to hold butter and other food, were placed in the spring to provide refrigeration in hot weather." Writing in "Crazy Quilt Memories," (New Market Volunteer Fire Department, 1989), Kathleen Paul Jones observes, "There was no refrigeration. The milk at our home and in many other homes, was put in a 'cooler'-a long tin bucket of rather small diameter-tied to a rope and let down in the well where it kept very nicely ...Some people were fortunate enough to have a nearby spring, and one family had a cave." Gentry (1962) observes that "Cellars or spring houses served as an effective substitute for modern refrigeration. Built over a spring...these cool shelters cut down on milk spoilage." The author is aware of a spring in Lawrence County (i.e., Milk Spring) apparently named for its use to cut down on milk spoilage.

Religion

Before there were established churches in Athens, Limestone County, evangelist Lorenzo Dow, among others, preached on the banks of the Big Spring (Crenshaw, 1876; Tanner, 1978; Tennessee Valley Historical Society, 1979). In the late 1800's and early 1900's, baptisms were regular events at Big Spring in Huntsville, Madison County (Betts, 1966). Regionally famous for its mineral springs and resort, Limestone County's Wooley Springs also saw its share of baptisms (Dunnavant, 1994). Talucah Cave, Morgan County, was developed by the Talucah Presbyterian Church as Rockcleft Presbyterian Village, a Christian camp, conference ground, and educational center featuring two underground auditoriums with seating capacity for 3000 (Anonymous, 1973a). Religious services, including marriage ceremonies, have been held there (Anonymous, 1973b).

Water Cress Farming

Watercress (Cruciferae-*Nasturtium officinale*) is native to Europe and Asia, common in Great Britain, widely naturalized in the United States and Canada, and introduced into the West Indies and South America. It is a semi-aquatic plant that grows best in limestone soil and clear spring water from a limestone source. It may be found growing wild in springs and near spring-fed streams.

Watercress first was grown commercially in Madison County by Dennis Water Cress, Incorporated just after the turn of the century. The company began operating near Jeff in 1908; it opened in Huntsville in 1915 (Hightower, 1969). During the heyday of local production from the 1940's to the early 1960's, Madison County was the largest winter producer of watercress in the nation. Dennis grew the leafy delicacy in ponds at nine sites for shipment to hotels, restaurants and wholesalers throughout the eastern half of the United States.

Dennis was the largest of three watercress companies operating in Madison County, the other two being Southern Water Cress and the Johnson Company (Smith, 1970). With all three companies in operation, Huntsville was billed as the "Watercress Capital of the World." Dennis stopped operating in 1969, and the other companies also went out of business; watercress was not commercially grown again in Madison County until 1978, when B & W Quality Growers started farming land it bought from Dennis (Faulk, 1997).

In New Market, B & W grows watercress in dozens of shallow beds filled with about a half-inch of water. It is planted in March and April, and harvested from May through late October. The spring that feeds the New Market watercress beds flows at 20 million gallons per day at a constant temperature of 68 degrees (Hightower, 1969). The same spring supplies water to the town of New Market.

Water Power

Based on drawings by Smith (1989), springs once were a significant source of waterpower to operate gristmills in Limestone County. The run from Town Springs (only one of the two springs, Big Spring, remains) in Athens was dammed, the water impounded, and a mill race constructed to channel water to Blackwood Mill (1847), later known as Charles and Holt Mill (1882). Apparently, Milhouse Mill was powered by water from Milhouse Spring: Smith's drawing indicates a race channeling water to the mill site from "Springs Branch Milhouse." Siniard Mill in west Limestone County also utilized a race of spring water combined with flow from Shack Branch to power the mill. Barrett Springs was the source of water to power Smith Mill (1900) at Capshaw. The author also is aware that Indian Spring (now known as Kelley Spring) once was the source of water to power a mill located on Indian Creek in Madison County.

Water Stop

Gravelly Springs, located on Waterloo Road about 15 miles west of Florence, Lauderdale County, served as a refreshment stop for early travelers on the Natchez Trace, which wound around the hill above the spring. Later, stage coaches made it a stopping place (Tennessee Valley Historical Society, 1962). During the era of steam locomotives, Wheeler Spring was used as a water stop. The spring is located on the General Joe Wheeler Plantation in Lawrence County.

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SINKHOLES AND SUBSIDENCE IN ALABAMA

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ABSTRACT

A prerequisite for subsidence is the presence of underground openings in rocks or unconsolidated materials. In karst areas in Alabama, these openings occur as solution cavities in carbonate rocks. Movement of ground water along joints or fractures in soluble rocks results in solution of the rocks and the formation of cavities. There are four basic mechanisms behind subsidence: (1) loss of support, (2) roof collapse, (3) raveling or soil erosion into openings, and (4) stratum thinning. Some significant change in the local environment affecting the soil and rock mass initiates sinkhole collapse and subsidence. This change is called the "triggering mechanism." Water, either surface or ground water, is generally the most important agent effecting environmental changes causing subsidence. These changes can be natural, such as the lowering of the water table during a drought, or can be caused by man (induced). Many sinkholes in Alabama are induced by water well pumpage, construction activity, blasting, or impoundment of water. Sinkhole activity is most frequent in Alabama where unconsolidated sediments overlie carbonate rock and/or large quantities of ground water are being withdrawn from carbonate rocks.

INTRODUCTION

Subsidence can occur subtly and slowly over large areas or locally and dramatically through collapse in a limestone terrain (Plate 1). A prerequisite for subsidence (land-surface sinking) is the presence of underground openings in rocks or unconsolidated sediments. These openings occur as (1) intergranular porosity and (2) larger openings referred to as cavities.

Cavities may form naturally, especially in soluble rocks, or they may be manmade. Movement of ground water along joints or fractures in soluble rocks results in solution of the rocks and the formation of cavities or caves.

Although there are numerous types of subsurface cavities, the most significant in terms of subsidence in Alabama are solution cavities found in carbonate rock terrains, although there are known instances of sinkholes forming over abandoned mines. Areas of Alabama underlain by near-surface carbonate rocks may be seen in Figure 1. Areas underlain by limestone or dolomite that have experienced extensive solution and are characterized by the presence of

subsurface cavities, sinkholes, and underground drainage are called "karst terrains." It is these karst areas which are most susceptible to sinkhole development and subsidence.

Figure 1. Distribution of carbonate rock outcrops in Alabama.

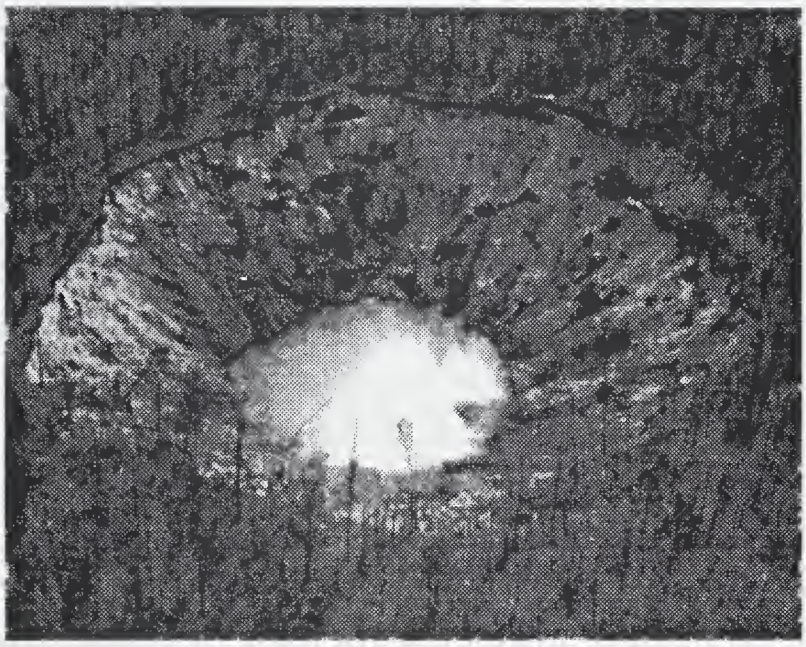

Plate 1. A large sinkhole known as the "December Giant" which formed overnight in rural Shelby County in 1972. The sinkhole measures 300 feet across and 100 feet deep.

