

FINAL

GEOLOGY IN THE VICINITY OF MONTEZUMA'S CAVE, SOUTHERN HUACHUCA
MOUNTAINS, COCHISE COUNTY, ARIZONA

by. Michael F. Doe
AUGUST 1985

For
Coronado National Memorial
United States Department of the Interior

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INTRODUCTION

The purpose of this report is to provide a better understanding of the geology and the geologic history of Montezuma's Cave. This report will also delineate the structural controls of the cave formation. It is hoped that this information will enable the Park Service to utilize this resource to its fullest extent.

This report has been prepared so that the reader may gain an understanding of the geologic structures and lithology of the mapped area, and also an appreciation of the regional geologic history. Understanding the complex geologic framework of southeastern Arizona will help clarify geologic structures in Montezuma Canyon. Further understanding will be aided by a glossary at the end of the report.

Coronado National Memorial was established to commemorate the early Spanish explorer Coronado who passed through this region in the mid 1500's. The memorial is bounded on the south by the border of the United States and Mexico. The western boundary runs west of Coronado Peak north past Montezuma Pass to a point just south of United States Land Monument #1274. The north boundary runs southeast to Montezuma Peak, then northeast to Ash Peak. The east boundary runs southeast to an unnamed peak in section 8 of T. 24 S., R. 21 E, then south to the U. S. border (see also figures 1).

The Memorial contains high desert vegetation such as oak, manzanita, pinyon pine, ocatillo, prickly pear cactus and several varieties of grasses. The study area is steep and rugged ranging from 5400 to 6200 feet above sea level.

GEOLOGIC SETTING

The geology around Montezuma's Cave and the visitor center is complex. Several episodes of deformation and intrusion have occurred throughout the geologic history of the mapped area which, on this small scale, reflects the complexity of southern Arizona geology (see geologic map and cross-section, plate 6 and 7).

The mapped area contains steeply northeast dipping late Permian strata that have been faulted and intruded during two events of igneous activity. The first and most outstanding intrusive is the Jurassic Huachuca Quartz Monzonite, which forms the bulk of Montezuma Peak. Blocks of older Paleozoic rocks exhibiting varying degrees of metamorphism are included around the top and outer perimeter of the stock. The Paleozoic blocks were apparently caught in the pluton during intrusion. The second stage of intrusion probably occurred in the Late Cretaceous through Tertiary Laramide Orogeny resulting in silicification of faults in the mapped area.

Since the Permian, southeastern Arizona has undergone

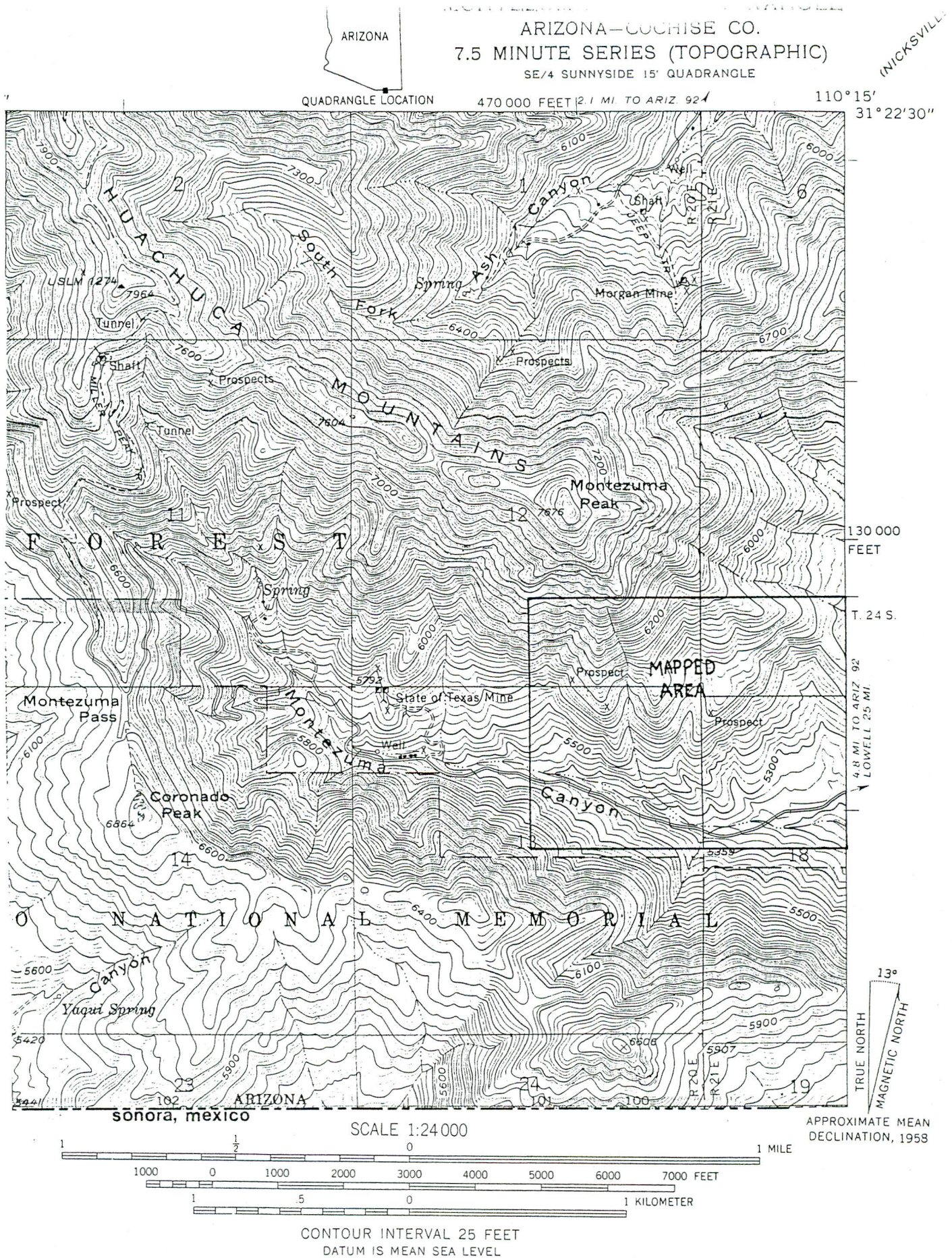


Figure 1. Location of mapped area and memorial.

