A Subaqueous Tectonic and Hydrothermal Origin for Colossal Cave, Arizona

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Abstract

Colossal Cave is a feature of both archeological and geological interest. Only recently has the cave system been systematically explored, and much work still remains to thoroughly document this extensive feature. The formation and development of the cave has not been adequately addressed in uniformitarian geological literature. Apparently, the naturalist interpretation cannot easily explain the problems that "uniformitarian time" creates in understanding the geologic history of the area and the formation of Colossal Cave. In contrast, Colossal Cave is easily addressed by the Creation-Flood framework. The uplift of the adjacent Rincon Mountains during the late stages of the Flood caused the recently deposited and semi-lithified sedimentary overburden to slide off and pile up around the base of the uplifted metamorphic core complex. During this event, the strata were subjected to the expulsion of both interstitial and hydrothermal fluids, which created preferential pathways through the carbonate strata and resulted in the formation of numerous cave systems. Following Floodwater withdrawal, speleothem development occurred in the open passageways where overlying carbonate source rocks were present. The eventual drying of the climate has resulted in dust accumulation rather than further carbonate mineral deposition.

Introduction

Colossal Cave is the only commercially developed cave system located in the 2,400 acres of Colossal Cave Mountain Park. While several other caves are known to exist within the property, they are not open to the public (see appendix). The park is located in a beautiful setting adjacent to the Rincon Mountains, approximately twenty-two miles southeast of Tucson, Arizona (Figure 1). The Rincon Mountains are part of the rather unique set of metamorphic core complex (MCC) mountains adjacent to the city of Tucson (see Froede et al., 2003). The geological history of the Colossal Cave area has presented an unwitting puzzle to uniformitarian scientists because the tectonism that uplifted the Rincon Mountains occurred much later than the original deposition of the carbonates that contain Colossal Cave. The contorted strata and development of the cave system challenge several uniformitarian assumptions regarding time and are best understood in the Creation-Flood framework.

Area Stratigraphy

The geology around Colossal Cave has been used by the local university as a teaching tool in the training of graduate students in earth science (Figure 2). Mapping of the sedimentary strata has provided hands-on experience in understanding the complex structural geology in the area around the caverns (Davis,

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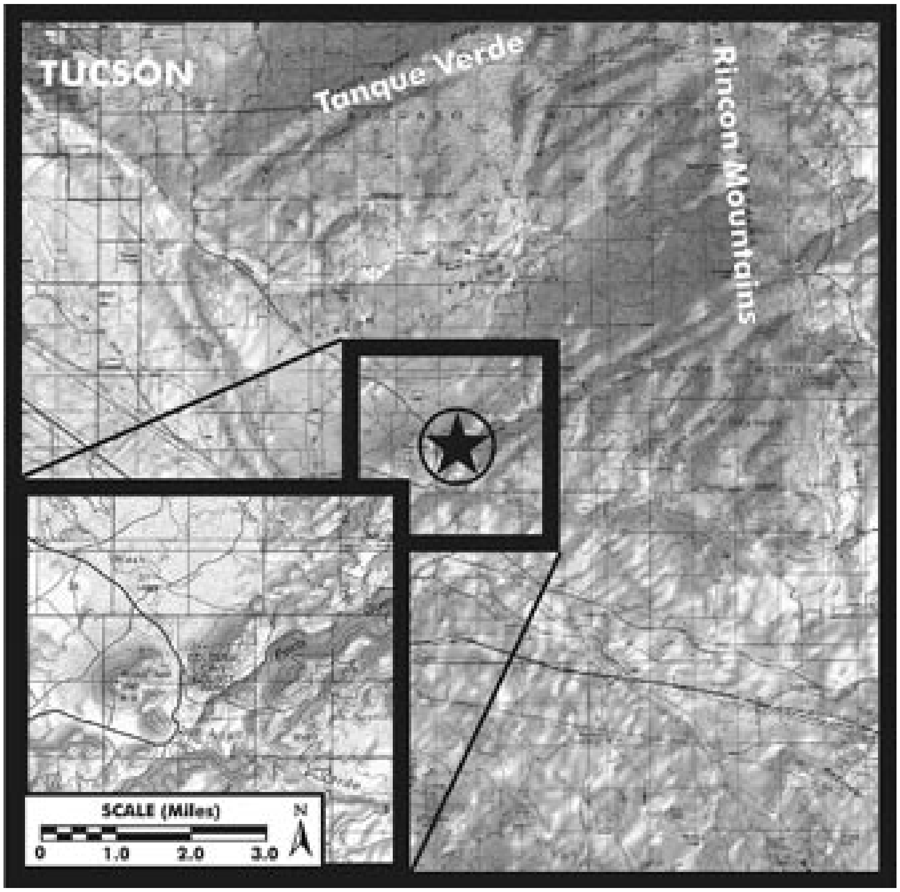

