

BULLETIN

OF THE

NATIONAL SPELEOLOGICAL SOCIETY

VOLUME 33

NUMBER 2

Contents

GROUND-WATER CHEMISTRY IN THE SIERRA DE EL ABRA

HISTORY OF (KENNY) SIMMONS CAVE

CAVES AS ARCHIPELAGOES

A CAVE SNAIL IN NORTHWESTERN FLORIDA

APRIL 1971

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CONTENTS

PRELIMINARY RESULTS ON THE GROUND-WATER GEOCHEMISTRY OF THE SIERRA DE EL ABRA REGION, NORTH CENTRAL MEXICO	Russell S. Harmon	73
A HISTORY OF (KENNY) SIMMONS CAVE	Peter M. Hauer	87
CAVES AS ARCHIPELAGOES	David C. Culver	97
NOTES ON THE OCCURRENCE OF THE SNAIL, <i>Euglandina rosea</i> , IN CAVES OF NORTHWESTERN FLORIDA	Richard Franz, David S. Lee, Peter B. Stifel	101
RECENT CAVE BIOLOGY PAPERS APPEARING IN OTHER JOURNALS	David C. Culver	104

The BULLETIN is published quarterly. The subscription rate in effect January 1, 1971: \$6.00 per year.

Office Address:

NATIONAL SPELEOLOGICAL SOCIETY
2318 N. KENMORE ST.
ARLINGTON, VIRGINIA 22201

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The BULLETIN is published quarterly in January, April, July, and October. Material to be included in a given number must be submitted at least 90 days prior to the first of the month of publication.

Preliminary Results on the Ground-Water Geochemistry of the Sierra de El Abra Region, North-Central Mexico

Russell S. Harmon *

ABSTRACT

Chemical analyses of 35 water samples collected from July 1969 to May 1970 were performed using standard wet-chemical and atomic absorption techniques for calcium, magnesium, sulfate, sodium, potassium, nitrate, and bicarbonate concentrations. In addition, most samples were analysed in the field at the time of collection for pH, calcium, bicarbonate, and dissolved oxygen concentrations.

Using the interpretive techniques of Garrels and Christ (1965) and Langmuir (1968), we found that most waters were saturated with respect to calcite and undersaturated with respect to dolomite. The extremely high $\text{Ca}^{2+}/\text{Mg}^{2+}$ ratios of the cave waters indicate derivation from a high purity limestone (the El Abra Limestone), while the low ratios of the surface waters indicate a source outside the El Abra region. Carbon dioxide pressures, and thus calcium concentrations at a given saturation level, were found to be at least an order of magnitude larger than those commonly reported for karst waters of the eastern and southern United States. Calculations based on data from this study indicate a rate of carbonate solution of about $25 \text{ m}^3/\text{year}$ for an area of approximately 1,500 square kilometers.

The large volume of these Mexican caves compared to those of the more northern latitudes appears to be directly proportional to the greater amounts of carbon dioxide and water available for the solutional process.

INTRODUCTION

Although the Sierra de El Abra region of the Sierra Madre Oriental is the most accessible karst area of Mexico, the exploration and mapping of the caves of the region are still at a preliminary stage. Thus, while a representative suite of caves, springs, and rivers was selected for this study, these sites cluster in five distinct areas: the El Pujal and Los Sabinos areas in the south, the El Abra Pass and Santa Clara areas in the north, and the Sierra de Guatemala area north of

the region (Figure 1). Thirty-five individual samples were collected from 20 different sites (Table 1) during the period from July 1969 to May 1970.

The climate of this region is temperate. Temperatures range roughly from zero to forty degrees centigrade, the average being twenty-four degrees. During the rainy season (mid-July to late September) about a meter of water falls in the valleys, with slightly more falling at higher elevations.

Soils are thin except in the valleys which support a dense tropical flora. This vegetation changes to thorny bush and then to dense forest as elevation increases.

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Figure 1. Sketch map of the Sierra de El Abra Region, North-Central Mexico (see Table 1 for a description of sampling areas).

TABLE 1. Index to Sample Locations

Sample	Location	Description
1	Sotano de Yerbaniz	water table lake - level 3
2	Sotano de Matepalma	standing pool
3	Sotano de Matepalma	water table lake
4	Sotano de Yerbaniz	water table lake - level 3
5	Sotano de Yerbaniz	standing pool - level 3
6	Sotano de Yerbaniz	standing pool - level 3
7	Sotano de Yerbaniz	standing pool - level 1
8	Cueva de Los Sabinos	cave stream
9	Cueva de Los Sabinos	cave stream
10	Sotano de Montcillos	stream
11	Cueva de Curva	water table lake
12	Cueva Grande de Arroyo Seco	water table lake
13	Gruta de Arroyo Seco	water table lake
14	Gruta de Arroyo Seco	pool at entrance to cave
15	Nacimiento de Rio Santa Clara	spring
16	Gruta de Arroyo Seco	pool at entrance to cave
17	Gruta de Arroyo Seco	water table lake
18	Cueva Grande de Arroyo Seco	water table lake
19	Rio Santa Clara	river
20	Cueva de Chica	pool 1
21	Cueva de Chica	water table lake, pool 4
22	Cueva de Chica	water table lake
23	Cueva de la Florida	lake
24	Cueva de la Florida	guano pool
25	Cueva de El Pachon	cave stream
26	Nacimiento de Rio Mante	spring
27	Cueva de El Pachon	cave stream
28	Pozo de El Pachon	well
29	Pozo de El Abra	well
30	Nacimiento de Rio Mante	spring
31	Pozo de Quintero	well
32	Sotano de Caballos Moro	surface lake at water table
33	Nacimiento de Rio Frio	spring
34	Nacimiento de Rio Frio	spring
35	Rio Tampaon	river

The Sierra de El Abra is a north-south trending limestone mountain range that extends from northwest of Ciudad Mante to southeast of Ciudad Valles. The range is a slightly folded, severely fractured Cretaceous paleo-reef system. Cavern development has occurred throughout the range but is more prevalent along the gently dipping western limb. The region is almost devoid of surface drainage since most of the runoff goes directly underground through extensive cavern and fracture networks. Ground waters surface at seven major springs, all at the break in slope of the eastern face of the range; each of the three largest springs has an annual flow of about 100 million m³/year. Russell, in an unpublished study of the water budget of the area, has indicated that during the July to September rainy season more than 475 million m³ of rainfall enters the subsurface as recharge.

SAMPLING AND ANALYTICAL PROCEDURES

All samples were collected from rivers, flowing springs, standing cave pools, cave streams, or lakes at the water table at a depth of at least 15 cm. The sample bottles were capped beneath the surface of the water to exclude air bubbles and then iced as soon as possible (15 minutes to 3 hours later). Laboratory analyses of alkalinity and pH were performed immediately after opening, always less than a month after collection.

Atomic absorption techniques were used to determine calcium, magnesium, sodium, and potassium concentrations. Sulfate concentrations were obtained by turbidimetric analysis. Alkalinity was determined by potentiometric titration with a standard acid. Nitrate concentrations were determined colorimetrically by the phenol-disulfonic acid method. The pH was measured using a Corning pH meter with buffers standardized to pH=6, 7, and 8 for comparison with field values.

Field pH measurements, taken with a Beckman or Hach portable meter and standardized to buffers at pH=6 and 8, were reproducible to 0.05 pH units. Laboratory

values of pH were not used in the subsequent calculations except for those cases where a field analysis was not possible. Alkalinities and calcium concentrations were both determined by standard titration techniques (acid and EDTA). A small syringe, accurate to 0.1 ml, was used to titrate 15 ml of sample. The alkalinity values were reproducible to ± 10 ppm, those of calcium to ± 5 ppm. Water temperatures were measured with a standard mercury thermometer. Analytical data is listed in Table 2.

WATER CHEMISTRY

The most important chemical variables in a study of karst waters are the carbon dioxide pressure, pH, Ca²⁺/Mg²⁺ ratio, and degree of saturation of those two ions. Lesser parameters are the specific conductance, dissolved oxygen content, and the pollution level.

Ca²⁺/Mg²⁺ ratio

A number of researchers, among them Holland and others (1964) and Jacobson and Langmuir (1970), have shown that the Ca²⁺/Mg²⁺ ratio of a ground water in a dolomitic terrain should approach unity, while the same ratio may be greater than 10 for ground waters in a pure limestone terrain. The Ca²⁺/Mg²⁺ ratios for the waters sampled ranged from 8.2 to 35.4 for the cave waters and from 2.8 to 15.8 for the surface and spring waters.

As expected, cave waters have Ca²⁺/Mg²⁺ ratios indicative of a pure limestone source, but the low ratios of the surface and spring waters are surprising until one considers two facts: the rivers have their sources outside the region in different rock types, and both the rivers and the springs are affected by agricultural and livestock pollution. These factors must be considered in any interpretation of this data.