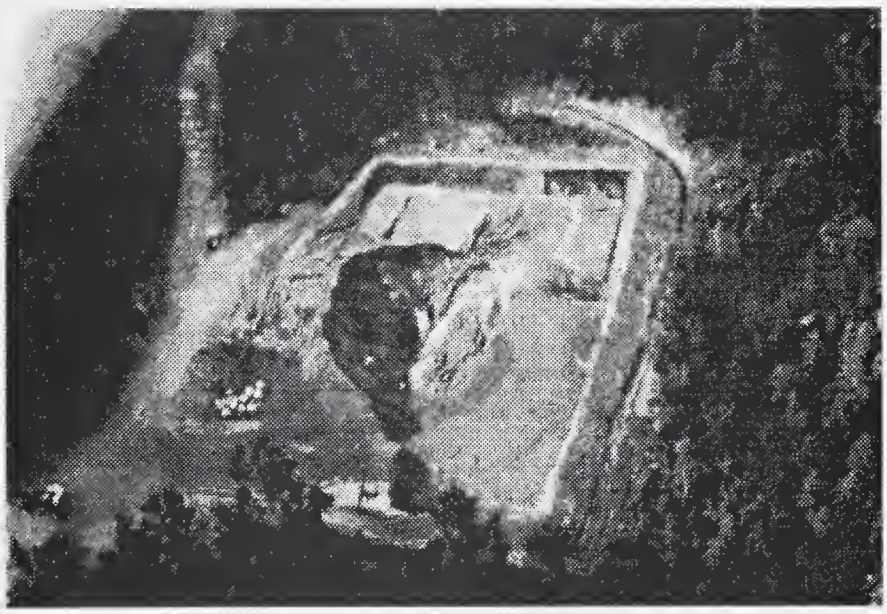

Plate 2. Sinkhole developed in Hale County in 1990 as the result of oil and gas drilling. The sinkhole formed as unconsolidated sands flowed downward with drilling fluid into karstic cavities in Paleozoic carbonate rocks.

MECHANISMS OF SUBSIDENCE

Solution subsidence and ground collapse can take a multitude of different forms and appear to have many different causes or mechanisms of subsidence. There are four basic mechanisms behind all types of subsidence (Newton, 1976):

1. Loss of support,
2. Roof collapse or collapse of unsupported openings,
3. Raveling or soil erosion into openings, and
4. Stratum thinning.

In each specific case of subsidence, more than one mechanism may be involved. The first three mechanisms are operable in most cases of subsidence from sinkholes in Alabama.

Loss of Support

Ground water can provide buoyant support to the roofs of subsurface cavities. Lowering the water table can remove this support and thus result in the collapse of the roof of the subsurface cavity.

Collapse of Unsupported Openings

The collapse of an unsupported opening results from the enlargement of the opening beyond the ability of the materials above to bridge it.

Unconsolidated sediments

Figure 2 illustrates the effect of lateral enlargement of cavities in unconsolidated sediments overlying carbonate bedrock that results in collapse of the unsupported opening. Lateral enlargement of such a cavity (on the left) occurs where the upward enlarging cavity encounters a bed unable to maintain its integrity. This often may occur near the position of a previous water table. The walls of the cavity expand outward until the roof eventually fails.

Consolidated sediments

Unsupported cavities in consolidated rock, such as limestone, collapse in a different manner. A truncated inverted cone of roof rock (dropout) falls into the cavity below; the overhang eventually sloughs off and is redistributed by ground water. The final opening is cone shaped.

Raveling

Raveling (or piping) is the slow erosion of unconsolidated sediments into an underground opening. Downward raveling requires (1) the presence of an underground opening and (2) sufficient seepage of water that erosion of the overburden can continue. There are two types of subsidence due to raveling:

(1) Sudden collapse due to the formation of cavities (domes) in overlying unconsolidated materials, and

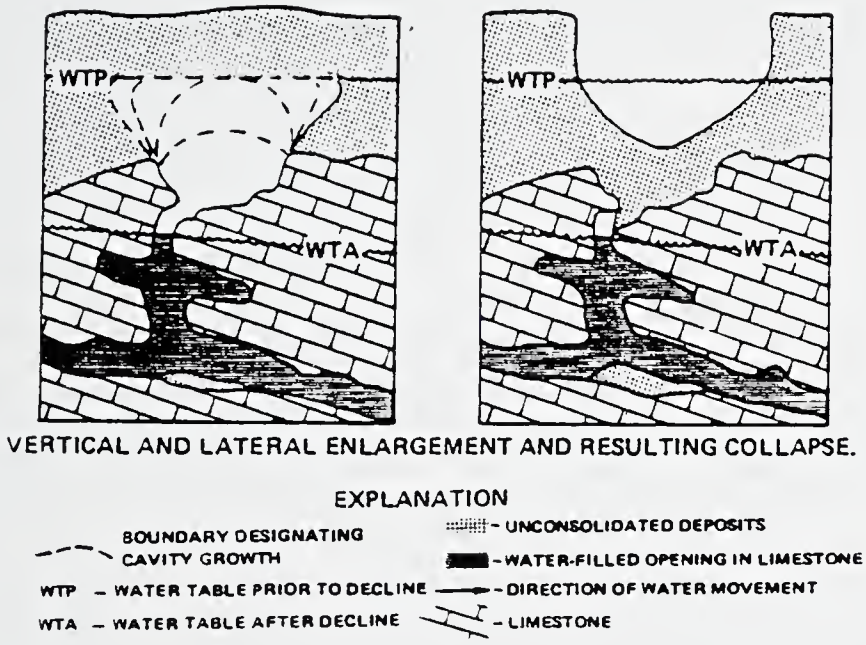

Figure 2. Development of a sinkhole by the vertical and lateral enlargement of a cavity in unconsolidated sediments (from Newton, 1976).

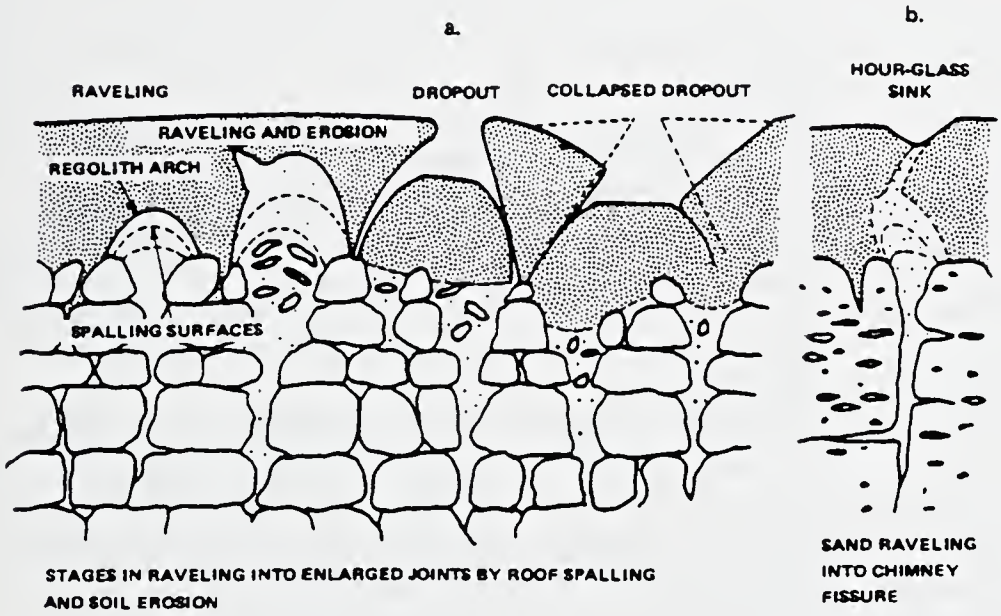

Figure 3. Development of sinkholes by raveling (from Sowers, 1976).