Figure 1. Topographic map showing location of Colossal Cavern in relation to the city of Tucson, Arizona, and the adjacent metamorphic core complex mountains. Detailed inset shows elevation contours at 164-foot intervals around the Colossal Cave area. The Paleozoic strata in which the cave system is developed were derived from the adjacent Rincon Mountains by gravity sliding. Modified United States Geological Survey Quadrangle (Tucson, Arizona [1994]—1:100,000 scale) using Maptech ©2001 software at 1X elevation.

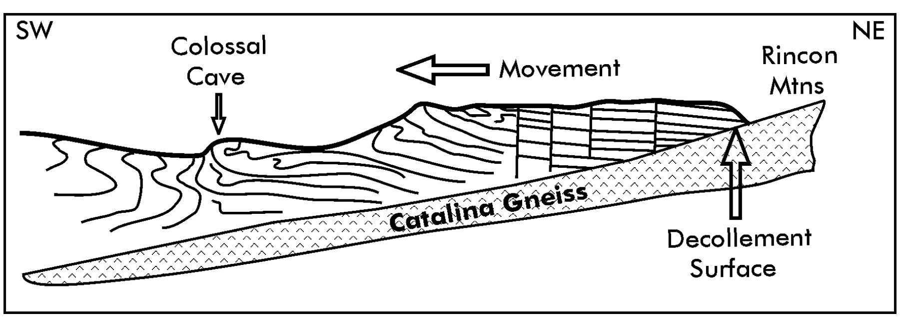

Figure 2. General diagram showing the Santa Catalina Fault surface over which the Paleozoic sedimentary strata have moved, creating gravity-induced folding. The location of Colossal Cave is approximated based on topography and stratigraphy. Modified from Davis et al., 1974.

et al., 1974). Regarding the sedimentary pile around Colossal Cave, Davis (1975) has written:

> Sedimentary rocks studied within the Colossal Cave domain are Paleozoic in age and form a sheet approximately 150 m thick that rests on the southeast limb of the Rincon Peak antiform. The rocks consist of limestone with interbedded shale and include formations of Cambrian through Permian age. In general, the strata strike east and dip 20°N. However, Arnold (1971) noted that the strike of the rocks in the northern part of the Colossal Cave domain defines a convex-southwestward arc. (p. 981.)

Regarding the presence of folds in the Paleozoic strata, Davis (1975) stated:

> Spectacular macroscopic recumbent and overturned folds pervade the sedimentary rocks in the Colossal Cave domain. The folds are best exposed in Posta Quemada Canyon in the northern part of the area ... the folds in the Colossal Cave domain have unbroken hinge zones. Profile analysis of the folds in the Colossal Cave domain was difficult because of the large size of the structures. Orientation relations of folds in the Colossal Cave domain indicate that the folds are overturned to recumbent with gently plunging axes and gently inclined axial surfaces. The exposed portions of the limbs of the asymmetric macroscopic folds are parts of Z-shaped asymmetric folds. (p. 982.)

A summary of the fold attributes for Colossal Cave as described by Davis (1975) is presented in Table I.