Carbon dioxide pressure

A major factor in the capacity of a water to dissolve carbonate rock is its carbon dioxide concentration, as this determines the amount of carbonic acid in solution. Rainwater in equilibrium with the atmosphere

TABLE 2. Analytical Data

Sample Number	Date Collected	Temp. (°C)	pH (I=lab) (F=field)	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	HCO ₃ ⁻	SO ₄ ²⁻	NO ₃ ⁻	log PCO ₂	log SC (calcite)
				(concentration, ppm)								
1	7/69	...	...	76	4	..	..	...	..	..	...	...
2	7/69	...	...	107	7	..	..	...	..	..	...	...
3	7/69	...	...	99	7	..	..	...	..	..	...	...
4	1/70	24.0	6.75(1)	102	7	..	..	462	50	1	-1.10	-0.13
5	1/70	23.5	6.76(1)	111	6	..	..	439	13	0.5	-1.13	-0.10
6	1/70	23.5	6.87(1)	116	6	..	..	421	10	1	-1.26	+0.01
7	1/70	24.5	7.20(1)	76	5	..	..	243	5	7	-1.82	-0.04
8	1/70	24.0	6.85(F)	116	4	..	..	370	7	30	-1.30	-0.06
9	5/70	24.0	7.55(F)	89	1	4	1	262	..	..	-2.14	+0.40
10	5/70	24.5	7.21(F)	115	4	8	2	376	..	..	-1.65	+0.31
11	5/70	24.0	7.56(F)	116	3	14	2	352	..	..	-2.03	+0.63
12	1/70	24.0	6.87(F)	128	5	..	..	416	17	4	-0.93	-0.25
13	1/70	24.0	6.60(F)	102	4	..	..	486	12	2	-1.27	+0.05
14	1/70	23.0	6.65(F)	131	4	..	..	416	19	2	-1.06	-0.18
15	1/70	23.5	6.88(F)	133	5	..	..	439	8	2	-1.26	+0.09
16	5/70	24.0	6.80(F)	102	..	..	..	306	..	..	...	...
17	5/70	24.0	6.39(F)	110	1	10	2	335	..	..	-0.89	-0.58
18	5/70	23.5	6.91(F)	104	2	16	1	315	..	..	-1.42	-0.11

TABLE 2. Analytical Data—Continued

Sample Number	Date Collected	Temp. (°C)	pH (I=lab) (F=field)	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	HCO ₃ ⁻	SO ₄ ²⁻	NO ₃ ⁻	log PCO ₂	log SC (calcite)
				(concentration, ppm)								
19	5/70	24.0	6.92(F)	89	2	16	1	274	..	..	-1.49	-0.21
20	1/70	25.0	6.78(F)	128	9	..	..	392	..	..	-1.20	-0.06
21	1/70	25.0	6.76(F)	196	10	..	..	674	5	2	-1.95	+0.30
22	5/70	24.0	7.05(F)	136	5	6	1	420	5	9	-1.44	+0.25
23	1/70	24.5	6.71(F)	116	6	..	..	416	20	24	-1.01	-0.16
24	1/70	24.5	6.59(F)	214	5	..	..	647	20	23	-2.48	+0.14
25	1/70	24.0	7.01(F)	214	5	..	..	671	20	3	-1.21	+0.57
26	1/70	23.5	6.82(F)	300	68	..	..	686	160	2	-1.17	+0.32
27	5/70	24.0	7.19(F)	157	3	20	1	478	..	..	-1.53	+0.50
28	5/70	24.0	6.87(F)	160	2	11	1	462	..	..	-1.23	+0.17
29	5/70	24.0	7.22(F)	155	2	8	1	470	..	..	-1.57	+0.52
30	5/70	23.5	6.58(F)	246	25	12	2	880	..	..	-0.67	+0.30
31	5/70	24.0	6.82(F)	102	2	32	5	335	..	..	-1.29	-0.20
32	5/70	24.5	7.20(F)	134	34	..	..	462	22	2	-1.56	+0.61
33	1/70	23.5	7.25(F)	255	14	..	..	475	22	3	-1.60	+0.64
34	5/70	23.5	6.85(F)	144	20	30	1	436	..	..	-1.23	+0.08
35	5/70	24.0	7.84(F)	239	39	18	2	910	..	..	-1.90	+1.52

should contain 3.5×10^{-3} moles/liter dissolved carbon dioxide. Thus, the amount of carbon dioxide in the soil zone or cave environment will determine the solutional capacity of a ground water in a carbonate terrain.

To date, most researchers have reported carbon dioxide pressures for karst waters in the eastern and southern United States in the range of 10^{-2} to 10^{-4} atmospheres (Murray, 1954; Back, 1963; Holland and others, 1964; Hanshaw and Back, 1970; Harmon, 1970; Jacobson and Langmuir, 1970; Thraikill, 1970). The carbon dioxide pressures for the waters sampled in this study varied from $10^{-0.80}$ to $10^{-1.60}$ atmospheres for spring waters, while those of the cave waters varied from $10^{-0.93}$ to $10^{-2.14}$ atmospheres (Figure 2). The carbon dioxide pressures of the cave waters decreased from January to May 1970 while those of the spring waters increased over the same period. The decrease in carbon dioxide pressures noted for waters from the same cave from winter to late spring is almost certainly related to the degassing of carbon dioxide from solution as the cave waters

equilibrated with the cave atmosphere. The increase in carbon dioxide pressures noted for the spring waters, a feature also reported by Thraikill (1970) from central Kentucky karst waters, is directly related to the decay of vast amounts of organic material deposited in the caves during the dry season and introduced into the ground water system during the rainy season.

Degree of saturation

The degree of saturation of a karst water with respect to calcite or dolomite is dependent upon many factors, the most important being pH, calcium and magnesium concentrations, bicarbonate concentration, the complexing of ions in solution, temperature, carbon dioxide pressure, and the ionic strength of the solution.

The physical chemistry of carbonate waters has been adequately described by Garrels and Christ (1965), Holland and others (1964), and Thraikill (1968). The techniques described by these researchers were used to calculate the ionic strength, individual ion activities, carbon dioxide pressure, and degree of saturation with respect to

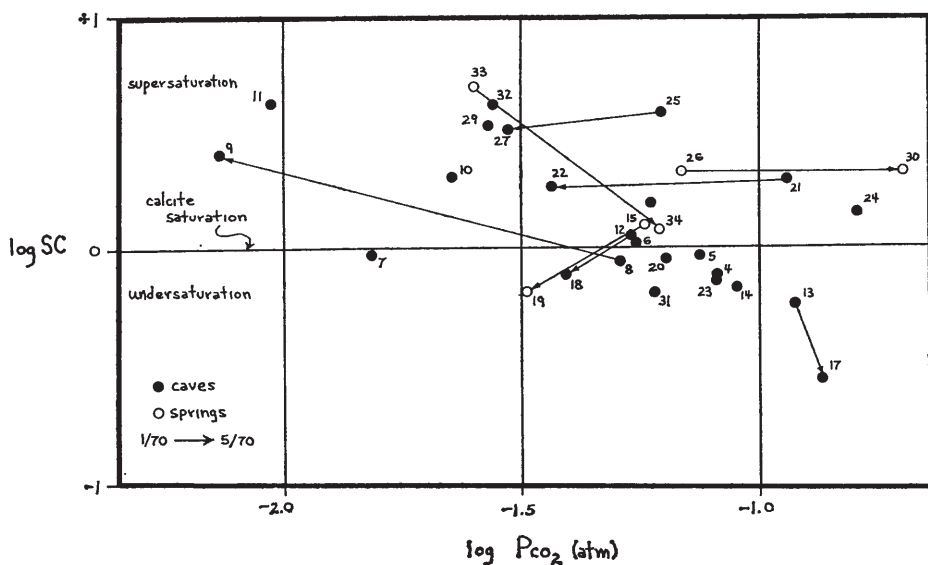


Figure 2. Log Saturation Coefficient [$\log SC$ where $SC = (K \text{ ion activity product}) / (K \text{ saturation})$] versus Log Partial Pressure of carbon dioxide in atmospheres ($\log P_{CO_2}$).

calcite and dolomite for the 35 samples on an IBM 360 computer using a program specially written for the purpose.

Using the calcite and dolomite saturation products of Langmuir (1968), we found 2 of the 35 samples analyzed to be saturated with respect to calcite. Most springs and surface waters were found to be saturated with respect to dolomite. Values for the ion activity product of calcite ranged from 10^{-7.76} to 10^{-8.97} for spring waters, while those of the cave waters ranged from 10^{-7.75} to 10^{-8.32}. Values for the ion activity product of dolomite ranged from 10^{-18.50} to 10^{-16.90} for cave waters, while those of spring waters ranged from 10^{-17.80} to 10^{-16.96}. Surface waters were consistently more saturated with respect to both calcite and dolomite than cave and spring waters. A strong trend toward decreasing calcium concentration from January to May 1970 was noted for both cave and spring waters (Figure 3).