(2) More gradual collapse due to downward flowage of cohesionless sands.

In the first case, downward seepage of soil can form a small dome in the soil, often at the top of bedrock. Continued seepage causes small slabs to peel off the inner surface of the dome so that it enlarges. This material falls to the bottom of the cavity and moves downward by seepage of water into the opening below. Eventually, the dome widens to the point that the soil cannot bridge the opening and the dome collapses.

Raveling and associated dome collapse typically develop over sewers or culverts and solution cavities in limestone. Domes as large as 50 feet have been reported above sewer pipes, and vertical shafts 75 feet deep, called "sinkhole pipes," have been reported from Missouri (Williams and Vineyard, 1976).

The second type of raveling develops in completely cohesionless sands in which capillary tension is small. This type occurs in periods of drought. The sand flows through a small opening much like sand in an hourglass. As a result a cone-shaped zone of subsidence develops at the ground surface. These sinks are called "hourglass sinks." One such sink is illustrated on the right-hand side of Figure 3. Plate 2 shows an hourglass sinkhole that developed in Hale County, Alabama, as the result of oil and gas drilling. Sand in the Cretaceous sediments of the Coastal Plain moved downward through the hole drilled by the well into cavities in the underlying karstic Knox Group. Ground water and drilling fluid facilitated downward movement of the unconsolidated sands into the cavity-riddled Knox carbonate rocks. The resulting sinkhole swallowed the drilling rig within just 2 hours.

TRIGGERING MECHANISMS

Some significant change in the local environment affecting the soil and rock mass initiates sinkhole collapses and subsidences. This change is called the "triggering mechanism." Water, either surface or ground water, is generally the most important agent effecting environmental changes causing subsidence.

Changes in the water table and movement of ground water can initiate hydrologic forces that can cause subsidence. These changes can be natural, such as the lowering of the water table during a drought, or may be caused by man.

Natural sinkhole collapses are rare, and man's activities initiate many sinkhole collapses. Subsidence triggered by man is said to be "induced." An induced sinkhole may develop within minutes or hours after the effects of man's activities alter existing geologic and hydrologic conditions. These induced sinkholes are particularly dangerous because

(1) Some form instantaneously,
(2) They often occur in significant numbers during a short time span, and
(3) They often occur in populated areas.

Triggering mechanisms for subsidence include:
(1) Lowering of ground-water levels (water-level decline),
(2) Changes in ground-water flow,
(3) Increased loading, and
(4) Deterioration.

Water level decline

Lowering ground-water levels is one of the most significant triggering mechanisms for subsidence in a karst terrain. Water-level decline may occur naturally or may be man induced. Factors causing declines in water levels include:

(1) Pumpage of water from wells,
(2) Localized drainage from construction,
(3) Dewatering from mining, and
(4) Periods of prolonged drought.

Lowering the water table has three immediate effects on an area in terms of subsidence.

1. Although the weight of the soil mass is reduced somewhat, this reduction is more than affected by an increase in effective stress within the soil or rock. Lowering the water table 1 foot increases the effective stress within the soil or rock and increases the effective weight by 40 to 50 lb/ft^3 (EPRI, 1985).

2. Lowering the water table also reduces capillary tension and temporary cohesion in cohesionless soils such as sand. For example, in damp fine sands, capillary cohesion can support large, open raveling domes, but if the sand becomes dry, the dome will collapse because cohesion is lost.

Lowering the water table changes the hydrologic regime such that other hydrologic forces or triggering mechanisms are set in motion.

Changes in Ground Water Flow

Movement of water through the ground is probably the most significant triggering mechanism for subsidence. Changes in ground-water movement can initiate hydrologic forces which cause subsidence. These hydrologic forces include:

1. An increase in the velocity of ground-water movement.
2. An increase in the amplitude or frequency of water-table fluctuations.
3. Movement of water from the land surface to openings in underlying bedrock where recharge previously was rejected because the openings were water filled.
4. Induced differences in hydrostatic head between two aquifers or an aquifer and a surface impoundment (Aley and others, 1972; Newton, 1983).

Those changes in ground-water flow that can cause subsidence include:

1. Increased velocity: The creation of a cone of depression in an area of ground-water withdrawal results in an increased hydraulic gradient toward the point of discharge and a corresponding increase in the velocity of ground-water movement. This increase in velocity can flush out the finer grained unconsolidated sediments that have accumulated in interconnected subsurface cavities. These sediments migrate downward to lower cavities. This increase in velocity of ground water plays an important role in the development of cavities in unconsolidated deposits.

2. Water-level Fluctuations: Pumpage of ground water causes fluctuations of the water table that are of greater magnitude and frequency than those occurring under natural conditions. This repeated movement of water through openings causes a repeated addition and subtraction of support to sediments as well as repeated wetting and drying.

3. Induced Recharge: An increase in recharge to an area underlain by cavities can result from:

a. A decline of the water table,
b. Diversion and rerouting of natural drainage,
c. Impoundment of surface waters, and
d. Flooding along streams and rivers.

In the case of a decline in the water table, surface waters are able to infiltrate cavities previously filled with water (Newton and others, 1973; Newton, 1976). Figure 4 illustrates this situation. In Figure 4a the water table is near or above the top of bedrock and openings in the bedrock are filled with water and provide support to overlying residuum. In Figure 4b a well has been installed and pumpage has lowered the water table. Any rainfall moves quickly through the residuum into openings in bedrock, resulting in the eventual collapse of residuum into the openings in bedrock and movement of these unconsolidated sediments to lower water-filled cavities.

Plate 3 shows a sinkhole that resulted from rerouting of natural drainage. Removal of timber in an area in Shelby County, Alabama, allowed increased recharge to the subsurface that caused the formation of 23 sinkholes, some up to 100 feet in diameter (Newton, 1976).

Impoundment of water on unconsolidated deposits overlying bedrock containing cavities, water-filled or not, can also induce recharge from the impoundments. Spray irrigation or waste disposal can also induce recharge to the water table and cause a sinkhole.

4. Induced Heads: Although most sinkhole studies relate sinkhole occurrence to declines in ground-water levels, raising levels may also cause sinkhole collapse. Construction of impoundments, lakes, or waste-disposal lagoons provides a source of recharge to water-table aquifers, thus raising the water table beneath these impoundments. The increased head can cause water to move downward into openings in the bedrock and cause the downward erosion of unconsolidated sediments overlying bedrock or within bedrock openings. This may result in loss of impounded waters.

Solution cavities in the bedrock beneath Logan Martin Dam in Alabama have caused considerable problems over the years. All cavities found during dam construction were grouted with cement. However, head from impounded water has caused repeated occurrence of sinkholes beneath Lake Martin near the dam and resulted in leakage of water beneath the dam and the need for constant maintenance (Jim Redwine, personal communication).