several tectonic events and as a result, structural details of each event have been camouflaged by later deformational structures (Davis, 1981). Throughout southern Arizona's deformational history new faults developed and older ones were reactivated. Those reactivated are called complex faults (Drewes, 1981). Because complex faults can undergo some movement in any deformational event it is virtually impossible to interpret the intricacies of the fault movements and relative directions except in generalized terms.

In the mapped area, mineralization has occurred along some faults, and also pervasively along bedding planes of the steeply dipping Permian units proximal to the Huachuca Quartz Monzonite stock. Economic mineral deposits are commonly associated with Laramide plutons, however, it is difficult to say if the mineralization was introduced during the Jurassic or Laramide plutonism (Drewes, 1981).

LOCATION OF STUDY AREA

The study area is located in the southernmost end of the Huachuca Mountains in Montezuma Canyon on the southwest flank of Montezuma Peak (see figure 1). The area includes portions of the Montezuma Pass Quadrangle (southeast corner of section 12, northeast corner of section 13 of T. 24 S., R. 20 E. and northwest corner of section 18, southwest corner of section 7 of T. 24 S., R. 21 E.), Cochise County, Arizona. The area mapped covers 387.4 acres within Coronado National Memorial. The visitors center and staff residences are within the map area.

PREVIOUS WORK

Previous fieldwork was done in 1968 by Philip T. Hayes and Robert B. Raup. They produced a map of the Huachuca and Mustang Mountains. Later, in 1981, Harold D. Drewes described the tectonics of southeastern Arizona which includes the area studied in this report. Studies of adjacent areas have been made in the Canelo Hills (Hayes, 1965) to the west, the east central Huachuclas (Weber, 1950), and the northern Huachuclas (Alexis, 1949). The regional tectonics have been and are still being studied extensively and information is constantly being reinterpreted with each published map.

PERMIAN LIMESTONE DEPOSITION

The Permian period lasted for 57 million years, from 280 million years before present (MYBP) to 223 MYBP. The Permian age rock units in the mapped area are the Colina Limestone, the Epitaph Formation, the Scherrer Formation, the Concha Limestone and the Rainvalley Formation. Part of the Epitaph Formation is missing where a sill of Jurassic Huachuca Quartz Monzonite intruded along its less competent bedding and the Rainvalley Formation was eroded away during a period of uplift (see figure 6).

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The bedding attitudes of stratified units in the vicinity of Montezuma's Cave strike about N55W and dip to the east at 40 to 60 degrees. Unless otherwise noted all of the units described have roughly the same bedding attitude.

The limestones in the vicinity of Montezuma's Cave are Permian units of the Scherrer Formation approximately 270 million years old. Montezuma's Cave itself is developed in the middle member of the Scherrer Formation.

Identification of the Scherrer Formation was made by association of the limestone and sandstone units. Identification using the fossil record was not possible because the limestone in the mapped area is locally metamorphosed and fossil evidence has been masked.

The lithology of the Scherrer Formation reflects the environment of deposition. In Permian time, widespread shallow seas covered the region and their gently sloping seafloors were sensitive to sea level changes; this is reflected in the interbedded nature of the sand- and siltstones (regressive environment) and interbedded limestones and dolomite (transgressive environments). The Permian was the last period and phase of the Paleozoic era, which was generally characterized by massive beds of limestones and dolomites.

The type-section of the Scherrer Formation is described as 65 feet of red siltstone at the base, 300 feet of white to brown sandstone with a few limestone beds in the lower part, 160 feet of limestone and dolomitic limestone, and 150 feet of white sandstone at the top (Bryant, 1968).

In the mapped area the Scherrer Formation was determined by lithologic association. The base is a tan to grayish-tan, thin to laminated, fine sand- and siltstone with several interbedded units of green-gray to gray dolomites and limestone. Upward, toward the middle of the section, the limestones become more frequent and massive. In the massive section, approximately 200 to 250 feet thick, Montezuma's Cave developed. Slight metamorphism destroy fossil evidence here and some epidote mineralization has occurred. The upper units of the Scherrer are predominantly white sandstones and siltstones like those of the lower unit; however, interbedded limestones are non-existent higher in the unit. The overall section is approximately 900 feet.

The Epitaph Formation is stratigraphically below the Scherrer. The type-section of the Epitaph is dolomitic in its lower 250 feet and its middle 400 to 500 feet are interbedded limestone, dolomite, sandstone and mudstone with much gypsum; whereas the upper 1000 feet are practically uninterrupted dolomite (Zeller in Bryant, 1969). However, in the mapped area part or all of the lower section is missing where quartz monzonite has intruded along bedding. Presence of the Epitaph is difficult to establish due to its gradational contact into the

Scherrer Formation.

The next lower limestone unit cannot be found in direct contact with the Epitaph. The contact of the limestone with the Epitaph was intruded by a sill-like intrusion of quartz monzonite and down-section the limestone faulted off by a northwest trending fault. This lower unit is a massive bed of gray to dark gray, striped, metamorphosed, sparitic limestone that has been highly fractured and faulted. Unfortunately, metamorphism has destroyed all megascopic fossil evidence. In some places blebs of fracture filling, druzy quartz crop out on the surface. The limestone has numerous solutional holes and is conducive to minor cavern development. Because the bedding attitudes of this limestone are similar to the attitudes of Scherrer Formation, the limestone is probably the Colina Formation.