Of particular interest was an isolated cave-spring system in the Santa Clara area west of the village of Felipe Angeles. This system includes a cave that drops to a small lake at the water table, a pool at the cave entrance at the same level as the lake, and a spring a few hundred meters away from the cave. All three of the sites showed a decrease in calcium concentration from January to May 1970 (Figure 4). At both times the pH and calcium concentrations increased from cave to spring with the pool water intermediate between the two. The cave waters were undersaturated with respect to calcite, while the spring waters were more saturated as a result of the change in environment from cave to spring.

pH

The field pH range of the cave waters sampled varied from 6.37 to 7.56 and that of the spring waters varied from 6.58 to 7.25, the spring waters generally having a

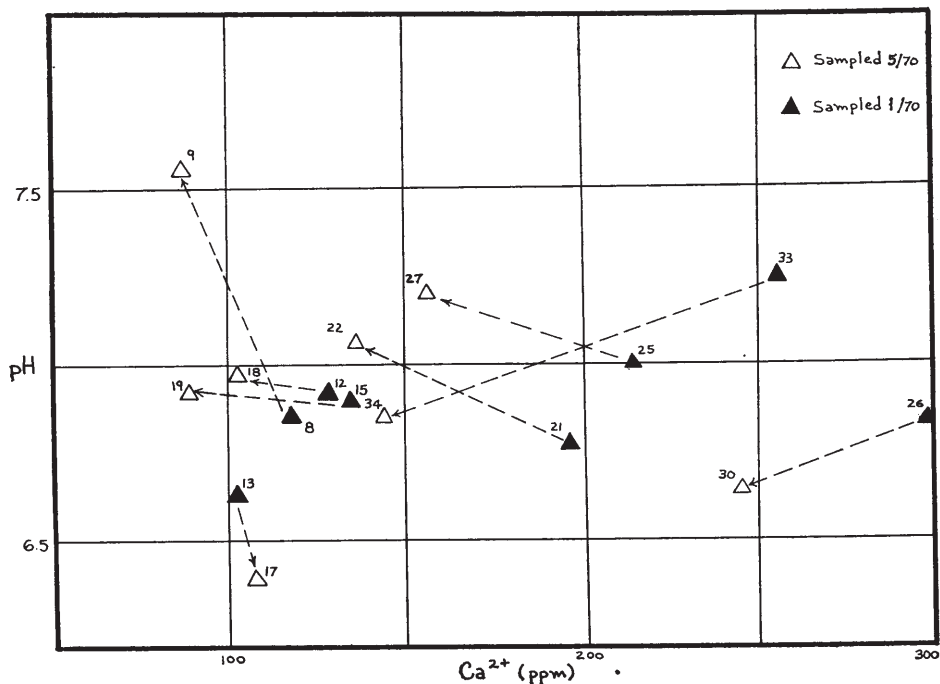


Figure 3. pH versus calcium concentration (Ca²⁺) in ppm for sites sampled 1/70 and 5/70.

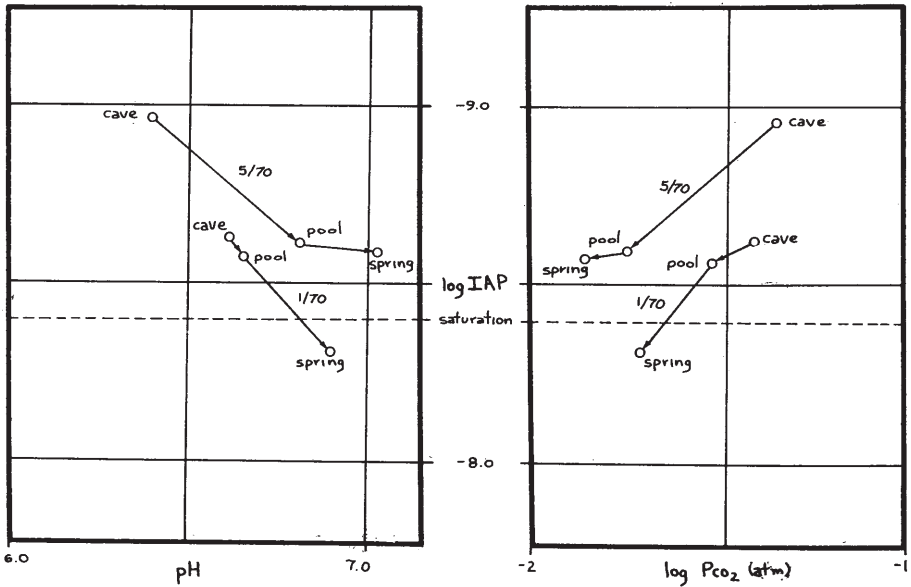


Figure 4. Some chemical parameters of the Santa Clara Cave-Spring System.

A. Log Ion Activity Product versus pH.

B. Log Ion Activity Product versus log P_{CO₂}.

Ion Activity Product=[(conc. Ca²⁺) (conc. CO₃²⁻)].

lower pH than the cave waters. The cave waters showed a general trend toward increasing pH from January to May 1970 which was in agreement with the decrease observed in the carbon dioxide pressure over the same period. Likewise, the trend toward decreasing pH for the spring waters during this period was in agreement with the increase noted in the carbon dioxide pressures (Figure 5).

Pollutants

The concentration of such ions and ionic groups as sodium, potassium, sulfate, nitrate, and chloride, which are accepted as common indicators of pollution, was low, ranging from 5 to 30 ppm. However, caves supporting large bat populations commonly had nitrate concentrations up to 25 ppm, while surface and spring waters generally had pollutant concentrations averaging 40 ppm.

DISCUSSION

During the course of this study, sampling occurred at three times: July 1969, January 1970, and May 1970. The following trends were noted for these three periods, suggesting an annual cycle in the water chemistry of the region (Figure 6).

July 1969 (Early part of the rainy season): lowest calcium concentrations, high pH values, lowest carbon dioxide concentrations, undersaturation with respect to calcite.

January 1970 (Mid-part of the winter dry season): highest calcium concentrations, lowest pH values, moderate carbon dioxide pressures, saturation with respect to calcite.

May 1970 (Last part of the dry season): moderate calcium concentra-

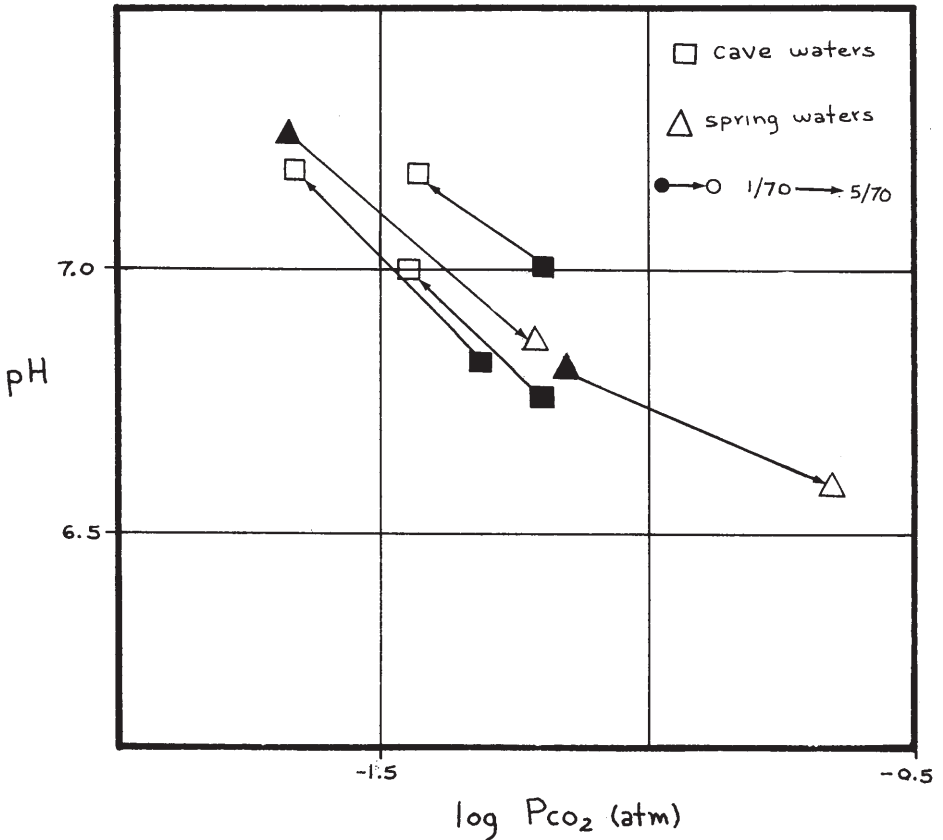


Figure 5. pH versus log PCO₂ for sites sampled 1/70 and 5/70.

tions, high pH values, low carbon dioxide pressures, saturation with respect to calcite.

Beginning in May, the last month in the 9½-month dry season, cave waters are generally just saturated with respect to calcite at a carbon dioxide pressure of about 10–1.4 atmospheres and a pH of about 6.8.

A ubiquitous feature of the caves of the El Abra region is the vast amount of bat guano, plant debris, and other organic material that either accumulates in the caves during the dry season or is washed in by summer floods. This organic matter, if oxidized, has the potential to act as a tremendous source of carbon dioxide, the most im-

portant factor in the solution of carbonate rock.

As previously noted, almost all of the rain that falls upon the El Abra region is concentrated within a 2½-month period from mid-July to late September and is quickly channeled underground through extensive cavern and fracture networks. Thus, most of the 475 million m³ of rainfall reaching the water table is able to dissolve or to produce large quantities of carbon dioxide. This acidity, together with the “mixing” effect as described by Bögli (1965), produces a ground water that, by the end of the rainy season, is very undersaturated with respect to calcite.