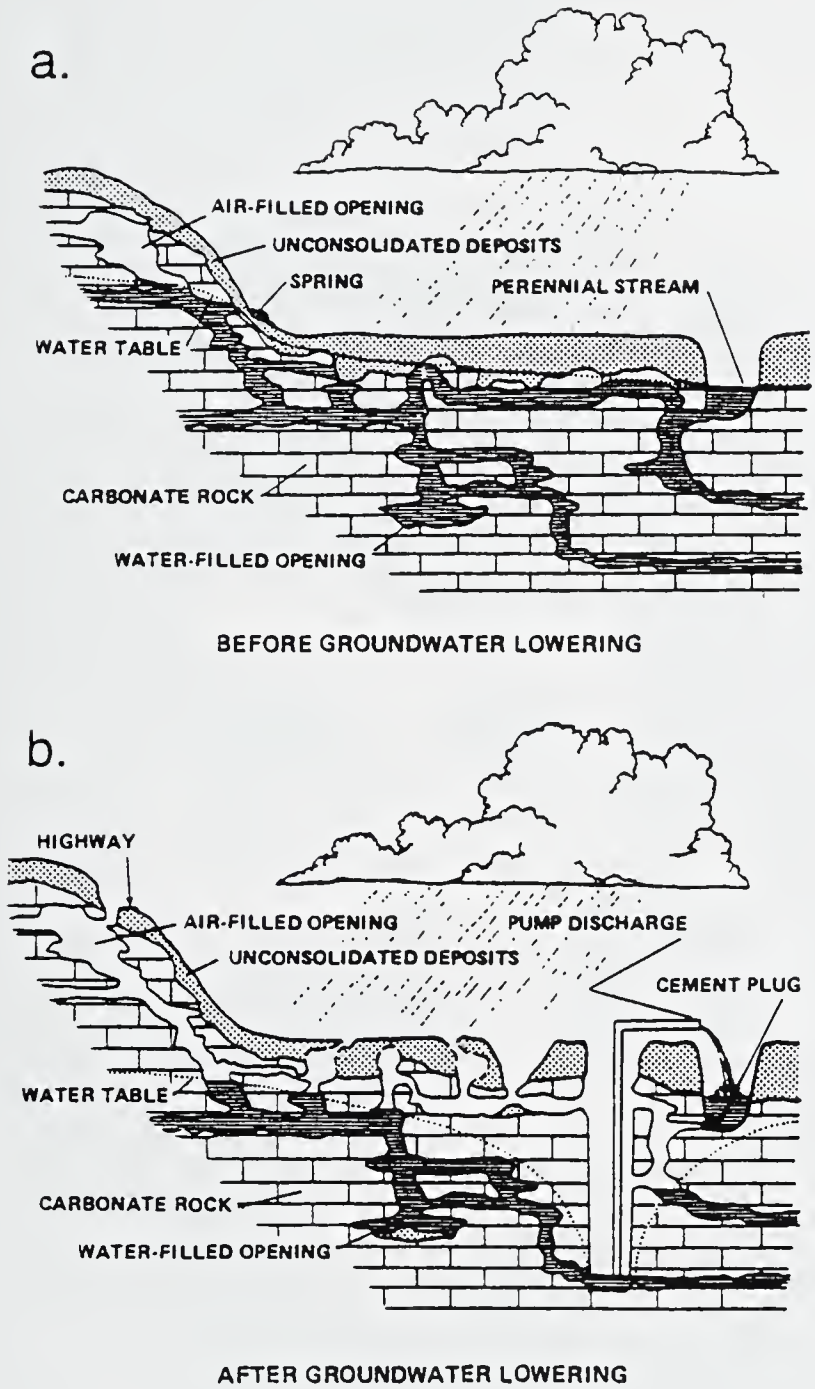

Figure 4. Diagram showing changes in geologic and hydrologic conditions resulting from ground-water withdrawal (from Newton, 1976).

Plate 3. Sinkhole collapse and loss of streamflow in Shelby County, Alabama.

Plate 2 shows an oilrig that subsided in Hale County in 1990 owing to the induced head of the drilling fluid. The rig was drilling at a depth of 755 feet when fluid was lost in the hole. Within minutes, the ground began to disappear beneath the rig. The entire process took less than 2 hours. Another well drilled across the road went to a total depth of 12,000 feet with no problems.

Loading

Increased loading on the surface increases stresses in the soil and rock surrounding an underground cavity and may eventually lead to failure. Dynamic load, such as shock and vibration induced by earthquakes, vibrating machinery, and blasting may induce structural collapse followed by surface settlement or flow in the form of quicksand. A study in Missouri indicated that 4 percent of man-induced collapses in carbonate rocks were caused by blasting (Williams and Vineyard, 1976).

Sinkholes may develop beneath a railroad track as vibration from passing trains triggers the subsidence. Vibrations from car traffic on highways can also cause sinkholes.

Increased loading from filling of impoundments or waste disposal facilities may also initiate subsidence.

Mechanism Interrelationships

In any given area of subsidence development, more than one, or possibly all, of the mechanisms above may cause sinkholes. Often one mechanism will trigger another. For example, along Interstate 59 in Birmingham, traffic vibration and a lowered water table from pumping in an adjacent quarry resulted in sinkholes forming under and along the Interstate. Ongoing subsidence in the area finally necessitated bridging of the sinkholes beneath the highway.

PROBLEM RECOGNITION

Early recognition of sinkhole or subsidence problems allows time for remedial action that can minimize or avoid future, often expensive, damage and safety problems. Although it is not possible to predict exactly when or where sinkholes may occur, a thorough site investigation to identify subsidence-prone areas prior to construction can reduce significantly the chances of future problems.

Often subsidence may be preceded by certain features at the ground surface that are indicative of potential sinkhole collapse. Early recognition of these warning signs can lead to initiation of preventative measures. Some of these warning signs are (Newton, 1976):

1. Circular and linear cracks or fractures in soil, asphalt, and concrete paving and floors.
2. Appearance of depressions in soil or pavement that commonly result in the ponding of water
3. Slumping, sagging, tilting, warping or misalignment of highways, rails, fences, curbing, pipes, poles, signboards, and other vertical or horizontal structures.
4. Downward movement of small-diameter vertical structures such as poles or posts.

5. Fractures in foundations and walls, sometimes accompanied by jammed doors and windows.
6. Small conical holes that appear in the ground in a relatively short period of time.
7. Diversion of drainage into small holes or fractures in the ground without rapid filling.
8. Sudden muddying of water in a well that has been producing clear water.
9. Discolored or dead vegetation in slight depressions.
10. Tilted or toppled trees with depressions at their bases.
11. Sudden draining of a pond or impoundment or inability of a new impoundment to hold water.
12. Sound of running water in the subsurface being emitted through small openings at the landsurface.
13. Continuous muddying of water at high pumpage rates during the development of a well.

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MINUTES
ALABAMA ACADEMY OF SCIENCE
SPRING EXECUTIVE COMMITTEE MEETING
Athens State University
Athens, AL

Wednesday, March 24, 1999

A. **Dr. Moore U. Asouzu, President of the AAS,** called the Spring Meeting of the AAS Executive Committee to order at 6:35 p.m. The minutes of the October 3, 1998, Fall Executive Committee Meeting were discussed. A motion was made by Dr. Barker with appropriate second, and the minutes were approved by the Executive Committee with change.

B. Officer Reports

1. Board of Trustees—Dr. Sam Barker. Six members were present: Dr. Sam Barker, Dr. Joe Thomas, Dr. Mike Moeller, Dr. Ken Marion, Dr. Prakash Sharma and Dr. Walter Wilborn.

2. President—Dr. Moore Asouzu submitted the following written report.

The following is a brief summary of the activities that I have been involved in since the Fall meeting of October 2, 1998, in fulfilling the duties of the office of President:

a. Coordinated details of the annual meeting with Dr. Jandebeur, Chair, Local Arrangement Committee, and Dr. Leven Hazelgrove, Executive Director of the Alabama Academy of Science.

b. Worked with Elected Officers, Committee Chairs, and Section Chairs as needed.

c. Worked with Dr. B.J. Bateman, State Counselor to the Junior Academy, in finalizing selection of the keynote speaker.

d. Sent congratulatory letter and invitation to Dr. Samuel Barker, the recipient of the 1999 Wright A. Gardner Award.

e. Made a congratulatory and invitation phone call to Drs. Gale Christopher and C. A. Sundermann, the recipients of the 1999 Carmichael Award.

f. Worked with Dr. Holland, AAS Secretary, in welcoming more than 50 new members to the Academy.

g. Updated and sent to each officer of the Academy

1) List of AAS Elected Officers

2) List of AAS Committees and Members

3. President-Elect—Larry Boots provided the following written report.

During the past year, the President-Elect has conferred with other members and officers of the Alabama Academy of Science as needed. Currently, chairman of the various committees are being appointed or reappointed, as the case may be. Subsequently, the committees will be reconstituted as needed.