In the southern mapped area the youngest Permian unit, the Concha Limestone, is thrust-faulted onto folded Bisbee Group sediments and lies unconformably below Triassic(?) - Jurassic volcanics. The section of Concha Limestone is a gray, fossiliferous, sparitic, massive limestone unit approximately 100 feet thick. Fossils include echinoid spines, crinoid stems, bryozoa and gastropods. Chert is moderately abundant in large nodules and discontinuous beds. The type-section of this limestone has a similar description.

MESOZOIC PLUTONISM, DEFORMATION, AND DEPOSITION

Rocks of late Permian to the late Triassic age are not found the mapped area. Erosion stripped off the entire Rainvalley Formation and some of the Concha Limestone. Eroded materials were deposited into an adjacent basin to the south and southeast (Drewes, 1981). This environment of erosion and deposition probably existed until the late Jurassic or early Cretaceous. During the late Triassic(?) - Jurassic, volcanic material was deposited in a basin that extended from slightly west of the southern Huachucas, northwest toward what are now the Tucson Mountains. Most of this volcanic material was deposited on the weathered surfaces of the Concha Limestone. The volcanics are grayish-red trachytic lava flows that contain blocks of the Concha near the base. The upper sections of the flow contain exotic blocks of other Permian units as old as Scherrer Formation siltstones and limestones (Simons, 1966). During or later in the Jurassic period, the Huachuca quartz monzonite intruded, lifting exotic blocks of the overlying Paleozoics.

Jurassic Plutonism

As the quartz monzonite pluton intruded the overlying strata, the edges of its outer parameters spread out along less competent bedding planes such as the siltstones of the Epitaph Formation. The distance these sills intruded was not far but was enough to interrupt the local stratigraphic sequence in the mapped area (figure 7). The monzonite stock also marbleized the limestone to varying degrees and in some outcrops of the Scherrer

Formation the siliceous beds showed epidotization.

Triassic Erosion and Deposition

The late Jurassic to early Cretaceous was a period of apparent tectonic quiescence in southeastern Arizona (Drewes, 1981). This resulted in the deposition of the lower Bisbee Group through gradual reduction of local topography. The Bisbee Group consists of extremely thick deposits of fluvial, estuarine, and some marine rocks, up to 8000+ feet in thickness. Four formations make up the Bisbee Group: The Glance Conglomerate, the Morita Formation, the Mural Limestone, and the Cintura Formation. In this report the Bisbee Group is undifferentiated. Bisbee Group sand- and siltstones (Morita Formation) are found in the mapped area south of the major northwest trending fault and to the south beneath the overthrust Concha Limestone.

Cretaceous-Tertiary Deformation

The Laramide Orogeny began in the Late Cretaceous or early Tertiary when the subducting Pacific (Farallon) plate and the Continental (North America) plate increased their rates of convergence (Coney and Reynolds, 1977). Because the subducting plate angle was very steep and the rate of convergence increasing, southwest to northeast oriented compression occurred throughout southern Arizona. This compression resulted in extensive crustal shortening and folding with northwest-oriented axes. Compressional response had two styles of regional faulting, northwest trending high angle complex faults and northeastern directed thrust faults (Drewes, 1981). Complications arose when geologic obstacles to thrust movement were encountered, such as Jurassic stocks that had penetrated high into the Paleozoic sequence or fault blocks bounded by complex faults with large uplift on their northeastern side (Drewes, 1981).

Theories on the nature of the faulting and folding in southern Arizona are varied. Davis, (1979), has pointed out that the magnitude of compression in southern Arizona was limited by reactivation of older Precambrian faults which absorbed much of the Laramide strain through high angle reverse faulting. Along with the high angle reverse faulting was low angle thrust faults that moved sections of strata up to 20 kilometers in a northeasterly direction. Drewes, (1981), interprets the Laramide compression differently. Drewes feels that the compression resulted in the development of several allocthonous plates that were thrust faulted distances up to 100 kilometers northeast. Within the plates differential stress caused northeast trending faults. The allocthonous plates also contained NW-SE oriented fold axes. Drewes places much less emphasis on the role of the Precambrian basement rocks. This subject matter is clearly beyond the spectrum of this paper but the differing thoughts must be pointed out.

In the mapped area a high angle, northwest oriented fault

with the northeast side uplifted, roughly traces the canyon bottom. For this report the fault will be called the Montezuma Canyon Fault. Vertical displacement along this fault was at least several hundred feet.

During the Cretaceous, movement on the Montezuma Canyon Fault brought the Bisbee Group silts- and sandstones into close proximity with the lower Permian units. As Laramide compression began, the sandstones and siltstones of the Bisbee Group were folded against the Permian Colina limestone at the Montezuma Canyon Fault scarp. The Permian units were rotated slightly to the northeast which resulted in some faulting along bedding planes that can be seen in Montezuma's Cave and in a fault found in the east drainage. The compressional regime also resulted in additional folding of the Scherrer Formation against the more resistant quartz monzonite stock, seen in the drainage near the west entrance of Montezuma's Cave (figure 6). Fractures occurred at the hinge zones of the folds. Compressive forces created ductility within the cherty layers of the Scherrer Limestone resulting in small parasitic folds. The compression also caused several low angle to horizontal fractures throughout the Scherrer limestone.

Meanwhile, during this same time period, rock units to the southwest were being thrust-faulted to the northeast. This resulted in the Concha Limestone being thrust over the folded units of the Bisbee Group. It also transported silicic volcanic materials that had been deposited over the Concha Limestone to the southwest into the mapped area.