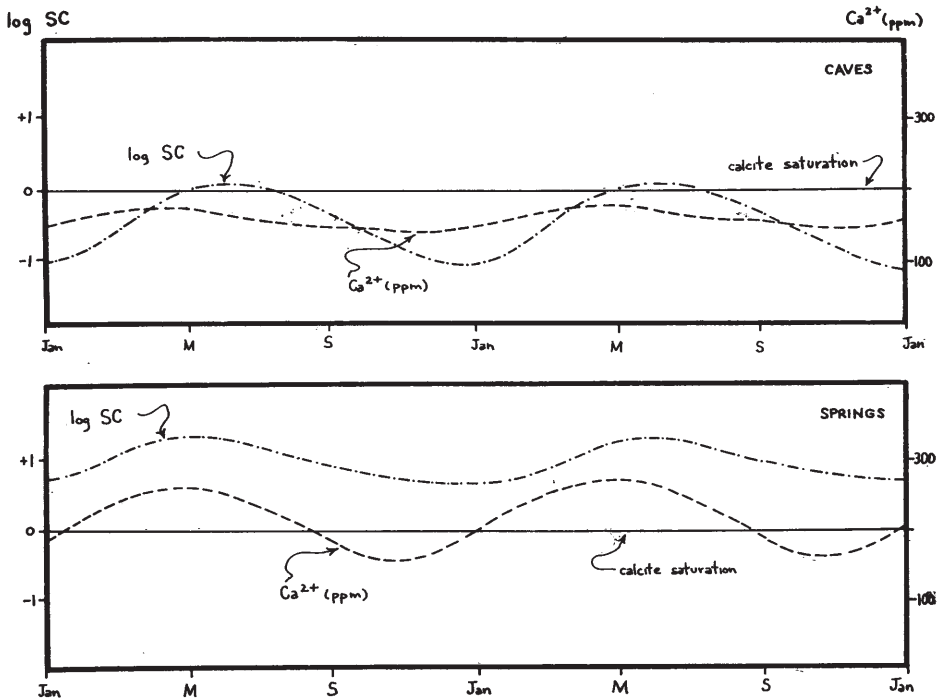


Figure 6. Seasonal changes of calcium concentration and saturation state of cave and spring waters.

- A. Log SC and Ca^{2+} ppm versus time for cave waters.
- B. Log SC and Ca^{2+} ppm versus time for spring waters.

This water is then able to dissolve calcite as carbonic acid attacks the limestone aquifer while the ground water moves underground from cave to spring. By mid-winter these ground waters have migrated to the springs, thus accounting for the very high calcium concentrations observed in the January samples. Spring waters with calcium concentrations exceeding 300 ppm are not uncommon during this time of year, which is in agreement with the one published chemical analysis by Bonet (1953), who reported a calcium concentration of 310 ppm at a pH of 7.1. At this time the calcium concentration of both cave and spring waters should begin to decrease from their winter highs and continue to decline throughout the spring, reaching a dry season low in

May just before the commencement of the summer rains.

Interesting implications also exist with regard to the rate of solution of the limestone of the El Abra region. As has previously been pointed out, the carbon dioxide pressures, and thus the calcium concentrations, of the water sampled are an order of magnitude greater than those commonly reported for karst waters of the eastern and southern United States (Back, 1963; Holland and others, 1964; Jacobson and Langmuir, 1970). This factor, with the temperate climate and the rainfall pattern, provides conditions in the Sierra de El Abra that are most favorable for cavern development.

A theoretical rate of solution was calculated using the unpublished work of

Russell on the hydrology of the region and the work of Jacobson and Langmuir (1970). Based on Russell's figure of 475 million m³ of available annual recharge water and Jacobson and Langmuir's value of at least 58 mg/liter for the amount of calcium in pure water saturated with carbon dioxide at 25 degrees centigrade and 10^{-2.2} atmospheres carbon dioxide pressure (a conservative estimate when considering cave atmosphere), calculations indicate that a minimum of 27.5 x 10⁹ grams of calcium could be dissolved annually. The presence of other ions in solution would increase the ionic strength of the solution and thus make this number even larger. Converting this to a corresponding weight of calcium carbonate, the figure becomes 68.9 x 10⁹ grams of limestone dissolved annually. Given a density of 2.71 for this limestone, a volume of 25.5 x 10⁶ liters would be dissolved in one year. This is a solution rate of 25 m³/year for an area of about 1,500 square kilometers.

Thus, if major cavern development in the region has only occurred since the last continental glaciation 10,000 years ago, the region should contain about 2.5 x 10⁵ m³ of cave passage.

To date, approximately 25 km of cave passage have been surveyed in the region with many more kilometers known but unmapped (Russell, personal communication). A study of 25 caves of the region indicates that the average cross-sectional area is on the order of 8 m². This figure is a minimal one as many caves have large rooms that are not included in the calculation of this number. If this cross-sectional area is multiplied by the length of surveyed cave passage, a volume of 2.0 x 10⁵ m³ is obtained, a figure which compares favorably with the theoretical volume calculated from chemical and hydrological data.

Thus, the fact that caves of the lower latitudes are generally much larger than their northern counterparts appears to be a function of the greater amounts of organic carbon dioxide produced, the pattern of concentrated rainfall, and the greater amounts of runoff directly into the subsurface.

ACKNOWLEDGEMENTS

Sincere thanks is given to the Association for Mexican Cave Studies for their continuing excellent work in the exploration and surveying of the caves of the El Abra region. William Russell deserves much of the credit for the thoughts and ideas concerning the hydrology cited. I would also like to express my thanks to Dr. Robert Mitchell, William Elliot, Don Broussard, William Sherborne, and Billy Campbell for their assistance in sample collection. Finally, I express my appreciation for Cricket! Haygood, who was my typist.

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Manuscript received by the editor October 1970

A History of (Kenny) Simmons Cave

By Peter M. Hauer *

ABSTRACT

Simmons Cave, Pendleton County, West Virginia, is basically a large room with three entrances. Its history is closely associated with that of the descendants of Leonard Simmons, who settled the area before 1768. The earliest recorded entry was in 1847. After an artificial entrance was opened about 1884, the cave was used for July 4th celebrations until the turn of the century. A commercialization attempt around 1929-1930 never got off the ground, but the cave gained considerable popularity again after the first NSS expedition to it in 1941.

Simmons Cave, Pendleton County, West Virginia, has been the site of considerable human activity for over a century. The cave is primarily one large room located in a small knoll. This room measures approximately 450 ft. in length and up to 150 ft. in width. Now entered directly by a man-made entrance, the room contains a small lower-level "lake" in addition to underlying parallel fissures and crawl-ways which emerge 20 ft. (vertically) below the artificial entrance, forming two natural entrances. One natural entrance is now quite choked with debris, while the other is intermittently choked. Despite considerable vandalism, the cave is fairly well decorated with small dripstone speleothems. It is briefly, but well, described in the three editions of *Caverns of West Virginia* (Davies, 1949, 1958, 1965). Figure 1 shows Davies' map from that book.

The cave's name is properly Simmons Cave, rather than Kenny Simmons Cave, since it has been associated with many generations of the family rather than with Kenny Simmons alone. A family tree for the Simmons is shown in Figure 2. The Simmons farm, whereon lies the cave, was settled by Leonard Simmons, who pioneered on the South Branch of the Potomac before 1768 and died in 1808 (Morton, 1910). He had five children by his wife Mary. Their son Henry, born on October 12th, 1760, built a brick house on the lower part of the

farm in 1812. This house, which still stands, was used as a headquarters by General Stonewall Jackson during the Civil War for planning the Battle of Franklin, which, incidentally, was never fought (Calhoun, ca. 1930). The same son, Henry, had six children. His wife was named Susan according to Morton (1910) but Mary according

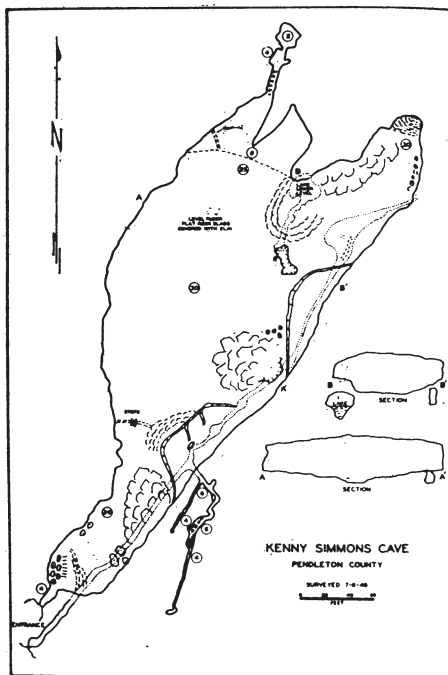


Figure 1. Davies map of Simmons Cave.

* American Spelean History Association, 1506 Miller St., Lebanon, Pa. 17042.