4. Second Vice President—Richard Hudiburg submitted the following written report.

I have had several discussions with the Chair of the Committee on Research, Anne Cusic of UAB, concerning the duties of that committee and website usage for the various competitions.

I have had several discussions with the Secretary of AAS about the development of the membership database.

I would like to reiterate a goal for the Academy to increase electronic connectivity via e-mail and web pages on the Internet.

5. Secretary—Priscilla Holland presented the following written report.

Membership by Section		Lifetime Members	New Members
Section 1	175	37	4/98 to 3/99
Section 2	64		81
Section 3	28		
Section 4	27		
Section 5	59		
Section 6	27		
Section 7	25	Members Paid- Current Year	
Section 8	32	482*	
Section 9	62		
Section 10	33		
Section 11	8		
Section 77	28		
Section 88	2	*Includes honorary, benefactors, and	
Undeclared	16	lifetime members.	
TOTAL	586		

6. Treasurer—Larry Krannich submitted the following written report.

The Treasurer's Report consists of copies of the following:
Information for Calendar Year 1998:
All Account Balances as of 12/31/98;
Activities Relative to 1998 Budget for the period 1/1/98 through 12/31/98;

Treasurer's Summary Report By Quarter for the period 1/1/98 through 12/31/98;
Treasurer's Summary Report By Account for the period 1/1/98 through 12/31/98.
Information for Calendar Year 1999:
All Account Balances as of 3/15/99;
Treasurer's Summary Report By Quarter as of 3/15/99 for the period 1/1/99 through 3/15/99;
Activities Relative to 1999 Budget for the period 1/1/99 through 3/15/99.

All account balances as of 12/31/98 were $70,212.26. Although the Academy budgeted a deficit of $14,565, the year ended with income exceeding expenditures by $7,160.80. This is primarily a result of not receiving any invoices for the printing of the Journal during calendar year 1998. Dues income for 1998 was slightly higher ($460) than in 1997, and meeting revenue was higher than anticipated. Income to the Gorgas category was not budgeted in 1998, but this was also entirely expended in the Gorgas competition. Although support for the Journal appears higher than budgeted, this is somewhat misleading, because $2,700 in support for 1999 was received and deposited in 1998. Thus, actual 1998 Journal support was down by $400. On the expense side, expenses for the annual meeting were less than budgeted, grant expenditures were less, office expenditures were up, and, as mentioned, there were no expenditures for Journal printing. The "Over Expenditures" that appear for Science Olympiad and Science Fair were paid from income received for both activities.

For the first quarter of 1999, our dues income is at the level expected. The income to the Gorgas category consists of $1,500 to the Academy for 1999 Scholarship expenses and $1,616 for the Gorgas competition fee that we receive from the Alabama Power Foundation. The remaining $1,000 was a reimbursement from Birmingham Southern for the Gorgas Scholarship recipient who transferred to the University of North Alabama. These funds were subsequently transferred to UNA. We also received a $1,000 gift from Vulcan Materials. Thus, we appear to be keeping within the budget for 1999 and do not anticipate any budgetary problems.

7. Journal Editor—James Bradley submitted the following written report for the period January through December 1998.

During this period 12 articles were submitted for review and 10 were published in the *Journal of the Alabama Academy of Science* (JAAS). Three of the normally four issues of the *JAAS* were published in 1999. October's issue was not published due to lack of articles submitted for review. I propose that a combined issue – October 1998/January

1999 – be published as soon as 5 or more publishable articles are available.

The Academy should be prepared to lose the circa $4,500 annual subsidy of the *JAAS* by the Auburn University Library as well as the Library's donation of labor and postage for the mailings sometime during 1999. I will need to ask the Academy to pay for secretarial help for the mailings if/when the Library no longer donates this service.

Far more articles need to be submitted to the *JAAS*. I suggest that beginning with the 1999 Annual Meeting, it be the Academy's policy that every symposium speaker be asked to submit a manuscript for publication in the *JAAS*, that the deadline for this submission be the date of the symposium, and that the July issue become the Symposium Issue of the journal.

Many presenters this year apparently failed to receive instructions for abstract submission. I recommend that in the future this form be mailed to every member of the Academy along with the call for titles and general meeting information. I also recommend that the deadline for abstract submission be moved from March 1 to March 15.

8. Counselor to AJAS—B. J. Bateman gave an oral report, stating that the AJAS is expecting an estimated 60 students and teachers to participate this year.

9. Science Fair Coordinator—Mary Thomaskutty – No Report

10. Science Olympiad Coordinator—Jane Nall presented the following written report.

The Alabama Science Olympiad currently consists of five Division C (grades 9-12) Regional Science Olympiad tournaments, four Division B (grades 6-9), and one Division A (grades 1-6). To date the estimated number of registered teams for 1999 include 68 Division C, 72 Division B, and 40 Division A. Following is a list of host institutions, regional coordinators, and Science Olympiad dates for 1999.

Regional Science Olympiads

University of Alabama - 27 February 1999 (Divisions C and B)
Bill Price (205) 348-5510; e-mail: bprice@coe.eng.ua.edu

Auburn University – 6 March 1999
http://members.aol.com/Scarey8355/alSO.html (Divisions C and B)
Steve Stuckwisch, Department of Mathematics, Parker Hall, Rm 228, Auburn University, AL 36849-5310 (334) 844-6575; e-mail: stuckse@mail.auburn.edu; web site: Auburn University Science Olympiad

Jacksonville State University – 6 March 1999 (Division C)
James Rayburn, Biology Department, Jacksonville State University, 700 Pelham Rd., N., Jacksonville, AL 36265-1602 (256) 782-5803; fax: (256) 782-5587; e-mail: jrayburn@succ.jsu.edu

UMS-Wright Prep. Sch. 27 February 1999 (Division B) Terry Lathan (334) 343-6399; e-mail: GOPJunkie@aol.com

Univ. of AL in Huntsville – 20 March 1999 (Divisions C and B)
Vanessa Colebaugh, UAH, Earth System Science Lab, Huntsville, AL 35899; (256) 922-5747; fax: (256) 922-5723; e-mail: vanessa@atmos.uah.edu

University of Mobile – 20 February 1999 (Division C) Jane Nall; e-mail: finsjdn@acan.net

State Science Olympiads

Division C State Science Olympiad
Troy State University – 24 April 1999
Gene Omasta (334) 670-3578

Division B State Science Olympiad
Alabama School of Mathematics and Science – 17 April 1999
Kay Kouadio, 1255 Dauphin St., Mobile, AL 36605 (334) 441-2100; e-mail: kkoua@olympus.asms.state.k12.al.us Thomas Fink, 1255 Dauphin St., Mobile, Al 36605 (334) 441-2100; e-mail: tomjfink@aol.com

The Division C State Tournament will be held at Troy State University on 24 April 1999; Division B at the Alabama School of Math and Science on 17 April 1999; and Division A at Auburn University on 1 May 1999.

State winners for Division C and B may advance to the National Science Olympiad, 13-15 May 1999, hosted by the University of Chicago in conjunction with the Field Museum/Planetarium/Aquarium.

We have experienced a substantial increase in Science Olympiad participation, which may qualify us to send two Division B teams to the national competition.

Anyone interested in learning more about the Science Olympiad program can access the Science Olympiad web page at: http://www.macomb.k12mi.us/science/sciloym1.htm.

The Science Olympiad is a volunteer effort and everyone who gives their time and expertise to make this program a success deserves the support and thanks of the Academy.

11. Counselor to AAAS—Katharine Mayne—No Report

12. Section Officers

I. BIOLOGICAL SCIENCES—Roland Dute submitted the following written report.

The Biology Section of the Alabama Academy of Science has 48 presentations scheduled involving 38 papers and 10 posters. The paper presentations will be held in three sessions to accommodate the Friday morning symposium. Our Friday afternoon session will begin at 2:00 to allow interested faculty and students time to discuss the poster presentations with their authors.