Laramide Plutonism

During the Early Tertiary, Laramide intrusion began. In the mapped area, most faults were silicified. Most silicification was confined to major faults such as the Montezuma Canyon Fault and smaller faults developed at or west of the quartz monzonite-Colina limestone contact. The bedding-parallel faulting, mentioned earlier, shows no evidence of silicification because the faulting did not extend through the quartz monzonite stock. Sulphide mineralization has occurred along the upper quartz monzonite-Scherrer contact with no evidence of silicification.

Extensional processes of the mid-Tertiary are not evident in the mapped area although evidence of it does exist throughout the many areas of southeastern Arizona. However, a Tertiary dike of dacite porphyry does cut across the mapped area along a northwest direction (figures 6 and 7).

Post-Laramide Erosion

Late Tertiary and Quaternary erosion resulted in the downcutting of Montezuma Canyon and the exposure of rocks on the north and south walls of the canyon. During this time, cavern development was taking place throughout the limestone units of the mapped area.

CAVERN DEVELOPMENT

Montezuma's Cave is located southwest of Montezuma's Peak in the center of the mapped area. The main or original entrance is on the west side of the ridge and the cave spans the width of the ridge. It has a second entrance that was opened by a prospector at the turn of the century. The cave temperature fluctuates according to outside temperature and weather conditions. The general cave environment is dry with an occasional seepage of moisture from periodic rainfall. The low humidity and fluctuating temperature are due to the presence of the east entrance which allows for cross ventilation and consequently escape of cavern moisture. Total length of the cave is 600 feet and passage size averages 20 feet high by 70 feet wide. Breakdown boulders cover sections of the floor but for the most part the floor is sandy and flat. Speleothems are sparse due to excessive vandalism but some do exist because of their great size. Three large broken columns near the east entrance have all been fractured by natural events.

The west entrance to the cave is formed by two faults that strike perpendicular to the main passage, erosion has now exposed the entrance (figure 6). The fractures occur at hinge zones but are not necessarily fractures directly due to the act of folding. Rather, the fractures are a result of compression against the quartz monzonite stock. The east entrance was also formed along a fault but was filled with boulders. This entrance is still filled with boulders, although, a small passage through has been opened.

Nearly every block of limestone in the mapped area has, or shows evidence of, cavern development. Aside from Montezuma's Cave, there are two other small explored caves, numerous fissures with depressed zones and collapse features filled with debris and secondary deposits of calcite. The genesis of these smaller caves is similar to most caverns developed along planar weaknesses such as faults or jointing patterns in bedrock. However, Montezuma's Cave has very unique structural constraints that result in its great size and unusual shape.

Normally, caves developing in limestone tilted like that of the Scherrer Formation will develop a passage cross-section like figure 2.

In figure 2, the cave is formed in tilted strata and the passage develops a shape that is parallel to subparallel to the strata. Stages of development would include the normal interjointed and interbedded solutional phases followed by eventual collapse of headwall slabs. Montezuma's Cave is developed in strata that is steeply dipping but the passage cross-sections do not have the expected shape.

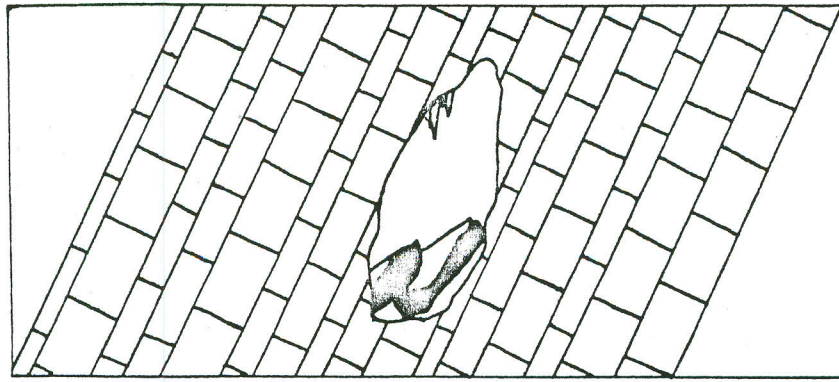


Figure 2. Expected cross-section.

In figure 3, a typical cross section of a passage in Montezuma's Cave is shown. Note that it has a very wide, arching

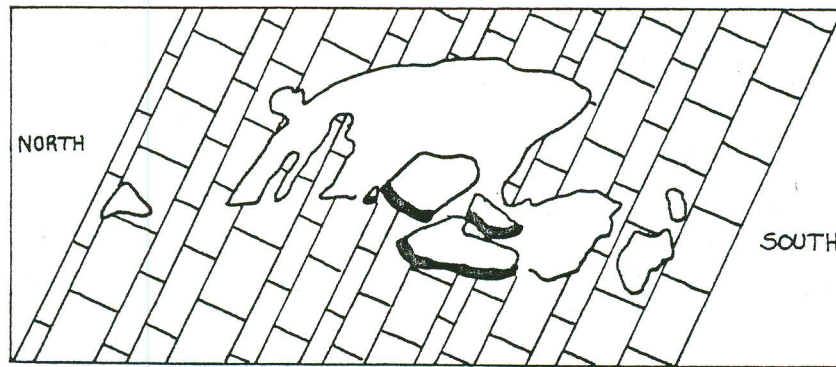


Figure 3. Cross-section from Montezuma's Cave.

roof that is nearly level. In some sections there are relic structures that hang down from the ceiling that are bedding planes extending into the passage.

The reason for the unusual shape of the passage in Montezuma's Cave is found in the geologic structures of the limestone. The tectonic events mentioned earlier influenced the eventual shape of the passage.

