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The Karel Absolon Centenary, 1877—1977

James Hedges* and Emil Coufalik†

Per Ardua ad Astra! Absolon.

Introduction

One of the saddest, most frustrating aspects of history is the cultural provincialism of historians. We may know what our own forebears accomplished, but we are too often ignorant of (or, at least, deny the significance of) the achievements other peoples and other times. So it is with speleology, especially, it seems, speleology in the United States.

Many of us have read and admired the works of Davis, Hovey, ES Balch, Packard, Cope, and Mercer. We know, at least by reputation, the efforts of western Europeans such as Martel, HE Balch, Buckland, Maull, and Cramer. The name of Jovan Cvijič may bring a flash of recognition, and that of Aleš Hrdlička is well-known as a result of his association with the Smithsonian Institution—but, whom among us knows the work of an equally important Central European contemporary of Cvijič and Hrdlička, Karel Absolon?

The language barrier is not entirely to blame for our ignorance of Absolon, for he published in English, French, and German, as well as in Czech. It may have been our chauvinistic myth that everything worth knowing has been discovered (or, at least, published) in the United States, or, perhaps, it was merely our pre-occupation with our own frontiers. Who was Absolon?

Biography

Karel Absolon was Professor of Geography and of Paleo-Anthropology at Charles University (Prague), founder of the Anthropos Institute (Brno), a zoölogist who discovered more than 600 new species of cave animals, a speleologist who was the pioneer explorer of the Macocha Abyss and of other major cave systems, a paleo-anthropologist and paleo-archæologist, and the acknowledged authority on the Pleistocene and on Pleistocene Man in Central Europe.

Born in Boskovice, Czechoslovakia on 16 June 1877, Absolon was the grandson of Heinrich Wankel, the founder of speleology and anthropology in Central Europe. His father, Villibald, an M.D. and general practitioner in Boskovice, died in 1882 and Absolon was raised by his mother, Caroline Wankel-Absolon-Bufka. Very early, he fell under the influence of grandfather Wankel and, inheriting the family enthusiasm and dynamism of the Wankels, by age 20 had determined to continue the lines of research initiated by Wankel. Most notable among these were to be: the Moravian karst, the Diluvial and Recent inhabitants of those parts of Europe most densely occupied by Stone Age Man—the Dordogne (France) and the Moravian karst, and the fossil and living faunas of the Dinaric karst.

Absolon graduated from the gymnasium at Brno and, in 1899, enrolled at Charles University, Prague. His studies there under the tutelage of the zoölogist Prof. Frič were supplemented by intervals spent with E.-A. Martel in Paris, with Albrecht Penck in Berlin, and at universities in Hallé, Leipzig, Bruxelles, and London. Frič, unfortunately, retired before Absolon completed his thesis and Frič's successor, Prof. Vejdovský, disliking Frič and wishing to insult him by rejecting his student's work, refused to accept it.

Perhaps Vejdovský merely forgot that he had allowed Absolon to continue. Be that as it may, Prof. Jan Palacky, hearing of the affair and knowing of Absolon's interest in geography, invited Absolon to write a geography thesis. This second thesis, based on material already in hand, was completed in three months. Entitled "The Problem of the Course of the Underground River Punkva," it was accepted in 1903 and published, in 1907, as "Kras Moravsky."

Absolon's genius had been recognized abroad while he was yet a student, and, upon graduation, he was offered the position of

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Figure 2. Portrait of Karel Absolon.

Assistant Director of the São Paulo (Brazil) Museum. However, he preferred to make his life's work the Moravian karst. After a few years as a teaching assistant at Charles University, he accepted the relatively well-paid post of Curator of the Pleistocene Department of The Moravian Museum in 1907.

Absolon's geographical studies in the Balkans enabled him to be exempted from military service in the Great War. He continued to teach at Charles, where he was to become a full professor in 1931, travelling there from Brno two days each week. In addition, he delivered hundreds of always popular educational lectures to lay audiences.

In 1920, Absolon chose as his wife Valerie Minkusiewicz-Hauska v. Zbranikov, an archaeologist who subsequently accompanied him on many of his expeditions. Two children came of this union: Dr. Karel B. Absolon, MD, Chairman of the Department of Surgery at Washington University Hospital Center (Washington, DC) and Valerie Block-Absolon, an ethnographer and botanist of Greenwich (Conn.) and Bermuda.

The Anthropos Institute, in Brno, was founded by Absolon in 1928. Originally only an "Exhibition of Contemporary Culture with a special part on the evolution of Man," it developed into an independent museum and scientific institute comparable to the Musée de l'Homme in Paris. At the same time, he created an independent Department of Prehistory, or Paleolithicum, at The Moravian Museum. The Anthropos Institute was re-established, after Absolon's retirement in 1950, as a part of The Moravian Museum.

Absolon founded the (now defunct) monthly magazine, *Příroda*, in 1930. Similar to the British magazine, *Nature*, it was supported by the income from the by-then commercialized Macocha Abyss.

Although a Czech nationalist in science, Absolon was politically an internationalist. His leadership in overcoming French opposition to the re-admission of German scientific societies into the international scientific community after the Great War was held against him during the German Occupation of Moravia (1939-1945). Forced into retirement, he was banned from the caves and from the museums. His personal library, including many manuscripts, was confiscated.

Banishment from the caves was for an eminently practical reason: the caverns were being used as magazines. The loss of his professional positions resulted, perhaps, from his strong-willed refusal to collaborate with the occupying German forces. However, Absolon continued to conduct field work on the surface of the Moravian karst throughout World War II, ignoring the Germans when they made demands upon him or driving them away by sheer personal dominance.

Absolon's library of books, maps, and unpublished manuscripts was returned to him largely intact after the war. His personal papers, including his famous drawings and photographs of the Museum collections, were hidden beneath bags of rice in the basement of the Community Hospital at Brno and survived the war unscathed, also. The prehistoric collections of The Moravian Museum were lost, sadly. Taken to the Mikulov Castle, south of Brno, for protection against bombing, they and the castle were destroyed at the approach of the Allied forces when the German major in charge ordered gasoline poured down the castle staircase and set afire. Ironically, the Museum, itself, was undamaged.

Being a nationalist, and having been one of the most prominent members of the ancient and famous Royal Academy of Bohemia, Absolon was unwilling to adjust to the Communist government formed after the collapse of the Third Reich. He was not asked (or perhaps, for philosophical reasons refused) to join the (communist) Czechoslovakian Academy of Science formed in 1949. Although remaining professionally active past the age of 80, he never regained his former prominence.

At the time of his death (10 July 1960), Absolon was Director Emeritus of The Moravian Museum and Professor Emeritus of Physical Geography and General Geography, Palaeo-Anthropo-Geography, and Palaeo-Ethnology at Charles University. He lies buried in the Central Municipal Cemetery in Brno, in a section reserved for eminent persons. The slab of Moravian limestone marking his grave bears the figures of a *Typhlogammarus* amphipod from the Veternitza Cave in the Dinaric karst and a pair of mammoth tusks symbolic, respectively, of his interests in zoölogy and in Stone Age Man.

He will be honored in this, his centennial year, by a special exhibit in the Anthropos Institute pavillion. In England, the Zoölogical Society of London, the Royal Geographical Society, and the International Speleological Congress will dedicate programs to his memory. A world congress of collembolists, held last year in Uppsala, Sweden, also was dedicated to his remembrance.

Work

Absolon's scholarly interests lay in three areas: physical geography and geomorphology, including dynamic speleology; zoölogy, including palaeontology; and prehistory, including anthropology. He had the good fortune in life to be able to work independently and to finish nearly all of his projects before he died.

In the years preceeding his death, Absolon viewed his work from the aspect of the cultural history of the (former) Duchy of Moravia and of Central Europe; he wished his pupils to remember him as a historian of the culture and development of the human race in Moravia. The most appropriate manner in which to introduce Absolon's work will be to place it within the framework of Central European geography and prehistory.

Geography

Absolon began his cave explorations in 1897, at the rather late age of 20. These were inspired by grandfather Wankel and, initially, emphasized zoölogy. However, his interest in geography was aroused at about the same time, as evidenced by the ease with which he prepared his second (geographical) thesis.

The Moravian karst. Absolon recognized three geographical units within the Moravian karst, termed simply the Northern, Southern, and Central Moravian karsts.

The Northern karst includes two mountain chains separated by the valleys of the Bečyk and Morava rivers. The western chain, lying between the towns of Štramberg and Litovel, contains important prehistoric sites, but is not speleologically significant. The eastern chain lies between the towns of Hranice and Přerov. Předmostí, where occur Wankel's and Absolon's important palæolithic sites, is a suburb of Přerov. The Hranická abyss and cave are well known for their beautiful aragonite deposits.

The Southern karst lies south of the Moravian capital, Brno, a city of 500,000 inhabitants. It includes the Pálava mountains. Near here, near the village of Věstonice (Wisternitz), Absolon discovered the clay figurine known as the "Venus of Věstonice."

The Northern and Southern Moravian karsts are of slight speleological importance, because alluvial sediments have obstructed the caverns. The Central Moravian karst is by far the most important and is the portion intended whenever "Moravian karst" is referred to.

The (Central) Moravian karst is developed on a plateau of Devonian limestone standing about 500m above sea level. Geographically, it is part of the Drahan plateau, itself a part of the Carpathian mountains, and extends from Brno northward 30 km to the towns of Sloup and Holštejn. The karst varies from 2 to 6 km in width. Cave systems have been developed within it on three levels, corresponding to river elevations during the three interglacial stages.

The Macocha Abyss in the Moravian karst, in area the largest collapse sinkhole then known, is 137½ m in depth. The Punkva, the subterranean stream along which the Abyss developed, is the largest cave river in the Moravian karst. To solve the mystery of Macocha and the Punkva, Absolon had to solve problems represented by (1) the upper and middle levels of the Punkva Cave—the so-called "dry access" to the Macocha Abyss, (2) the "wet access" along the Punkva south from the Abyss to its resurgence, and (3) the submerged system of passages extending north from the Abyss to the headwaters of the Punkva at the northern end of the karst, near Sloup and Holštejn.

A route to the bottom of the Abyss had been developed by alpinists in the Seventeenth Century. Absolon mounted expeditions there in 1901, '03, '05, '07, and '09, succeeding in the discovery of the upper and middle levels in 1909. A detailed account of these explorations was published in the first volume of "Moravsky Kras." The "wet access," along the lower course of the Punkva, was opened to the public in 1914. The surrounding area is now one of the largest tourist attractions in Central Europe, having received about 300,000 visitors in 1974.

Absolon deduced from the topography of the karst that there was an extensive system of passages north of the Abyss. He investigated many sinkholes above the cave, but was unable to penetrate the domain upstream for more than a few hundred feet. Returning to Macocha after the Great War, he adapted mining technology to cave exploration in an effort to reach the upstream portions of the Punkva cave system from the Abyss.

The skepticism of mining and other authorities as to the feasibility of Absolon's plan to drive an adit 500m through

Figure 3. Absolon was a favorite subject of newspaper cartoonists. This cartoon was drawn on the occasion of the opening of the Anthropos Museum.

saturated limestone made it difficult to obtain money. Nonetheless, Absolon persevered, and the adit was successfully completed in 1929. The water level was reduced 6m, but some areas of the cave still were submerged.

Pumps were installed which lowered the water level another 12m. Finally, in February of 1933, "Nautilus" submersible pumps were obtained capable of draining the lowest sump and a new portion of the cave became open for exploration. Fortunately, this drastic lowering of the natural water level did not destroy local spring- and well-water supplies; water-tables in the karst are extremely local and independent of one another. A documentary motion picture of Absolon's work at Macocha was made by the producer B. Lachmann and is preserved in The Moravian Museum.

The Dinaric karst. The Dinaric karst, in Jugoslavia, was Absolon's second most-beloved region. This, the largest karst in the world, includes an area of 60,000 sq/km in Slavonia and Montenegro. The underground rivers Ombla, Timavo, and Buna there are the largest cave streams in the world.

Absolon's expeditions to the Dinaric karst, mounted before the Great War, yielded three volumes of reports, each dedicated to one of the three underground rivers. Neither these, nor his 1:75,000 maps of the 62 divisions of the Dinaric karst, have been published.

Zoölogy

As a young man, Absolon wrote primarily on zoölogy. His work, performed in a day when little was yet known about cave fauna, emphasized collecting and taxonomy. Absolon scoured the whole of Europe and northern Africa for specimens and is credited with the discovery of over 600 new species of cave animals. "Les Animaux Aveugles," in which he describes and analyzes the ecology of these, remains unpublished.

Living species in the caves of the Moravian karst are either Tertiary relicts or alluvial species. Absolon classified them as: (1) eutroglobiontes, which live only in caves at 7° to 10°C and having 97% to 100% RH) (2) troglophilidae, which migrate into caves when surface conditions become less favorable for them (*i.e.*, in winter); and (3) trogloxenae, which sometimes are carried into caves involuntarily by floods or other accidents.

Collembola, especially Balkan collembola, were a special interest. Absolon's 42-chapter monograph on the "Collembola of the World," which occupies 3m of shelf space in manuscript, unfortunately remains unpublished.

He also was interested in unusual surface forms, such as *Thermosbaena mirabilis*, which inhabits hot springs in the Sahara. His 1916 study of Staphylinid beetles is still being quoted, today. Although he personally authored reports on many of his discoveries, some of the material obtained during his journeys was distributed to others for identification and publication. Ksenemann's monograph, "Troglopedetini," for example, was based on collections made by Absolon.

Anthropology

Absolon's interest in human prehistory, like that in geography and zoölogy, was inspired by grandfather Wankel. He studied caves in their totality—their geology, geography, zoölogy, and human inhabitants both old and new. Absolon's work in prehistory and anthropology should be understood within four contexts: (1) Moravian prehistorians before Absolon, (2) archæological techniques and systematic research, (3) the life of prehistoric peoples, and (4) the Anthropos Institute.

Prehistorians before Absolon. Prehistoric studies in Moravia were begun before 1860 by grandfather Wankel and by his contemporaries Martin Kříž and Jan Knies. The dawn of prehistory occurred on 22nd March 1870, when Wankel lectured before the Imperial Anthropological Society, in Vienna, on his 1867 excavations at the upper Mousterian site of Býčí Skála. This lecture aroused an immediate storm, for Wankel's work at Býčí Skála, like Buckland's earlier excavations in Devon, in demonstrating the antiquity of Man antagonized the clergy. Fortunately, Wankel managed to paper over the conflict by twisting religion to fit the facts of science, and Moravian anthropological research survived.

When Wankel left Blansko and settled in the university town of Olomouc, in northern Moravia, Absolon accompanied him. Wankel's subsequent discovery of the Předmostí site, which occurred while Absolon was a student at the Archepiscopal Gymnasium in Olomouc, whetted Absolon's enthusiasm and afforded him an opportunity to learn archæological techniques, prehistory, and the art of pen-and-ink drawing for which he later became famous.

Archæological techniques and systematic research. Absolon's paleo-anthropological and pre/proto-historical studies were begun in a small way when he returned to Brno in 1907. However, it was not until 1921, when he extended Wankel's excavations at Předmostí, that Absolon commenced extensive research in the subject.

At Ondratice and Otaslavice, Absolon found proof that (upper Paleolithic) Aurignacian Man lived in open-air encampments, as well as in caves. New excavations at Wankel's Býčí Skála site revealed that early Man shared the cave with bear and, also that his diet included mammoth.

The Pekárna Cave studies were Absolon's most brilliant archæological work. Sediments in this cave incorporate cultural remains extending from those of 100,000-year-old bear hunters to those of the Iron Age. Another of his famous sites was Dolni Vestonice. There, he found the carved ivory "Venus of Vestonice" which led him to do a comparative analysis of prehistoric female representations.

It was at Předmostí, however, that Absolon began and ended his work as a prehistorian. This, Wankel's most famous site, yielded some 30,000 artifacts, including the figurine of a mammoth carved from a mammoth's tusk. Absolon's monograph, "Předmostí," has just been readied for publication and will be issued by the Czechoslovakian Academy of Sciences. Also to be published soon is his second-most important prehistoric monograph,-the "Atlas of Stone Artifacts."

Life of prehistoric people. Absolon wished to understand the biological and mental expressions of ancient man—his crafts, his art, and his techniques. Wall paintings were a special interest. Absolon owned copies of all the wall paintings known to exist in Europe, perhaps of all the wall paintings in the world.

Another of his special interests was primitive mathematical operations. He regarded early men, though primitive, as, nonetheless, *Homo sapiens*. Absolon proved that early men did not use their fingers in simple arithmetics; they used the spaces between the fingers: they counted to 4 (or, perhaps, to 6) on one hand and to 8 (or to 12) on both. Thus, the duodecimal was shown to have been one of the first arithmetical systems developed.

Anthropos Institute. Absolon's published works made Moravia world famous and its capital a center for European pre- and proto-history. The Anthropos Institute, in Brno, founded by Absolon in 1928 and now directed by his successor, Jan Jelinek, next to the Musée de l'Homme in Paris is the most important European institution dedicated to ancient Man. Absolon wished it to be known as "the museum dedicated to fossil Man and his cultures."

Absolon's anthropological discoveries were reported in the United States by Alex̆ Hrdlička, in the *American Journal of Physical Anthropology*; they are summarized in Sir Arthur Kieth's "New Discoveries Related to the Antiquity of Man" (1931). Absolon's anthropological work also was featured in the *National Geographic magazine* (Patric, 1938).

Hydrology

At the end of the Nineteenth Century, European geographers were concerned with the question of karst ground water: does it remain in discrete streams, or is it a static mass within the fissures of the limestone? Penck accepted the static water hypothesis, while Cvijič, Katzer, and Martel advocated the stream hypothesis.

Absolon was greatly influenced by Penck, and by Grund, von Knebel, and Cvijič, whom he met in Penck's school, but his work in the Moravian karst showed that, while stagnant water may occur in some caves during times of low recharge, most karst waters exist as continuously flowing streams. Martel and de Martonne accepted Absolon's finding: Martel visited the Moravian karst in 1914, while de Martonne came in 1923. Penck refused to believe what Absolon had found, however, until, at Absolon's insistence, he travelled to Moravia in 1932.

Lectures

Absolon was a fascinating lecturer. Trained in rhetoric, he had a fine sense of humour, which enabled him to create an image of the past in the modern senses of his listeners. He also was a keen photographer and pioneered in the use of hand-tinted projection slides before the Great War. Among his more popular topics were the lost continents of Atlantis and Mu, the Bermuda Triangle, the Mediterranean region and the Sahara, and early Central American cultures.

Mu, which lay between the Indian subcontinent and Madagascar, was once the center of Indo-European culture, according to Absolon, and it was there that the original human language was spoken. He pointed out that, in all Indo-European languages, the word for "mother" begins with the letter "M". The "mu" in the oldest human language signified "mother" and the Land of Mu was, metaphorically, The Mother.

Spelæologist

In Czechoslovakia, Absolon is accepted as the founder of scientific spelæology. He is remembered as a man of personal charm, gentility, intelligence, and wit, whose outstanding personality attracted numerous pupils and co-workers. It is unfortunate that recent unsettled political and economic conditions have prevented any of these from achieving as great a reputation as their teacher.

Absolon postulated two goals to his pupils and associates: (1) the scientific and technical conquest of the Moravian karst, and (2) the development of safe caving techniques. Of the first, much already has been said.

The three major technical obstacles to cave exploration are breakdowns, alluvial fills, and water. Absolon's method of bypassing breakdowns was published recently by Coufalik and Kala (1968). His procedure for driving shafts requires that passages be intersected by adits driven from the bases of shafts, not by the shaft itself, in order to minimize the danger to workmen from collapse of the shaft floor. The work must be carried out at the least possible risk to health and safety. Only three of Absolon's pupils have lost their lives in caving accidents: J. Nemac was killed by a rockfall in the Catherine Cave in 1941, and M. Slechta and I. Rahradnicek drowned in sumps near the Macocha Abyss in 1970.

Absolon The Man

When Absolon returned to Brno from Prague in 1907, he set for himself difficult goals. Foremost among these was to continue the lines of research initiated by grandfather Wankel, *i.e.*: to put on a scientific basis the study of the recent and ancient inhabitants of the Moravian karst, its geography, and its underground fauna.

Absolon realized that an interdisciplinary approach would be necessary to solve the problems of the karst. He insisted on detailed, meticulous examination of every subject and on the photographing of all significant features. He shared with Faraday the dogged endurance to complete an investigation and to see it into print; with Goethe's "Faust," eagerness and enthusiasm for science; with Beethoven, the ability to associate diverse characteristics, to formulate the problem, and to synthesize many observations into a coherent hypothesis. Finally, he possessed the gift of clarity in expression, so that his ideas could be quickly grasped and tested.

Eighty-six foreign expeditions are recorded in Absolon's diaries. His objectives ranged from the fauna of warm springs in the Sahara to the glacial geology of the Alps, Pyrenees, Caucasus, and Siberia.

His personal library was enormous. It included the writings of Nineteenth Century travellers and explorers in Africa and Asia, as well as scientific publications complementing his own work. His archives contained photographs, manuscripts, maps, excavated jewellery and other artifacts, as well as zoological specimens and curios.

Absolon's writing energies were never exhausted. After retiring from teaching and administration, he devoted himself to research and writing. Including unpublished manuscripts, his works include over 350 titles. An extensive correspondence occupied Absolon weekly; he exchanged letters with all important world figures. In addition, he served as Editor of the *Journal of the Moravian Museum* from 1920 until 1938 and, again, from 1950 onward, besides founding and editing the journal, *Příroda*.