Later Davis (1977) added to the understanding of the area around Colossal Cave when he stated:

> The low-angle juxtaposition of relatively unmetamorphosed...upper Paleozoic strata directly on cataclastically deformed augen gneiss represents one of the puz-

Table I. A summary of fold attributes noted by Davis (1975; Table 1) for the sedimentary pile around the Colossal Cave area.

Attribute	Colossal Cave
Dominant rock type	Limestone
Sheet thickness	150 meters (164 yards)
Structural position	South limb of Rincon Peak antiform
Surface profile	Tight with sub-angular-to-chevron hinge zones
Layer form	Class 1C – (see Ramsey, 1967)
Attitude of underlying gneiss	N. 70° W., 30° SW.
Orientation of folds	Recumbent to overturned. Axes: 15° E. Axial surfaces: N. 15° W., 20° NE.
Asymmetry	Overturned basinward

> zling characteristics of metamorphic core complexes. During the arching, some of the lower Paleozoic strata were rendered ductile through metamorphism and flowed down the structural gradient. The effect of this deformation is inferred to have been a thinning of the strata by flow and a diminishing of the stratigraphic interval separating the upper surface of the crystalline rocks and the relatively unmetamorphosed upper Paleozoic and Cretaceous units. No special preparation was necessary to prepare the units for gravity-induced folding. *Layering, not faults, joints, or cleavage, is the obvious control for the fold deformations* ... the folds, are flexural slip and flexural flow, types in which layer control is dominant (Donath and Parker, 1964). If dynamic metamorphism had preceded the gravity-induced folding, one would expect that such an event would be disclosed by some form of early cleavage or fold set. These are not seen. The thermal event in the Rincon Mountains area weakened the units and caused them to yield by folding, not along pre-existing secondary structural weaknesses, but along primary layering. (p. 1214, italics added)

In summarizing the history of the sediment pile in which Colossal Cave developed, Davis (1977) stated:

> I see no reason to depart from my chief conclusions regarding timing that (1) "most of the gravity-induced folding accompanied the 28 to 24 m.y. uplift" and (2) "it is probable that some low-angle displacement or gravity-induced folding accompanied emplacement and (or) incipient uplift of the gneiss. (p. 1215.)

Escabrosa Limestone

Colossal Cave is formed in the Paleozoic Escabrosa Limestone. Several smaller limestone layers overlie this unit, separated by siliciclastic sediments (i.e., sands, silts, and clays). The limestone has been described by Bryant (1968):

> The Escabrosa ranges in thickness from about 600 to 750 feet. The unit is typically coarse-grained, light gray to white limestone, commonly containing a very high percentage of crinoidal debris. Bedding is thick to massive, and clastic content is very low. Fossils in the Escabrosa are not very abundant except for the prevalent crinoidal debris, but in general the unit is less fossiliferous than most of the younger formations. Throughout most of southeastern Arizona it is overlain disconformably by the Horquilla Limestone (Pennsylvanian). (p. 36.)

According to Beus (1989), the limestone varies in composition with the addition of chert in some locations and in others as a crinoidal grainstone. Regarding the paleontology of the formation, he added:

> The Escabrosa contains a variable invertebrate fauna including abundant brachiopods and corals and less common mollusks and trilobites. Conodonts and foraminifera indicate an age of late Kinderhookian through late Meramecian for this unit. (p. 304.)

A uniformitarian framework define the Escabrosa Limestone as lower/middle Mississippian and corresponds to an age ranging between 363 to 333 Ma (Harland et al., 1990).

Formation of the Rincon Mountains

The Rincon Mountains lie to the north of the unmetamorphosed but highly deformed Paleozoic strata from which Colossal Cave is formed. The mountains are part of the Santa Catalina-Rincon-Tortolita crystalline complex (Keith et al., 1980) and are interpreted as having

Figure 3. Conduits exposed in the side of the limestone block present clear evidence of water development. These features would have formed initially under subaqueous conditions and further developed once groundwater dropped below the level of the cave.