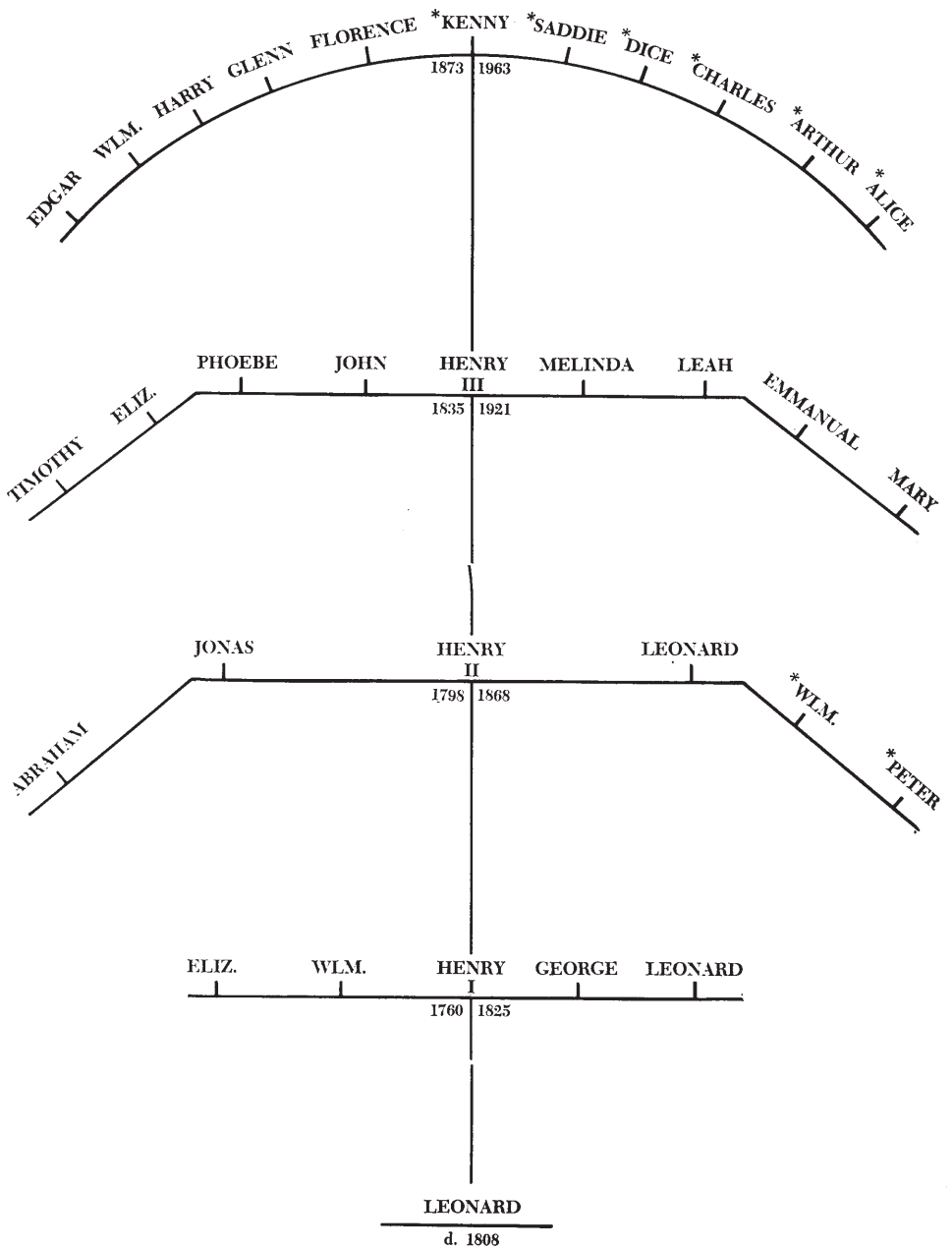


Figure 2. Simmons family tree relative to Simmons Cave.

* Indicates known association with the cave.

Unidentified Simmons family wall names: Jacob (1847 wall); A. L. (1896); Erasmus (1897).

to his own will. In his will, written two years before his death on September 7, 1825, he directed that five gallons of apple brandy be supplied annually to his wife until her death (Simmons, 1823). This is of interest in regard to activities in the cave 70 years later of his grandson, Henry III.

The first known entrance into the cave is recorded by names on the cave wall accompanied by the date of May 7, 1847. To be certain which names should be associated with that date is not possible, since there are other names and dates present on the wall, but the most likely are John Ham— and William Simmons. Less certain are J. J. Ferguson, W. H. Mason, Peter Simmons, and Jacob Simmons (family relationships unknown). Still others are nearly obliterated. William Simmons (born 1800) and Peter Simmons were sons of Henry I (Morton, 1910). Also associated with this date is the word "OUT", beneath which is a roughly down-pointing left hand, inscribed just above the connection from the main room to the lower-level passages and the lower entrances (Figure 3). Since the artificial entrance wasn't opened until about 37 years later, this inscription is excellent evidence that the more tortuous lower ways into the cave were used at an early date. Of the two possible lower entrances, the one presently fully choked with rock was probably used. The opening to this is more obvious, old wooden torches are present,

and the bedrock is polished from the passage of numerous persons directly into the now choked constriction. The other side of this constriction can be seen a short way inside the alternate lower entrance, which itself is intermittently choked a few feet further in. A successful traverse of this other lower entrance in early 1969 could not be repeated in February, 1970 without some excavation.

For the 31-year period following the May 7, 1847 explorations, no activities were recorded. Inscriptions, with the names obliterated, again appeared next to the 1847 spot in 1878. These mark the beginning of the era of the most intense activities in the cave. A chronology of cave wall inscriptions for this era is given in Figure 4. Five of the children of Henry III are recorded in this listing. It is interesting to note a 1911 date near these earlier inscriptions. The date has been applied by carbide lamp, a rather early use since miner-type carbide lamps weren't marketed until 1900.

About this time (ca. 1884), Henry Simmons III and a "nomadic Irishman", John Gillespie, employed by Wes Benson on the turnpike (now Rt. 220) adjacent to the farm, explored the lower entrances to the cave. Gillespie talked Simmons into employing Samuel Simmons (family relationship not known) to dig open the theorized upper entrance to the cave. William W. McClung somehow determined this point by an above-

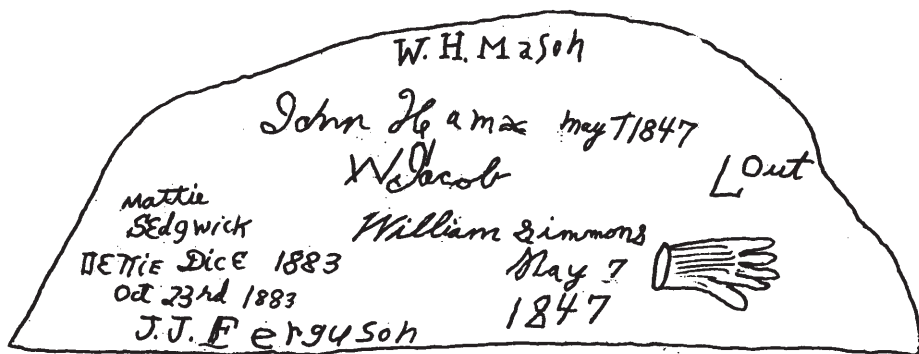


Figure 3. Partial facsimile of 1847 wall inscriptions.

Figure 4. Chronology of Wall Inscriptions.

- 1847: May 7, William Simmons, Jacob Simmons, J. J. Ferguson, Peter Simmons, John Ham__, W. H. Mason. Note text for discussion of these names.
- 1878: On 1847 wall, no names.
- 1882: E. O. Larrick, June 23d.
- 1883: C. L. Von Bonhorst, Ap. 20th, Ohio. Saddie (Simmons), Dice (Simmons), Oct. 23rd.
- 1885: Date on back wall, no names.
- 1886: Date on back wall, no names.
- 1889: Date on back wall, no names.
- 1892: Date on back wall, no names.
- 1893: S. H. Ralston, June 4th, name on back wall and lower level.
- 1896: A. L. Simmons, back wall.
- 1897: Aug. 6, Erasmus Simmons.
- 1901: A. D. Simmons, Feb. 12, back wall. Also Ap. 24th (or 14th), Age 24, A. K. Simmons (Alice).

NOTE: An undated Kenny Simmons inscription appears on the back wall.

ground survey, and once the work was completed, easy and direct access was gained to the main room.

During the excavation, Charles Simmons, a son of Henry III, entered the lower entrance and was trapped in the cave when his light source was extinguished. Although he could hear the laborers at work, they could not hear him. He was not rescued until his father returned home that evening. His long vigil occurred at a spot where 'chipmonks had carried in nuts' (probably activities of the cave rat, *Neotoma*). The account of this excavation process was recorded by H. J. Calhoun, Sr., who also recorded the resulting activities created by the new entrance and the commercialization attempt more than 40 years later (Calhoun, ca. 1930).

During the last decades of the Nineteenth Century, Henry Simmons III lorded over the most active period in the cave's history (Figure 5). Annual July 4th celebrations



Figure 5. Henry Simmons III (seated) with wife Mary, aged 81 and 76, respectively. Standing are their 11 children: (right to left) Charles, Edward, Will, Alice, Florence, Kenny, Saddie, Harry, Dice, Arthur, and Glen. Charles was trapped in the cave around 1884, and the names of Alice, Kenny, Saddie, Dice, and Arthur are all found inscribed in the cave. Photograph taken in front of 1812 homestead during September 6, 1916 family reunion. Courtesy of Evelyn (Simmons) Nesselrodt.

were conducted in the cave, and Calhoun notes that one year a brass band played patriotic music for 800 or 900 persons in the room at one time (probably an exaggerated figure). A dance floor was constructed on the flattest part of the cave floor, about mid-way into the room, and tickets used for the 1895 Independence Day Celebration are labelled: "Simmons' Cave, July 4, 1895, Admit One, Music, Dancing, Swinging, Etc." (Figure 6). The etcetera may refer to boating on the water table "lake," although an extant sunken pair of relic boats (Figure 7) are only about 40 years old, according to the current owner.

Another activity was feasting. Ample evidence of this can be seen in the cave, where the base of an iron cookpot rests behind two large columns. Charcoal there indicates that it was used in the cave, despite the problems that smoke would have produced. The traditional family apple-brandy mentioned previously in the will of Henry Simmons I was still being produced 70 years later by his grandson, Henry Simmons III,



Figure 7. Relic boat in lower level "lake", photographed in 1967. Photo by author.

SIMMONS' CAVE.
JULY 4, 1895.

ADMIT ONE

**MUSIC, DANCING, SWING-
 ING ETC.**

Figure 6. An 1895 ticket to July 4th celebration. Photo by D. N. Brisson.

and "it may be said that this added materially to the enjoyment and hilarity of these occasions" (Calhoun, ca. 1930). The neck of an antique bottle, found by the author in a crack near the dance floor area, may have originated from this source. The 1895 tickets do not have a price on them, but supposedly cost one dollar (Anon., 1942), which might have paid for the cost of a band, the food, brandy, etc.