Absolon was known for his scientific independence, broad interests, mastery of subjects, and thorough aquaintance with the literature. He accumulated memberships, most of them honorary, in over 45 professional societies, among them "Chevalier" of the French Legion of Honor. Karel Absolon epitomized the motto of the Wankel family, "per ardna ad astra."

Acknowledgements

This summary is based on material contributed by Karel Absolon's son (Dr. Karel B. Absolon, MD), by Absolon's wife (Valerie), and on Dr. Emil Coufalik's own recollections of his former associate and mentor. A preliminary draft was reviewed by Dr. Jan Jelinek (Brno), Dr. Henry Field (Cocoanut Grove, Florida), and Dr. Dale Stewart (McLean, Virginia), in addition to having been passed through the normal review procedures of the *BULLETIN*.

However, it is and must be considered to be merely anecdotal, a journalistic report on Absolon's life and accomplishments. There is no definitive published biography of Karel Absolon in any language. We hope that this brief overview may stimulate some scholar or aspiring graduate student to take upon himself what surely would be a highly rewarding and extremely useful analytical study of Karel Absolon and his place in the history of science.

Note Added in Proof: The Czechoslovak Communist Party attitude toward Absolon is indicated by the following quotation from a recent popular work (Svoboda and Tuckova, 1963): (Describing the "honorary center" of the Brno Central Municipal Cemetery, p. 320) ". . . a few hundred meters from the main entrance, on one of the terraces, is a heap of limestone slabs marking the grave of Prof. Karel Absolon. The tombstone bears only these terse comments: "Moravian karst, " "Macocha," "Dinaric karst," "Ombla," "Vestonice," "Anthropos." Absolon created a great legacy—but, as sometimes happens, his deplorable political character is in total antithesis to it. His work shall live, but his reactionary past shall be forgotten."

Publications Mentioned In The Text

Absolon, Karel (1905-08) — Kras Moravský: Prague, A. Wiesner, 168 pp.

————(1916) — Berich uber die Hohlenbewohnende Staphyliniden der Dinarischen und angrenzenden Karstgebiete: *Coleopterologische Rundschau* 5(1):132-151 and 5(3):1-18.

————(1970) — Moravský Kras: Prague, Academia, 2 vo.

———— and M. Ksenemann (1942) — Troglopedetini: Vergleichende Studie über eine altertümliche höhlenbewohnende Kollembolengruppe aus dem dinarishcen Karstgebieten; Bericht uber eine naturwissenschaftliche Forschungsreise und biospeleologische Erforschung der Insel Brac, Brazza in Dalmatien: *Studien aus dem Gebiete der allgemeinen Karstforschung, der wissenschaftlichen Höhlenkunde, der Eiszeitforschung und den Narchbargebieten, Biol Ser* 16, 57 pp.

Coufalik, Emil and M. Kala (1968) — The Mining Engineering Methods in the Research of the Moravian Karst: *Speleol. Soc. Greece, Bull.* 9:219-223.

Keith, Arthur (1931) — New Discoveries Relating to the Antiquity of Man: NYC, Norton, 512 pp.

Patric, John (1938) — Czechoslovaks, Yankees of Europe: *Nat. Geog. Soc. Mag.* 74:173-225.

Svoboda, Alois and Anna Tuckova (1963) — Ceskoslovensko zeme Neznama: Prague, Orbis.

* Absolon's complete bibliography may be obtained free of charge from: Cave Files Committee, National Speleological Society, Cave Avenue, Huntsville, Ala. 35810.

REVIEW—*The Vampire Bat*, Dennis C. Turner. Baltimore: Johns Hopkins University Press, 1975. 145 pp., bibliography. $12.00.

In this field study of the behavior and ecology of *Desmodus rotundi*, a species of vampire bat found in the tropical dry deciduous forest of Guanacaste Province, Costa Rica, the author hypothesizes that *D. rotundi* follows a basic ecological principle: as food variety increases, selectivity of feeding patterns becomes more specific. Most previous studies of the vampire bat have been carried out in Mexico or in Trinidad, although three species of vampire bat are common from Mexico to Argentina and Chile.

The book is divided into chapters dealing with: (1) a description of vampire bats and of past research on the topic, (2) methodology used in the fieldwork, (3) population estimates, (4) predator-prey relationships, (5) prey selectivity in domestic livestock, (6) social behavior of *D. rotundi*, (7) seasonal effect on reproduction and predator-prey relationships, (8) comparison of cave (Palo Verde System) and forest bat characteristics, (9) vampire-bat control methods, and (10) a summary of the findings and comments on *D. rotundi's* future. Collectively, the chapters display the author's painstaking attention to detailed fieldwork and his meticulous analysis of raw data by means of statistical techniques.

Cavers who are interested in doing research or in finding out more about vampire bats will find Turner's 128-entry Spanish and English bibliography an excellent starting point. He liberally footnotes the material, which allows one to look up the original sources.

Results of the research show that *D. rotundi* has become species-specific in its prey—100% of the bats sampled contained equine or bovine blood, exclusively. Observations on feeding habits revealed a pronounced preference for European breeds, calves, and estrous cows. This was a function of the less dense spatial distribution of the prey and their resultant vulnerable position in the herd.

This indicates that the vampire bat population is highly correlated with man's use of the land, and that man is now the agent responsible for the geographical distribution of *D. rotundi*. Even the birth cycle of the vampire bat has changed to reflect its dependence on domestic animals.

A major drawback of this and similar works is the micro-geographical approach. *D. rotundi* is such an adaptable species that in-depth ecological studies of it may have little or no significance outside of the study area. Another potential problem in interpreting the results is the author's over-reliance on the chi-square statistical technique, especially where he found few cases in some sample categories. This is further aggravated by his failure to analyze objectively the great importance of multiple bat feedings from a single incision on prey animals, which is known to occur. Without such statistics, many of the population analyses are questionable or, at best, inferential.

Such studies of *D. rotundi* are important to Costa Rica and other Latin American countries, due to the incidence of trypanosomiasis, encephalomyelitis, and paralytic rabies in livestock. *D. rotundi* is the primary vector of these diseases, which cause over $100 million damage to livestock in Latin America each year. Turner's work is an important contribution toward understanding how the predator's habits can be used against it. Various control methods are discussed, with the author favoring a predator-specific method of intrarumenal application of anticoagulants over non-specific methods which damage beneficial bat species.

"The Vampire Bat" is not overly technical and is written in an easy-to-read style. Pictures, graphs, and tables add to the value of the text. It is highly recommended reading for anyone interested in the life of the cave.

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Lineaments and the Origin of Caves in the Cumberland Plateau of Alabama

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ABSTRACT

Caves occurring in the horizontal limestones of the Cumberland Plateau in northern Alabama are classified as "simple" or "complex", based on factors of size, depth, and multi-level and parallel passage development. Complex caves are deep caves, by definition, but simple caves are also considered to be deep if there is 100 ft of vertical development in a horizontal distance of 200 ft. The locations of these caves are examined relative to nine lineaments visible on aerial photographs and satellite imagery of the area. The predominant trends of NW-SE and N-S are visible in the lineaments and in the orientation of re-entrant valleys of the Plateau.

Location of springs and caves along lineaments is attributable to greater solution along the zones of fracturing. This is particularly true at lineament intersections, where cross-fracturing occurs. Simple caves may form anywhere as a result of normal jointing and rock solubility. In areas of moderate to high relief, (a) deep simple caves form along lineaments and (b) complex caves form at the intersection of lineaments. In areas of low relief resulting from solutional activity, remnants of caves and other evidence of karstification are found along lineaments.

Introduction

"Caves are where you find them", is an expression that has often been used to rationalize the apparently anomalous location of a particular cave. Obviously, however, a combination of hydrologic, lithologic, and structural factors determine which particular zone in a mass of soluble rock will be dissolved to form a cave. This paper demonstrates that mappable structural features in the Cumberland Plateau of northeast Alabama have been the primary influence in the localization of solutional activity in that area. As a consequence, the location and origin of many large caves and pits can be explained.

Geologic Setting

The Appalachian Plateaus province extends diagonally across northern Alabama as the Cumberland Plateau. It is formed of Mississippian limestones capped by Pennsylvanian sandstones and shales. The rocks are essentially horizontal, with a gentle regional dip to the southeast off the flank of the Nashville Dome. The rocks are locally disturbed by a Valley and Ridge structure, the Sequatchie anticline, which occurs within the Plateau. The Tennessee River has eroded its valley along the axis of the anticline from the Alabama-Tennessee state line to a point near Guntersville, Alabama, where the river leaves the anticline to flow west (Fig. 1).

In northeastern Alabama, the Plateau surface dips gently from an elevation of 1800 ft at the Alabama-Tennessee line to 1100 ft near the Tennessee River at Guntersville. Relief is 500-700 ft in most areas, but may be considerably less where outlying remnants of the Plateau have lost their protective caprock and are being rapidly lowered.

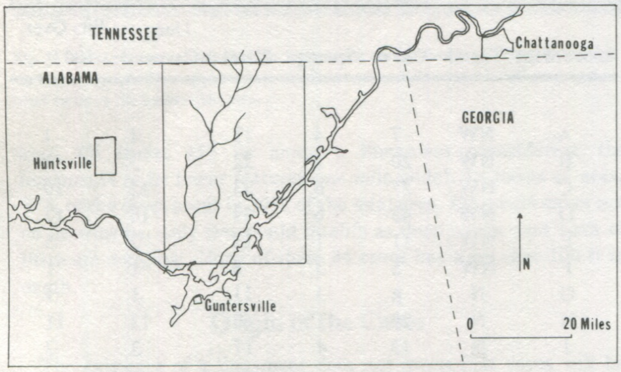

Fig. 1. Location map showing the drainage of the Paint Rock River and adjacent areas of of the Cumberland Plateau studied in this paper.

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Definitions

For the purpose of this study, caves will be classified as "simple" or "complex". A simple cave is one that can be easily represented in a two-dimensional plan view. Passages are small-to-moderate in size, few large chambers occur, and pits and domes are usually less than 100 ft in vertical dimension. A complex cave is one with multi-level passages, parallel pit development (*i.e.*, separate pits developed at approximately the same level within the cave), large chambers, large passages, and great depth that is usually achieved over a short horizontal distance.

By definition, complex caves are deep caves, but a simple cave will also be referred to as "deep" if it has at least 100 ft of vertical development within a horizontal distance of 200 ft. This limits the adjective "deep" to those caves with steep vertical development as opposed to those which may attain great depth over a long passage gradient. The three types of caves that result from these definitions are shown in profile in Figure 2.

The structural features to be examined relative to the origin of caves are lineaments. Lineaments are thought to be linear zones of closely spaced vertical fractures (Lattman and Parizek, 1964, p. 79). These zones are more susceptible to weathering processes than is the surrounding rock, resulting in a subtle expression of the feature on the land surface. In some cases, the feature may be visible in the field, but, more commonly, it shows up only on aerial photographs or satellite imagery. Lattman (1958, p. 569) has offered the following definition: "A photogeologic lineament is a natural linear feature consisting of topographic (including straight stream segments), vegetation, or soil tonal alignments, visible primarily on aerial photographs continuously for at least one mile, but which may be expressed continuously or discontinuously for many miles."

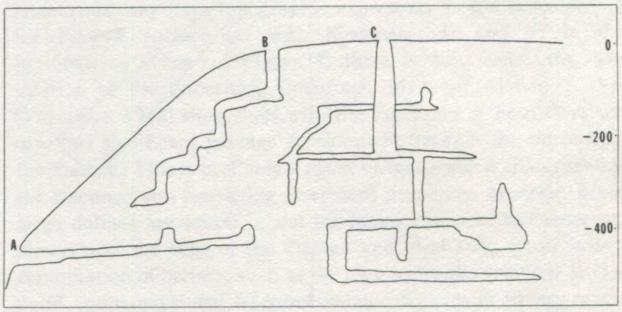

Fig. 2. Profiles of the three types of caves resulting from the definitions used in this article. A—simple cave; B—deep simple cave; C—complex cave.

Valley Trends and Lineaments

The valleys in this region, locally referred to as coves, are steep-walled re-entrants into the Plateau with flat, alluvium-covered floors. They form by sapping of the sandstone caprock as the underlying limestone is dissolved (Hack, 1958). The horizontal bedrock of the area offers no lithologic control of valley development, so that any preferential orientation of the valleys may reflect structural features.

The drainage basin of the Paint Rock River was studied, using topographic maps. Each valley within the basin was divided into straight segments whose length and orientation were recorded. The rose diagram (Fig. 3) summarizes these measurements. The diagram shows a strong NW-SE trend and a smaller N-S trend.

The preferred orientation of the valleys can be explained as preferential weathering along lineaments. Detailed study of topographic maps, aerial photographs, satellite imagery, and NASA aircraft photographs by this writer and other workers has revealed numerous linear elements in the Plateau area of northern Alabama (*e.g.*, Drahovzal, *et al.*, 1974). In the area studied in this report, the most obvious features trend NW-SE and N-S. Similar trends were noticed by the Alabama Geological Survey in a study of an area 100 mi to the south, in east-central Alabama (Powell, *et al.*, 1970). Figure 4 is a drainage pattern map of the area studied in this report, with nine lineaments marked on it. It should be noted that the alignment of streams is only one kind of lineament and, therefore, this map is illustrative rather than definitive.

Lineaments are believed to be zones of closely spaced fracturing, where permeability (and, consequently, solubility) is greater than in the surrounding rock. Where two lineaments intersect, the resulting fracture zone has even greater permeability and solubility (Lattman and Parizek, 1964; Sonderegger, 1970).

Springs and caves are indicators of the increased permeability and solutional activity along lineaments. Table I is a tabulation of known caves and springs along the lineaments shown in Figure 4.

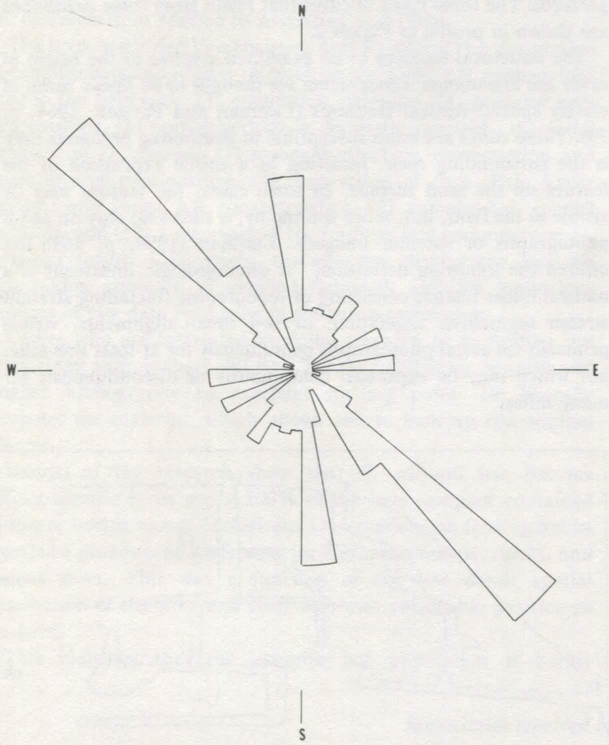

Fig. 3. Rose diagram, showing orientation of valleys in the area studied.

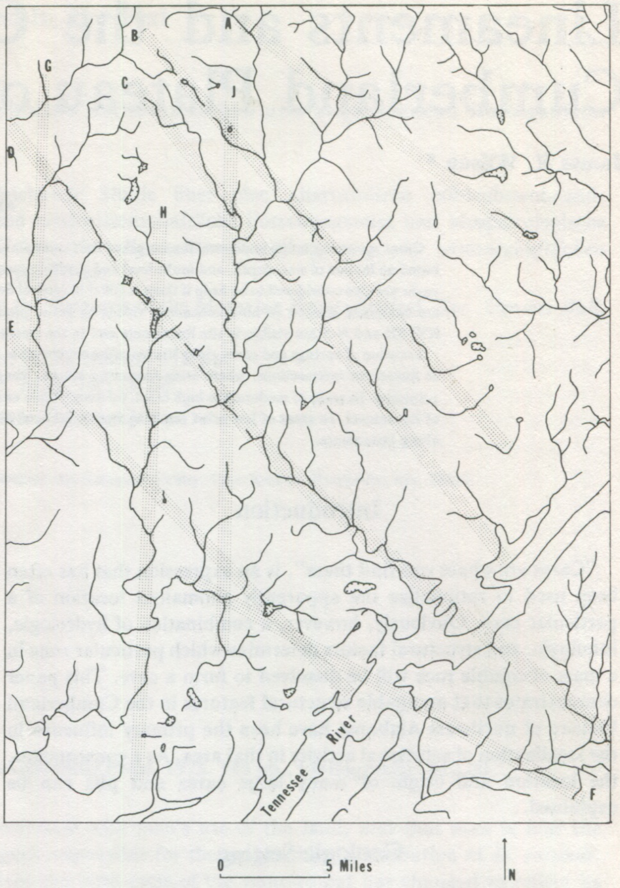

Fig. 4. Drainage map showing nine lineaments that occur in this area. Factors other than straight stream segments may also indicate lineaments. The location of this map is shown by the rectangle in Figure 1.

The number of caves is further broken down to show the number of deep caves (as previously defined) and the number of pits over 100 ft in depth. This table is based on information in the Alabama Cave Survey (Varnedoe, 1973) and on the personal knowledge of this writer.

The results are even more impressive when compared with the number of caves not on lineaments. Considering only the northwest quarter of Figure 4 (where the location of lineaments and number of caves are best known), it is found that there are 149 caves in this

TABLE I. Caves and Springs Along Lineaments

Lineament	Trend	Caves	Springs	Total	Deep Caves	Pits Over 100 ft
A	NW	7	4	11	1	1
B	NW	20	2	22	3	1
C	NW	27	6	33	12	10
D	NW	43	6	49	16	17
E	NW	11	1	12	2	5
F	NW	5	3	8	1	1
G	N	8	3	11	1	1
H	N	29	11	40	12	11
J	N	13	4	17	3	2

Note: Caves discharging water were counted only as a cave, not as a cave and a spring. Caves at the intersection of two lineaments were counted on both lineaments.

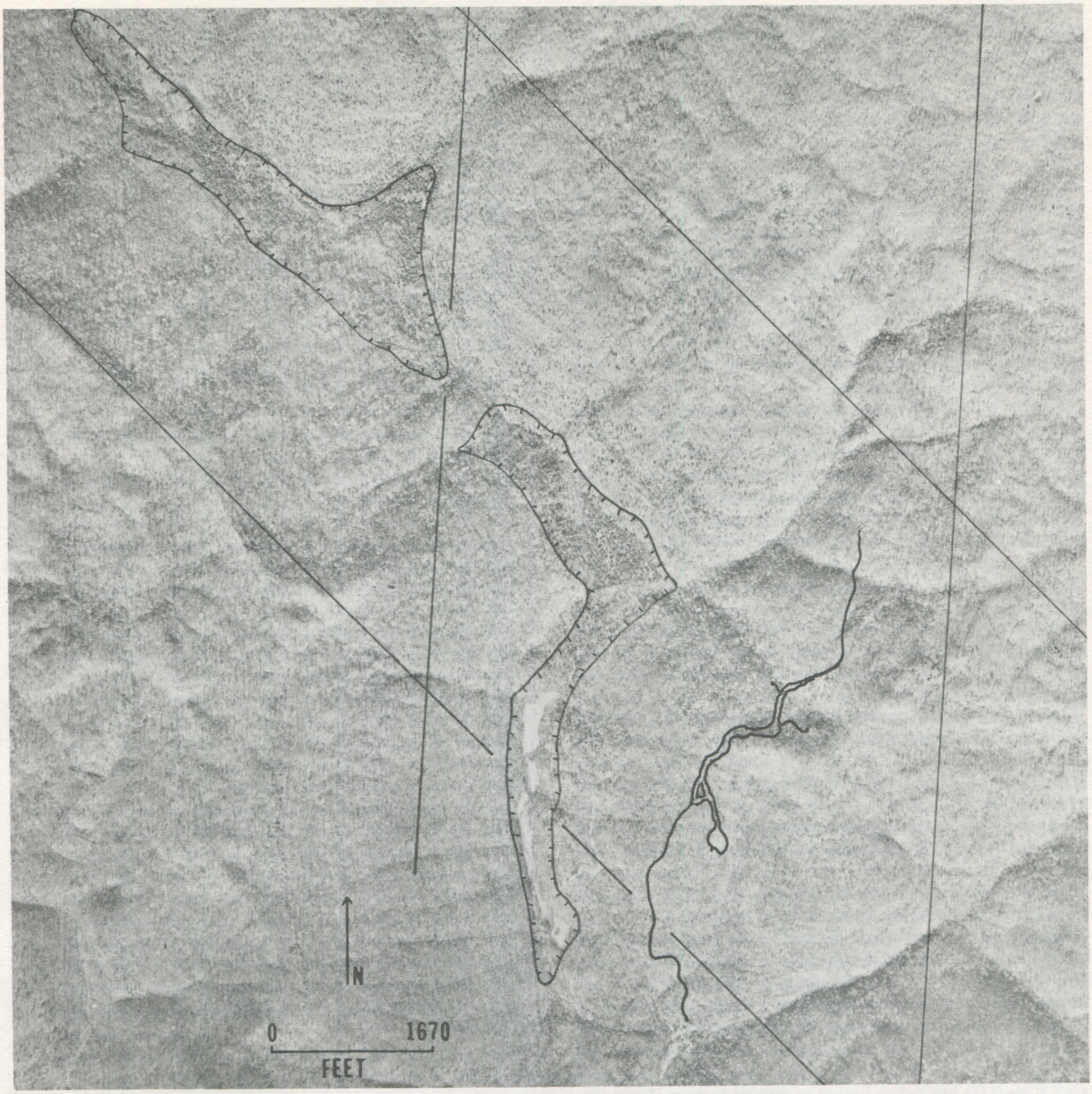

Fig. 5. Aerial photograph showing the intersection area of lineaments D (NW-SE) and H (N-S). An outline map of the Engle Double Pit system and two blind valleys have been drawn on the photograph. The suggested area of influence of each lineament is indicated by the solid lines. Note the aligned streams along lineament D and the right angle bend in the southernmost blind valley in the intersection area.

area. Of these, 115 lie along a lineament (considering the lineaments to be linear features one mile wide). In terms of area, 77% of the caves occur in 30% of the total area. Of the 34 caves not on lineaments, only two would qualify as deep caves, and both of these are marginal. None of these 34 caves has a pit over 100 ft in depth.