Figure 4. A vertical complex of individual conduits (perpendicular to the cave floor) that originated underwater and converged to form the larger passage through the limestone. Features like this one require subaqueous formation and development—a situation that uniformitarian scientists have not yet addressed in their historical model at Colossal Cave.

initiated during the Laramide orogeny (late Cretaceous—70 Ma) with uplift continuing at discrete intervals into the late Oligocene (22 Ma; Coney, 1980). The formation of the Rincon Mountains predates late Tertiary basin-range faulting.

The Rincon Mountains formed by the injection of Tertiary granitic melts into preexisting Precambrian granite. This created uplift and resulted in large-scale block faulting and rotation. The upper few thousand feet of the crystalline rocks became sheared as they moved laterally under gravitational force. This created a broad mylonitic zone of deformed metamorphic rocks. Above this area of tectonic stress, a décollement surface formed whereby overlying Paleozoic sedimentary strata moved laterally across the uplifting mountain toward the basin floor. Water is viewed as an important component for all of this tectonic activity in both uniformitarian position (Coney, 1980) and young-earth creation (Froede et al., 2003).

Colossal Cave Formation and Development

According to Cockrum and Maierhauser (1996), following the creation of the Rincon Mountains, "hot, mineral-bearing solutions caused part of the silica and hematite from some layers (especially the Bolsa quartzite) to be dissolved and redeposited in the cracks and crevices of some of the fractured layers" (p. 5).

However, they do not credit this hydrothermally-charged water with forming the cave system, rather they stated that:

> Colossal Cave was formed by the slow action of water seeping into the rocks and dissolving away part of the limestone. Although the general pattern of passages in the limestone appears to be in a northwest to southeast direction, no one level of water flow occurred throughout the cave. In fact, the various chambers and tunnels have been described as an irregular maze. (Cockrum and Maierhauser, 1996, p. 6–7.)

In describing the present state of knowledge regarding Colossal Cave, they further stated (p. 7):

> the Cave (sic) was formed sometime during the Pliocene Epoch of the late Tertiary, about one to two million years ago. In any case, as it exists today, Colossal Cave is thought to be about 600 feet in length and 380 feet at the widest part. Earlier, the Cave was probably longer, for both the northwest and the southeast ends of the caverns and chambers appear to be filled with plugging material from the eroding hillsides. The total length of all the known passages is about two miles. (Cockrum and Maierhauser, 1996, p. 7.)

During my cave tour, I observed several locations within the cave where water played a dominant role in its creation (Figures 3 and 4). An examination of just the commercial portion of the cave by scientists knowledgeable of cave formation and development would redefine the origin of this cave from subaerial to subaqueous.

Perhaps the best information in support of a subaqueous hydrothermal origin for Colossal Cave comes from the analysis of dogtooth spar calcite crystals collected from within the cavern. Peachey (1999) stated that:

> The initiation of speleogenesis appears to have occurred in the interval following mid-Tertiary (late Eocene-early Miocene) movements due to the local MCC but before late Tertiary (mid-Miocene-early Pliocene) interruption by the Basin and Range orogeny block-faulting—locally between 20–18 mya and 15–12 mya. *It is hypothesized that hot brines carrying H_2S encountered the buried limestones. Oxidation of the H_2S then created H_2SO_4 which dissolved the carbonate in a manner largely seen at Carlsbad Caverns.* (p. 23, italics added)

He further speculated that:

> If ongoing work demonstrates the validity of this explanation, Colossal Cave as well as several other southern Arizona caves will become known as the first representatives of a previously undescribed subcategory of hypogenic (deep) cave development. (Peachey, 1999, p. 23.) [Editor's Note: This is not the first time that this dissolution process has been proposed. In 1988, Mârza and Silvestru first mentioned hydrothermal karst phenomenon associated with Neogene metasomatic sulphide ore deposits from Rodna Veche (Mârza, Ioan and Silvestru, Emil. 1988. Studia Universitatis "Babes-Bolyai," *Geologica-Geographica,Cluj-Napoca*, XXXIII, pp. 77–81). In 1990, Silvestru introduced the category "hypogenic karst" based on his cave and karst studies and he noted that many Americans were ignorant of French and Romanian karstology references! (See Silvestru, E. 1990. Propositions pour une classification litho-génétique des formes karstiques et apparentées. *Karstologia*, La Rivoire, France. Nr.15, pp. 55–57).]