A new vice chair will be chosen at Thursday's business meeting.

II. CHEMISTRY—Tracy P. Hamilton—No Report

III. EARTH SCIENCE—Daniel O'Donnell gave an oral report. He reported that this year all Earth Science presentations are posters. Presentations were made to Geology Departments at universities throughout the state to increase membership, as well as to private industry.

IV. GEOGRAPHY, FORESTRY, CONSERVATION & PLANNING—Chukudi Izeogu submitted the following written report for 1998-99.

a. Membership: Last year (1998) twenty persons were registered in Section IV of the Alabama Academy of Science (AAS). Currently, the membership list has grown to twenty-six. This represents a 30% increase over the 1998 number. As in the past, the membership includes students.

b. Papers: the number of papers for presentation during the spring 1999 meeting stands at twelve in addition to one poster presentation. Thus, the number of papers for this year is at the same level as last year's. As in the past years, the topics reflect the wide range of interests and disciplines in Section IV. Moreover, students have continued to show interest in presenting papers.

c. General: Since last year, regular contact has been maintained with the Executive Director and the Secretary of the Academy. We hope to continue to work hard to gain more visibility on university campuses, to

recruit more members, and increase the number of paper presentations in our section.

V. PHYSICS & MATHEMATICS—John T. Tarvin submitted the following written report.

The Physics participation at the AAS Spring Meeting is slim due to the scheduling of the AAS meeting – it coincides with the 100th Anniversary Meeting of the American Physical Society, held in Atlanta. Consequently, a large percentage of our members are in Atlanta instead of in Athens. This time conflict happens every year – as far as my experience is concerned; I recommend that the scheduling committee investigate the possibility of moving the AAS Spring Meeting forward – or backward – one week to avoid this perennial conflict.

Dr. Menon has requested that I retain the section chair through next year (2000), after which he will assume the chairmanship. I am agreeable to this plan – since the 2000 meeting is being held at Samford University – and will formalize this plan during our sectional Business Meeting on Thursday, March 25, 1999.

There has been a dramatic increase in participation of the Samford Department of Mathematics, Engineering and Computer Science. I hope to see this trend continue, and to have an increased participation of the physics community as well, for the 2000 meeting.

VI. INDUSTRY AND ECONOMICS—T. Morris Jones—No Report

VII. SCIENCE EDUCATION—Helen Benford submitted the following written report.

A letter describing the diversity of membership and interests in the Science Education section was sent to members of Section VII, AAS officers, section chairs and vice-chairs in December. It carried an appeal to promote participation in Section VII. We received ten titles for the Science Education paper session at the Annual Meeting. This is a larger number of presentations than we have had in recent years. To all of you who encouraged submission of papers, Section VII extends its thanks. Please continue to support by attending some of the presentations.

An inquiry was sent to Section VII members in December in an effort to develop a database that would include members' specific areas of interest within Science Education. Response has been poor. A follow-up attempt will use a check-off type of

questionnaire. It would be helpful if the AAS membership lists included e-mail addresses.

Section VII has a membership of 24 as of the March 1, 1999, listing received. We continue to support a multi-section membership policy whereby AAS members could list more than one section (perhaps primary and secondary affiliations). This would allow members to identify their interests both in a science discipline and in the teaching of science. It would give Section VII a larger mailing list through which to solicit papers, draw audiences, and communicate goals. Strengthening Section VII would contribute to the overall strength of the Alabama Academy of Science.

Section VII encourages a science education theme for the Academy-Wide Symposium at the 2000 meeting at Samford University.

VIII. BEHAVIORAL AND SOCIAL SCIENCES—Jerald Burns—No Report

IX. HEALTH SCIENCES—Barbara Wilder—No Report

X. ENGINEERING AND COMPUTER SCIENCE—Alan Sprague—No Report

XI. ANTHROPOLOGY—Curtis E. Hill—No Report

13. Executive Officer—Leven Hazelgrove submitted the following written report.

Since the Fall Executive Meeting, October 3, 1998, at SRI we have been working on the following projects during the last five months:

a. Set up and prepared the Gorgas Scholarship Program for Science Talent Search in cooperation with the Westinghouse (Now Intel) Scholarship Science Service, Inc., D.C. for the Athens State University, March 26, 1999, meeting with the leadership of Dr. Ellen Buckner, Co-chair and Dr. Thomas S. Jandebeur, Local Chair.

b. Prepared for bulk mail 700 "Call for Paper Titles" for Athens State University meeting for March 24-27, 1999, edited by Dr. William J. Barrett.

c. Sent development letters to 3 industrial companies and foundations with positive reply from one, Vulcan Chemical of Vulcan Materials.

d. Sent handwritten notes and brochures to 25 outstanding Scientists and Engineers, Mathematicians and potential members whose "write-up" appeared in local publications.

e. Site visit with Dr. Tom Jandebeur, Professor and Head, Biology Administration and his local committee for the AAS dates: March 24-27, 1999, at Athens, AL with Drs. Buckner, Asouzu, Bush, and Bateman.

f. Prepared 12 abstract forms for the Athens State University meeting, March 24-27, 1999 for eleven section chairs and 650 printed programs.

g. Your director studied flora, fauna and pollution in the USA, February 10-13, 1999, with the Alabama Fisheries Association, Gulf State Park, with Drs. Marion and Angus.

h. Set up the 76th Annual Meeting with the able direction of Dr. Tom Jandebeur, Professor of Biology, Athens State University, Athens, AL, March 24-27, 1999.

i. Prepared with Dr. Larry Davenport (205) 870-2574, fax (205) 870-2479, the 77th Annual Meeting to be at Samford University, March 29 – April 2000.

j. Trying to get the AL Legislature to grant AAS exemption from sales tax! Anyone know anyone?

C. **Committee Reports**

1. Local Arrangements—Tom Jandebeur presented an oral report. He reported that 79 individuals have pre-registered for the Annual meeting.

2. Finance—Sam Barker submitted the following written report.

Last fall, nearly at the end of three-quarters of the 1998 budgetary year, the Executive committee apparently faced an operating deficit of over $5,000. Our anticipated income of $4,500 from the 1998 annual meeting had not been received, and added to that, dues receipts had lagged considerably. In true dramatic fashion, our Treasurer announced that he had received the meeting income check just the previous day. To add to this good news, although we didn't know it until the fourth quarter actually was completed, dues receipts for that period were excellent.

These, and other items detailed in the first paragraph of the Treasurer's Report for 1998 have resulted in a paper surplus of income expenditures, not of a few hundred dollars, but of $7,161. That is all fine, but it did cost to print the Journal; $14,000 was in the

budget, based on the previous years' costs. The books are closed on the 1998 year, so the surplus stands. If the missing costs come in during the 1999 Budget Year, the deficit may rise to haunt us.

As usual, with our Spring Meeting coming in March, less than one quarter into this budgetary year, it is very difficult for me realistically to assess the Academy's chances of going through another year in the black. As 1999 progresses, some items of income may appear to be more favorable than we anticipated when drawing up the budget late in 1998. Unless expenditures rise extraordinarily, perhaps we should propose a budget for the much-maligned year 2000 in balance at the $30,000 level. With reserves of about $70,000, it would be more confidence inspiring to face this new Millennium without a proposed deficit.

3. Membership—Adriel Johnson—No Report

4. Research—Anne M. Cusic provided the following written report.

The Chairperson of the Committee on Research received only 20 requests for application materials related to the Student Research Award Competitions, Student Research Grants, and Student Travel Awards. The low number of requests was most likely due to many students going directly to the web page for application materials. Several students contacted me for the web address after receiving the Academy Newsletter which contained an error in the address. I recommend that use of the website for next year. (http://www2.una.edu/psychology/hudiburg.htm.)