Origin of the Caves

The existence of a lineament does not mean that caves will be found everywhere along it. Fracturing of the rock is certainly an incentive for cave development, but other factors must be considered. Probably, the most important is the availability of water. In this regard, it should be noted that, even though lineaments may have topographic expression on the sandstone of the Plateau surface (as with lineaments D and F, in the southeastern corner of Figure 4) there is not, necessarily, any solution of the underlying limestone. Maps of Alabama caves (Varnedoe, 1973) show that, with the exception of Fern Cave, no cave has significant passage development beneath the caprock of the Plateau. This is probably a result of interbedded shales sealing the fractures and restricting downward movement of water. Many large dolines are found in the sandstone caprock, but these are always near the edge of the Plateau and, probably, result from a combination of factors, such as the high hydraulic gradient at that point and expansional fractures created by gravity sliding of the sandstone blocks.

Once the limestone along a lineament is exposed, solution of the rock would be quite rapid. Where streams of aggressive water flow off the sandstone and encounter a fractured zone, the likelihood of a cave forming would be very high. In areas of moderate-to-high relief, solutional activity would tend to produce a deep cave, since the fractures would allow considerable vertical permeability.

When two lineaments intersect, a zone of intense fracturing occurs that may be quite large, depending on the widths of the lineaments and their angle of intersection. This creates a large volume of rock in which water flow is not restricted to any particular direction by a paucity of joints. Block collapse also is facilitated by the cross-fracturing, which leads to the formation of large chambers and passages. Incidentally, the amount of fracturing is probably a determinative factor in the degree and type of speleothem development found in a cave. It might be expected that caves at lineament intersections would be more decorated than other caves in the area. This is the observed situation at the two caves described in the next section.

Because valleys tend to form along the lineaments, intersecting lineaments are often topographically expressed as valley junctions. Degradational processes act very rapidly here, and few caves are preserved. This is the situation we see today. Of the ten intersections depicted in Figure 4, five occur in broad valleys (CJ, DG, DJ, EG, and FJ) and two are in areas of subdued topography with solution valleys and sinking streams (EF and EJ).

Complex Caves

Of the three lineament intersections that occur in limestone and are exposed in the slopes of the Plateau, two are the sites of complex caves. At the third intersection, there are remnants of what was probably another complex cave.

The Engle Double Pit system is at the intersection of lineaments D and H and is an excellent example of a complex cave. It has a 236 ft entrance pit and a parallel 200+ ft dome, the TAG Shower. Bryson's Pit (157 ft) and Rob's Pit (180 ft), both within the cave, are approximately at the same level. In addition to large rooms and passages, five distinct levels have been mapped in the central part of the cave. The cave is 5.4 mi long and 520 ft deep (R. W. Schreiber, personal communication, 1969), with most of this depth achieved in a horizontal distance of a few hundred feet. The intersection area and a simple outline of the cave are shown in Figure 5.

Fifteen miles south of Engle Double Pit, is the intersection of lineaments E and H and another complex cave. Fern Cave has more than 15 mi of multi-level passage and many pits, including 437 ft Surprise Pit. As mentioned earlier, passage in this cave goes beneath the sandstone caprock of the plateau. Since no similar occurrence is known in this area, it is interpreted as another manifestation of the intensive fracturing.

Lineaments B and J intersect in an area marked by six caves and a large collapse doline. The doline, known as Hard Sink, is approximately 1000 ft in diameter and 100 ft deep. It is located on the slopes of the Plateau, several hundred ft above the valley floor and is thought by this Writer to represent collapse of the overlying rock into a large pit or cave system. Similar features would result at Surprise Pit or at the entrance to Engle Double Pit, should collapse occur there.

Conclusions

Other students have remarked upon the association of caves with lineaments (*e.g.*, Hollyday, *et al.*, 1973), but the theme developed here is more specific. In the area studied:

(1) Simple caves may form anywhere, as a result of normal jointing and rock solubility.

(2) In areas of moderate to high relief:

(a) deep, simple caves tend to preferentially develop along lineaments, and

(b) complex caves tend to preferentially develop at the intersection of lineaments.

(3) In areas of low relief resulting from solutional activity, remnants of caves and other evidence of karstification are often

Within any given area factors other than lineaments may exert considerable influence so the above statements will not be universally applicable.

In attempting to confirm the ideas presented above, members of the Huntsville Grotto of the National Speleological Society were contacted with the suggestion that they search three specific areas for caves. Two of these areas were subsequently examined. An area near the intersection of lineaments D and J yielded no new caves. In the second area, along lineament E southeast of its intersection with H, several pits were found including one 130 ft deep. This is the situation to be expected along a single lineament.

Further confirmation of the conclusions of this paper occurred when cavers pushed a known cave on lineament B to a depth greater than 400 ft (Smith, 1975a), then discovered a new cave nearby which reached a depth of 453 ft (Smith, 1975b). In view of these discoveries and the information presented in this paper, cavers should re-evaluate known caves on obvious lineaments.

Although more study is needed to fully substantiate the ideas presented here, it is the opinion of this Writer that the location and gross morphology of many caves in northeastern Alabama, and, perhaps, elsewhere, can be explained as a consequence of lineaments.

Literature Cited

Drahovzal, J.A.; T.L. Neathery; and C.C. Wielchowsky (1974) — Significance of Selected Lineaments in Alabama, **IN**: Third Earth Resources Technology Satellite-1 Symposium:*NASA Spec. Publ.* **351(1)**:897-918.

Hack, J.T. (1958) — Interpretation of Cumberland Escarpment and Highland Rim, South-Central Tennessee and Northeast Alabama: *U.S. Geol. Survey, Prof. Paper* **524**:C1-C16.

Hollyday, E.F.; G.K. Moore; and C.R. Burchett (1973) — Preliminary Assessment of a Tennessee Lineament, **IN**: University of Tennessee (Tullahoma) Space Institute, Remote Sensing of Earth Resources, Vol. 2, pp. 119-128.

Lattman, L.H. (1958) — Techniques of Mapping Geologic Fracture Traces and Lineaments on Aerial Photographs: *Photogrammetric Eng.* **24**:568-576.

——————— and R. R. Parizek (1964) — Relationship between Fracture Traces and the Occurrence of Ground Water in Carbonate Rocks: *Jour. Hydrol.* **2**:73-91.

Powell, W.J.; C.W. Copeland; and J.H. Drahovzal (1970) — Delineation of Linear Features and Application to Reservoir Engineering using Apollo 9 Multi-Spectral Photography: *Ala. Geol. Survey, Inf. Ser.* **41**:1-37.

Richard Schreiber, Rt. 2 Box 6, Rising Fawn, Ga. 30738.

Smith, M.O. (1975a) — Discoveries: *NSS News* **33**:71.

——————— (1975b) — Southeastern Area: *NSS News* **33**:196.

Sonderegger, J.L. (1970) — Hydrology of Limestone Terranes—Photogeologic Investigations: *Ala. Geol. Survey, Bull.* **94**:C1-C27.

Varnedoe, W.W., Jr. (1973) — Alabama Caves and Caverns: privately published, 45 pp and maps.

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Alternatives to the Letter Writing Approach in Conservation

Gene Hargrove *

ABSTRACT

The traditional, letter-writing, approach to the solution of conservation problems is often ineffective, because it reveals the conservationists' weaknesses and generates hostilities without producing the desired results. An alternative approach, useful in attacking land-use problems at lower governmental levels, is action by a Conservation Task Force (CTF) to obtain official coöperation. Such action involves support from the NSS Board of Governors, a carefully prepared CTF report, an efficient organizational structure, the use of outside advisors, and careful, secret (behind-the-scenes) preparation, including the development of a favorable press and close contact with public officials. It is less likely to create adversary relationships and leaves the power base ambiguous, resulting in greater effectiveness.

Introduction: The Failure of Traditional Methods

Over the years, a traditional approach to conservation problems has developed. This approach involves starting a committee, seeking public support, and influencing public officials through letter-writing campaigns. In this paper, I will offer an alternative to this approach.

I am offering alternative suggestions because I have come to believe that, in most cases, the letter-writing technique is slow and inefficient, and I do not believe that it will work at all for most of the problems facing NSS conservation activists.

As many football coaches have noted, when someone throws a pass, three things can happen and two of them are bad. The situation is similar in the letter-writing campaign.

If the campaign involves enormous numbers of people in good cross section, it can be quite effective. However, (1) the letter-writing campaign quantifies exactly the community support for a conservation issue (and if it demonstrates lack of public support, it can be akin to cutting one's own throat), (2) the campaign may reveal to the recipient of the letters that the support, even when substantial, is not from people whom he considers politically important, (3) the campaign may generate letters so garbled that only a general positive attitude toward the cause is apparent, without communicating an expected course of action, (4) the letter campaign can generate open hostility toward the conservation cause by irritating the recipient, who might have prefered the chance to settle the issue without a big hulla-baloo, and (5) the letter campaign may turn the attention of the recipient away from the issues to an analysis of who started the campaign and how, and who responded.

Generally, public officials prefer to pick their own issues and control them and are likely to be much more responsive if contacted in advance for advice and coöperation.

In my opinion, the conservation movement's primary successes have, to date, been in opposition to the actions of government and big business due to a general national distrust of these segments. Many cave-conservation problems, however, will involve caves which do not have national or state significance and whose destiny must be resolved at the county level. The most obvious tool, at this level, will be county zoning, a tool available at almost any place in the United States where caves are located on private property.

Land Use Problems and Solutions

At this point, I should define a conservation problem for the purposes of this paper. I am not concerned here with cave traffic or cave vandalism; I mean a problem involving improper land use by property owners or land managers—improper land use which will cause the destruction of the cave life or of the cave itself (particularly water pollution, quarrying, etc.).

While they may not work in all cases, the alternatives which I consider to be most useful to cave conservationists are (1) action through an NSS Conservation Task Force (CTF), (2) legal action through state land fraud laws, water pollution laws, or other land use statutes, (3) county zoning, and (4) a large-scale educational program aimed at changing the attitudes of the people toward the preservation of natural phenomena, living and non-living.

Such an education program is beyond the scope of the present discussion, but is important and necessary. The major conservation effort in the NSS today, at the member level, is oriented toward keeping the general public ignorant of caves in order to prevent increased traffic and possible exploitation. This policy lacks foresight, in that we can hardly expect the general public to support specific cave conservation efforts and legislation if they are kept ignorant of the value and importance of caves and the consequent need to protect them.

Legal action is unlikely to gain popular public support; and, unless the state or local prosecutors are willing, it is unlikely that it will get off the ground. Because of high costs, legal action will require public support and the attendant large scale educational program.

Zoning is a viable alternative, provided the county officials can be convinced of the importance of cave protection measures, based on the need for public safety, consumer protection, and prevention of public health problems which might develop as a result of improper use of the land over the endangered cave.

Unlike the educational program, legal action and zoning can be included in the first listed alternative, action by an NSS CTF. I will be concerned with this alternative for the balance of this paper, dealing specifically with cases in which (1) the problem cannot be completely resolved by state or federal action and (2) there is little likelihood of adequate numerical support through a grass-roots letter-writing campaign. In other words, these are suggestions on how to succeed without broad public support.

This approach involves close coördination with state officials and agencies, careful preparation of a specific course of action, careful preparation of the news media to cover the CTF's effort and to give the illusion of public support, and the actual carrying out of the dramatically staged course of action with careful timing. This may involve one to two years preparation during which the project is kept secret followed by a short, but intensive public effort.

Main Elements

NSS Support

The CTF must have an official position approved by the NSS Board of Governors, defining alternative courses of action. The

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position must be general, in order to allow compromises in obtaining support from local factions. The Devils Icebox CTF, for instance, ended up resolving most of its problems midway between the first and second level recommendations of the Board of Governors.

Task Force Report

The CTF must begin, immediately after its formation, to prepare a CTF report. Optimally, this report should be multipurpose, providing both technical information for government agencies and readable information for the general public. The Devils Icebox CTF (Hargrove, 1973) accomplished this, primarily, by general introductions and numerous illustrations. In fact, farmers wives called me to say that the CTF report was so intriguing that they could not put it down. At the same time, technical and scientific aspects were not sacrificed.

Organizational Structure

The most difficult problem is CTF structure itself. In most cases, one person emerges as the moving force behind the entire operation. While out of keeping with the view that the CTF should operate democratically on the basis of committee meetings, such a leader is operating on a basis which is comparable to the administrative structure found in almost every business, administrative agency, and the American military. The most efficient organizational structure is one in which some one person is ultimately responsible, with others performing specific tasks under his (or her) direction. If the leader performs well, the CTF should move forward far more efficiently than it would if it were governed in all respects by committee action. The strength of this structure is that it permits decisions to be made on a timely basis, covering subtle differences which a committee cannot really handle.

Under this structure, a CTF chairman should never embark hastily upon a course of action. He should seek the advice of the CTF members and interested advisory personnel and determine that the action is acceptable and likely to be effective.

Psychological studies in chess decision (A.D. deGroote, analyzed in Hargrove [1974] pp. 103-220) have shown that a player often develops feelings very much like foreknowledge, which give an indication of what he may maximally and minimally expect to accomplish. The player investigates courses of action until he finds one which closely approaches his maximum level of expectancy. Such mental techniques do not ensure that the decision is correct. In fact, we must realize that situations are normally so complicated that a right solution, in an absolute sense, is beyond calculation. Still, feeding the information through the ultimate responsible person in the organizational structure does provide adequate solutions in most cases, even though they may not always be the optimum.

Outside Advisors

In order for this system to work, the CTF chairman must surround himself with advisors who are experts in their fields. These advisors need not be NSS members, or even CTF members. The Devils Icebox CTF used a local advisory staff of over 25 people, including: professors of sanitation and agricultural engineering, three biologists, the head of the health department, the head of the city parks and recreation department, a professor of law, a former assistant attorney general, the representatives of the clean water commission, representatives of the park board, representatives of the geological survey, coördinators with such groups as the League of Women Voters and the Sierra Club, and several local politicians who provided extensive behind-the-scenes support and advice even though not committed publicly.

Because of their diverse backgrounds and knowledge of local conditions, these advisory personnel (who had no official connection with the CTF) were often more instrumental in reaching correct decisions than the members of the CTF. The CTF Chairman should enlist such advisors early in the effort.

In the case of the Devils Icebox CTF, most CTF members performed specific functions at some point in the effort, added the prestige of their names, and otherwise remained outside of the CTF decision-making channels. Decisions were made by a small steering group, tempered by the advice of the NSS Conservation Chairman and the local non-NSS advisors.

Goals, Planning and Secrecy

If the conservation effort is to be successful, some realistic goal must be formulated and pursued, including intermediate steps in the process. This effort must involve extensive and continuing contact with public officials and agencies and various private groups. All persons who may feel involved *must* be contacted and their opinions taken into consideration. Those who are not involved may well throw a wrench into the gears when you crank up the machine.

With the Devils Icebox, this approach worked very well at the state level, with the State Park Board adopting much of the NSS position and the Clean Water Commission endorsing that position. These actions did not occur accidentally. They were the result of two years of coördination with the state agencies.

In general, I believe that preparation for the CTF effort should be kept secret (*i.e.*, premature public exposure should be avoided) until everything is ready. Essentially, things are minimally ready when a report can be handed out to anyone who might potentially object to the CTF position. If CTF public exposure occurs before it can adequately present its case, opponents are likely to discredit the CTF by raising issues which the CTF cannot yet resolve.

In my opinion, this need for secrecy discourages the CTF from seeking local financial support until after it is ready for public dialogue, which is in complete disagreement with present NSS policy encouraging CTF's to seek local financial support from the very beginning.*

The essential problem with the NSS approach is that the public and the newspapers will remain intensely interested in a project for only a short time. In the case of the Devils Icebox CTF, media coverage included favorable daily news articles for almost two months. After that, it became very difficult to get news coverage at all.

A general fund-raising campaign may decrease subsequent press coverage and public interest at the critical moments. In addition, it may warn potential opponents, who can then prepare to block the CTF objectives.† If secrecy is maintained, however chances of success are increased and the possibility of impressive news coverage is heightened.

Initial preparation should be viewed as similar to the staging of a dramatic presentation. The CTF chairman should have his primary and secondary courses of action set up in such a manner that, barring unforeseen difficulties, the public effort will be nothing more than the public enactment of a pre-arranged plan delineated with appropriate governmental authorities and agencies.

* *Editor's note*: That policy has recently been modified; interest-free loans from the NSS Save-the-Caves Fund are now available to CTF's.

† Secrecy applies to the public, not to your opponents. You should be in close contact with the latter. Opponents will not react or take the CTF seriously, in most cases, until its activities are being covered by the news media. The Devils Icebox CTF coördinated its activities with all of its opponents, who, in turn, pretended to coöperate, until the media campaign began. Confidential coördination between a CTF and its opponents is one of the best ways to prepare for the public effort. Opponents will probably be willing to speak with CTF representatives in order to learn something about the CTF and its objectives. In many cases, opponents will do nothing, hoping that the CTF will never complete its preparations.

Preparation and Timing

It should be especially stressed that the effort sketched here requires in-depth preparation and exact timing. Two points need to be emphasized:

Publicity. It is necessary to develop a favorable press before you begin. Hopefully, the CTF can gain an introduction to the press through an interested local public figure. Once contact is established, someone in the press should be given background in depth but be kept from printing until the CTF is ready.

Despite tendencies toward inaccuracy, newspapers do operate, for the most part, in terms of a code of ethics. If you ask them not to do something and appear to take them into your confidence, there is every likelihood that they will coöperate. In addition, the background period will often prepare the newspaper reporter psychologically so that he (or she) will gradually develop a sense of tension which may be unleashed when you give them the word, thus guaranteeing major emphasis in the paper.

By means of news releases, press coverage can be continued even without complete coöperation from newspapers. These should be one page, double-spaced, with short paragraphs (in the style of a newspaper story), and with the exact date and time of release noted. Since radio stations generally have inadequate staffs, they will likely use almost anything which is both newsworthy and of local interest. Using the lead paragraph plus one additional item from the text (until all points have been aired), radio news broadcasts will attempt to give the illusion of continuing coverage during the day. Such radio coverage will often force newspapers to use the story, as well.

Letters to the editor, because they represent the views of a single individual or group, carry less weight, and should be used only as a last resort. However, letters to an offending official, used as a basis for a news release, are one of the broad range of actions available to the CTF about which a news release may be prepared.

Timing is important in getting out the news. Continued coverage can sometimes be achieved (especially after an unfavorable event) by releasing information about the *possible* courses of action that the CTF is considering. This procedure both allows time for further consideration of the action and creates a need for a follow-up story if the first is used. In addition, this approach has more dramatic impact. For instance, a story that the CTF is *thinking* about contacting the governor, etc., followed by a story that the CTF did contact the governor, is more likely to focus public attention on the action and issue longer and more deeply than a single story about the appeal to the governor.

Negotiation. Close contact with the public officials and agencies (the ones who generally receive those letters) should permit the officials to coöperate with the CTF most effectively. Unlike the letter campaign, this approach permits the target official to prepare himself and reach some agreement with the CTF before he undergoes public scrutiny. Also, in my own experience, I found that the public officials were worried about related issues and problems which I had failed to recognize or had not considered significant. My direct contact with these people permitted me to locate and eliminate these potential blocks before they could become a hindrance.

This approach has the important advantage of avoiding an adversary relationship. Once such a relationship is established, the possibility of coördination and compromise is almost completely eliminated, and the possibility of quick, favorable action is drastically reduced. The letter campaign is much more likely to create these inhibitive adversary relationships. The method of personal contact described above permits maximal opportunity to join the bandwagon without public embarrassment, since it does not involve early public opposition. Further, these officials are unlikely to oppose ideas and policies which they feel they have helped to create.

Finally, the method of personal contact preceding public action leaves the CTF's power base ambiguous and makes the CTF potentially more threatening than had the base been clarified by a letter-writing campaign. In this connection, extensive coördination with state officials and agencies and with various conservation and political organizations (even when they cannot directly influence the issue) presents a web of connections to the local politician which will probably make the CTF appear much more credible and powerful than it really is. Once these various factions are directed toward CTF goals, they represent a significant power base which can carry forward the desired action in a natural and seemingly inevitable manner.

Summary

In this paper, I have been critical of letter-writing campaigns and have presented some methods, which I called "alternatives," to that approach. I do not want to claim that there are never circumstances in which letter-writing campaigns are appropriate and, perhaps, even the best course of action; however, I do feel that the methods described above will often work when the letter approach will not, and that they will also be effective in circumstances favorable to letter campaigns, either in conjunction with them or in place of them.