Relics other than those just mentioned include remnants of dance floor wood and some footprints in dried clay at a spot protected by an overhanging wall (Figure 8). Evidently, the men's shoes were square-toed, and the women's shoes were tiny with thick, low heels. A few scattered torches are also found.

The date of the last celebration is not known, but sometime around the turn of the century, visits became less frequent and more irregular. Then, sometime within the decade after the August 15, 1921 death of Henry Simmons III, Kenny Simmons, the

new owner, gave Noah W. Sites an option to commercialize the cave (Calhoun, ca. 1930).

Sites supposedly opened some additional passages, and there is a large trench, possibly from this period, in the northern end of the room where someone tried to dig open an extension. A rough survey, probably made during this period, resulted in the first crude map of the cave (see Figure 9). For some reason, perhaps the Crash of '29, interest was lost and the project never went any further.

Activities in the cave again lagged until 1941. By this time the tiny, unincorporated village in the area was known as Cave, West Virginia, and a Cave Post Office had been established at one of the Simmons's homes. On May 4, 1941, the newly formed National Speleological Society visited the cave in the persons of George Dare, Mabel Smith, Lila Miller, Bob Huestis, Leo Miller, Herman Volmer, William Stephenson, James Fowler, and others. The original field trip



Figure 8. Early shoeprints near dance floor area. Photo by Robert Riese.

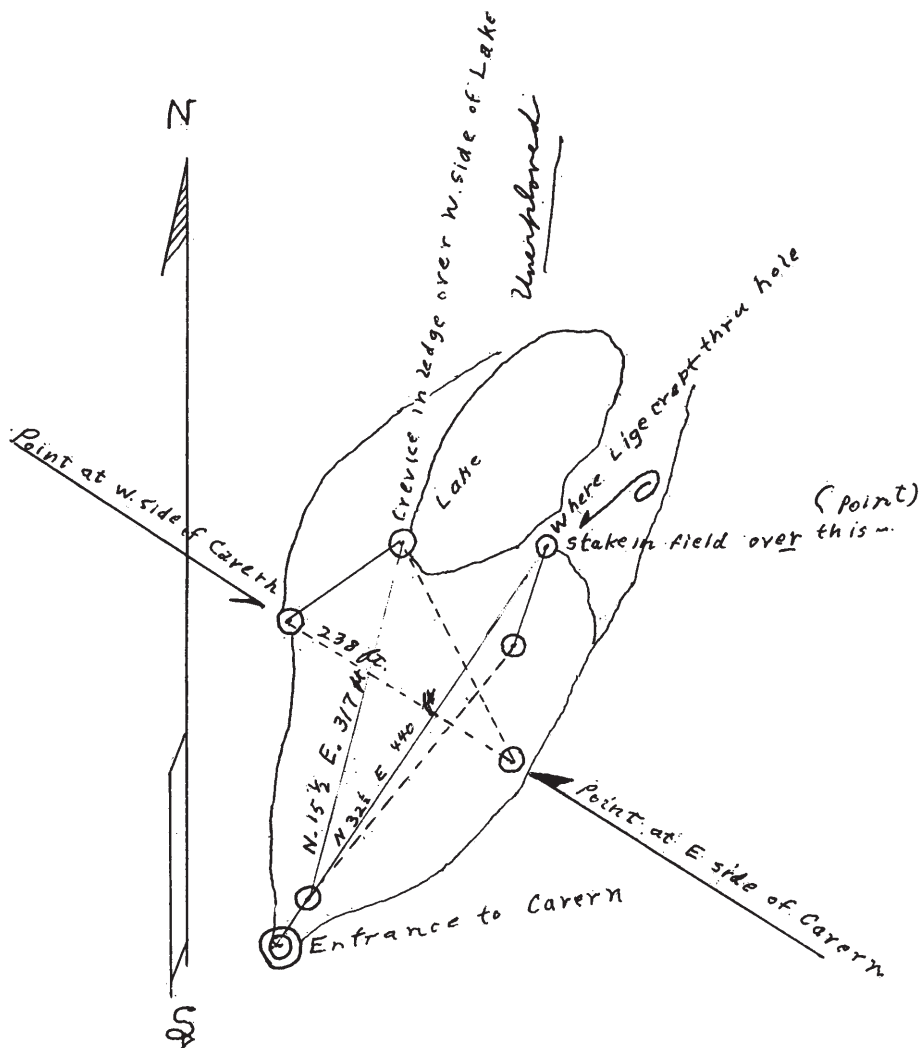


Figure 9. First map of Simmons Cave: unsigned, undated. Possibly from period of 1929-1930 commercialization attempt.

report is preserved in the NSS Cave Files, and two accounts (Anon., 1941, 1942) of the expedition were published in the second and third volumes of this Bulletin. During this first NSS trip, the cave was surveyed by Dare, Stephenson, and Huestis; the survey notes and baseline are also preserved in the NSS Cave Files, accompanied by a map which appears to be a preliminary sketch of

William Davies's July 6, 1948 map. The 1948 map has been published in all three editions of *Caverns of West Virginia* (Davies, 1949, 1958, 1965).

With the cave known to the NSS, with the publication of *Caverns of West Virginia*, and with, shortly thereafter, a photograph of the cave's boat and lake in *Life* (Anon., 1950), the weekend popularity of Simmons

Cave was permanently established. This popularity was enhanced by the hospitable nature of the elderly Kenny Simmons, whose interest in the cave had obviously not lapsed, since in 1950 he requested aid in rebuilding the door over the upper entrance (Anon., 1950). In 1952 an illustrated feature article about the cave appeared in the *Washington Sunday Star Magazine* (Hamilton, 1952). Sometime between then and 1963, the cave was designated an air-raid shelter, although it would offer little comfort or protection under long emergency conditions.

Kenny Simmons, the last direct link with the Gay Nineties period of the cave's history, died on October 1, 1963, at the venerable age of 90. The boats previously mentioned were usable in that year (Gipe, 1963) but have since deteriorated to full relic status.

The cave is still regularly visited and mentioned in various publications, and if litter and late wall inscriptions are removed and vandalism permanently halted, the beauty and historic interest of Simmons Cave would be returned indefinitely.

ACKNOWLEDGEMENTS

The author would like to thank Mrs. Evelyn (Simmons) Nesselrodt for making the Calhoun paper, the family photograph, and a copy of the 1895 ticket available. Alice Steinke furnished data from the NSS Cave Files, and the Clerk of the Pendleton County Court House aided in locating the Simmons family wills. Members of the York Grotto, NSS, were helpful in field trips to the cave, which involved tedious work finding inscriptions and relics, and in photography.

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Manuscript received by the editor December 1970

Caves as Archipelagoes

By David C. Culver *

ABSTRACT

An analogy is drawn between caves and archipelagoes. Using the formal theory developed for the number of populations of a species present in an archipelago, it was possible to obtain estimates of migration and extinction rates for crustaceans in caves of the Greenbrier Valley of West Virginia. In general, these estimates agreed with what is known about the species' biology.

For many years islands have been recognized as possessing unique flora and fauna different from large continental areas. Their separation from the mainland has meant that new species are introduced only occasionally as individuals are transported to the island. The reduced competition from new species has resulted in the preservation of many species which have become extinct on the continent. In addition, genetic drift, or the accumulation of random changes in the breeding population due to its small size, has more easily produced changes in the island populations.

Various authors have suggested that caves have similarities with islands. Both are discontinuous habitats, *i. e.*, islands are separated by water and caves are separated by limestone. Islands are not completely isolated because animals and plant seeds occasionally get blown or rafted to the island. Likewise, caves are not completely isolated from one another because cave animals move through small channels in the limestone, or in the case of aquatic animals, they move through groundwater or subsurface water (Holsinger, 1969). Furthermore, both caves and islands contain highly modified, 'peculiar' animals (see Carlquist, 1965, for descriptions of many of the unusual island species). Finally, both islands and caves contain relatively few numbers of species.

Many islands cannot be considered as isolated entities receiving migrations from a

large mainland. Islands commonly occur in large groups, or archipelagoes, more widely separated from the mainland than they are from each other. Migrations of species from one island to another will be more frequent than the introduction of a new species from the mainland. From the physical nature of caves in a karst valley, it is clear that the caves are analagous to a series of islands (an archipelago) with migrations among them rather than to a single island with migrations from a large mainland source area.

Although the facts about island populations have been known for many years, detailed explanations have been slow in coming forth. Until recently, two mutually overlapping explanations of the small numbers of species were widely accepted. First, because islands were isolated, most species took a long time to get there. Therefore, part of the reason that islands have few species is that most species hadn't had time to reach the islands, and the number of species would increase as time went on. Second, many groups such as land mammals were unlikely to migrate, so that the potential number of species on islands was less than on the mainland. These same arguments can be used to explain the low numbers of species in caves. For example, aquatic insects may not be found in caves because of their physiological inability to live and reproduce in darkness (Culver, 1970a).

These theories may be correct, but they do not provide an adequate formal framework for considering the general problem

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of explaining the number of species present on an island or in a cave. MacArthur and Wilson (1967) have suggested such a theory. Their basic approach was to consider the number of species present as a balance between immigration and extinction. Because the problem is so complex, some simplifying assumptions must be made. MacArthur and Wilson chose to assume that all species were equivalent. They then looked at the effect of area of the island and its distance from the mainland on the number of species present. I have applied this model, as modified by Simberloff (1969), to the aquatic crustacean communities in caves in the Greenbrier Valley of West Virginia (Culver, 1970b). What I found was that two factors were the major determinants of the number of species present in a cave. (1) Those caves that flooded severely in the spring had fewer species than those caves that did not flood severely. (2) The random effects of immigration and extinction influenced the number of species present.