It should be noted that the dominant uniformitarian model for cave development remains the carbonic acid dissolution of carbonate rock typically above the groundwater table (e.g., Jennings, 1985; James and Choquette, 1988; White, 1988; Ford and Williams, 1989; Palmer, 1991; Gillieson, 1996).

The concept of cave formation and development by sulfuric acid speleogenesis was first proposed by Egemeier (1981). In 1990, Hill proposed that Carlsbad Caverns (and other caves within the Guadalupe Mountains) were formed by sulfuric-acid dissolution. She linked the migration and upward leakage of underlying oil and gas deposits to the formation of sulfuric acid in groundwater that moved along joints and sedimentary structures forming the caverns (Hill, 1990). An excellent summary of the sulfuric acid theory of speleogenesis is found in Jagnow et al. (2000). More recently, Naturalists have added microbial catalysis as a possible source of sulfuric acid for cave formation (Engel et al., 2004).

Problems with Lithification and Tectonism

Uniformitarian stratigraphy defines the Escabrosa Limestone as having formed during the Mississippian Period (363 to 333 Ma). The timing of the uplift of the Rincon metamorphic core complex mountains initiated during the Laramide orogeny (70 Ma) and continued in several pulses into the late Oligocene (22 Ma). The amount of time separating the end of carbonate deposition from the beginning of tectonic uplift ranges from 263 to 311 million years (Ma). The concept of "time" within the philosophy of uniformitarian earth history is not typically given much thought. However, I believe that Colossal Cave presents a rather striking example of too much time in the constraints of the uniformitarian paradigm.

The Escabrosa Limestone is one of several stratigraphic layers that repose deformed at the base of the Rincon Mountains (Figures 5a and 5b). The contorted limestone strata reflect semi-lithified folding, not brittle faulting. We should expect that tectonism occurring hundreds of millions of years following the deposition of the Escabrosa Limestone would break rather than bend and deform the strata. We would not expect the strata to remain semi-lithified over the course of hundreds of millions of years and then behave plastically as a result of tectonism. The concept of applying deep-seated metamorphism to create movement, thinning, and plastic deformation to overlying well-lithified sedimentary strata has not been demonstrated scientifically. The folded and contorted limestones provide no evidence of the effects of metamorphism. The excessive time between deposition and uplift creates serious problems and questionable concepts for the uniformitarian philosophy.

The theory of plate tectonics (PT) asserts that mountain building on the continents occurs primarily as a function of plate collision or subduction. Tectonism is understood to take many millions of years with the typical rate of uplift measured in inches per year or even inches per century. However, this concept of mountain building does not appear to apply to the MCC mountains adjacent to Colossal Cave. These mountains are viewed as having formed due to the injection of a Tertiary-age granitic melt over the course of at least three (possibly more) episodes of tectonism, spanning up to 50 Ma. This period of MCC tectonism is bracketed by the Laramide orogeny and basin and

Figure 5. (A, *left*) Looking northeast up Posta Quemada Canyon, which is just to the southeast of Colossal Cave. The canyon sidewalls exhibit strata in both near-horizontal and contorted orientation. (B, *below*) A close-up of the far end of the canyon. The physical form of the layered sediments clearly supports Davis's contention that these strata moved under gravitational force. Young-earth creationists contend that all of this (i.e., sediments and tectonics) can be attributed to the global flood of Genesis.

range extensional tectonics and yet directly unrelated to either. This is another example where existing PT theory provides no credible support to the understanding of the orogenic history of the area (see Reed, 2000).