In those cases where a group elects to undertake a letter-writing campaign, I would recommend that it be preceded by careful preparation of the type discussed in this paper. When broad public support does exist, the letter approach may be an excellent way to demonstrate this support. The letter campaign, however, should be coördinated with the politicians or agencies involved and should have a definite, well-thought-out objective.

Acknowledgements

The author wishes to express his thanks to W.P. Bishop and to R.R. Stitt for extensive and creative editing of the text.

Conservation Editor's Note: KEEP THOSE CARDS AND LETTERS COMING! Cards and letters from constituents and a watchful public *do* play an important function. They carry the clear message that someone out there is watching, and they do receive a thoughtful reading—all of them, particularly when the public comment is requested by or required of the agency. As Gene Hargrove suggests, there are better ways to shape policy. But, those cards and letters accomplish one important goal—they assure that an action will not be taken without the knowledge that someone approves or disapproves. Your letter may not get them to do what you want, but you may be sure that it will tell them what you want and cause at least one person on the staff to think about it.

Literature Cited

deGroot, A.D. (1965) — Thought and Choice in Chess: NYC, Basic Books, 463 pp.

Hargrove, Gene (1973) — Report of the Devils Icebox-Rockbridge Park Conservation Task Force: *Mo. Speleol.* **13**:58-106.

———— (1974) — Wittgenstein and Ethics: Univ. Mo.-Columbia thesis, 360 pp.

Naturally Formed Mudballs in an Iowa Cave

Stewart B. Peck*

ABSTRACT

Naturally formed mudballs, composed of clay, silt, and sand, with a concentric internal structure, occur in one room of Hunters Cave, Iowa. They probably formed with the aid of a flowing silt-laden stream, as did the skullites of a New York cave, but streams are not now present in Hunters Cave.

The purpose of this note is to describe the occurrence and possible modes of origin of mudballs found in Hunters Cave, Jackson County, Iowa. The mudballs occur only in the Paradise Room (indicated as site 38 in the map in Christiansen, 1961) and were present when I discovered the room by digging open its low crawlway entrance. The room is roughly rectangular in plan, with a maximum width of about 10 m and an average ceiling height of 1.5 m. Many phreatic solution pockets are present in the Niagara (Silurian age) dolomite wallrock of the room. The mudballs occurred in shallow depressions in the flat silt floor at the room edges, where the solution pockets form alcoves with the floor. From seven to about 40 loose mudballs were in each depression, and the balls individually ranged from 10 to 40 mm in diameter, with most being about 20 mm (Fig. 1). They were imperfectly spherical, and some had conspicuously flattened areas.

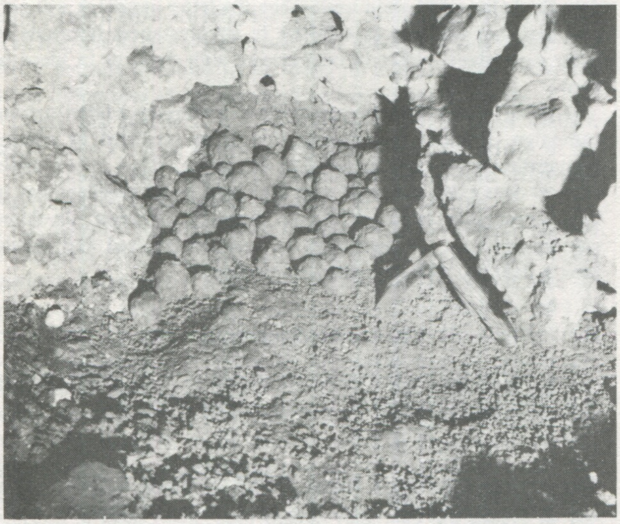

Fig. 1. A nest of naturally formed mudballs in Hunters Cave. The position of the balls has been reconstructed, since their original position was disturbed by dirt from a nearby excavation. Knife for scale.

The balls are mostly composed of a fine, dark silt. Clear quartz sand and irregular masses of tan clay are scattered throughout, and the clay is vaguely arranged into an indistinct series of concentric shells. No definite nucleus is present. The balls contain no minerals that effervesce in hydrochloric acid. In water, they soon separate into individual silt, clay, and sand particles. The largest sand grains are less than 0.1 mm in diameter. The balls may have some organic content because, when sealed in a container for two weeks to preserve their moisture, a white mold grew over them.

The method of formation of these balls is of interest. Haas (1927) described one mechanism for the origin of naturally formed mudballs. When blocks of clay are undercut and fall into a moving body of water, their corners are softened and worn away, and a spherical mass results. Kindle (1923, p. 635) notes the presence of such balls along the Bay of Fundy. Bull (1965) has observed balls formed in this way ranging in size from 1 inch to 2 feet in diameter in California. However, formation of the Hunters Cave mudballs in this manner is unlikely because clays from banks, or from clay lumps eroded from dolomite solution pockets, are generally of a more uniform composition, are unstructured or flatly layered rather than being concentricly layered, are relatively impervious to water, and do not disintegrate quickly.

Gardner (1908) described a process which seems a more adequate explanation. When being carried in overloaded or "super-concentrated" water, fine clay particles may adhere together with or without a nucleus. A soft nodule will form, grow, and become rounded by rotation, gathering particles as it is propelled by currents. The limit to the ball size is dependent on the strength of the current. Patton (1922) observed balls supporting Gardner's hypothesis.

Bell (1940), Leney and Leney (1957), and Kugler and Saunders (1959) observed situations intermediate to these two, in which balls were moulded and abraded from pieces of material from the sides of a stream channel and then grew by accretion until they were armored with pebbles. Such balls must form and be deposited quickly before the core becomes wet, or they would be destroyed in transport.

Gardner's hypothesis can thus explain the concentric layers of the Hunters Cave mudballs, but questions yet remain. Were variations in currents responsible for grouping the balls along the room edge? And while this method of mudball formation may occur in the arid and flashflood prone southwest, where flowing water can become overloaded with clay), it seems less liely to be applicable to Hunters Cave, which has no streams, nor any wallrock scallops indicating the former presence of streams, and is not known to capture any surface flood waters. If running water was instrumental in making these mudballs, it must have been under conditions no longer in existence.

Lastly, Kastning and Queen (1973) have proposed that fixation of sediments in flowing water in caves may be by bacterial action. They report a sedimentary structure, called "skullites", that is similar to Hunters Cave mudballs in that a skullite is composed of silt and sand in concentric layers, is 10 to 20 mm in diameter, and occurs in nests. Kastning and Queen suggest that local flood water currents and, perhaps, bacterial sediment fixation may have formed skullites. Demonstrating even a partial bacterial responsibility for the Hunters Cave mudballs, while it may be true, may no longer be possible.

Specimen samples are deposited in the petrology collections of the United States National Museum of Natural History, Smithsonian Institution, Washington, D.C. Dr. William B. White kindly reviewed a preliminary manuscript.

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Literature Cited

Bell, H.S. (1940) — Armored Mudballs: *Jour. Geol.* **48**:1-31.

Bull, W.B. (1965) — Alluvial Fans and Near Surface Subsidence in West Fresno County, California: *U.S. Geol. Survey, Prof. Paper* **437**:A1-A71.

Christiansen, K.A. (1961) — The Collembola of Hunters Cave: *NSS Bulletin* **23**:59-63.

Haas, W.H. (1927) — Formation of Clay Balls: *Jour. Geol.* **35**:150.

Gardner, J.H. (1908) — The Physical Origin of Certain Concretions: *Jour. Geol.* **16**:452-458.

Kastning, Ernst and Michael Queen (1973) — Skullites—Unusual New Sedimentary Formation Discovered in Skull Cave, New York (*abs*): *NSS Bulletin* **35**:29.

Kindle, E.M. (1923) — Range and Distribution of Certain Types of Canadian Pleistocene Concretions: *Geol. Soc. America, Bull.* **34**:609-648.

Kugler, H.G. and J.B. Saunders (1959) — Occurrence of Armored Mud Balls in Trinidad, West Indies: *Jour. Geol.* **67**:563-565.

Leney, G.W. and A.T. Leney (1957) — Armored Till Balls in the Pleistocene Outwash of Southeastern Michigan: *Jour. Geol.* **65**:105-106.

Patton, L. (1922) — In Support of Gardner's Theory of the Origin of Certain Concretions: *Jour. Geol.* **30**:700.

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Selected Abstracts From Recent Meetings

NSS Convention, Decorah, Iowa, 13-15 August 1974

Speleo-Rosette, A New Speleothem Term: A Nomenclature Revision of the Term—Oulopholite

Angelo I. George*

This paper revises a morphological classification of the rosette-oulophlite nomenclature of Locke (1842; and an unlocated paper circa 1842-1844). White (1968) suggested three currently acceptable synonyms for oulopholite((1) gypsum flower, (2) fleurs de gips, and (3) rosette. A new term, "speleo-rosette" is proposed for a special crystal habit or aggregate occuring in caves. Speleo-rosettes show great similarity to the selenite rosettes described from the coastal mudflats of the Laguna Madre, Texas and from the Trucial Coast of Saudi Arabia. Their crystal habit is distantly related to that of the barite and calcite sand crystals described by Pettijohn (1949).

A speleo-rosette is hereby defined as a crystalline selenitic aggregate which displays symmetric, semi-symmetrical, or radiating crystal growths. Its development is primarily by the accretion of single discoid or blade euhedral selenite crystals (c-axis parallel to the plane of flattening) showing interpenetration, giving rise to subparallel to radial arrangements extending away from the point of attachment (walls, ceilings, floors, breakdown, or other speleothems). As crust, stalactites, stalagmites, columns, and nodules, their interiors are often a dense meshwork of dicoid crystals having a coarse or porous appearance. Stalactitic forms often have large, hollow interiors and thin walls lined by mega (macro) drusy selenite crystals extending inward into the void. A middle portion consists of gypsum grains which are intergrown rosettes whose c-axes are perpendicular to the stalactitic growth axis, giving a radial appearance extending outward from the central void. The outer layer is covered by large blade and/or discoid selenite rosettes.

Crusts, like stalactites, may not be related to pores, interstitial openings, joints, or bedding planes. Speleo-rosettes, instead, suggest an analogous diagenesis to terrestrial mudflat selenite rosettes. They were precipitated from the interiors of cave passages filled with sediment. Cave fill acts as an aquifer transmitting a concentrated charge of calcium sulfate. Precipitation occurs interstitially within the host sediment; speleo-rosettes are, therefore, post-depositional in origin.

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An Ecological Study of Blanchard Springs Caverns, Arkansas

James L. Grove, Jr. * and Michael J. Harvey *

Blanchard Springs Caverns is located in the Ozark National Forest, north-central Arkansas. The caverns are being developed as a tourist attraction by the U.S. Forest Service. An ecological study of 2.6 miles of passage not yet open to the public was conducted from November 1972 to December 1973. Temperatures, including maximum and minimum between visits, and relative humidities were recorded at 25 stations every three weeks. Near the entrance, temperatures fluctuated between -7C and 14.5C; they remained a constant 14.5C deeper in the cave. Relative humidity was generally 100%. Stream alkalinity, hardness, pH, and dissolved oxygen were measured and found to vary only slightly throughout the year. Approximately 50 species of animals have been recorded.

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Fig. 1. Map of the upper Elk River basin: 1. Beales Insurgence, 2. Linwood Spring, 3. Mill Run Spring, 4. Whirlpool Sink, 5. Split Rock Spring, 6. Cemetery Swallowhole, 7. Sharps Cave, 8. Big Spring Fork Spring, 9. Old Field Fork Spring, 10. Mill Creek Sink, 11. Douglas Fork caves, 12. Simmons-Mingo Cave, 13. My Cave, 14. Sink of the Elk River (Black Hole), 15. Falling Spring Cavern, 16. Elk River springs.

Karst Hydrology in the Upper Elk River Basin, West Virginia

Douglas M. Medville*

ABSTRACT

Characteristics of subsurface flow through a karsted limestone aquifer in eastern West Virginia were studied, using stream tracing techniques and surface and subsurface surveys. The aquifer consists of gently dipping limestones of the (Mississippian) Greenbrier Group and can be characterized as free-flowing with capping and perching beds. The locations of major resurgences are influenced by these beds. The study area is 92 sq mi in area and comprises the upper part of the Elk River drainage basin. Although carbonate rock in the area crops out over only 6 sq mi, it is exposed in and immediately adjacent to the streambeds of the area. Consequently, while karst features are limited, all runoff from the area enters the aquifer, flows generally downdip for distances of up to 9 mi and, ultimately, rises at a second-magnitude alluviated spring at the northern end of the area. Subsurface flow is usually well behaved. The valleys are underdrained, generally via solutionally enlarged bedding-plane partings. The northern part of the study area is traversed by a major lineament trending N65°E. Over half of the known cave passages in the area are developed along this lineament. The entire flow of the Elk River sinks as it crosses the lineament, and interbasin transfer of water takes place along it. Previous findings, that the water table is represented by the major cave streams at base-level and, indeed, that these streams determine their own water-table gradients, are confirmed.

Introduction

The headwaters of the Elk River are located in northern Pocahontas and southern Randolph counties, West Virginia and drain an area of 92 sq mi. In this paper, the upper Elk River basin is defined as that area drained by the Elk, lying south of Valley Fork of the Elk. (Fig. 1). This junction coincides with the northernmost exposure of limestones of the Greenbrier Group in the Elk River drainage. Average annual precipitation is 48 in. The population, concentrated at the communities of Slaty Fork and Linwood, is under 400.

The Elk River, a northward flowing tributary of the Ohio, rises in the Allegheny Plateaus province. Headwater ridges reach elevations of 4200 to 4500 ft and consist of rocks of the (Upper Mississippian) Mauch Chunk and (Lower Pennsylvanian) Pottsville formations. The area is deeply dissected. The Elk River and its tributaries range from 2300 to 3000 ft in elevation and flow through narrow, steep-sided valleys. The youngest rocks exposed in the area are those of the (Middle Mississippian) Greenbrier Group, a sequence of limestones containing thin, interbedded layers of shales and sandstones. A complete description of the Greenbrier Group can be found in various county geological reports of the W. Va. Geological and Economic Survey, in McCue, *et al.* (1939), and in Wells (1953). Locally, the Greenbrier Group is about 320 ft thick. Figure 1 is a planimetric map of the geology and hydrology of the study area. The top of the Greenbrier is exposed only along and immediately adjacent to the beds of the Elk and its tributaries and, consequently, can be seen in only 6 of the 92 sq mi in the basin. Features characteristic of karst, such as swallowholes, sinks, and blind valleys, are not nearly as prominent as in the aerially extensive limestone outcrops found further south in the state and described in White and Schmidt (1966) and in Jones (1973).

Structure

The major geologic structure in the study area, the Deer Park anticline, trends N20°E and crosses the eastern part of the drainage basin. The larger part of the basin and all significant karst features lie to the west of the anticlinal axis, where the regional dip is 3 to 4 degrees to the northwest. Faulting in the study area is limited, typically consisting of low-angle thrust faults, with displacements of up to a few feet. One other structural feature should be noted—a fracture zone trending N65°E across the northern part of the study area. This feature plays a significant role in the hydrology of the area and will be discussed in some detail below.

Stratigraphy

That part of the Greenbrier group exposed in the study area is described below, in ascending stratigraphic order. In general, descriptions are taken from Price (1929) and are supplemented by observations made in the course of field work.

Patton limestone

Dark grey, partly oölitic, sandy and impure, with stylolites in upper part. Only the upper 20 ft are exposed in the study area, along U.S. 219, 0.5 mi west of Linwood.

Taggard shales and limestone

This consists of a lower red shale, 15 ft thick, a limestone about 5 ft thick, and an upper red shale, 10 ft thick. While its surface exposure is limited to the area just west of Linwood, the upper Taggard shale can be seen in several caves. As an aquitard, it plays a major role in exerting stratigraphic control over subsurface drainage in the study area.

Pickaway limestone

Hard, stylolitic, weathers yellow and varies in thickness from 30 to 40 ft. In the study area, several caves are found in it, just above its contact with the underlying upper Taggard shale.

Union limestone

The major cave former in the study area: 135 to 150 ft thick and in two parts. The lower (Fredonia) portion, 60 to 70 ft thick, is light grey, slightly sandy, oölitic, and, near its base, crossbedded. Separating the lower portion from the upper (Gasper) portion is a 5 ft thick sandstone bed (Bethel sandstone). This member serves as a minor perching bed. Several shafts are formed just below it. The upper portion of the Union limestone is 70 to 80 ft thick and is lithologically similar to the lower portion.

Greenville shale

A light-grey, thin-bedded, calcareous shale, 18 to 20 ft thick. A major aquiclude, it separates the Alderson limestone above from the main carbonate sequence of the Greenbrier group below.

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Alderson Limestone

The youngest member of the Greenbrier group, dark-grey, shaley, weathering yellow, 40 ft thick. It is not a significant cave former in the study area.

Methodology

Field work in the study area was undertaken by many individuals over a period of 8 years. Surface reconnaisance has resulted in the discovery of all major springs, swallow holes, sinks, and over 100 cave entrances. At the downstream end of Dry Fork of the Elk, where cave development in the study area is most pronounced, distances between and relative elevations of cave entrances and major karst features were determined via survey using a tripod mounted Brunton compass and tape. All caves in the area were surveyed, using either a hand-held Brunton or a Suunto compass/clinometer and tape.

Subsurface drainage routes were traced, using sodium fluorescein dye ($C_{20}H_{10}Na_2O_5$). Activated coconut charcoal (6-14 mesh) in screen mesh containers were placed in suspected resurgences for each trace conducted. Detectors were left in place for a period of time sufficient for the dye pulse to pass through and were then removed. Dye was elutriated from the charcoal by placing it in a 10% solution of KOH in ethanol. The presence of adsorbed dye was determined using a Turner model 111 fluorimeter.

The combination of cave surveys and dye traces have resulted in a fairly complete picture of the nature of the subsurface flow net in the upper Elk River basin. Following several weeks of minimal rainfall in early October, 1974, discharge measurements were taken. At that time, low flow conditions prevailed in the study area, with all discharge consisting of groundwater runoff from the higher clastic rocks surrounding the river valleys. In each major sub-basin and at the downstream end of the upper Elk River basin, streamflow was determined using a wading rod and a low velocity "Price" current meter. These measurements should be accurate to $\pm$ 5% of true discharge.

Regional Karst Hydrology

A general description of karst hydrology in the upper Elk River basin is given below. More detailed discussions of each of the three sub-basins of the upper Elk River follow.

In general, the carbonate sequence in the upper Elk River basin can be described as a free-flow aquifer with capping and perching beds (White, 1969). This aquifer is anisotropic, with subsurface flow concentrated in solution channels generally developed along bedding-plane partings parallel or sub-parallel to the dip. Large, integrated, dendritic caves containing free-surface streams account for a majority of the total discharge. All streams in the basin ultimately sink, with the entire low flow discharge being through a single spring draining the entire 92 sq mi area.

Streams rising on the higher clastic rocks above the Elk and its major infeeders flow on the surface to the upper Union limestone. Within 30 ft of the top of this limestone, these streams either sink into enlarged joints (typically dropping 20 to 60 ft vertically and stratigraphically), or sink into gravel and cobbles in their beds (the actual point of sinking being ill-defined and varying with flow conditions). In the study area, shafts formed by vadose water are almost always found at the Greenville shale/Union limestone contact and, as described in Brucker, Hess, and White (1972) and in Sweeting (1973), convey water vertically from the surface through the limestone to essentially horizontal solutional openings at depth.

The direction of sub-surface flow is controlled by regional structure, the hydraulic gradient following the regional dip to the northwest. This flow is through openings initially developed along bedding plane partings, although cave passages climb stratigraphically in the downstream direction to resurgences at springs at the top of the Union limestone where it passes below river level. This contrasts with the subsurface flow pattern described by Wolfe (1964) for the Swago Creek basin, 25 mi to the south, where both structural and lithologic control of cave passages is absent.

Subsurface flow in the study area is generally, but not always, well-behaved, with valleys being underdrained by streams sinking in limestone and rising at springs several miles down valley. Examples of misbehaved subsurface flow paths (these crossing beneath surface drainage divides), have been observed in the area and will be described below.

The drainage pattern generally observed in the upper Elk River basin, *i.e.*, water moving vertically through joints and then flowing downdip through solutionally enlarged bedding-plane partings, has been previously noted in papers by Baker (1973), Williams (1964), Stringfield and LeGrand (1969), and Medville and Werner (in press). Two exceptions to this pattern in the study area should be noted, however. In the Linwood area, both subsurface flow and valley alignment are along the strike. Caves drop stratigraphically, and springs are on the upper Taggard shale where it is brought to the surface near the axis of the Deer Park anticline. In the northern part of the study area, cave development and the direction of subsurface drainage are controlled by a major fracture zone crossing the area at N65°E. Here, solution is along closely spaced, parallel joints following this fracture zone, all drainage is to the southwest, and, where the Elk River crosses the fracture zone, it becomes an interrupted stream; its entire flow usually sinking into joints along its bed. At this point, the Elk River drops vertically for 110 ft, leaves the fracture zone, and flows in subsurface channels 5 mi to the northwest, gradually climbing stratigraphically. The Elk and all other streams sinking in the northern part of the basin rise at a second-magnitude alluviated spring at the top of the Union limestone. The influence of this fracture zone upon the hydrology of the upper Elk River basin will be discussed at greater length below.