In figure 4, the same cross-section of passage seen in figure 3 is shown with the geologic structures. A combination of conditions had to be present in order to complete the development of the cave. First the limestone was proximal to a hot, igneous body which increased the grain size. Then the limestone was rotated towards the northeast which caused fractures to develop along bedding planes within the section. The bedding parallel faulting allowed easier access of acidic waters into the limestone. Further compressional events fractured the limestone at low angles as it was compressed against the quartz monzonite stock. Finally, burial beneath sediments helped increase the acidity of the groundwater and higher groundwater tables provided an ideal cave forming environment.

The structures controlling the development of the roof are two (possibly three) low angle fractures that run nearly

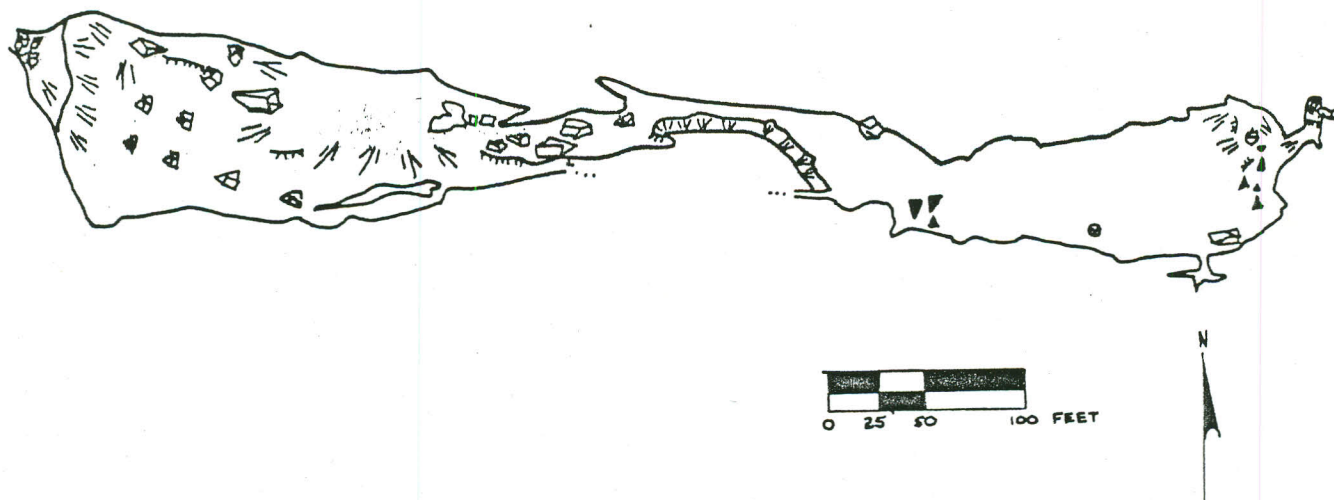
horizontally across the tilted strata. The fractures show no relative movement but were probably open enough to allow for water flow and solution of limestone and eventually played the role as parting points for ceiling collapse.



Figure 4. Cross-section from Montezuma's Cave showing geologic structures.

Depending on the height of the local water table and/or the proper hydrologic conditions, Montezuma's Cave, at one time, acted as a water course or spring. Evidence of water flow can be found in passages along the south wall. Scallops, erosional features, created by free flowing water and frictional turbulence that eroded irregularly spaced concavities up to three inches in diameter and one-half inch deep. The scallops indicate water flow towards the east entrance at rates less than .4 feet per second (from Curl in Sweeting, 1973). The scallops seem to be confined to the smaller passages of the caves where hydraulic variations would have the greatest affect.

PLAN VIEW OF MONTEZUMA'S CAVE, COCHISE CO., AZ.



—Explanation of Symbols—

- ▼ STALACTITE
- ▲ STALAGMITE
- ◻ BREAKDOWN
- ≡ SLOPE LINES DIVERGE DOWNHILL
- ⊙ PIT
- ⌋ DROP IN CEILING

Figure 5. Plan view of Montezuma's Cave.

GEOLOGIC TIMESCALE

Era	Period	Epoch	time interval
(in millions of years)			
Cenozoic	Q Quaternary	Holocene	.01 - present
		Pleistocene	1.8 - .01
	T Tertiary	Pliocene	5? - 1.8
		Miocene	23 - 5?
		Oligocene	38 - 23
		Eocene	53 - 38
		Paleocene	65 - 53
	K Cretaceous		135 - 65
		J Jurassic	192 - 135
		T Triassic	223 - 192
Paleozoic	P Permian		280 - 223
	P Pennsylvanian		321 - 280
	M Mississippian		345 - 321
	D Devonian		405 - 345
	S Silurian		432 - 405
	O Ordovician		495 - 432
	C Cambrian		570 - 495
Precambrian			570 - 4500

GEOLOGIC CROSS-SECTION OF THE VICINITY AROUND MONTEZUMA'S CAVE, CORONADO NATIONAL MEMORIAL, HUACHUCA MTNS. COCHISE, ARIZONA