Seventeen students applied for the Travel Grants. Sixteen were awarded with one student withdrawing her application. Nineteen students submitted completed applications for entering the Student Research Awards Competition. One student withdrew from the competition; thus 18 students are competing for the awards in 5 Sections of the Academy. All of the students are entered in the paper competitions. There were 7 applications for Student Research Grants.

The Vice-Chairpersons will need to provide the names of the competition winners for the Student Research Awards to me before the annual meeting banquet scheduled for Friday, March 26.

Two items concerning the Research Committee need to be addressed by the Committee. These points might be worthy of discussion by the Executive Committee. The first deals with a request made by a Section Chair to the Research Committee this year. The inquiry was: If no student enters the poster competition of a section, can the section give two paper awards? Currently the rules state a $50 award for the best paper and $50 for the best poster. Since there is no provision in the rules of the Research Committee to do otherwise, the

two committee members who have been on the committee the longest decided that, at least this year, only one paper award could be presented for each section. Does the Executive Committee feel that a provision should be made to modify the current award rules?

The second point concerns students applying for awards or grants who are not, at the time of application, members of the Academy. This year I accepted the applications but informed the students that the eligibility requirements state that to receive the monetary awards the applicant must be a member of the Academy. I plan to discuss with the Research Committee the possibility of adding a requirement that the student must be a member of the Academy by the deadline for receiving applications for the research awards and grants. Input from the Executive committee would be beneficial.

5. Long Range Planning—Ken Marion submitted the following written report.

The committee considered a number of items generated from an informal discussion at a dinner for the Executive Committee hosted by Birmingham Southern College previous to the Fall AAS Executive committee meeting. The Long-Range Planning Committee's recommendations or suggestions center around budgetary issues.

a. Raising of Annual Dues and/or Registration Fees: It may well be time for a modest increase in annual membership dues. It has been several years since the last increase. Most other societies have higher annual dues and an AAS membership does include a journal. It was felt that a modest increase would not deter current members from renewal. Further, it was felt that meeting registration fees for senior Academy members should always be kept high enough to ensure that the Academy can receive at least a small amount of monies as income from the annual meeting. A significant profit from the annual meeting should not be the aim; instead, the aim would be to mandate that there would be no monetary loss.

b. Journal Issues: The Committee recommends that an Ad Hoc Committee (perhaps composed of Journal Editor, Associate Editors, and Editorial Board) be formed to 1) monitor The Journal expenses and make recommendations to address expense issues, if warranted and 2) investigate the possibility of placing The Journal (at least partially) on the Internet. It may reduce costs, but problems of indexing, getting on databases, and access may outweigh the benefits. It has probably come time to consider exploring this issue.

c. 2-Year Presidency: This issue was discussed. There is no recommendation at this time. One benefit would be having the

experience gained in a first-year present again. This may have distinct benefits for carrying through initiated programs. Perhaps ideas should be explored which would make better use of either the past president or president-elect.

d. Change of Meeting: The idea of shortening the meeting to Friday afternoon and just having a luncheon meeting was a thought that was considered.

6. Auditing-Sr. Academy—Denny Bearce—No Report

7. Auditing-Jr. Academy—Danice Costes provided the following

written report.

This is a report of the Alabama Junior Academy of Science Auditing Committee for the July 1997-July 1998 financial year. We have examined the books provided by the Alabama Junior Academy of Science Treasurer, Dr. B.J. Bateman. We are satisfied ourselves that the receipts and expenditures, as presented to us, are correct and that all expenditures are legitimate expenses.

The net worth as of June 30, 1998, is $18,567.03.

8. Editorial Board and Associate Journal Editors—Douglas Watson/Larry Wit/Bill Osterhoff. The following written report was provided.

I am pleased to announce that the following institutions have supported the Journal of the Alabama Academy of Science as benefactors:

Samford University
University of South Alabama
Auburn University at Montgomery
Tuskegee University
University of Alabama
University of North Alabama
Jacksonville State University
Birmingham Southern
University of Alabama/Birmingham
The University of Montevallo
University of West Alabama
Troy State University

9. Place and Date of Meeting—Tom Bilbo submitted the following report.

Plans for future meetings:

Annual Meeting	Location	Local Arrangements Chairperson
2000 March 29—April 1	Samford University Birmingham, AL 35229	Dr. Larry Davenport
2001	Auburn University Auburn , AL 36849	
2002	University of West Alabama -Station 7 Livingston, AL 35470	
2003	Jacksonville State University 700 Pelham Road North Jacksonville, AL 36265	Dr. Frank Romano

10. Newsletter—Lynn Stover/Tom Jandebeur—The following oral Report was given.

There is a need for articles for the spring newsletter. Mail information to Lynn Stover.

11. Public Relations—Myra Smith—No Report

12. Archives—Troy Best provided the following written report.

Several items have been submitted for deposition in the archives, but we still need to obtain photographs (especially of members of the Executive Committee), committee reports, minutes of the AAS Executive Committee meetings, etc.

If you have items that you believe may be worthy of inclusion in the AAES Archives, please send them to me or to Dr. Dwayne Cox, the archivist in charge of AAS materials at the Auburn University Ralph B. Draughon Library.

Again, I encourage all officers and members of the AAS to donate significant documents, photographs, etc. to the archives.

13. Science and Public Policy—John Frandsen provided the following written report.

Members of the Committee: S. Brande (UAB), J. Frandsen—Chair (AU), Dail Mullins (UAB), R. Rowsey (AU), and S. Sign (ASU).

Status of Distribution of NAS Booklets *Teaching About Evolution and The Nature of Science*. About 120 of these booklets were distributed to Alabama biology teachers at the NSTA Regional Convention, in Birmingham last November. We hope to complete mailing of these booklets to the more than 700 remaining teachers within the next few

weeks. The committee expresses its sincere thanks to Dr. Eugenie Scott, of NSCE, Dr. Robert S. Davis, Alabama State Department of Education, and Ms. Cissy Bennett, State Coordinator for the National Association of Biology Teachers, for their vital assistance in this project.

Chair Needed for Academy's Environmental Panel—This panel was established to monitor environmental issues in the state and bring those possibly meriting the Academy's concern to the attention of the Chair of the Science & Public Policy Committee. Though it has been in existence for several years, the panel has not accomplished its mission because of the lack of a Chair willing and able to devote sufficient time to the panel's business. A qualified environmental scientist is urgently needed for this position.

The need for an active environmental panel will increase over the next few years. A story in the *New York Times* recently reported that the Administration intends to work with the Congress to transfer much of the responsibility for environmental quality back to the states.

The Academy and Science and Public Policy in Alabama Inasmuch as several members of this committee, including the Chair, have expressed a desire to be replaced, it is perhaps an appropriate time for reflection.

The area with which this committee is charged is vast. It obviously includes science education in the public schools, environmental and industrial policies, and all of the other matters where governmental policies affect science—and where scientific knowledge and expert opinion should affect these policies. How can a committee of six deal with all of this effectively? In the past, we've done what we have by limiting our concerns primarily to education. One way to increase our involvement beyond this would be to have a larger committee, or to have a number of subcommittees, each charged with responsibility for a discrete area. Hard as it's been to get people to serve on the little committee we have, how can we recruit sufficient qualified volunteers to expand our membership or create subcommittees?
The world has changed much since the Academy was founded. As its environment changes, its mission and operations must be continually reviewed and modified. The scientific community as such increasingly needs an influential voice in the halls of state government. The only collective voice of that community in this state is the Academy. Those who make public policy must not depend for expert background on experts paid by special interests. The Alabama Academy of Science is a unique deposit of scientific information and expertise. State government would benefit greatly by drawing from that deposit. As of this time, the only governmental agency to have sought out the Academy is the Department of Education.