Karst Hydrology in Sub-Basins of the Elk

In the upper Elk River basin, three infeeders: Big Spring Fork, Old Field Fork, and Dry Fork drain 77% of the surface area of the basin and account for 76% of the measured low flow discharge of the Elk River at the northwest (downstream) end of the study area. While these sub-basins are, for the most part, hydrologically independent, some inter-basin transfer of water does take place.

Drainage in the Big Spring Fork sub basin

Big Spring Fork is a westward-flowing tributary of the upper Elk River and drains an area of 21.6 sq mi. This stream rises to the east of the Deer Park anticline and crosses the anticlinal axis 0.5 mi west of Linwood. It then flows sub-parallel to the dip for 4.0 mi to its junction with Old Field Fork, where the combined flow of the two streams is first designated as "Elk River".

About half of the discharge into upper Big Spring Fork is derived from two springs in the vicinity of Linwood. These springs are, stratigraphically, the lowest resurgences in the study area and are perched on the upper Taggard shale, where it is brought to the surface by the anticline. The springs drain areas to the north and the south of Big Spring Fork, subsurface flow moving along the strike. This is in contrast to the rest of the study area, where all subsurface drainage is parallel or sub-parallel to the dip, and resurgences occur just beneath capping beds.

The first of these springs is just west of U.S. 219, at Linwood, and flows from a small cave. Throughout this cave, the upper Taggard shale is seen in the floor of the passage. The spring is the downstream end of a major solution conduit draining areas immediately to the north and west of the cave and, also, part of Dry

Fork of the Elk 2 mi north of the cave entrance (and north of a surface drainage divide). The phenomena of misbehaved drainage was described previously by White and Schmidt (1966) for another karst area in West Virginia; this is one of two known examples in the study area.

Strike-controlled drainage in the upper Big Spring Fork valley is also observed in Mill Run, a northward-flowing tributary of Big Spring Fork. Mill Run and its infeeders sink in their beds, into shafts 20 to 60 ft deep in the upper Union limestone. These streams drop stratigraphically, flow south for 1.0 to 1.5 mi, and resurge at the Pickaway limestone/Taggard shale contact, 10 ft above river level.

Downstream of the Linwood and Mill Run springs, Big Spring Fork is an interrupted stream, sinking and rising twice in its bed. Subsurface flow is well-behaved and solution conduits underdrain the stream valley. Under all but flood conditions, the entire flow of Big Spring Fork sinks into joints in the Union limestone, one mile west of Linwood, and rises at a river level spring 0.5 mi west, again through enlarged joints in the Union limestone. Discharge from this spring (Split Rock spring) was measured at 2.75 cfs under low flow conditions. The river then flows on the surface for a short distance, gradually sinking in its bed. The riverbed is then dry for 2.5 mi, until the final rising is reached at a spring 0.5 mi east of Slaty Fork, where the top of the Union limestone passes beneath the surface.

The Slaty Fork spring (probably the "Big spring" of Big Spring Fork) is one of the major resurgences in the study area. This spring emerges at the level of the bed of Big Spring Fork, which, at this point, consists of a bare limestone pavement. Water emerges both from alluvium along the river bank and from joints in the river bed. It should be noted that, during periods of high discharge, a considerable suspended sediment load is carried by water rising at this spring, the sediment consisting mostly of fine sand.

Low flow discharge at the Slaty Fork spring has been measured at 3.25 cfs. The difference between this discharge and that at the Split Rock spring, 2.5 mi upstream represents the contribution of infeeders to Big Spring Fork which sink at the upper Union limestone. The largest of these streams (a southern infeeder to Big Spring Fork, 1.0 mi. west of the Split Rock spring) has been traced to the Slaty Fork spring. It can be concluded that the Slaty Fork spring is the ultimate outlet for all water sinking in the Big Spring fork valley, since all sinking streams in this valley have been traced to it, discharge is sufficient to account for all observed flow, and there is no noticeable increase in discharge between the spring and the point 0.5 mi. downstream where the top of the Alderson Limestone passes beneath the surface.

Cave Development in the Big Spring Fork sub-basin

While over 40 caves are known to exist on the south side of Big Spring Fork, these consist merely of shafts with blocked drains, dry caves representing abandoned conduits, and short segments of the underground drainage net on that side of the river. In contrast, solutional development on the north side of the river is dominated by a single major conduit, Sharps Cave.

With over two miles of surveyed passage, Sharps Cave is one of the larger caves in the study area. The cave is developed in the Union limestone and lies 700 ft to the north of Big Spring Fork. Sharps Cave consists, essentially, of an east-west trending trunk passage 3000 ft. long. Much of this passage averages 100 ft in width and 30 ft in height. The stream in Sharps Cave flows west, paralleling the flow of Big Spring Fork, and is derived partly from a recharge area to the north and east of the cave and partly from water lost from the bed of Big Spring Fork to the cave at its upstream end. As with all other water in the valley, the cave stream has been traced to the Slaty Fork spring, 2.5 mi to the west.

Sharps Cave apparently developed in two stages, the first occuring when the elevation of Big Spring Fork was 70 to 80 ft higher than it is at present. Solution was initiated by seepage from the river flowing along a bedding plane parting at or near the elevation of the current cave ceiling and continued until the passage reached its current configuration. Evidence for such development is given by passage morphology, by anastomoses on the cave ceiling (Ewers, 1966) where it is not modified by rockfall, and by the relative elevations of the ceiling and of the river. This passage, now dry and abandoned by the cave stream, can be followed for over 2000 ft to a terminus in clastic fill.

The second stage in the development of Sharps Cave occured when Big Spring Fork had downcut in its bed to about the present level. Then, the cave stream (derived from infiltration from the hillsides above the cave and, probably, from that part of Big Spring Fork which continued to flow into the cave) downcut 30 to 45 ft below the floor of the original passage, forming the entrenched canyon through which it now flows. The upstream end of the cave is only 300 ft north of Big Spring Fork and a few ft lower than the river bed. Since much of the river sinks in this vicinity during low flow conditions, it is reasonable to assume that part of the cave stream is still derived from the surface stream.

Because its passages maintain a relatively constant vertical separation at two distinct levels, Sharps Cave would appear to support the hypothesis that cave passage elevations are accordant with former stabilized water table elevations.

It has been noted above that, at its upstream end, the stream in Sharps Cave is slightly lower than the bed of Big Spring Fork. Over its entire length, the gradient of the cave stream is 140 ft per mile, this gradient exceeding that of the river (about 50 ft per mile). Consequently, at its downstream end, the cave stream is 50 ft lower than the riverbed. Measurements of that component of the regional dip which parallels the axis of the cave have averaged 1.5° (138 ft per mile). Since no stratigraphic drop has been observed along the cave stream, it would appear that the stream follows this component of the true dip over its traversible length.

It should be noted that the elevation of the cave stream at its downstream end is about 2730 ft and that of the Slaty Fork spring to which it has been traced is 2725 ft. For the remaining 1.5 mi distance between these two points it can be concluded that: (a) the hydraulic gradient is negligible, (b) the continuation of the cave stream climbs stratigraphically to the top of the Union limestone, (c) the water table should be represented by the base-leveled cave stream, as argued by White and Schmidt (1966) and, indeed, (d) the water table gradient is determined by this stream, as concluded by Ford (1965).

Finally, it should be pointed out that, at the downstream end of the cave, the height and width of the passage are less than 1 ft and over 30 ft, respectively. The passage morphology between this point and the spring probably consists of a solutionally enlarged bedding-plane parting in which essentially closed-channel flow-conditions prevail.

Drainage in the Old Field Fork sub-basin

Old Field Fork is the largest tributary of the upper Elk River and drains an area of 30.7 sq mi. Old Field Fork rises on the north side of Red Lick Mt., flows north for 9 mi, and joins Big Spring Fork at the town of Slaty Fork. As with other tributaries of the upper Elk River, Old Field Fork and its branches rise on clastic rocks of the surrounding mountains and are downcut to the upper limestones of the Greenbrier group. This downcutting, however, is not as pronounced as in the valley of Big Spring Fork, and, for most of its length, only 40 to 60 ft of carbonate rock are exposed above the stream bed.

Within the valley of Old Field Fork, the maximum exposure of the Greenbrier group occurs in the vicinity of Mill Creek, a major tributary entering from the west. While the development of karst features in this sub-basin is limited, it should be pointed out that, for most of the year, both Mill Creek and the stream flowing in the unnamed valley to the north sink in their beds upon reaching the upper Union limestone. The capacity of the sub-surface channels to accept water is, apparently, limited, since, after heavy rainfall, these streams flow on the surface for their entire lengths, discharging into Old Field Fork. Old Field Fork, itself, usually sinks into gravel in its bed, the point of sinking varying with flow conditions. Subsurface flow is to the north-northwest, subparallel to the strike and is well behaved, underdraining the valley.

All water sinking in this sub-basin has been traced to a spring in the bed of Old Field Fork 0.5 mi south of the town of Slaty Fork.

Under base-flow conditions, all of Old Field Fork rises at this spring; discharge has been measured at 3.06 cfs. Water rises through joints trending N30°E in the riverbed, which, at this point, consists of a bare pavement on the top of the Union limestone. While the vertical drop between the sink and rise of the river is 250 ft, there is no net stratigraphic drop. Since caves have not been found beneath the valley of Old Field Fork and its subsurface flow regime has not been observed, the nature of the solution conduits beneath it are not known. It can reasonably be assumed, however, that these conduits follow a single stratigraphic horizon (the top of the Union limestone) for their entire length.

Downstream of the rise of Old Field Fork, flow is entirely on the surface, as the top of the westward dipping Greenbrier group passes beneath the river bed at its junction with Big Spring Fork. The combined flow, now designated as the Elk River, is to the north. After three miles, the river again cuts down into the Greenbrier carbonates one mile south of its junction with Dry Fork.

Drainage in the Dry Fork/Douglas Fork sub-basin

Dry Fork and its tributary Douglas Fork drain the eastern part of the upper Elk River basin north of Big Spring Fork and join the Elk River about halfway between the town of Slaty Fork and the confluence of the Elk with Valley Fork. The total drainage area is 12.6 sq mi. In contrast with the sub-basins described previously, the beds of Dry and Douglas forks are usually completely dry, with all flow being subsurface. Dry Fork flows directly downdip (4° dip; direction = N30°W) over its 4 mi length, is downcut to the base of the Union limestone near its headward end, and follows that stratigraphic horizon to its junction with the Elk River.

The pattern of subsurface drainage in both valleys is similar to that observed in the Big Spring Fork area; streams sink into joints and shafts at the top of the Union limestone, drop stratigraphically to the base of the Union, and then flow downdip through solutionally enlarged bedding-plane partings which underdrain the valleys.

At the upper end of Dry Fork, this pattern is modified by anomolous drainage along the strike to the south, and some water flows from the Dry Fork to the Big Spring Fork sub-basin. In March 1974, under conditions of fairly high flow, 41 oz of Fluorescein dye were placed in a sinking tributary on the south side of Dry Fork and charcoal traps were placed at the following locations: the Linwood spring (2 mi south of the sink), Big Spring Fork downstream of the spring, the stream in My Cave 4 mi to the west of the sink (beneath the downstream end of Dry Fork), and in a stream flowing through a karst window on Douglas Fork upstream of its junction with Dry Fork. The traps were retrieved and tested one week later. Strongest positive results were obtained from the traps in the Linwood spring, with progressively weaker positive test results from traps placed further downstream in Big Spring Fork. Positive results almost as strong as those obtained from the Linwood spring were also obtained from those traps placed in the My Cave stream. Other traps, including those placed in the Douglas Fork karst window were negative. Thus, part of the water sinking at the upstream end of Dry Fork flows downdip for 4.0 mi toward the Elk River, and part of it flows along the strike for 2 mi to Big Spring Fork (Fig. 1). It is not known which of the two flow paths would be followed in periods of low flow. The recharge area for each of these infeeders to upper Dry Fork is quite small, typically about 0.5 sq mi, and, under low flow conditions, the volume of water in them is insufficient for reliable dye traces to be conducted for the two-to-four mile distances involved. Consequently, a determination of flow paths as a function of discharge, as described by White and Schmidt (1966), has not been carried out in the study area.

The subsurface flow of Dry Fork has been observed only in one small cave, near the upstream end of the valley. Here, the stream is about 20 ft below the surface, flows through an enlarged bedding plane parting for a few feet, and is lost in a rockfall. In contrast, the subsurface flow of Douglas Fork can be seen in, and has been traced through, 4 caves, these having a combined surveyed length of about 3000 ft. The largest of these, Swecker Stream Cave, contains 1700 ft of surveyed passage and, although considerably smaller than Sharps Cave, is similar to it in passage morphology. In Swecker Stream Cave, Douglas Fork flows through a solutionally enlarged bedding-plane parting averaging 10 ft high and 40 ft wide. The stream has gradually entrenched itself in the floor of this passage, forming a canyon 6 to 8 ft wide and up to 40 ft deep. As in Sharps Cave, the remnant of the original passage can be followed at the top of the canyon for a few hundred feet before it becomes choked with clastic sediments. The cave stream is lost in a rockfall, but is seen again in another cave 0.5 mi down valley. The stream appears a third time one mile down valley, in Widows Cave, a karst window with penetrable passage extending to sumps 150 ft upstream and downstream of its entrance.

At some point beyond the downstream sump in Widows Cave, the conduits carrying the subsurface Dry and Douglas forks join. The combined flow, continuing downdip and down valley toward the Elk River, is observed 2 mi to the west, near the downstream end of Simmons-Mingo Cave and, again, at the upstream end of My Cave.

To summarize the pattern of cave development in the valleys of Dry and Douglas forks: Solution occurs along enlarged bedding-plane partings underdraining the valleys. Direction of flow is downdip. The depth at which solution takes place is not great, typically being 10 to 30 ft beneath the valley floors. Stratigraphic control of the cave passages was not observed in any of the caves entered and it appears that the solution conduits are accordant with the bed of Elk River.

Solution Along a Lineament: Simmons-Mingo and My Caves

The pattern of solutional development changes abruptly at the downstream end of the valley of Dry Fork of the Elk and, indeed, across the northern part of the study area. Here, a substantial fracture zone, trending N65°E, crosses the study area, intersects Elk River 0.5 mi south of its junction with Dry Fork, passes beneath Mingo Knob, and enters the Tygart River drainage basin. Both the pattern of cave development and the direction of subsurface flow along this zone differ substantially from that observed elsewhere in the study area.

A fracture trace has been defined by Lattman (1958) as a "natural linear feature consisting of topographic (including straight stream segments), vegetal, or soil tonal alignments, visible primarily on aerial photographs, and expressed continuously for less than one mile". Those greater than 1 mi he termed "lineaments". In Parizek, White and Langmuir (1971), it was noted that "in carbonate terranes, surface sags and depressions 2-10 feet deep may develop along fracture traces or open sinkholes 10 to over 50 feet deep may occur". Palmer (1969) described zones of fracture in the Indiana karst, stating that "these zones are composed of swarms or clusters of joints commonly belonging to the same joint set" and that "fracture zones may attain lengths as great as several miles".

Fig. 2. Sink of the Elk River at Black Hole. Photo by Robert Thrun.

The lineament crossing the study area, as seen on aerial photographs, can be followed for about 5 mi and is manifested, primarily, as a series of straight stream segments aligned N65°E. The alignment of sinks and cave entrances along the lineament is evident. Examples are as follows: Mingo Run is an eastward-flowing tributary of the upper Tygart River. It intersects the lineament 1.5 mi west of the river and, at this point, changes direction, flowing at N65°E for a mile. Several streams on the west side of Mingo Knob, upon reaching the vicinity of the lineament, change direction and flow in relatively straight channels for distances of 800 to 1500 ft, always trending S62-68°W. Where Elk River crosses the lineament, the direction of flow of the Elk turns from due north to N65°E for a distance of 600 ft before turning again to the north. At this downstream point (under most flow conditions) Elk River sinks into a cave along the lineament (Fig. 2). The greatest concentration of cave entrances in the study area occurs where the lineament crosses the valley of Dry Fork of the Elk; here, a dozen cave entrances are found within 500 ft of the valley floor.

Additional evidence for the existence of the lineament can be found in the alignment of cave passages along it. Over half of the surveyed cave passage in the study area is found here. The largest caves, Simmons-Mingo and My caves, contain over 6 mi of surveyed passage and, hydrologically, are the most significant caves in the area.

Simmons-Mingo Cave

This is the largest cave in the study area and contains over 4 mi of surveyed passage. It is developed along the lineament for a linear distance of 10,000 ft and has 440 ft of relief. The cave entrance is on a hillside on the south side of Mingo Run, at an elevation of 3000 ft, in the upper Union limestone. The cave passage immediately drops 225 ft, to a stream flowing on the lower limestones of the Greenbrier group. It should be noted that, in this cave, the Taggard shales do not act as a perching bed, for the cave passage drops beneath them very near the entrance. The cave consists, essentially, of a single passage developed along several closely spaced (6 in. to 6 ft) parallel joints. It trends S60-70°W for its entire length, following the lineament and passing directly beneath Mingo Knob. The source of the cave stream, Mingo Run, partially sinks in its bed as it flows along the lineament. Thus, as previously noted, the cave serves as a conduit which diverts water from the Tygart River to the Elk River basin. The stream in Simmons-Mingo Cave can be followed for

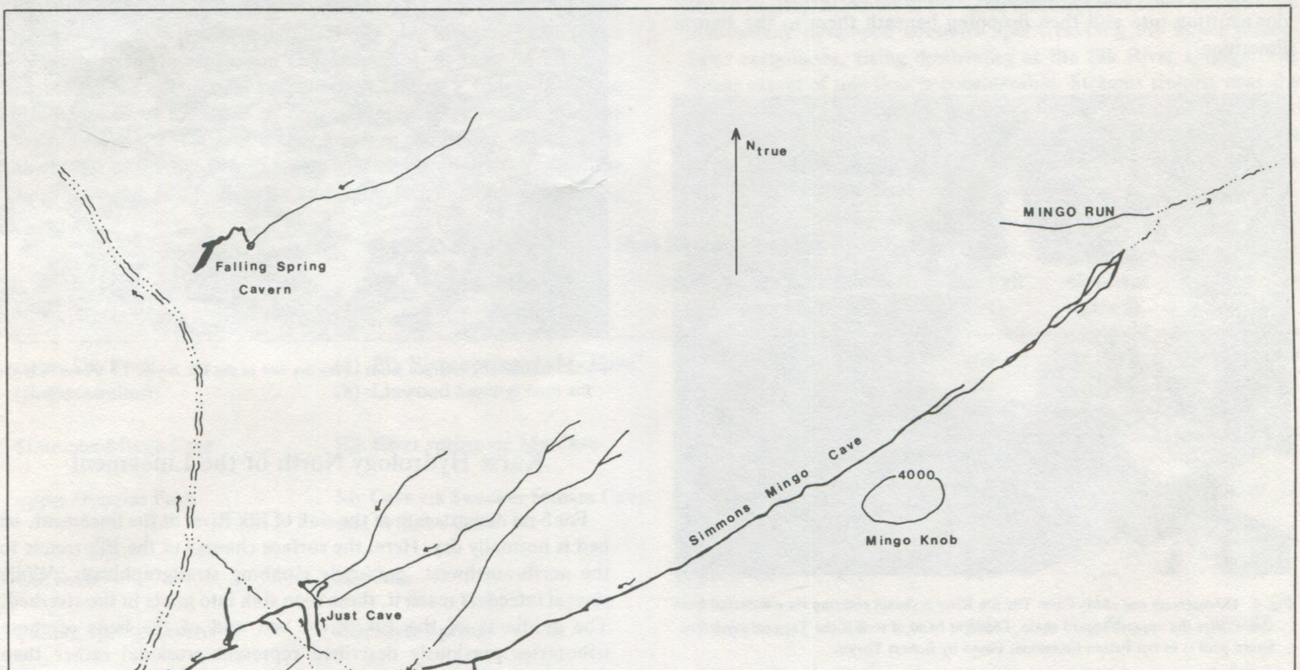

Fig. 3. Topographic and solutional features in the vicinity of the lineament crossing the Elk River basin.

about a mile and is then lost in rockfall. Continuing along dry passage for another mile, one then encounters a much larger stream than was seen beneath the cave entrance. This stream enters from the southeast, at a point where the cave passage approaches the north side of the Dry Fork valley. It contains the combined flow of the subsurface Dry and Douglas forks, as well as that of the Simmons-Mingo entrance stream. This large stream can be followed upstream and downstream for several hundred feet to sumps.

My Cave

My Cave, although physically distinct from Simmons-Mingo Cave, is a hydrological continuation of the latter. The stream at the downstream end of Simmons-Mingo Cave flows into and through My Cave, entering it via a sump at its upstream end. Discharge under low flow conditions was measured at 1.90 cfs. The distance between the two sumps is about 1500 ft; the vertical separation is less than 20 ft.

My Cave, primarily developed in the Union and Pickaway limestones, has an entrance on either side of the Dry Fork streambed and a third, 0.5 mi to the southwest, 50 ft above the sink of Elk River. As with Simmons-Mingo, directional orientation of the passage in My Cave and the alignment of the cave entrances are along the lineament at N65°E. The positions of both caves with respect to each other and with respect to the lineament are shown in Figure 3. Although the passage size in My Cave is considerably larger than that in Simmons-Mingo (averaging 50 ft in width and 50 to 100 ft in height), its configuration is similar, development being along vertical joints. The entrances and upstream part of My Cave are in the Union limestone. At a point 1200 ft from the upstream end of the cave, the cave stream drops 40 ft through the Pickaway limestone to the upper Taggard shale. The stream then flows directly on the Taggard shales for a distance of 1000 ft, gradually downcutting into and then dropping beneath them to the Patton limestone.