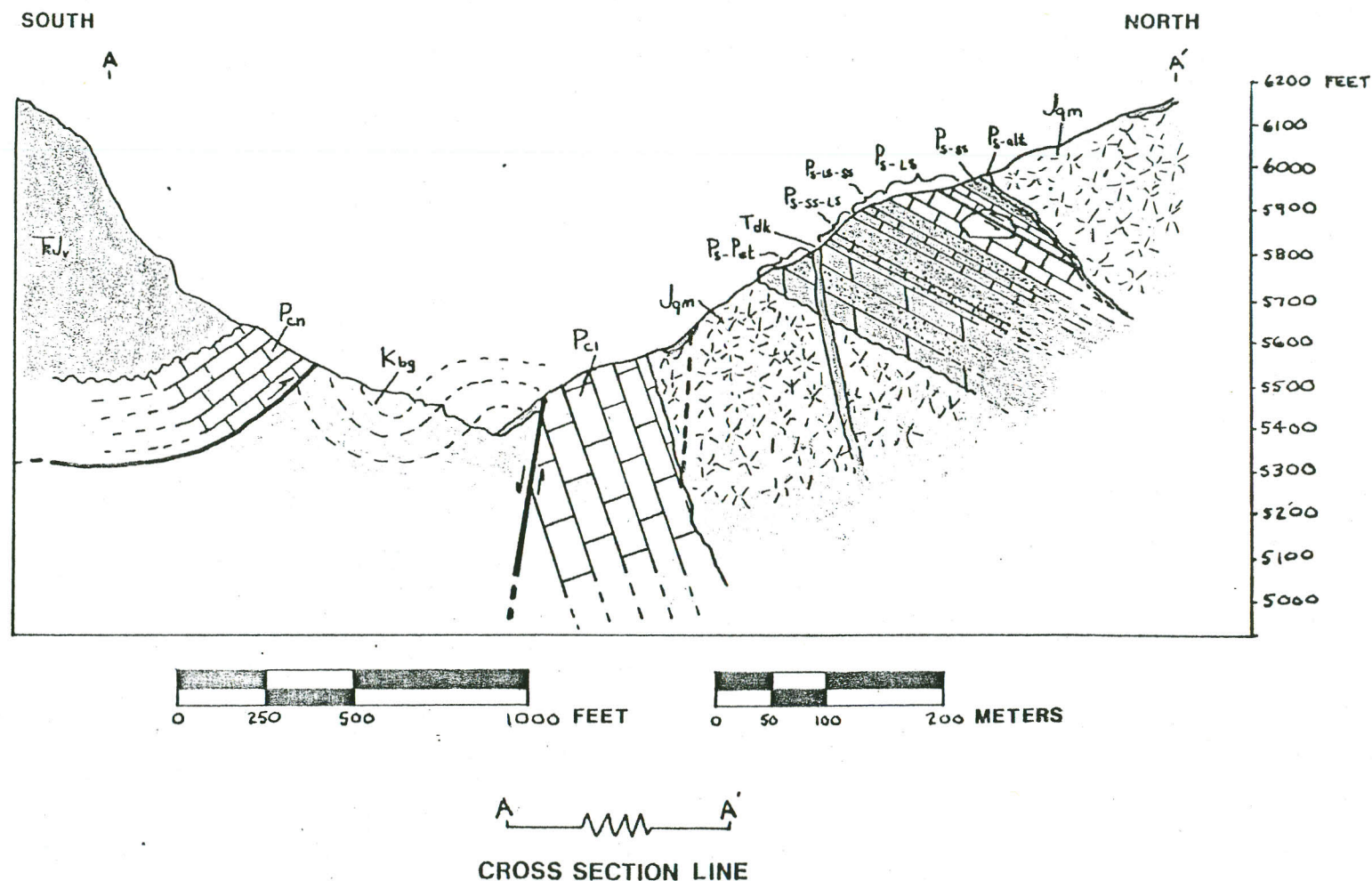
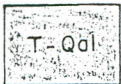
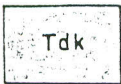
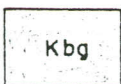
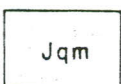
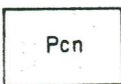
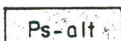
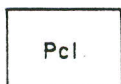
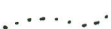
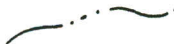


Figure 7. Geologic cross-section of the mapped area.

EXPLANATION FOR MAP AND CROSS-SECTION

QUATERNARY		Alluvium, unconsolidated sand up to boulders.
TERTIARY		Dacite porphyry; greenish-gray, contains phenocryst of feldspar and amphibole.
CRETACEOUS		Bisbee Group undifferentiated; red siltstones and sandstones, probably Morita Formation.
JURASSIC		Huachuca Quartz Monzonite; medium to coarse grained equigranular rock; pink orthoclase, white plagioclase, gray quartz, some biotite.
TRIASSIC		Triassic?-Jurassic, grayish-red, trachytic lava flow. Contains exotic blocks of Paleozoics (Concha limestone) near its base.
PERMIAN		Concha Limestone; light gray, thick bedded, abundant chert nodules, fossiliferous, sparitic, moderate slope former.
		Scherrer Formation: Ps-alt; dark tan- to brown, metamorphosed calcareous sand- and siltstone. Ps-ss; white quartzite fine- to medium grained with minor, thin bedded limestone. Ps-ls; gray, massive limestone, coarse grained (marbleized), with sandy chert nodules. Ps-ls-ss; tan sand- and siltstone with thin, interbedded, light gray limestone. Ps-Pet?; tan calcareous sand- and siltstones with interbedded, moderately thick, coarse grain dolomite, possibly the Epitaph Dolomite.
		
		
		
		
		
		Colina Limestone: gray to dark gray, massive, sparitic limestone, sugary texture, highly fractured and weathered slightly metamorphosed, striped or banded color.