Uniformitarian scientists assert that much of the sedimentary overburden above the uplifted MCC mountains simply slipped off the side of the mountains during uplift (e.g., Davis et al, 1974; Davis, 1975; 1977; 1980; 1987). This would imply a steady, rapid rate of uplift in order to maintain the integrity of the strata and prevent its erosion over the subsequent hundreds of millions of years (see Froede et al., 2003).

Creation-Flood Framework

As previously noted, the physical condition of the deformed and contorted strata that form Colossal Cave suggests that sediments moved off the rising Rincon Mountains as semi-lithified strata. Uniformitarian scientists have stated that the formation of the metamorphic core complex mountains strongly supports a setting with abundant water and it is reasonable to expect that the Flood-deposited semi-lithified strata would have moved from off the top and/or side of the rising MCC mountains during subaqueous tectonism. The subsequent formation and development of the cave system would coincide with conduit development due to the expulsion of both connate and hydrothermal waters associated with subaqueous orogenesis in a manner consistent with the karstification and cave formation processes discussed by young-earth creationists (Silvestru, 2001; 2003; Woodmorappe, 2001).

Eventual Floodwater withdrawal coupled with a wet weather post-Flood climate (Oard, 1990) would be conducive for speleothem development at a rapid rate. The further lithification of the limestones coupled with a drying climate would see a decrease in calcium carbonate deposition within the cave. The weather experienced by this portion of Arizona today has terminated any further development of calcite deposits in Colossal Cave, and dust deposition and accumulation now predominate (Figure 6).

Conclusion

It is incumbent for creationists to define the rock record within the context of

Figure 6. The flowstone presents clear evidence that it was created in subaerial conditions in a manner typical to speleothem development. The drying of the climate since the end of the Ice Age has transformed the cave from active calcite deposition during wet periods to experiencing only present-day dust accumulation.

biblical history. The purported passage of millions of years between the watery deposition of the Paleozoic strata and onset of considerable tectonic uplift is not supported by the empirical evidence found in this area of study. That uniformitarian scientists readily acknowledge the abundance of water in the formation of metamorphic core complex mountains and invoke hydrothermal fluids to erode and redeposit silica within the adjacent contorted and deformed strata should be applauded. The more important question for the uniformitarian interpretation begs for an answer defining the source of all this water.

The Creation/Flood framework provides an interpretation consistent with the physical evidence. Simply stated, the semi-lithified Flood-deposited sediments slipped from the top or side of the Rincon Mountains while being uplifted subaqueously during the Flood. The strata slumped adjacent to the uplifted mountain and were further altered as interstitial and hydrothermal fluids moved through them. Speleothem development occurred following Floodwater withdrawal but has terminated in today's dry weather setting. Dust covers much of the flowstone today.

Appendix

An interesting story was recently posted on the *Tucson Citizen* web page regarding the discovery of a new cave on park property. The cave has been named La Tetera—Spanish for tea kettle. Many of the explored rooms are reported as being barren of speleothems and containing sand on the cave floor. However, several newly discovered rooms contain dripstone, flowstone, and rare cave crystals described as "Disneyesque" by the cave's explorers. The following is a summary of the information provided on the web page (Kimble, 2004):

> In January 1996, a Colossal Cave employee observed a geyser of steam shooting at least six feet into the air. The steam was reported to be coming from a 3.5 inch-diameter opening in the ground. Over the course of several years the opening widened and six years following its discovery the first cave explorers entered and lowered themselves to the sandy floor of the cave. The interior is reported to be hot with humidity near 100 percent; however, there was no flowstone or dripstone in the immediate area. A number of prehistoric animal bones (e.g., horse, camel, tortoise, frogs, snakes, and rodents) were found around the floor area and how this material got there remains a mystery. Over the course of many months, five initial rooms were mapped. Additional rooms were subsequently identified following the discovery of moving air coming from a small cave wall opening. The heat and humidity provide for continued cave dripstone and flowstone formation where it has developed. Crystals cover a large room in a newly discovered area and progress in cave mapping has stopped until a means can be determined to further explore the cave system without destroying the delicate cave crystals. While exploration of the cave has only proceeded down to around 100 feet below the ground surface, spelunkers believe that it continues much deeper. They hope to continue exploration once they determine how to proceed and not destroy the delicate cave formations. It is estimated that La Tetera is approximately 10 million years in age.