Fig. 4. Downstream end of My Cave: The Elk River is shown entering via a waterfall from above, over the upper Taggard shale. The light band of rock is the Taggard limestone. Sump pool is in the Patton limestone. Photo by Robert Thrun.

The downstream end of My Cave is at a point 650 ft northeast of and 110 ft below Elk River, where the latter flows into a small cave (Black Hole). At the downstream end of My Cave, its stream enters a sump. Directly opposite the entry of the cave stream into the sump and 30 ft above it, a second stream enters the passage via a waterfall (Fig. 4). The discharge of this latter stream is roughly twice that of the cave stream. The stream entering via the waterfall is that part of Elk River which flows into Black Hole above, the flow having been traced with fluorescein dye (flowthrough time: 15 to 20 min). At some point beyond the downstream sump, the water leaves the lineament and flows to the north-northwest, resurging at a spring in the bed of the Elk River 5.0 mi downstream of its sink at Black Hole. This spring is at the top of the Union limestone.

Fig. 5. Dry bed of the Elk River two miles south of the Elk River springs. Solutional potholes are in the Union limestone.

Fig. 6. Solutionally enlarged joints in the dry bed of the Elk River, 2.5 mi south of the Elk River springs.

Karst Hydrology North of the Lineament

For 5 mi downstream of the sink of Elk River at the lineament, its bed is normally dry. Here, the surface channel of the Elk trends to the north-northwest, gradually climbing stratigraphically. While several infeeders reach it, these soon sink into joints in the riverbed. The gradients of the Elk River bed and of the beds of those tributaries previously described represent erosional rather than graded alluvial surfaces; these riverbeds typically consist of limestone. The dry bed of the Elk is one of the largest such streambeds in West Virginia, typically being 40 to 50 ft wide (figs. 5 and 6). While, in some places, solutional enlargement of joints in the riverbed is pronounced, (Fig. 6), these rarely exceed 6 to 8 ft in depth. At no place do the joints allow human access to the subsurface flow of the Elk.

The pattern of cave development to the north of the lineament is similar to that observed elsewhere in the study area, *i.e.*, passages

Fig. 7a. Upper Elk River spring at high stage, discharge is 220 cfs. Photo by Eberhard Werner.

Fig. 7b. Upper Elk River spring at low flow. All discharge (11 cfs) is at lower Elk River springs, 500 ft downstream.

are developed along solutionally enlarged bedding-plane partings and trend downdip. The largest cave, Falling Spring Cavern, is 0.5 mi east of Elk River and 0.5 mi north of the lineament. The entrance is the swallow hole of Falling Spring Run and is a (generally) vertically walled sink 40 ft deep and over 100 ft across. While several other swallow holes exist in other tributary valleys of the Elk, these are considerably smaller than that of Falling Spring Run and contain little traversible passage.

The resurgence of Elk River and, indeed, the final resurgence of all springs sinking in the 92 sq mi study area is found at three alluviated springs 500 ft apart at the northern end of the area. These springs are at the top of the Union limestone where it passes beneath the surface. In these respects, they are similar to other springs described in this paper, differing only in size. Discharge at the springs was measured in October, 1974, at the end of a two month period of minimal precipitation and at a time when local stream levels, as indicated by observation of stage recorders in the area, were at a 2 year low. Under low-flow conditions, discharge at the lowest of the Elk River springs was measured at 10.75 cfs. The upper springs, 500 ft upvalley and a few feet higher, were entirely dry. Under conditions of higher flow, discharge from all 3 springs has been measured at over 250 cfs, with over 80 percent of this flow being from the upper spring (Figs. 7a and 7b). Fluorescein dye placed in tributaries of the Elk and in the Elk itself where it sinks has been traced to all springs.

Summary

The Elk River springs represent the ultimate outlets of a large free-flow carbonate aquifer with confining beds, as described by White (1969). Under conditions other than those of abnormally high discharge (when part of the Elk does flow on the surface for its entire length), all water in the 92 sq mi study area sinks and flows in solutionally developed conduits upon reaching the upper Greenbrier carbonates, rising downvalley at the Elk River springs. The linear extent of this flow is considerable. Streams sinking near the headwaters of Dry Fork for example, flow in conduits for over 9 mi and drop 950 ft before resurging at these springs. A complete summary of known subsurface flow paths is given in Table I. Table II is a summary of discharge measurements.

TABLE I. Stream Tracing Data for the Upper Elk River Basin.

Dye placed in:	Resurgence	Travel Time	Distance (miles)	Total Fall (feet)	Gradient (ft/mi)	Flow Direction
upper Dry Fork (Beales swallet)	(a) Elk River spring via My Cave (b) Linwood Spring	7 days 7 days	8.7 1.8	950 300	109 167	N70W, N20W S10E
Simmons-Mingo Cave	Elk River spring via My Cave	24 hours	6.0	300	50	S65W, N20W
upper Douglas Fork	My Cave via Swecker Stream Cave and Widows Cave	6 hours	2.5	600	240	N80W
Elk River	My Cave	20 minutes	0.1	110	—	N65E
Falling Spring Cavern	Elk River Springs	7 days	3.8	250	66	N30W
Mill Run (Big Spring Fork)	Mill Run Spring	7 days	1.2	300	250	N15W
Cemetary Swallowhole	Slaty Fork Spring	7 days	2.2	250	115	N80W
Sharps Cave	Slaty Fork Spring	14 days	2.0	50	25	S80W
Linwood Cave	Linwood Spring	6 hours	0.4	100	250	S10E
Mill Creek (Old Field Fork)	Old Field Fork Spring	2 weeks	3.0	250	83	N10W

TABLE II. Summary of Base Level Discharge Measurements in the Upper Elk River Basin.

Location	Low Flow (cfs)
Split Rock Spring (Big Spring Fork)	2.75
Slaty Fork Spring (downstream Big Spring Fork)	3.25
Old Field Fork Spring	3.06
My Cave Stream	1.90
Elk River Spring*	10.75

* Flood stage measured at 252.80 cfs in April, 1975.

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Literature Cited

Baker, V.R. (1973)— Geomorphology and Hydrology of Karst Drainage Basins and Cave Channel Networks in East Central New York: *Water Resources Research* 9:695-706.

Brucker, R.W.; J.W. Hess; and W.B. White (1972) — Role of Vertical Shafts in the Measurement of Ground Water in Carbonate Aquifers: *Ground Water* **10**:6.

Ewers, R.O. (1966) — Bedding-Plane Anastomoses and Their Relation to Cavern Passages: *NSS Bulletin* **28**:133-140.

Ford, D.C. (1965) — The Origin of Limestone Caverns: A Model from the Central Mendip Hills, England: *NSS Bulletin* **27**:109-132.

Jones, W.K. (1973) — Hydrology of Limestone Karst in Greenbrier County, W.Va.: *W. Va. Geol. Econ. Survey, Bull.* **36**, 49 pp.

Lattman, L.H. (1958) — Techniques of Mapping Geologic Fracture Traces and Lineaments on Aerial Photographs: *Photogrammetric Eng.* **24**:568-576.

McCue, J.B.; J. B. Lucke; and H.P. Woodward (1939) — Limestones of West Virginia: *W. Va. Geol. Econ. Survey, Rept.* **12**, 560 pp.

Medville, D.M. and E.W. Werner (1974) — Hydrogeology of the Death Canyon Limestone, Teton Range, Wyoming, **IN**: H.W. Rauch and Eberhard Werner (Eds.) — Karst Geology and Hydrology, Proceedings of 4th Conference: Morgantown, W. Va. Geol. Econ. Survey, pp. 95-102.

Palmer, A.N. (1969) — A Hydrologic Study of the Indiana Karst: Indiana Univ. thesis, 181 pp.

Parizek, R.R.; W.B. White, and Donald Langmuir (1971) — Hydrogeology and Geochemistry of Folded and Faulted Rocks of the Central Appalachian Type and Related Land Use Problems: *Pa. State Univ., College Earth Min. Sciences, Circ.* **82**, 181 pp.

Price, P.H. (1929) — Pocahontas County: W. Va. Geol. Econ. Survey, 531 pp.

Stringfield, V.T. and H.E. LeGrand (1969) — Hydrology of Carbonate Rock Terranes—A Review: *Jour. Hydrol.* **8**:349-417.

Sweeting, M.M. (1973) — Karst Landforms: NYC, Columbia Univ. Press, 362 pp.

White, W.B. (1969) — Conceptual Models for Carbonate Aquifers: *Ground Water* **7**:3.

————— and V.A. Schmidt (1966) — Hydrology of a Karst Area in East-Central West Virginia: *Water Resources Research* **2-3**:549-560.

Wells, Dana (1950) — Lower Middle Mississippian of South-Eastern West Virginia: *Am. Ass'n Petrol. Geologists, Bull.* **34**:882-922.

Williams, P.W. (1964) — Aspects of the Limestone Physiography of Parts of Counties Clare and Galway, West Ireland: Cambridge Univ. thesis, pp.

Wolfe, T.E. (1964) — Cavern Development in the Greenbrier Series, West Virginia: *NSS Bulletin* **26**:37-60.

Characterization of Karst Soils by Near Infrared Spectroscopy

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ABSTRACT

Soil reflectance spectra in the near infrared and visible regions exhibit features that can be used to characterize the soils. The degree of iron hydration is related to a band at 900 nm. Clay content is related to several water bands in the near infrared. The visible spectrum can provide a quantitative expression of soil color through a set of absorbance ratios. Measurements have been made of 24 surface and 24 cave soils from the Central Kentucky Karst. Surface soils are grouped, by the measurements, into red limestone residual soils, brown residual soils, and yellow-brown fluvial soils. Cave soils fall into two very distinct groups: those from passages above 500 feet elevation and those from base level passages below this elevation. Two distinct sediment sources for the Flint Mammoth Cave System are indicated.

Introduction

Clastic sediments are transported into caves from a variety of sources. In general, however, a primary source must be the surface soils from overlying karst topography and from soils on other rocks adjacent to or overlying the karstic strata. The transported soils are mixed with each other and with residual clastic material from the cavernous rocks. The origin of the final cave sediment is usually obscure, and sources are difficult to determine. Cave sediments, as a result, are among the least understood features of the cavern environment.

Several approaches to understanding cave sediments have been devised, although none can be said to have been extensively tested. The stratigraphy and lithology of the sediments can be studied and the sediment minerals, particularly the heavy minerals, determined. Cave soils can then be related to surface sources by similarity in heavy minerals, as Davies and Chao (1959) attempted for the sediments in Mammoth Cave. In effect, the cave sediments are regarded as a peculiar type of sedimentary rock. Unfortunately, the detailed study of a single passage, Columbian Avenue, in the Flint Mammoth Cave system (Carwile and Hawkinson, 1968), shows that facies changes along the sediments occur over very short distances, and tracing a stratigraphic layer is likely to be meaningless. A better alternative seems to be to regard cave sediments as fluvial deposits of a rather special sort and search for sedimentary structures and markers that will indicate source area, as Wolfe (1973) did in his investigation of cave sedimentation in the Greenbrier Limestone karst of West Virginia.

The present investigation utilizes the light-reflecting properties in both the visible and near-infrared regions of the spectrum to compare underground and surface soils and to provide some clues to source areas. Karst areas are noted for their bright red soils, as contrasted with the brown soils on most other rocks. What this investigation accomplishes is a quantification of the color of the soil and the extension of "color" beyond the range perceived by the human eye.

The Central Kentucky Karst was used as a field area, because of the wide variety of surface soils and because of some interesting unanswered questions concerning the cave sediments. The background geology of the central Kentucky karst is described in the review papers of White *et al.* (1970) and Quinlan (1970). The underground soils were all collected from passages in the Flint Mammoth Cave System. This system lies beneath the Chester Cuesta, which is capped with upper Mississippian sandstones and shales. At least some of the water that flows through the cave system is derived from catchment areas on the Sinkhole Plain, a doline karst to the southeast of the plateau. Also, streams flow from the east and sink at the margin of the Sinkhole Plain. The catchment areas of these sinking streams lies on the lower Mississippian Warsaw formation, a shaley limestone that yields brown residual soils. Bright red soils of the classic terra rosa type are found in the upland areas of the Sinkhole Plain.

Soils

Surface soils were collected from the B-horizon where the soil profile was exposed in roadcuts. One traverse was made across the Sinkhole Plain along Route 90 from Glasgow to Cave City and from Cave City along Route 70 up onto the Chester Cuesta to Mammoth Cave National Park. Residual soils were collected from road cuts north of Green River, and several samples of red sand were collected from weathered outcrops of the Pottsville (Caseyville) sandstone. Red residual soils were collected from the Sinkhole Plain, and fluvial soils were collected from the floodplains of two of the larger sinking creeks (Sinking Creek and Little Sinking Creek), from the mouths of Echo River Spring and Pike Spring, from the bottom of Cedar Sink, and from the Green River floodplain. In all, 24 surface soils were analyzed.

Samples of cave sediments were collected at various times between 1961 and 1973, in the course of other investigations of the cave system. From a total collection of some 70 soils, 24 were selected for spectroscopic investigation. Those chosen were from major passages in the cave system. Usually, several samples from the same passages were included.

Surface Soils

The brown soils (*e.g.*, Munsell 7.5 YR 5/8) to the southeast of the Sinkhole Plain belong to the Baxter-Talbott-Dickson association. They are residual soils formed by weathering of the shaley and cherty Salem and Warsaw formations (Latham, 1969).

Sinkhole Plain soils belong to the Cumberland-Pembroke association. These soils are complex. The bright red Cumberland soils (*e.g.*, Munsell 2.5 YR 4/8) form as a weathering residuum of the St. Louis and Ste. Geneviève limestones only on well drained upland areas between the dolines. Soils on the sides and bottoms of dolines are more poorly drained and tend to be brown or orange.

The plateau soils belong to the Weiker-Caneyville-Wellston-Zanesville association. In general, they are brown soils (e.g. Munsell 5 YR 5/8) and are often sandy, because of the presence of the Big Clifty, Hardinsburg, and Caseyville sandstones on the Plateau. No soil survey is available for Edmonson County, so no effort has been made to investigate the details of these soils.

The larger streams that sink at the eastern margin of the Sinkhole Plain flow on an apron of alluvium. These streams deposit fluvial soils that are dark brown (Munsell 10 YR 5/6) where exposed on the stream banks. Little stratification is in evidence.

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The upstream section of Little Sinking Creek extends into Barren County, where the flood plain material is classified as the Melvin silt loam.

The soils on the Green River floodplain are yellow (*e.g.*, Munsell 10 YR 4/4 or 7.5 YR 4/4) and consist largely of quartz sand. The big springs that drain the cave system and the karst area emerge some distance back from the river and drain to it through surface channels. The sediment on the banks of these channels and near the spring mouths is a yellow sand very similar to the river sediments. Since Green River floods up to 60 ft, the spring mouths are completely covered at least every few years, and it is not clear whether the spring mouth sediments are derived from the spring outflow or are backflooded from Green River. Some evidence that they come through the cave system is provided by the karst fensters Cedar Sink and Mill Hole, which have similar sediments along their short surface exposures of the karst stream. Similar sediments, with some admixed brown clayey material, are found near stream level in Owl Cave, a short segment of low-level trunk opening off the north end of Cedar Sink.

Cave Soils

Sediments occur in nearly all passages of the cave system and range in thickness from fractions of a meter to tens of meters. They are generally well stratified. The sediments in the upper levels of the cave are a complex of gravels, sands and silts, complexly interbedded. Much of the sedimentary sequence appears to be nearly pure quartz sand with enough other material to give the soils a pronounced orange color (*e.g.*, Munsel 5 YR 5/8). Rounded quartz pebbles derived from the basal Caseyville sandstone are common in the sediments and as channel deposits. Many measured sections and a few sketches and photographs of exposed sediment profiles may be found in Davies and Chao's 1959 report.

The baselevel soils are quite different in appearance from the higher level soils. They are brown and appear to contain more clay. Interbedded yellow sand with brown silt and clay (*e.g.*, Munsell 10 YR 4/4) occurs in passages such as Columbian Avenue that are close to Green River.

The separation between upper level sediments and baselevel sediments appears to occur at an elevation of about 500 ft. Sediments in passages below this elevation all have the appearance of the baselevel type, while passages above this elevation contain the orange silts, sands, and gravels.

This study considered only major passages. Upper level sediments were selected mainly from sections of passage well under the caprock, where the influence of breakdown and surface infiltration of water and sediment from caprock collapse was not in evidence. Sampling from smaller passages, particularly from shaft drains, which transport sediments directly from the overlying plateau into the cave system, would almost certainly have complicated the picture. The distribution of measured samples is tabulated in Table 1.

Spectroscopic Measurements

Surface soils were collected in small plastic bags. Cave samples were collected and stored in small glass bottles. All samples were dried to laboratory ambient for more than a year before measurements were made. Ten to 20 g of soil were crushed in an agate mortar. No attempt was made to fine-grind the material, so quartz grains and other particles remained at their original size. The ground soils were packed into 2 cm diameter, 0.3 cm deep sample cups milled from block aluminum, pressed with a stainless steel plunger to a flat surface, and wetted with carbon tetrachloride to increase adhesion and to prevent the samples from falling from the vertically mounted holders. The solvent was allowed to evaporate before the samples were measured.

TABLE 1. Sources of Cave Soils.

Passage	Elevation	No. of Samples
Upper Level Passages		
Upper Salts Avenue	650	3
Main Cave	600	3
Dyer Avenue	600	4
Turner Avenue	575	2
Edwards Avenue (Great Onyx)	550	2
Big Avenue (New Discovery)	550	2
Baselevel Passages		
Pohl Avenue	475	5
Columbian Avenue	450	2
River Hall	450	1

All spectra were obtained with a Beckman model DK 2A spectrophotometer, with an integrating-sphere diffuse-reflectance attachment. A Kodak $BaSO_4$ optical paint was used on the reference plaque. Spectra were measured through the near-infrared regions from 2500 to 500 nm with a PbS solid state detector and through the visible region from 700 to 350 nm with a photomultiplier detector. In all cases, the instrument was adjusted to give a 100% reading when $BaSO_4$ was measured in both beams.

A representative set of near-infrared spectra is given in Figure 1. At the infrared end of the spectrum are three relatively sharp bands at 1400, 1900, and 2200 nm. These have been attributed to vibrational overtones of water and/or hydroxyl, incorporated in clay minerals. Spectra of two reference clays, kaolinite and nontronite (Mathews, 1972; Mathews, Cunningham and Petersen, 1973) show strong bands in this position. The relative intensity of the three bands varies somewhat when different samples are compared, suggesting that several clay minerals are represented in the spectra and that they occur in the soils in varying proportions.

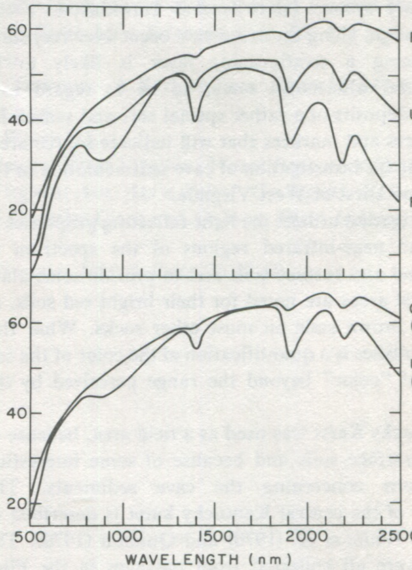

Figure 1. Near-infrared spectra for selected surface and cave soils.

There is a broad band centered at 900 nm. This feature is almost certainly due to the presence of iron. A feature of similar line shape appears in the reflectance spectrum of both hematite and goethite (Hovis, 1965). The origin of the band is not known with certainty. It is likely an intervalence electron transfer band due primarily to Fe^{3+} exchanging an electron with a trace of Fe^{2+}.

The spectra for the three selected surface soils are all very similar, and the same bands appear. However, the intensity of the absorption is much stronger in the red karst soils than in the brown upland soils. The flood plain soils exhibit little spectral detail of any kind. A similar situation prevails in the cave sediments. The upper level soils show absorption features with about the same intensity as the upland soils, while the base level soils are nearly featureless. An exception to this general pattern is a single soil from Big Avenue in New Discovery, which contained nearly 50% gypsum. The vibrational bands of the water of hydration in $CaSO_4 \cdot 2H_2O$ are superimposed on the three water bands of the clay minerals and change the pattern. The 1900 nm band is greatly enhanced in intensity, and several new bands appear in this region.

The reflectance of the same selected group of soils in the visible region of the spectrum is shown in Figure 2. Since the soils are highly absorbing, particularly in the blue region of the spectrum, the curves are plotted as absorbance (A) rather than as percent transmission [$A = -\log T$]. Each spectrum is a monotonic curve showing high reflectivity in the red and poor reflectivity in the blue. The spectrum of the karst soil slopes upward very steeply, indicating that the sample is reflecting mainly red light, which, of course, is just what one observes in the color. The curves for the upland soils and the floodplain soils are each less steep, indicating some reflectivity in the yellow and green regions of the spectrum and an overall brown and yellow color, respectively. Again, the spectra of the cave soils from the upper levels have much the same appearance as the spectra of the upland soils, and the baselevel cave soil spectra much resemble the spectra of the floodplain soils. The curves are not quite featureless. There is a distinct shoulder or plateau at about 450 nm. This feature, like the 900 nm band, is related to the presence of ferric iron.