SYMBOLS

	contact		thrust fault, teeth in upper plate
	contact located approximately		uncertain location of thrust fault
	concealed contact		stream bed
	strike and dip of bedding		road
	fault		surface opening
	fault located approximately		anticline
	fault, showing dips		

SYMBOLS CONTINUED ON NEXT PAGE

SYMBOLS (cont)

 fault, showing trend and plunge of linear features (D, down-thrown side; U, upthrown side)

 unconformity

 syncline

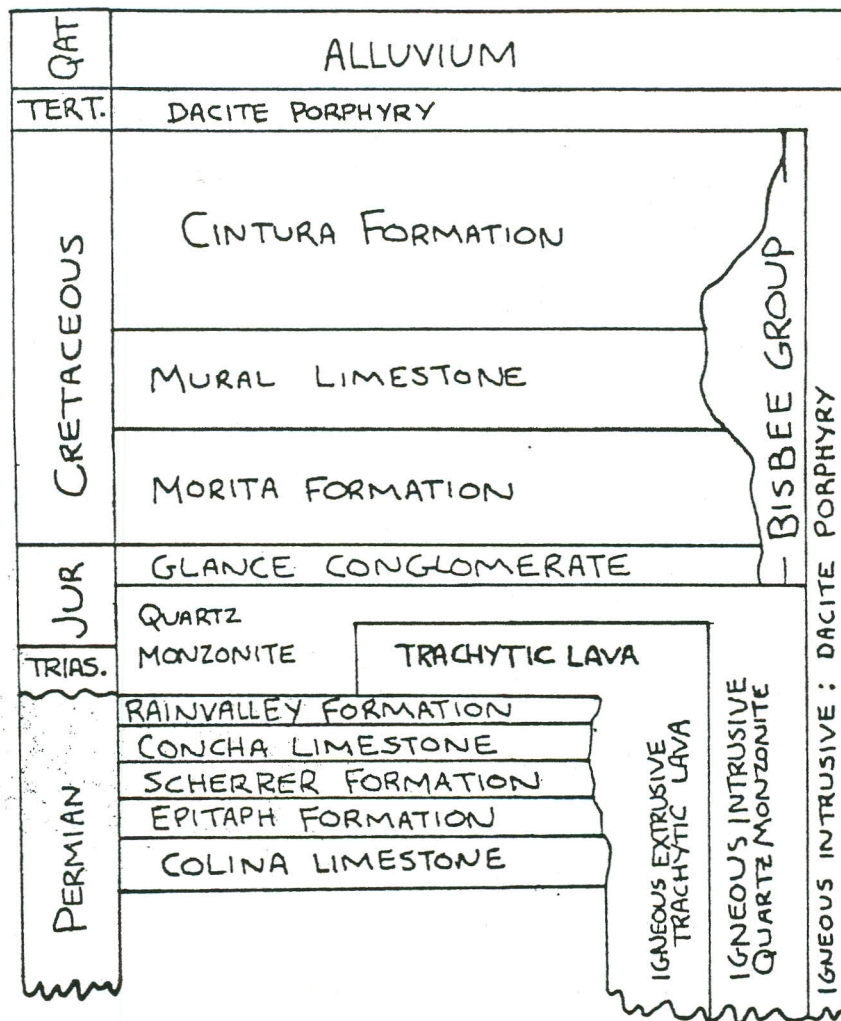


Figure 8. Idealized stratigraphic section with igneous intrusives chronologically coordinated.

SUPPLEMENTAL GLOSSARY FOR GEOLOGIC REPORT

Bedding - In sedimentary or stratified rocks, the division planes which separate the individual layers, beds or strata.

Cretaceous - Geologic time period that existed from 135 million years before present (m.y.b.p.) to 65 m.y.b.p. during the Mesozoic Era.

Dolomite - A magnesian rich carbonate ($\text{CaMg}(\text{CO}_3)_2$) rock. It occurs in a great many crystalline and noncrystalline forms the same as pure limestone, and among rocks of all geologic ages.

Environment of deposition - The sum total of all external conditions that may act upon an organism or depositional area that influence the existence or development of that are during deposition.

Epidotization - Emplacement of the mineral Epidote ($\text{Ca}_2(\text{Al},\text{Fe})_3(\text{SiO}_4)_3(\text{OH})$) by introduction of element rich fluids that react with the intruded rock to deposit epidote.

Fault - A fracture or fracture zone along which there has been displacement of the sides relative to one another parallel to the fracture.

Formation - The primary unit of formal mapping or description. Most formations possess certain distinctive or combinations of distinctive lithic features. Boundaries are not based on time criteria. Formations may be combined into groups or subdivided in members.

Fossil record - The remains or traces of animals or plants which have been preserved by natural causes in the earth's crust exclusive of organisms which have been buried since the beginning of historic time. Fossils naturally associated in a stratum; they possibly were derived from more than a single fossil community. The presence and abundance in the rock are called the fossil record.

Geologic structures - For this report 'geologic structure' will be a generalizing term that refers to large bodies of rocks and minerals, fractures and faults they might contain, and the various orientations they might have with each other.

Igneous - Formed by solidification from a molten or partially molten state. Said of the rocks of one of the two great classes into which all rocks are divided, and contrasted with sedimentary. Rocks formed in this manner have also been called plutonic rocks, and are often divided for convenience in plutonic and volcanic rocks, but there is no clear line between the two.

Igneous activity - Refers to any geologic activity involving molten rock, either deep, subsurface intrusive rocks or extrusive volcanic rocks.

Intrusive - Having, while fluid, penetrated into or between other rocks, but solidifying before reaching the surface. Said of plutonic igneous rocks and contrasted with extrusive.

Jurassic - The middle of three periods comprising the Mesozoic Era. Also the system of strata deposited during that period. (see also the 'Geologic Timescale').

Laramide Orogeny - Lower Cretaceous to Mid Tertiary (80 - 40 m.y.b.p.) processes that resulted in crustal deformation and mountain building through flexures and folds of strata, faults, and emplacement of plutons.

Limestone - A bedded sedimentary deposit consisting chiefly of calcium carbonate (CaCO_3). Limestone is the most important and widely distributed of the carbonate rocks and is the consolidated equivalent of limy mud, calcareous sand, or shell fragments.

Lithology - The physical character of a rock, generally as determined megascopically or with the aid of a low-power magnifier.

Marbleized - Metamorphism of rock that is composed essentially of calcite and/or dolomite. This process of recrystallization results in a coarser grained rock.