This work provided some insight into the effect of various aspects of the cave itself on the number of species present, but it did not consider differences between species. To proceed further we must consider caves as similar to archipelagoes rather than isolated islands. Levins (1969 and in prep.) has formulated an archipelago model that allows us to consider differences between species. He makes the simplifying assumption that all islands are identical. He proposes that:

$$dN_i/dt = m_i N_i (T - N_i) - x_i N_i$$

where, for caves in place of islands,

T = total number of caves

N_i = number of caves occupied by species i

x_i = extinction of species i per cave per year

m_i = probability that migrants of species i from a given cave reach another given cave in one year.

From the definitions, the number of migrations of species i arriving in a given cave in one year from any other cave is clearly

$N_i m_i$. Levins has shown that at equilibrium ($dN_i/dt = 0$):

$$\dot{N}_i = T - x_i/m_i \quad \text{or} \quad \dot{p}_i = 1 - x_i/m \quad (1)$$

where $m^{(i)} = m_i T$, $p_i = N_i/T$, and \dot{p}_i and \dot{N}_i stand for the equilibrium values of p_i and N_i .

The application of this model to the Greenbrier Valley aquatic cave species is complicated by the presence of two types of caves (flooders and non-flooders) while the model refers to only one type. Therefore, another simplifying assumption must be made. I will assume that the migration rate into a cave ($N_i m_i$) is the same for all caves and is therefore independent of the hydrology of the cave. Three species (the amphipods *Stygonectes emarginatus* and *Stygonectes spinatus* and the isopod *Asellus holsingeri*) disperse only through subsurface water; they do not disperse through surface springs and streams. There is no reason to believe that caves that flood receive less subsurface water, especially since the three species can disperse through water only a few meters below the ground (see Holsinger, 1969). On the other hand, the amphipod *Gammarus minus* can disperse via springs and surface streams (Holsinger and Culver, 1970). This means that caves that flood would receive more *Gammarus minus* because the flood waters would contain *G. minus*. Therefore the migration rates of *G. minus* cannot be calculated, and I will concentrate on the other three species for the rest of the paper. Two estimates of $N_i m_i$ were obtained (Table 1) for *S. spinatus*, *S. emarginatus*, and *A. holsingeri*.

One final assumption is needed to complete my attempt to use the model. Most populations of *A. holsingeri*, *S. spinatus*, and *S. emarginatus* in caves that flood are small and marginal. Therefore, many animals are unlikely to migrate successfully from these populations both because the populations are small and because they would tend to be washed into surface springs. Since none of the three species have been found in springs, most that are washed out can be reasonably assumed to be killed. Therefore I will assume

TABLE 1. Estimates of $N_i m_i$ for *Stygonectes spinatus*, *Stygonectes emarginatus*, and *Asellus holsingeri*. $N_i m_i$ is equal to the number of colonizations of species i in one cave in one year.

Species	Upper Martha's Cave data	Rimstone pool data ^a
<i>S. spinatus</i>	1.0	0.9
<i>S. emarginatus</i>	1.0	0.9
<i>A. holsingeri</i>	0.5 ^b	0.7

^a Data from rimstone pools isolated from the main stream passages in four caves (see Culver, 1970b).
^b Data from Martha's Cave.

that only populations in caves that do not flood show any migration.

Let us now return to the equilibrium equations:

$$\dot{N}_i = T - x_i/m_i \quad \text{and} \quad \dot{p}_i = 1 - x_i/m^{(i)}$$

From the faunal lists (Culver, 1970b and Table 2), estimates of \dot{p}_i for both flooding and non-flooding caves can be obtained. With the estimates of $N_i m_i$ in Table 1, there is now enough information to solve for both migration and extinction rate. Since we assumed that only populations in caves that do not flood ever migrate,

$$[1/p_i^*](m_i N_i^*) = [T/N_i^*](m_i N_i^*) = m_i T = m^{(i)}$$

where p_i^* is the proportion of non-flooding caves in which species i is found, and N_i^* is the total number of non-flooding caves where species i is found. Thus, although neither T nor N_i^* is known, an estimate for $m^{(i)}$ for each species is obtained. Then using \dot{p}_i for flooding and non-flooding caves, we can obtain estimates of x_i (Table 3).

The numbers of Table 3 have no meaning *per se*. Ideally, I should attach confidence intervals to the estimates of $m^{(i)}$ and x_i . However, the amount of data involved is small, and I prefer to use a more heuristic approach to these results. What is more

TABLE 2. The number of records of each of three species in caves that flood and caves that do not flood. $N_i/T (=p_i)$ is given in parentheses. The ratio N_i/T is known, but not the actual values of N_i and T . Complete fauna lists are available in Culver (1970b).

Species	Non-flooding cave ^a	Flooding cave ^b
<i>S. spinatus</i>	10 (0.67)	1 (0.08)
<i>S. emarginatus</i>	7 (0.47)	2 (0.15)
<i>A. holsingeri</i>	7 (0.47)	3 (0.23)

^a Species lists from 15 caves were available.
^b Species lists from 13 caves were available.

TABLE 3. Extinction and migration rates for *Stygonectes spinatus*, *Stygonectes emarginatus*, and *Asellus holsingeri* in flooding and non-flooding caves.

Species	Cave Type	$x_i/m^{(i)}$	$m^{(i)}$	x_i
<i>S. spinatus</i>	Flooding	0.92	1.42	1.31
	Non-flooding	0.33	1.42	0.47
<i>S. emarginatus</i>	Flooding	0.85	2.02	1.72
	Non-flooding	0.53	2.02	1.07
<i>A. holsingeri</i>	Flooding	0.77	1.28	0.99
	Non-flooding	0.53	1.28	0.68

important than the accuracy of the results is the biological meaning the numbers have and the additional experiments they suggest. There are three predictions from independent evidence that can be made concerning the relative values of the migration and extinction rates.

First, since *S. spinatus* has a smaller range than *S. emarginatus* or *A. holsingeri* (Holsinger, 1969; Steeves, 1969), it might be expected to have a lower migration rate. In fact, *S. spinatus* has a lower migration rate than *S. emarginatus* but a higher migration rate than *A. holsingeri*. Therefore, differences in migration rate do not appear to explain differences in geographical range.

Second, since *A. holsingeri* can better withstand current than either *S. emarginatus* or *S. spinatus* (Culver, 1971), the difference in extinction rate of *A. holsingeri* in flooding and non-flooding caves would be expected to be less than the difference for either *S. spinatus* or *S. emarginatus*. This is

in fact the case (Table 3). Therefore, differences in extinction rate between flooding and non-flooding caves are explained by differences in ability to withstand current.

Finally, *S. emarginatus* is the most strongly affected by competition, especially with *G. minus* (Culver, 1970a), and it should have the highest extinction rate in both flooding and non-flooding caves. This is also borne out by the data (Table 3). As a corollary, the high migration rate of *S. emarginatus* may be a compensation for the high extinction rate because of competition.

In summary, I have suggested that the differences in migration and extinction rates of *S. emarginatus*, *S. spinatus*, and *A. holsingeri* can be accounted for, in part, by differences in ability to withstand current and in intensity of competition. I have not unequivocally demonstrated this, and this paper is designed to suggest approaches to cave ecology rather than to present important results.

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Manuscript received by the editor September 1970

Notes on the Occurrence of the Snail, *Euglandina rosea*, in Caves of Northwestern Florida

By Richard Franz,¹ David S. Lee,² and Peter B. Stifel³

ABSTRACT

The predatory snail, *Euglandina rosea*, was found to be a common troglodene of several caves in Jackson and Washington Counties, Florida. It is believed that the snail collections represent portions of resident cave populations because: (a) the collections included a broad range of growth stage, (b) there is an abundant food supply available, (c) the snails utilize these caves for egg-laying. Data concerning nest sites, eggs, and hatching snails are included.

The predatory gastropod, *Euglandina rosea* (Ferussac), has been found to be a common troglodene of northwestern Florida caves. Forty-five snails, eleven alive and thirty-four empty shells, were collected from eight cave systems surveyed during 1969-70. Most individuals were found on the rich, humic-soiled cave floors, but a few living snails and empty shells were found in shallow depressions in the walls a few feet above the floors of the caves. One small individual (approximately 15 mm long) was observed on the moist wall of a dome-pit 15 feet above the cave floor. All live snails and empty shells were found within or near the twilight zone of the caves.

All caves harboring populations of these snails were situated near the margins of fluvial swamps, with the exception of Falling Waters Cave in Washington County. The vegetation in the swamps consists mainly of bald cypress *Taxodium distichum* and gum *Nyssa aquatica*; sweet-gum *Liquidam-*

ber styraciflua, red maple *Acer rubrum*, live oak *Quercus virginiana*, and numerous other kinds of trees grow on the surrounding higher ground. Rich, moist soil with a thick humus layer and scattered exposures of limestone are characteristic of the area.

The caves are formed in the very permeable Eocene and Oligocene limestones of the Crystal River, Marianna, and Suwannee Formations and characteristically have low, broad, interconnecting passages between small rooms. Many caves have several entrances. In caves close to the river swamps, entrances are developed along the sides of weathered limestone outcrops, whereas in caves developed away from swamps, entrances often are typical sinkholes. Many of the caves are subject to periodic flooding.