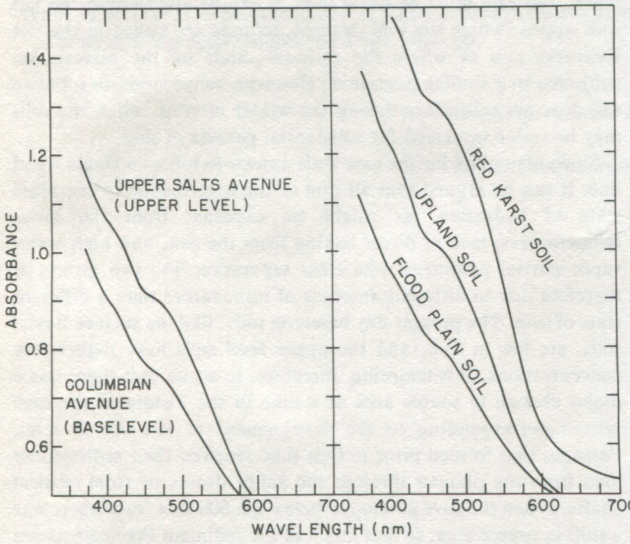

Figure 2. Visible spectra for selected surface and cave soils.

Comparison of Soil Spectra

The diffuse reflectance spectra of the soils makes possible a quantitative comparison of their optical properties. Of several numerical comparisons made, two are reported here.

The intensity of the 1900 nm water band was compared with the intensity of the 900 nm iron band. Figure 3 shows how the bands were measured. A baseline was drawn across the background of each band and the ratio of band peak to baseline determined. Since concentration of absorbing centers is proportional to the absorbance rather than to the transmittance, the logarithms of these ratios were plotted against each other in Figure 4. The scatter is considerable. In general, the fluvial soils have low values of both

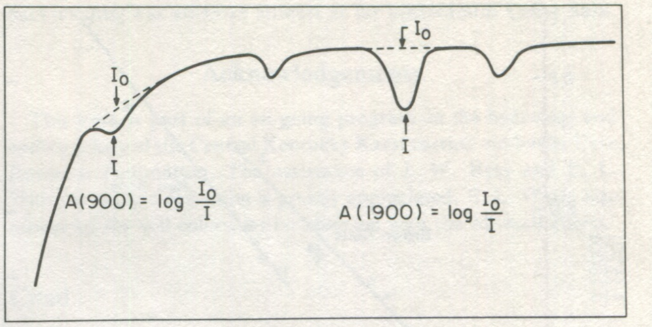

Figure 3. Illustrating the method of drawing a baseline and calculating the absorbance of the 900 nm and 1900 nm near-infrared bands.

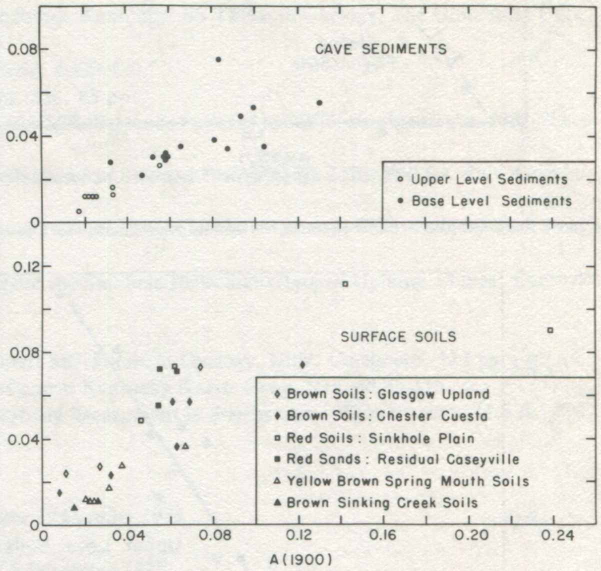

Figure 4. Plots of the absorbances of the 900 nm band (a measure of iron) and the 1900 nm band (a measure of clay content) against each other.

iron and water absorbance. The red karst soils tend to have high values, and the other soils plot somewhere in between. The upper level soils are fairly well separated from the baselevel soils by this method, with the baselevel soils, like the fluvial soils, having low absorbance values of both iron and water. As a generality, the spectral comparison shown in Figure 1 can be said to hold for all samples measured.

The visible spectra were analyzed by comparing the absorbance at several wave-lengths. Selected were 450 nm (blue), 525 nm (green), and 600 nm (red). Plots of different combinations of these measures against each other produced a quite definite separation of the soils. Most definite was the plot of the blue/red ratio against the green/red ratio, shown in figures 5 and 6. Since the wavelength separation of the measurements is constant, these ratios are essentially measures of the overall slope of the line against the slope of the blue end of the line. If the visible spectra had consisted of straight lines, measures of the slope on two different intervals would have produced the same number and the resulting plot would have been a straight line with a 45° slope. Since the spectra exhibit a distinct curvature, the green to red segment has a different average slope from the blue to red segment.

The surface soils are rather neatly separated into three sequences. The red limestone residual soils fall along one straight line segment, on which also plot two bright red weathered sands from the Caseyville formation. The brown soils fall on a second sequence, offset from the red soil sequence. The brown soils from the eastern margin of the sinkhole plain are not distinguished from

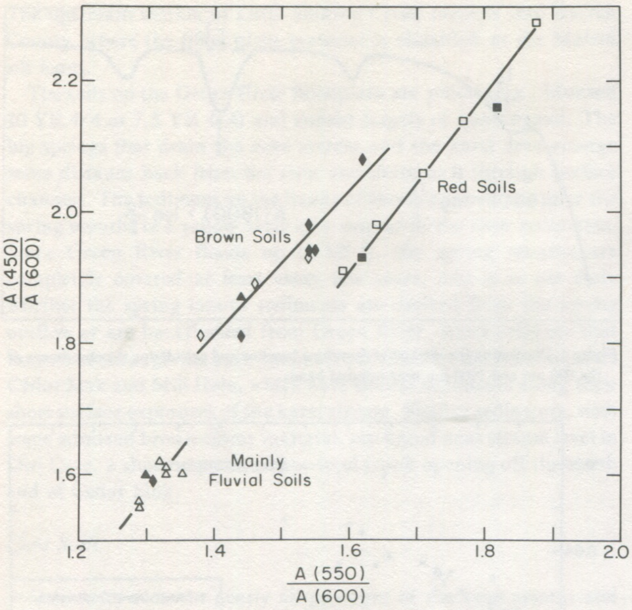

Figure 5. Color ratio plots for surface soils. Legend for data points is same as in Figure 4.

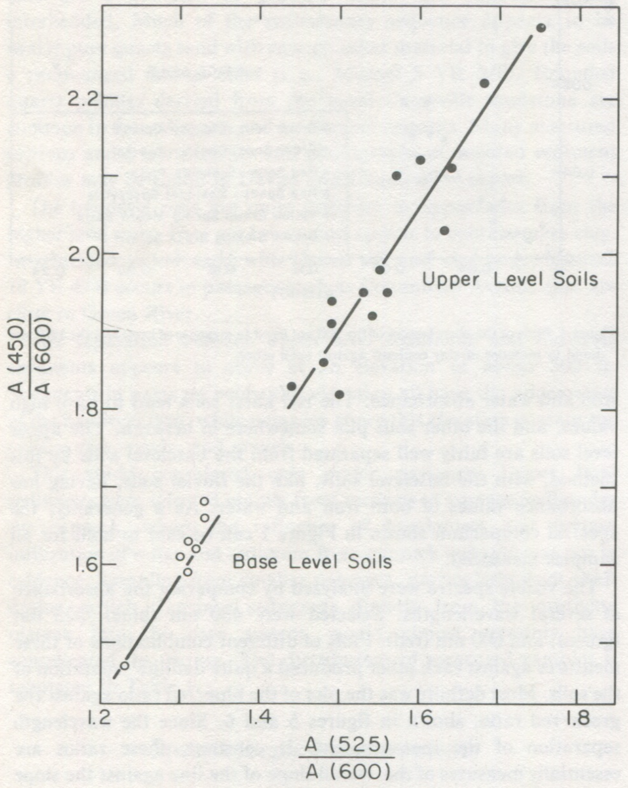

Figure 6. Color ratio plots for cave soils. Legend for data points is same as in Figure 4.

the residual soils from the Plateau. Considering the diversity of soil types, however, the regularity of the plot is surprising. The fluvial soils, spring mouth soils and river floodplain soils fall into a tight group in the lower corner of the diagram. There are two anomalies: One plateau soil plotted with the fluvial group. It was a residual soil from the Big Clifty formation and was, essentially, a yellow sand that looked much like the fluvial soils. Of the two sinking creek floodplain soils, one fell with the brown residual soils and one fell with the fluvial group. Since the physical appearance of these two soils is nearly identical, it is difficult to explain the anomaly.

The cave soils fall onto a single trend line, but in two quite distinct groups. Again, the upper level soils clearly group separately from the baselevel soils. There is no elevation relation along the line of upper level soils. Two samples from Turner Avenue, for example, plotted at nearly opposite ends of the line.

If the two comparisons (Fig. 4 and figs. 5 and 6) are superimposed, it is found that the baselevel soils from the cave system in each case fall directly over the plots of fluvial soils. Likewise, the upper level soils have the same characteristics as the brown Plateau soils. No sediments were found in the cave that have a spectral reflectance like the red limestone residual soils.

Discussion and Conclusions

What has been demonstrated is that the surface and underground soils of the Central Kentucky Karst can be placed in quite distinct groups on the basis of their spectral reflectance characteristics and that the underground soils bear a close relationship to the surface soils. The interpretation of these results in terms of the geomorphic history of the cave system is less certain. With the exception of the water bands in the infrared spectra, everything else measured was related to the behavior of iron in the sediments. Iron is essentially the only coloring agent in the sediments. Clay and quartz, the two main constituents, are colorless. It further appears that the groupings are determined by the amount and state of hydration of ferric iron. The points on the upper right of Figure 5 probably represent surface soils with fairly high concentrations of iron, but, in the red soil sequence, the iron is more dehydrated. The interpretation of the cave soils turns precisely on the rate at which these dehydration reactions take place. The rate must be fairly slow. It can be argued that the red soils appear where the well drained uplands are baked in the hot Kentucky sun or where the residual sands on the plateau are subjected to a similar treatment. However, rehydration to a brown soil does not take place during the winter months, when the soils may be water saturated for substantial periods of time.

Since the points for the cave soils appear to follow a single trend line, it can be argued that all iron in the cave soils is in the same state of hydration, as might be expected from the lower temperatures, lack of direct baking from the sun, and high water vapor partial pressures. The clear separation into two groups is therefore due to different amounts of iron, rather than a different state of iron. The present-day baselevel soils, like the surface fluvial soils, are low in iron, and the upper level soils have higher iron concentrations. It is tempting, therefore, to argue that there was a major change in source area at a time in the history of the cave system corresponding to the development of the 500 ft level. Passages that formed prior to that time received their sedimentary load from the plateau through the valley drains or from vertical shafts. When the cave developed below the 500 foot level, there was a shift in source area, so that much of the sediment then came from the Sinkhole Plain. The material now found in the baselevel passages and at the spring mouths could be derived from the sinking creek sediments, if a bit more of the iron were leached out of it during transportation over the substantial distance from the source points to the cave. This would be consistent with a view favored by Miotke (Miotke and Palmer, 1972; Miotke and Papenberg, 1972) and by Wells (1973) that the drainage of the Sinkhole Plain has been toward the Barren River through much of its history and that the underground drainage from the Sinkhole Plain to Green River is a piracy event of relatively recent origin.

Unfortunately for this tempting hypothesis, there is the curious coincidence that the break between the two types of cave sediments at the 500 ft level also is coincident with the high water level of highest-stage modern floods. Green River has an exceptional flood behavior, and flood crests 60 ft above the 425 ft pool stage have been observed in the past several decades. It is, therefore, difficult to discount the hypothesis proposed by Davies and Chao (1959) and by Collier and Flint (1964) that the baselevel sediments in the cave system were derived from Green River and were transported into the cave by baselevel backflooding. Recent work on the hydrology of the cave system has tended to discount the effectiveness of the backflooding mechanism, but it would certainly account for the similarity of the reflectance characteristics between baselevel sediments and fluvial sediments, if both were derived from the same source. This would imply that transport of river sediment by backflooding was effective at least as far upstream as Cedar Sink.

Acknowledgements

This work is part of an on-going program on the hydrology and hydrogeology of the Central Kentucky Karst carried out by the Cave Research Foundation. The assistance of J. W. Hess and E. L. White in sample collection is greatly appreciated. E. L. White also measured the soil colors, by comparison with the Munsell charts.

References Cited

Collier, C.R. and R.F. Flint (1964) — Fluvial Sedimentation in Mammoth Cave, Kentucky: *U.S. Geol. Survey, Prof. Paper* **475**:D141-D143.

Davies, W.E. and E.C.T. Chao (1959) — Report on Sediments in Mammoth Cave, Kentucky: U.S. Geol. Survey, Adm. Rept. to U.S. Nat'l Park Service, 117 pp.

Carwile, R.H. and E.F. Hawkinson (1968) — Baselevel Sedimentation, Flint Ridge, Kentucky: BS Thesis in Geology, The Ohio State Univ., 95 pp.

Hovis, W.A., Jr. (1965) — Infrared Reflectivity of Iron Oxide Materials: *Icarus* **4**:425-430.

Latham, E.E. (1969) — Soil Survey of Barren County, Kentucky: U.S. Dept. Ag., 85 pp.

Mathews, H.L. (1972) — Application of Multispectral Remote Sensing and Spectral Reflectance Patterns to Soil Survey Research: PhD Thesis in Agronomy, The Pa. State Univ., 110 pp.

————; R.L. Cunningham, and G.W. Peterson (1973) — Spectral Reflectance of Selected Pennsylvania Soils: *Soil Sci. Soc. America, Proc.* **37**:421-424.

Miotke, F.-D. and A.N. Palmer (1972) — Genetic Relationship between Caves and Landforms in the Mammoth Cave National Park Area: Würzburg, Böhler, 69 pp.

———— and Hans Papenberg (1972) — Geomorphology and Hydrology of the Sinkhole Plain and Glasgow Upland, Central Kentucky Karst: *Caves Karst* **14**:25-32.

Quinlan, J.F. (1970) — Central Kentucky Karst: *Mediteraneé* **7**:235-253.

Wells, S.G. (1973) — Sinkhole Plain Evolution in the Central Kentucky Karst: MS Thesis in Geology, Univ. Cincinnati, 124 pp.

White, W.B.; R.A. Watson, E.R. Pohl, and Roger Brucker (1970) — The Central Kentucky Karst: *Geog. Rev.* **60**:88-115.

Wolfe, T.E. (1973) — Sedimentation in Karst Drainage Basins along the Allegheny Escarpment in Southeastern West Virginia, U.S.A.: PhD Thesis in Geography, McMaster Univ., 455 pp.

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Revised manuscript accepted 6 December 1975.

The Greenbrier Caverns: Discussion

M.D. Dyas*

Publication of "The Greenbrier Caverns", by John M. Rutherford, with Bob Handley, ought to be understood partly in view of a complicated history of interactions between the authors and certain members of the District of Columbia Grotto, which adopted study of the subject cave system in 1970 and is presently pursuing same under auspices of the N.S.S. Research Advisory Committee. Prospects of the Rutherford/Handley paper had been of considerable concern to D.C. Grotto, not only with respect to caver-owner relations problems in the Organ Cave vicinity, but because it had been hoped that Rutherford and Handley would contribute to a comprehensive report on the system which D.C. Grotto intends to publish in the not-too-distant future under the auspices of the West Virginia Speleological Survey. Following are some brief comments on points covered in "The Greenbrier Caverns":

First, as the authors allude to, disagreement over the system's preferred name has arisen. The D.C. Grotto supports the term "Organ Cave System", not only because area residents are unfamiliar with "Greenbrier Caverns" (a name invented by Handley and Rutherford in the late '50's), but because "Organ Cave" is the name of the rural community under which the system is developed, as well as of the most important and historic entrance. With respect to specific wishes of the owner of the Organ and two other entrances, it is urged that speleologists refer to the system as "Organ Cave System" in future writings.

The authors' statement that, "...major new discoveries do not appear to have been made" during the D.C. Grotto phase of exploration deserves some elaboration. Aside from approximately doubling the system's surveyed extent, D.C. Grotto parties have made a host of relatively "minor" discoveries which, taken together, total several miles. Probably the most significant of these is a northward extension of the Upper Stream Passage, which overlies the vicinity of the Hedricks-Masters "Y" and totals several thousand feet.* On the other hand, it is regretable that the authors chose to repeat an estimate of 44-plus miles for the system, despite correspondence to Mr. Rutherford last year in which I emphasized that this figure was exagerrated. (Incidentally, the tenth entrance to the system has recently been found.)

Paleontological collecting in the Organ System has continued from time to time since the authors' Table II was assembled. Of particular interest are recent finds of Pleistocene porcupine and dire wolf remains.

The authors' statement that a perched stream from the Lipps entrance complex drains to the lower Lipps-Humphreys trunk appears to be in error. Recent exploration has followed the Lipps entrance stream away from the main upper Lipps passage, to a near-sump, which may be forced in the winter of 1976-77. No known tributaries to lower Lipps-Humphreys appear to account for this water, and there may be an undiscovered drainage between lower Lipps and Jones Canyon.

The author's discussion of Foxhole Cave (or Foxhole #1) much as if it were a part of the system is interesting and probably appropriate, although a physical connection still eludes explorers. It may be noted that, by entering through a means probably unknown to the authors, D.C. Grotto has surveyed Foxhole to a length of approximately two miles.

Mention of the names of several owners of entrances to the Organ System by the authors is commendable. It should be noted that, with the exception of those owned by Mr. R. L. Sarver, all entrances remain open in conjunction with the D.C. Grotto project; however, the owners do not desire general visitation.

Note added in proof: On 13 November 1976, a D.C. Grotto diving team penetrated the 300 ft-long sump at the SW "end" of the Bowen ("Big") Canyon and explored over 3000 ft of new trunk passage, with side leads. This extension could continue over another mile towards the presumed resurgence of the system on Second Creek.

Reference

Rutherford, J.M. and R.H. Handley (1976) — The Greenbrier Caverns: *NSS Bulletin* **38**:41-52.

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The Greenbrier Caverns: Reply

John M. Rutherford* and Robert H. Handley†

We think our article can be fully understood on its own merit and without reference to "interactions" between the West Virginia Association for Cave Studies, Inc., (WVACS) and the District of Columbia Grotto of the National Speleological Society (DCG). In a rather imprecise manner Dyas' comments cover a lot of ground, some of which is not heavily endowed with speleologically redeeming values. In 1970 when DCG preempted WVACS' efforts in the Greenbrier Caverns and took over work in the system, a "bargain" was made. In return for promises that DCG's subsequent survey data would be made available to them, WVACS gave DCG their 17 miles of survey data plus myriad comments on the many miles of known-but-yet-to-be surveyed passages and on the leads and areas of the system considered most promising. At that time it was also made clear that, based on WVACS' work there, we intended to publish in the *Bulletin* a speleogeographic article on the Greenbrier Caverns.

Dyas is well aware that DCG never provided WVACS with their promised new survey data, and hence we are puzzled by his apparent concern about our citation of their "44-plus miles" figure. Dyas did not tell us what the correct figure was, nor did he even tell us that that figure was exaggerated. What he did say, in 1975 after our paper had been accepted and he was trying to impede its publication, was that we should not "...assume he [DCG Chairman and coordinator of their Greenbrier Caverns project] always meant what he said (i.e., 44-odd miles of cave?)" We did suspect the cited figure was high, but it was the only number we could find to document. Were Dyas truly concerned lest someone refer to a figure he knew to be inflated, we feel it regrettable that in those intervening years he did not write the editor of the *NSS NEWS* to clarify the situation.

The porcupine remains were removed from the system as early as 1970 but, as Dyas knows, our attempts to obtain details from DCG for suitably acknowledged inclusion in our Table II went unanswered. We also relayed to DCG, to no avail, the owner's request that those bones be forwarded to the Carnegie Museum, where all bones recovered from the system by WVACS had been sent.

We did not claim, nor did we mean to imply, that throughout the entirety of the perched level above the Humphreys and Lipps trunk passages there presently are active streams. (In the editing process our original words "drainage lines" were changed to "tributaries".) Our only intended point was that a perched level exists at both places.

We do not think the pages of this journal are suitable for debating the proper name for a large, integrated cave system. Whether there may be a local community named Organ Cave is surely immaterial. We think two salient facts are the following. The owner of "Organ Cave" owns only 5-10% of the known cave in the system. At least one other owner, who owns much more of the system, definitely does not want things from, or portions of, his part of the system to be referred to as "from the Organ Cave System" by speleologists or anyone else.

Finally, we are pleased to find Dyas confirming our surmise that "...major new discoveries do not appear to have been made..." by the DCG project. We are also pleased that they have found a new access route into Foxhole Cave, since the last information we had was that they were trespassing despite the owner's express objections. And contrary to Dyas' implication, we have *not* been asked to contribute to any DCG "not-too-distant future" publication on the system. We would, however, be pleased to consider such a request should a detailed proposal be made to us.