The presence of a deep-seated heat source supports the idea that hydrothermal processes probably created this cave system. It is interesting that sufficient heat still exists today allowing for continued dripstone and flowstone development despite its alleged old age. The reference to high humidity without extensive speleothem development in various cave passages is curious in that the system yet remains in its present state even after "10 million years."

Again, the concept of deep time does not appear to match the physical evidence described in this newly discovered cave.

Acknowledgments

I thank George F. Howe for his excellent and capable field assistance and companionship in guiding me around Arizona over the years and for igniting my interest in metamorphic core complex mountains. This effort has benefited greatly from the constructive reviews provided to me by A. Jerry Akridge, John Reed, and Emmett Williams. However, any mistakes that may remain are my own. I thank my wife Susan for allowing me the time and opportunity to conduct and report my work. Glory to God in the highest (Prov. 3:5–6)!

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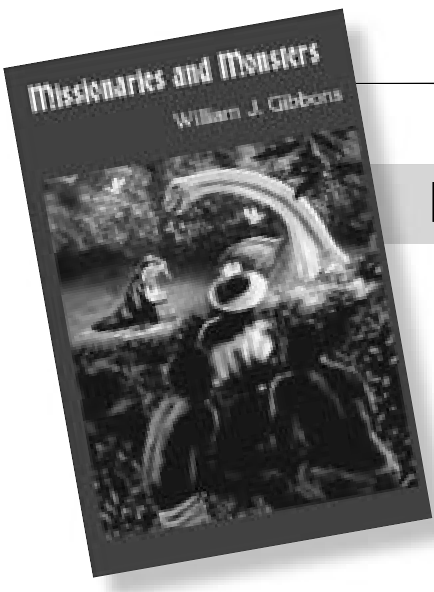

Book Review

Missionaries and Monsters (second edition)

by William J. Gibbons

Coachwhip Publications, Landisville, PA, 2006, 103 pages, $9.95.

“There are more things in heaven and earth, Horatio, than are dreamt of in your philosophy.” Such were the words of Hamlet in Shakespeare’s play. All too often people are trapped by the limits of their experience. William Gibbons’ exploration of cryptozoology, *Missionaries and Monsters*, invites readers to go outside the limits of what they think and believe, and take a look at the reports of others which are almost beyond belief.

Gibbons takes the reader on a journey through descriptions of several different types of reported monsters including the Loch Ness monster and similar creatures, sea serpents, dragons, large snakes, strange apes, and other interesting creatures. Gibbons does not try to convince the reader that all of these creatures exist. Instead, he makes the reader aware of the reports of these creatures to understand that the search for them is more than a fool’s errand. Some reports may turn out to be fictional, and others may be real, but the search is an informed one. Whether you consider these stories plausible or not, the book is filled with story after story of page-turning excitement for any age or background.

Gibbons writes from a young earth perspective, and even includes Behemoth from the book of Job in his list of accounts. For creationists, this book provides a good but incomplete guide to the variety of reports of animals, both amazing and presumed extinct, and can provide those who wish to be “living fossil hunters” with an idea of where and what to look for. For others, the book serves as a reminder that there is more to God’s creation than what lives in the backyard and in the local zoo.

The book’s main shortcoming is minor but pronounced. While a short bibliography is included, there are few citations throughout the entire text. This makes verification and further research very difficult. This book appears to be a primary source for many accounts, but it is difficult to tell because of the lack of footnoting.

What is obvious, however, is that much lurks in the earth’s remote places, and whoever is willing to seek out the inhabitants of such areas is likely to be rewarded. The author is part of a team that is exploring the Cameroon in search of Mokele-Mbembe, a sauropod dinosaur, recent eyewitness reports of which are recorded in the book.

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