Metamorphism - Process by which consolidated rocks are altered in composition, texture, or internal structure by conditions and forces not resulting simply from burial and the weight of subsequently accumulated overburden. Pressure, heat, and the introduction of new chemical substances are the principal causes, and the resulting changes, which generally include the development of new minerals, are a thermodynamic response to a greatly altered environment.

Mineralization - To impregnate or supply with minerals. Minerals that were deposited through chemical reactions or by mineral rich hydrothermal fluids.

Paleozoic - One of the eras of geologic time that existed from 223 m.y.b.p. to 570 m.y.b.p.. It collectively includes the Cambrian through the Permian (see also the geologic timescale).

Permian - The last of seven periods of the Paleozoic Era; also the system of rocks deposited during that period. (see also 'Geologic Timescale').

Plate - One of the many large segments of the earth's crust (lithosphere) varying in thickness from 50 to 250 km. and including a portion of the upper mantle.

Pluton - A body of igneous rock that has formed beneath the surface of the earth by consolidation from molten rock.

Quartz monzonite - Basically a granite (igneous) type rock characterized by a specific percentage of minerals which classify it as quartz monzonite.

Regression - Gradual contraction of a shallow sea resulting in the emergence of land as when sea level falls or land rises.

Sandstone - A cemented or otherwise compacted sediment composed predominantly of quartz grains, the grades of the latter being those of sand.

Siliceous beds - Beds or strata of rock that range in thickness from 2 mm to 20 cm and laterally continuous in some places and in small pockets in other areas.

Silicification - The introduction of or replacement by, silica. Generally the silica formed is fine-grained quartz and druse quartz emplaced by hydrothermal fluids.

Sill - An intrusive body of igneous rock of approximately uniform thickness and relatively thin compared with its lateral extent, which has been emplaced parallel to the bedding of the intruded rocks.

Siltstone - A very fine-grained consolidated sedimentary rock composed predominantly of particles that are between 1/16 and 1/256 mm in diameter.

Stock - A body of plutonic rock that covers less than 104 square kilometers has steep contacts (generally dipping outward), and although it usually cuts bedding when it intrudes, it can also spread out along bedding.

Strata - Plural of stratum. Stratum is a section of formation that consists throughout of approximately the same kind of rock material; a stratum may consist of an indefinite number of beds, and a bed may consist of numberless layers; the distinction of layer and bed is not always obvious. 2. A single sedimentary bed or layer, regardless of thickness.

Subducting Plate - In plate tectonics it is the depressing and passing of one plate (see def. of plate) margin of the earth under another plate.

Tectonic Quiescence - A relatively long time of non mountain building processes that promote the development of flat lying terrains.

Transgression - Gradual expansion of a shallow sea resulting in the progressive submergence of land, as when sea level rises or land subsides.

Triassic - The earliest of the three periods of the Mesozoic Era. This time period existed from 223 m.y.b.p. to 192 m.y.b.p.. (see also 'Geologic Timescale')

Unit - An individual body of rock. This term is used to refer to a particular body or bodies of rock that were specified before or as a spacial reference.

Volcanic material - Varieties of rock that result from a volcanic event. These varieties include trachite and pumice.

REFERENCES CITED

- Alexis, Carl Odman, 1949, Geology of the northern part of the Huachuca Mountains, Thesis (Ph.D), University of Arizona.
- Bryant, D.L., 1968, Diagnostic Characteristics of the Paleozoic Formations of Southeastern Arizona: Ariz. Geol. Soc., Guidebook III, pp. 33-47.
- Coney, P.J., and Reynolds, S.J., 1977, Cordilleran Benioff Zones: Nature, v. 270, p. 403-406.
- Davis, George H., Regional Strain Analysis of the Superposed Deformations in southeastern Arizona and the Eastern Great Basin, Az. Geol. Soc. Dig., Vol 14, pp 155-172, 1981.
- Drewes, Harold D., Tectonics of Southeastern Arizona: U.S.G.S. Professional Paper 1144, 1981.
- Hayes, Philip T., Huachuca Quartz Monzonite, Huachuca Mountains, Cochise Co., U.S.G.S. Bull., 1254-A, p. A29, 1967.
- Hayes, Philip T.; Raup, Robert B., Geologic Map of the Huachuca and Mustang mountains, Southeastern Arizona: U.S.G.S. misc. geol. inv. I-509,G37015, scale 1:48000, 1967.
- Hayes, Philip T., Mesozoic Stratigraphy of the Mule and Huachuca Mountains, Arizona: U.S.G.S. Professional Paper 658-A, 1970.
- Hayes, Philip T., Cretaceous Paleogeography of Southeastern Arizona and Adjacent areas. U.S.G.S. Professional Paper 658-B, 1970.
- Hayes, P.T., Simons, F.S., and Raup, R.B., 1965, Lower Mesozoic extrusive rocks in southeastern Arizona-The Canelo Hills Volcanics: U.S. Geol. Survey Bull. 1194-m, 9 p.
- Lange, Arthur, Introductory Notes on the Changing Geometry of Cave Structures, Cave Studies, no. 11, p. 69-90, Publication of Cave Research Associates, 1959.
- Nations, Dale: Stump, Edmond. Geology of Arizona, general reference. United States, Hunt Publishing Company, 1981.
- Simons, Frank S.; Raup, Robert B.; Hayes, Philip T.; Drewes, Harold, Exotic Blocks and Coarse Breccias in Mesozoic Volcanic Rocks of Southeastern Arizona, in Geological Survey Research, 1966, U.S.G.S. Professional Paper 550-D, p. D12-D22, illus., 1966.
- Sweeting, Marjorie M.. Karst Landforms. Great Britain; Macmillan Press LTD, 1973.
- Weber, Robert Harrison, 1950, Geology of the east-central Huachuca Mountains, Thesis (Ph.D), University of Arizona.