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The Relationship between Man and Karst: Discussion

Stephan Kempe*

The karst rock map of Germany presented by Kopper and Young (1976, Fig. 2) is in error. Besides the karst areas, it depicts also the variscides. Harz, Rheinisches Schiefergebirge, Spessart, Odenwald, Schwarzwald, Thüringer Wald, Erzgebirge, Böhmischer Wald, and Bayrischer Wald consist of shale, arkose, sandstone, schist, gneiss, and granite. Signature misinterpretation of the

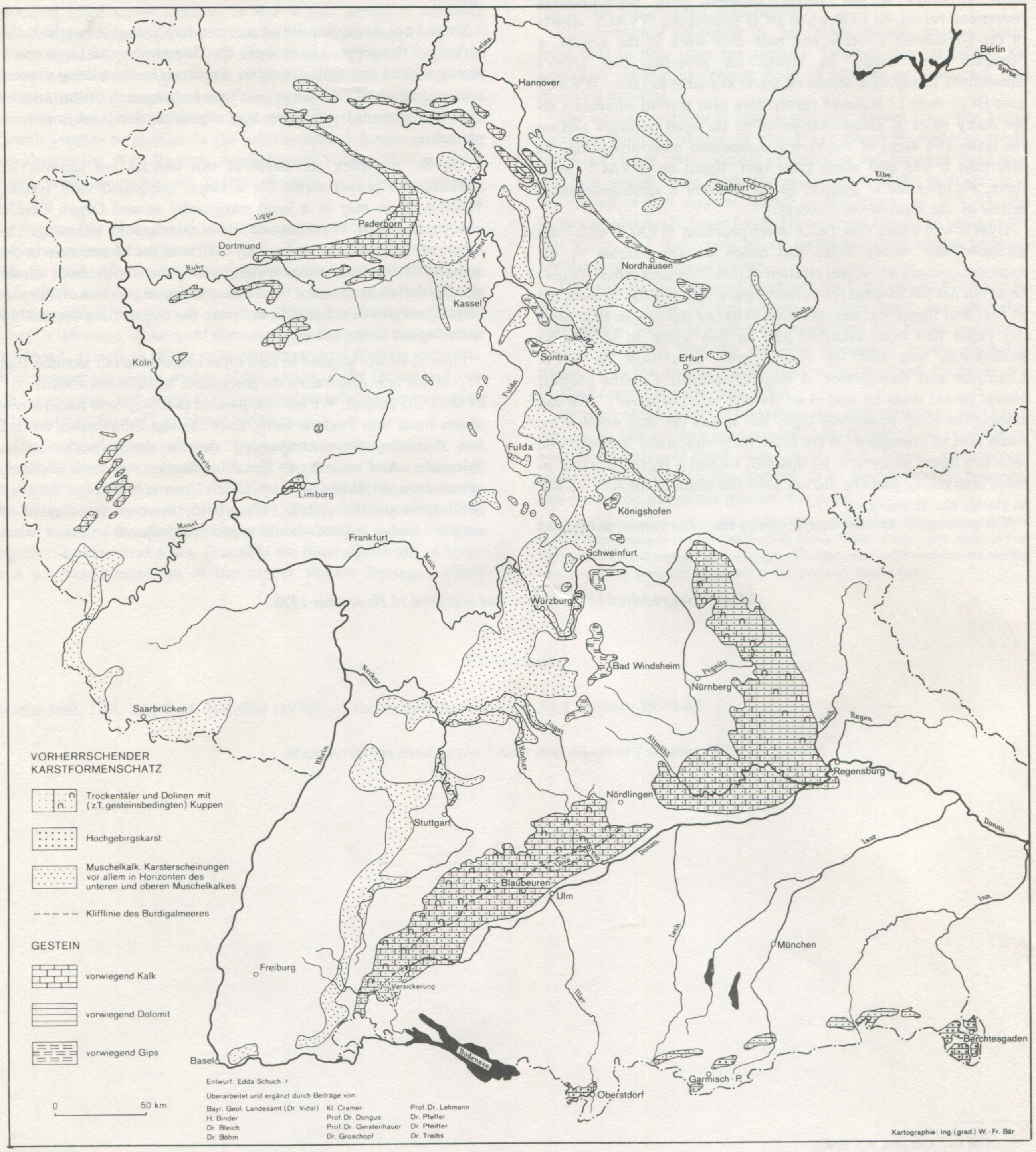

Figure 1. Die Karstlandschaften Deutschlands.

Geol.-Paleontol. Institute, Universitat Hamburg, Bundesstrasse 55, D-2 Hamburg 13.

original source may have caused this mistake.

Gerstenhauer (1969) has published a map of the German karst areas which is presented herewith for comparison (Fig. 1). It will be seen that the percentage of karst area in Germany is much less than 25%, as estimated by Kopper and Young.

Literature Cited

Gerstenhauer, Armin (1969) — Die Karstlandschaften Deutschlands mit einer zweifarbigen Karte: *Abh. Karst — Hohlenkunde*, **r. A h. 6.**

Kopper, J.S. and Christopher Young (1976) — The Relationship between Man and Karst: *NSS Bulletin* **38**:17-26.

Manuscript received by the Editor and accepted 22 August 1976.

Selected Abstracts From Recent Meetings

NSS Convention, Decorah, Iowa, 13-15 August 1974

Status of the Bat Plecotus Townsendii Virginianus in Kentucky

Michael J. Harvey*

It is estimated that less than 5000 *Plecotus townsendii virginianus* survive in a few caves of Kentucky, Virginia, and West Virginia. A single hibernating colony may represent the entire Kentucky population. The colony was estimated to contain 1000 in October 1963, 850 in March 1964, and 1000 in March 1965. On 13 March 1974, less than 500 individuals were present, indicating an approximate 50% decrease in the population during the previous nine-year period.

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Diel Activity of the Grotto Salamander, Typhlotriton Spelaeus

William H. Wratherred, Jr. * and Michael J. Harvey *

Diel activity of the troglobitic salamander, *Typhlotriton spelaeus*, was studied from 24 May through 27 August 1973 at the Ozark Underground Laboratory, Taney County, Missouri. Thirty-two salamanders were marked for individual identification. Activity data were recorded during 213 two-hour periods. Observations were made during all hours of the day and night. Activity was greatest between 0800 and 1800, with a peak at 1600. Minimum activity was recorded between 2200 and 0400.

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Conservation and The Cave Register

Nick Noe *

Cave registers may become one of our best means of promoting cave conservation. Inefficiency and the lessons of the past have taught us that sustained effort will be necessary to achieve a better public cave conservation attitude. The problems of maintaining an efficient cave register program are many and complex. Construction, repair, supply, analysis, and processing can be costly, as well. This commitment should be made before it becomes too late. The register serving as a tool for public education is not without controversy among cavers. The alternatives of secrecy, gating, caver certification may prove less viable in the face of increased public pressure. Even the impact of the register upon the cave itself must be considered. The ultimate question one must consider is: "Will the register benefit the cave?".

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Thomas Ashe and The Great Catacomb Legend of Fayette County, Kentucky

Angelo I. George*

Between 1810 and 1814, an astounding series of events swept through eastern America and spread all the way to the European continent: Mummies were found in the caves of Tennessee and Kentucky. Ordinarily, this would not stimulate much attention, but these mummies were thought to have been embalmed just like Egyptian mummies (Swartz, 1967). What is even more remarkable, there is a legend which recounts that hundreds of mummies, each wrapped in linen were discovered in a catacomb or cave near Lexington, Kentucky in 1776; this was substantiated by Thomas Ashe, who visited the site in 1806.

The legend rests with statements made by Ashe (1808), most noted as an unreliable English traveler of slight veracity and a gifted imagination for physical and historical events. Late 19th and 20th Century historians generally agree that Ashe fabricated the catacomb legend.

The catacomb legend pre-dates the discovery of the Tennessee and Kentucky mummies by four years! It should be pointed out that Ashe did conduct an extensive (although rarely quoted) literature search of each geographical area that he visited (these he plagiarized). I believe that a portion of the catacomb story is based upon a real event. Ashe is alleged to have visited Lexington in 1806, when the town was at the crossroads of the saltpeter industry, commerce, and communication. It is very likely, judging from the frequency of discovered mummies from the Mammoth Cave region, that a similar mummy find may have been made prior to 1806. Ashe, being an opportunist for fantastic frontier tales, changed the locale of the discovery to one with which he was more familiar and within the context of his travel book.

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Did the Australopithecines Prefer Karst Terrain?

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Kopper and Young's article on "the relationship between prehistoric man and karst" provides an example of the difficulties inherent in any such attempt at generalization. After noting that an "anomalous" proportion of fossil hominids have been found in association with karst/soluble-bedrock terrain, the authors attempt to establish that this distribution reflects the fact that a high proportion of the early hominids were *living* in these areas because of the presence of "unique conditions and resources that were important to [their] survival." In and of itself, this hypothesis is extremely interesting. However, there are some weaknesses in the discussion presented by Kopper and Young, *especially* if one is to extrapolate from Pleistocene Europe to all of the Plio-Pleistocene. A brief discussion of the African australopithecine material should be enlightening.

First, determining the number of sites and individuals for the African australopithecines is by no means an easy, clear-cut task. Insofar as the former is concerned, an important question would revolve around the classification of the Omo River and East Rudolf areas. If both were to be viewed as individual sites, then the percentage of australopithecine sites associated with karst/soluble-bedrock" terrain would be anywhere from 38.5% to 45.5%, depending upon the classification of the Kanapoi and Lothagam Hill fragments (the latter of which is curiously missing from Kopper and Young's "Table II"). On the other hand, if each of the fossil localities *within* the Omo River and East Rudolf areas were to be viewed as an individual site, then the aforementioned percentages would shrink to 4.1%, or less (based upon data presented by Howell and Coppens, 1976, and by Leakey, 1976). In either case, the resultant percentages would differ considerably from the summary figure (of 92%) presented by Kopper and Young. Insofar as the number of individuals is concerned, again, some important questions would need to be answered. For instance, the figures for the South African australopithecines in Kopper and Young's "Table II" would seem to indicate that the authors were dealing with estimates of the number of *individuals* at each site (as opposed to the number of *fossil specimens* at each site) (see Table I). As Mann (1975) has emphasized, the determination of such figures is difficult. The best that can be expected in such an analysis is merely a "rough estimate" of the number of individuals at each site. If the figures used by Kopper and Young did represent the number of fossil specimens at each site, then their information should be corrected (see Table I). Finally, it should be noted that similar problems have been encountered with the East African material—*i.e.*, either Kopper and Young were relying on estimates of the number of individuals at each site, or they were using out-dated information (see Table II). It was these estimates (of the number of sites and of the number of individuals per site) which formed the basis of Kopper and Young's "significant anomaly" in the occurrence of fossil hominids. In the case of the African australopithecines, this "anomaly" would seem to be either non-existent or greatly reduced in magnitude.

Nonetheless, if such an "anomaly" did exist, the question of its significance would also remain. Kopper and Young have attempted to grapple with this question, and again, it would seem that their emphasis of European Pleistocene material has led them into overgeneralization. First and foremost, they have dismissed the concept of preferential preservation with little discussion. In doing so, they seem to have ignored two important points: (1) caves are inherently complex systems (*i.e.*, each must be examined individually, as environmental differences can occur within and between them, and each has the potential to have gone through a myriad of depositional and/or erosional cycles) (Butzer, 1971 and 1976), and (2) "preservation" is an unlikely phenomenon (Cornwall, 1964)—it is the exception rather than the rule, and thus virtually any preserved specimen represents a case of preferential preservation.

In turning to the African australopithecines once again, the available fossil material would seem to indicate that (contrary to the implications of Kopper and Young's data) the South African Plio-Pleistocene cave deposits were extremely *good* sites for bone preservation through fossilization. As Brain (1958 and 1967a) has repeatedly demonstrated, surface-derived debris was calcified, *in situ*, by the lime-rich solutions percolating through these deposits, forming massive accumulations of bone-rich breccia. Although the deposits would not, of course, preserve every piece of material introduced into the caves, the quantity of material preserved would seem to indicate that these sites *would* represent a classic case of preferential preservation—the amount and type of material preserved might well give an inaccurate picture of the composition and distribution of living populations—especially when taken to be

TABLE I. South African Australopithecines.

	Number of Fossils (from Kopper and Young, 1976)	Number of Individuals (from Mann, 1975)	Number of Fossil Specimens (from Mann, 1975)
Makapansgat	30	8-13	28
Sterkfontein	40	(28-43)*	(117)*
Kromdraai	6	5-6	9
Swartkrans	60	(79-94)**	(218)**
Taung	1	1	1

* Includes material from the Sterkfontein "Type Site" and the Sterkfontein West Pit

**Includes the "Telanthropus" material

TABLE II. "Australopithecines" from the Omo River and East Rudolf Localities.

	Number of Fossils (from Kopper and Young, 1976)	Number of Fossils (from Leakey, 1976; Howell and Coppens, 1976)
East Rudolf	30	110*
Omo River	13	231*

*Includes some specimens attributable to *Homo*

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indicative of all of Africa.

Finally, one other topic of particular importance to the South African australopithecine deposits is not discussed by Kopper and Young. This concerns the mode of accumulation of the deposits in question. As Kopper and Young have concentrated upon fossil material from the Pleistocene of Europe, the question of how the fossils came to be incorporated into the cave deposits may seem (to some investigators) to be trivial. However, again, if the investigations and explanations of Kopper and Young are to be carried into the African Plio-Pleistocene, then the question of the mode of accumulation of the South African australopithecine deposits must be mentioned. As Howell (1959, p. 838) has noted, "The sites may have been (i) natural crevices into which animals fell, (ii) crevices into which bone accumulations were swept by natural agencies, (iii) carnivore lairs into which prey or scavenged carcasses were carried, (iv) rubbish heaps, or (v) actual occupation sites of the australopithecines." Nearly every one of these alternatives has received some form of support in the literature. However, the consensus of opinion now appears to revolve around three primary accumulators (for the larger mammalian fossils): hyaenas (Klein, 1975), leopards (Brain, 1967b and 1969), and/or the hominids themselves (Brain, 1975; Dart, 1957). It should be noted that there is still disagreement as to the accumulators of the fossil material at certain sites (*cf.* Dart, 1957 and Klein, 1975). Also, certain investigations would seem to indicate that different accumulators operated at different sites (Brain, 1975). Nonetheless, the implications for Kopper and Young's study should be fairly obvious, for even if there were evidence for a "significant anomaly" in the occurrence of the australopithecines, and even if preferential preservation were to be ruled out as an important factor in this analysis, the significance of the aforementioned "anomaly" would still be in question: we might well be dealing with the "preferences" of a carnivore with a penchant for australopithecines!

In summary, a disproportionate number of the Pleistocene hominids in Europe and Asia might have frequented the karst/soluble-bedrock terrain, and maybe they did so for reasons other than that of shelter in caves. However, insofar as the African australopithecines are concerned, either they didn't partake of the interesting advantages hypothesized for the karst/soluble-bedrock terrain (in which case, interesting social-evolutionary questions arise), *or* the mode of analysis employed by Kopper and Young is simply not applicable to the australopithecines, at least not at the present state of our knowledge.

Literature Cited

Brain, C.K. (1958) — The Transvaal Ape-Man-Bearing Cave Deposits: *Transvaal Mus. Mem.* **11**, 131 pp.

————(1967a) — Procedures and Some Results in the Study of Quaternary Cave Fillings, **IN**: W.W. Bishop and J.D. Clark (Eds.)—Background to Evolution in Africa: Chicago, Univ. of Chicago Press, pp. 285-301.

————(1967b) — The Transvaal Museum's Fossil Project at Swartkrans: *S. A. Jour. Sci.* **63**:378-384.

————(1969) — The Probable Role of Leopards as Predators of the Swartkrans Australopithecines: *S. A. Arch. Bull.* **24**:270-171.

————(1975) — An Interpretation of the Bone Assemblage from the Kromdraai Australopithecine Site, South Africa, **IN**: R.H. Tuttle (Ed.)—Paleoanthropology Morphology and Paleoecology: The Hague, Mouton, pp. 225-244.

Butzer, K.W. (1971) — Environment and Archeology: Chicago, Aldine, 703 pp.

————(1976) — Geo-ecological Perspectives on Early Hominid Evolution, **IN**: C. Jolly (Ed.)—African Hominidae of the Plio-Pleistocene: London, Duckworth, IN PRESS.

Cornwall, I.W. (1964)—Bones for the Archaeologist: London, Phoenix House, 261 pp.

Dart, R.A. (1957) — The Osteodontokeratic Culture of *Australopithecus prometheus: Transvaal Mus. Mem.* **10**, 105 pp.

Howell, F.C. (1959) — The Villafranchian and Human Origins: *Science,* **ns 130**:831-844.

———— and Y. Coppens (1976) — An Overview of Hominidae from the Omo Succession, Ethiopia, **IN**: Y. Coppens, F.C. Howell, G.L. Isaac, and R.E.F. Leakey (Eds.) Earliest Man and Environments in the Lake Rudolf Basin: Chicago, Univ. Chicago Press, pp. 522-532.

Klein, R.G. (1975) — Paleoanthropological Implications of the Nonarcheological Bone Assemblage from Swartklip I, South-Western Cape Province, South Africa: *Quaternary Research* **5**:275-288.

Kopper, J.S. and Christopher Young (1976) — The Relationship between Man and Karst: *NSS Bulletin* **38**:17-26.

Leakey, R.E.F. (1976) — An Overview of the Hominidae from East Rudolf, Kenya, **IN**: Y. Coppens, F.C. Howell, G.L. Isaac, and R.E.F. Leakey (Eds.)—Earliest Man and Environments in the Lake Rudolf Basin: Chicago, Univ. Chicago Press, pp. 476-483.

Mann, A.E. (1975) — Paleodemographic Aspects of the South African Australopithecines: *Univ. Pa. Publ. Anthr.* **1**, 171 pp.

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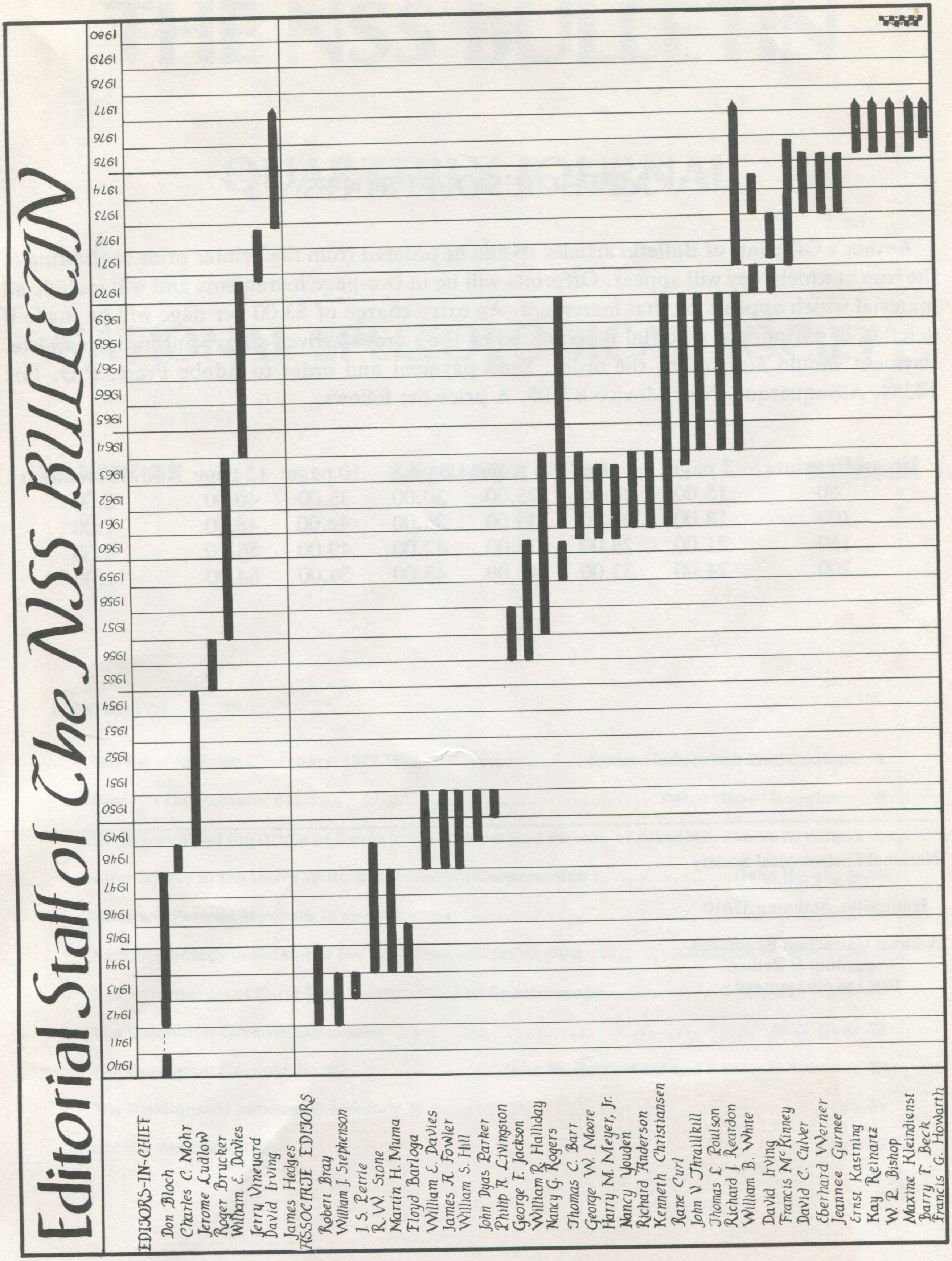
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