If we wish the Academy to have greater influence in shaping public policy in the state, here are two changes that might be considered:

a. Moving the Academy office to Montgomery, because it is the seat of state government. In association with this, the Executive Director would become a part-time lobbyist, a familiar face in the statehouse during legislative sessions, an acquaintance of every legislator important in shaping public policies relevant to science.

b. Providing the Science and Public Policy Committee with sufficient funds to reimburse the costs of its members for participation in committee affairs. These funds should pay for attendance of members at pertinent hearings of the legislature and state boards, as well as a limited number of workshops, conferences, etc., relevant to the committee's interests. In this last year alone, there have been several important conferences and workshops on environmental issues that should have been attended by committee members, but the costs precluded their attendance.

14. Gardner Award—Ellen McLaughlin provided the following written report.

a. Requests for nominees for the Gardner Award were made through the Alabama Academy of Science Newsletter.

b. In addition, letters of request for nominations were sent to 70 or 80 members representing most schools, colleges and universities in Alabama.

c. The Wright A. Gardner Award Committee selected the following nominee for this award from three excellent choices:

Samuel B. Barker, Ph.D.—Distinguished Professor Emeritus, University of Alabama at Birmingham, Professor in Departments of Pharmacology, Physiology and Biophysics, first Dean of the Graduate School and ardent supporter of the Alabama Academy of Science.

d. The other very fine nominees will be held over for consideration next year.

15. Carmichael Award—William J. Boardman submitted the following written report.

The committee selected the outstanding paper published in Volume 69 (1998) of the *Journal of the Alabama Academy of Science* to receive the Emmett B. Carmichael Award. Since the fall issue (October, 1998,

No. 4) was not available at balloting time, papers in that issue will be judged with those in Volume 70 (1999) for the award next year.

The announcement of the recipient(s) of the award and the title of the paper will be made at the presentation at the banquet of the 1999 meeting.

16. Resolutions—Gerald Regan submitted the following written report of resolutions to be presented at the Annual Banquet.

Be it resolved by the executive committee that the following script be employed at the appropriate time:

Each year the Academy recognizes individuals who have served it in an exceptional manner.

a. First and foremost we recognize Jerry F. Bartlett, president of Athens State University for graciously hosting the 76th annual meeting of the Alabama Academy of Science.

b. The Academy would also like to recognize Thomas S. Jandebeur, chairperson of the local arrangements committee for the many weeks of planning and hard work that enabled us to have this very successful annual meeting.

c. Lastly the Academy thanks Moore U. Asouzu for his able leadership of the Academy as its president during the past year.

The Academy would like to take a moment to recognize the following members of the Academy whom it has lost through death over the past year:

Herman Davis Alexander	William Ray Laseter, Sr.
Charles Edwin Butterworth, Jr.	Larry Ludwick
Charles E. Feazel	Charles S. Sherer
Edward J. Griffith	Wynelle Doggett Thompson
George Vernon Irons, Sr.	Bertie Mae Warren

The Academy notes, finally, the loss through death of the Honorable George C. Wallace, who although he was not a member of the Academy, fostered the growth of science in the state.

17. Nominating Committee—Richard Hudiburg presented the following written report.

The nominating committee has commitments/interest from the following individuals for election to the indicated offices:

President	Larry Boots (2000)

President-Elect	Richard Hudiburg (2000)
Second Vice-President	Roland Dute (2000)
Treasurer	Larry Krannich (1999-2002)
Editor of AAS Journal	James Bradley (1999-2002)
Trustees	B. J. Bateman (1999-2002) Wayne Finley (1999-2002) Ken Marion (1999-2002) Walter Wilborn (1999-2002) Prakash Sharma (1999-2002)

18. Mason Scholarship—Michael Moeller submitted the following written report.

We had six completed applications for the William H. Mason Fellowship this year. After considering all the application material, the committee has selected Ruth Borden for the $1000 fellowship and she has been notified of this award. Ms. Borden received a B.S. with a math major from Birmingham-Southern College and a M.S. degree with a major in mathematics from the University of Alabama at Birmingham. She is returning to the University of Alabama at Birmingham for the fifth year program in education leading to a teaching certificate in mathematics, from the University of West Alabama for the $1000 fellowship.

The committee chairperson is very appreciative of the work of Dr. Malcolm Braid and Dr. Sandy Caudle in reading and rating the applications.

19. Gorgas Scholarship Program—Ellen Buckner presented the following written report.

We are pleased to report that there were 25 Alabama entrants in the Intel National Science Talent Search, almost 50% more than 1998. There were also four national Semifinalists from Alabama, all of whom are among the Gorgas finalists. Twelve finalists were selected based on course work and reviews of their scientific papers. All twelve are competing in the final judging on Friday. You are invited to view the exhibits Friday afternoon as listed in the Gorgas Program.

We are also pleased to report that 14 Alabama Colleges and Universities responded to our letter asking for commitment regarding additional scholarships offered to Gorgas finalists or winners. Several were first time offers. There continues to be strong support statewide for the Gorgas competition among institutions of higher education.

The teachers and students are to be commended for their outstanding work.

D. **Old Business** – None

E. **New Business**

Dr. Larry Witt offered a suggestion that the membership join with a university consortium to promote undergraduate research, using the Academy's Annual Meeting as a place for students to present their research findings. The membership took the suggestion for future consideration.

F. **Adjournment**

The meeting adjourned at 10 p.m.

Respectfully submitted,

Priscilla Holland, Secretary
Alabama Academy of Science

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INSTRUCTIONS TO AUTHORS

Editorial Policy: Publication of the *Journal of the Alabama Academy of Science* is restricted to members. Membership application forms can be obtained from Dr. A. Priscilla Holland, Office of Research, UNA Box 5121, University of North Alabama, Florence, AL 35632-0001. Subject matter should address original research in one of the discipline sections of the Academy: Biological Sciences; Chemistry; Geology: Forestry, Geography, Conservation, and Planning; Physics and Mathematics; Industry and Economics, Science Education; Social Sciences; Health Sciences; Engineering and Computer Science; and Anthropology. Timely review articles of exceptional quality and general readership interest will also be considered. Invited articles dealing with Science Activities in Alabama are occasionally published. Book reviews of Alabama authors are also solicited. Submission of an article for publication in the implies that it has not been published previously and that it not currently being considered for publication elsewhere. Each manuscript will receive at least two simultaneous peer reviews.

Submission: Submit an original and two copies to the editor. Papers which are unreasonably long and verbose, such as uncut theses, will be returned. The title page should contain the author's name, affiliation, and address, including zip code. The editor may request that manuscripts be submitted on a diskette upon their revision or acceptance.

Manuscripts: Consult recent issues of the *Journal* for format. Double-space manuscripts throughout, allowing 1-inch margins. Number all pages. An abstract not exceeding 200 words will be published if the author so desires. Use heading and subdivisions where necessary for clarity. Common headings are: **Introduction** (including literature review), **Procedures** (or **Materials and Methods**), **Results, Discussion,** and **Literature Cited.** Other formats may be more appropriate for certain subject matter areas. Headings should be in all caps and centered on the typed page; sub-headings should be italicized (underlined) and placed at the margin. Avoid excessive use of footnotes. No not use the number 1 for footnotes; begin with 2. Skip additional footnote numbers if one or more authors must have their present address footnoted.

Illustrations: Submit original inked drawings (graphs and diagrams) or clear black and white glossy photographs. Width must not exceed 15 cm and height must not exceed 20 cm. Illustrations not conforming to these dimensions will be returned to the author. Use lettering that will still be legible after a 30% reduction. Designate all illustrations as figures, number consecutively, and cite all figures in the text. Type figure captions on a separate sheet of paper. Send two extra sets of illustrations; xeroxed photographs are satisfactory for review purposes.

Tables: Place each table on a separate sheet. Place a table title directly above each table. Number tables consecutively. Use symbols or letters, not numerals, for table footnotes. Cite all tables in the text.

Literature Cited: Only references cited in the text should be listed under **Literature Cited.** Do not group references according to source (books, periodicals, newspapers, etc.). List in alphabetical order of senior author names. Cite references in the text parenthetically by author-date.