We have records of *Euglandina rosea* from the following northwestern Florida caves: Jackson Co. Geromes Cave, 2 mi. N. of Marianna, 10 July 1969 (1), 28 August 1970 (1); Well No. 3 Cave, 3.3 mi. N. of Marianna, 25 June 1970 (9); Veters Cave, near Florida Caverns State Park, 21 June 1970 (3), 27 August 1970 (10); Kramers Cave, Florida Caverns State Park, 23 June 1970 (1); Pottery Cave, Florida Caverns State Park, 20 July 1969 (1), 3 August 1969

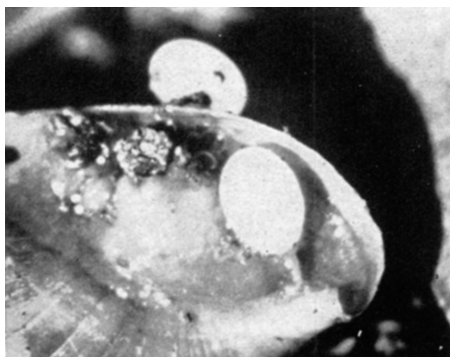
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(1), 20 June 1970 (5), 28 August 1970 (6); River Cave, Florida Caverns State Park, 22 June 1970 (4); Judges Cave, near Florida Caverns State Park, 29 August 1970 (2); Washington Co. Falling Waters Cave, Falling Waters State Park, 24 June 1970 (1). Apparently mature individuals in our collections are generally smaller than shells measured by Pilsbry (1946, p. 190), but a broad range of growth stages is represented.

Ten eggs of *E. rosea* were found in Veters Cave on 21 June 1970. They were in a pyramidal pile in a small cavity approximately 2 feet above the cave floor (Figure 1), resting on a damp mixture of clay, fine humus, and broken snail shells. They were whitish, soil-stained, hard, and brittle; and they measured 5.9 to 6.5 (6.3) mm in length and 4.5 to 5.1 (4.7) mm in width. Bits of broken snail shell, humus, and fine sand clung to the shells. On 23 June 1970 a snail 50.3 mm long from Veters Cave deposited ten eggs (Figure 2); all but four of them were later crushed by movements of the snail. These eggs were slightly adhesive when deposited. An individual 47.8 mm long from Kramers Cave deposited 12 eggs



from Veters Cave depositing an egg.

over a 23 hour period on July 9-10, 1970. The shells of these eggs were glistening white but were otherwise similar in appearance to those found in Veters Cave. At the time of deposition this latter set of eggs measured 5.8 to 6.6 (6.3) mm in length and 4.5 to 5.0 (4.8) mm in width. The eggs of these three clutches from Jackson County averaged 2.1 mm longer and 1.5 mm wider than the eggs reported by Ingram

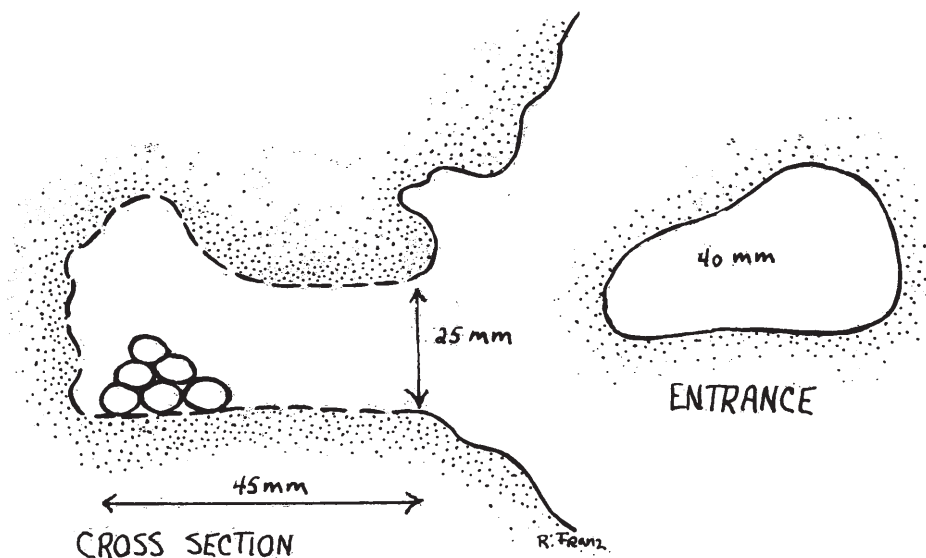


Figure 1. A nest site of *Euglandina rosea* containing 10 eggs, from Veters Cave, Florida Caverns State Park, Jackson County, Florida.

and Heming (1942) for this species. The three clutches were established in separate containers and were brought back to the laboratory, where they failed to hatch, apparently from insufficient moisture. On 27 August 1970, 27 hatched eggs were found in a small cavity (similar to the other nest site) on the floor of Vetter's Cave. The openings in the eggs which enabled the snails to escape their shells were similar to those pictured by Ingram and Heming (1942). Young snails measuring 6.5 to 6.9 mm long were collected 15, 20, 58, 110, and 138 cm from the nest site. Additional specimens of recently hatched snails were collected in Geromes and Pottery Caves on 29 August 1970. Although five young *E. rosea* were kept together in a small container, no cannibalism was noted.

Euglandina rosea is commonly associated with damp microhabitats, under logs or other cover near water (Pilsbry, 1946). Because of this, the snail would seem to be

pre-adapted to the dark, cool, humid sanctuaries offered by caves. The finding of individuals of various stages of growth indicates that these snails are common inhabitants of some caves in northwestern Florida. Several other species of gastropods also occupy these caves, *i. e.*, *Anguispira alternata crassa* (Walker), *Haplotrema concavum* (Say), *Mesodon inflectus* (Say), *M. thyroidus* (Say), *Vitridens demissus* (Binney), providing an abundant potential food supply for the active, predaceous *Euglandina*.

We would like to thank Ed Vetter for the photograph used as Figure 2, and Roger Sanderson, David Kramer, Dennis Slifer and David Weaver for assistance in the field. Captains Jim Stevenson and Joe Fredericks were most cooperative in allowing our survey of the caves within Florida State Parks. The snails have been deposited in collections of P. B. Stifel and the Natural History Society of Maryland.

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Manuscript received by the editor September 1970

RECENT CAVE BIOLOGY PAPERS APPEARING IN OTHER JOURNALS

Prepared by the Biology Section of the National Speleological Society

Christiansen, K. A. 1970. Invertebrate populations in the Moulis Cave. *Annales de Speleologie* 25:243-277.

The author discusses the results of baiting studies done in 1962 and 1968. The introduction of two species of *Collembola* between 1962 and 1968 greatly altered the distribution patterns of other species. Microclimate, competitors, and food affect local density of a species, and the factors controlling distribution are even more complex.

Culver, D. C. 1970. Analysis of simple cave communities. I. Caves as islands. *Evolution* 24:463-474.

The author analyzes fauna lists for 28 caves in the Greenbriar Valley of West Virginia. The number of aquatic species present in a cave is strongly influenced by the hydrological regime. Stochastic effects of continuing immigration and extinction were also important.

Culver, D. C. 1970. Analysis of simple cave communities: niche separation and species packing. *Ecology* 51:949-958.

Niche separation and species packing for 3 amphipod and 1 isopod species from West Virginia caves were examined. Two species alter their microhabitat when a competitor is present. Competition is for space rather than food.

Gittleson, S. M., and R. L. Boozer. 1970. Protozoa of underground waters in caves. *Annales de Speleologie* 25:91-106.

A survey of 12 water sites yielded 54 species of Protozoa. *Bodo*, *Monas*, *Amoeba*, and *Colpoda* were the most common genera. A key with numerous drawings is presented.

Henry, J. P. and G. Mangiez. 1970. Contribution à la systématique des Asellides (Crustacea, Isopoda). *Annales de Speleologie* 25:335-368.

A world-wide revision of the isopod genus *Asellus*. North American cave species are

put in two genera: *Conasellus* and *Pseudo-baicalasellus*. Evolutionary relationships of the cave species are also discussed.

Holsinger, J. R., and D. C. Culver. 1970. Morphological variation in *Gammarus minus* Say (Amphipoda, Gammaridae), with emphasis on subterranean forms. *Postilla* 146:1-24.

A discussion of the morphological variation of an amphipod common in caves throughout the Appalachians. Pictures and descriptions of various stages of eye degeneration in the species are also given.

Jegla, T. C., and T. L. Poulson. 1970. Circannian rhythms—I. Reproduction in the cave crayfish, *Orconectes pellucidus inermis*. *Comparative Biochemistry and Physiology* 33:347-355.

Cave crayfish from McCubbin's Cave in Breckinridge Co., Kentucky showed an endogenous annual rhythm in molting and reproductive cycles in the laboratory. The authors suggest that some event associated with heavy run-off from surface precipitation synchronizes the individuals' endogenous rhythms in the field.

Kamp, J. W. 1970. The cavernicolous Grylloblattodea of the western United States. *Annales de Speleologie* 25:223-230.

The author discusses the primitive orthopteroids in ice caves. Most populations apparently date from the late Pleistocene.

Mitchell, R. W. 1970. Total number and density estimates of some species of cavernicoles inhabiting Fern Cave, Texas. *Annales de Speleologie* 25:73-90.

The Mexican free-tailed bat was found to have a population size of about 5000, very much less than originally supposed. Guano-philic had large populations. Problems associated with mark-recapture and quadrat studies are discussed.

