1160a

STATE OF FLORIDA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
Virginia B. Wetherell, *Secretary*

DIVISION OF RESOURCE MANAGEMENT
Jeremy A. Craft, *Director*

FLORIDA GEOLOGICAL SURVEY
Walter Schmidt, *State Geologist and Chief*

Open File Report 60

The geology of Warm Mineral Springs, Sarasota County, Florida

by

Frank R. Rupert

Florida Geological Survey
Tallahassee, Florida
1994

ISSN 1058-1391

The geology of Warm Mineral Springs, Sarasota County, Florida.

Frank R. Rupert, P.G. 149

Abstract: Warm Mineral Springs is a 70 meter deep water-filled sinkhole in southern Sarasota County, Florida. Mineral-rich anaerobic water enters the sink through a spring vent near the bottom of the north wall of the sink. In 1991, divers explored and mapped the spring's primary conduit to its terminus, a distance of 53 meters. Twenty-one geological samples were collected at three meter depth intervals from the north wall of the sink for stratigraphic analysis. The samples revealed the sinkhole is developed in carbonates belonging to the Miocene Arcadia Formation of the Hawthorn Group. This unit is unconformably overlain by Pleistocene Ft. Thompson Formation and undifferentiated Pleistocene sands. A map of the spring cave and a geologic section for the sinkhole are illustrated.

Introduction

Warm Mineral Springs is situated in southern Sarasota County, Florida, approximately 12 kilometers southeast of the city of Venice (Figure 1). The area surrounding the spring is generally flat, sandy, terrain characteristic of the Gulf Coastal Lowlands geomorphic zone (White, 1970). Land surface elevation at the spring is about three meters above mean sea level.

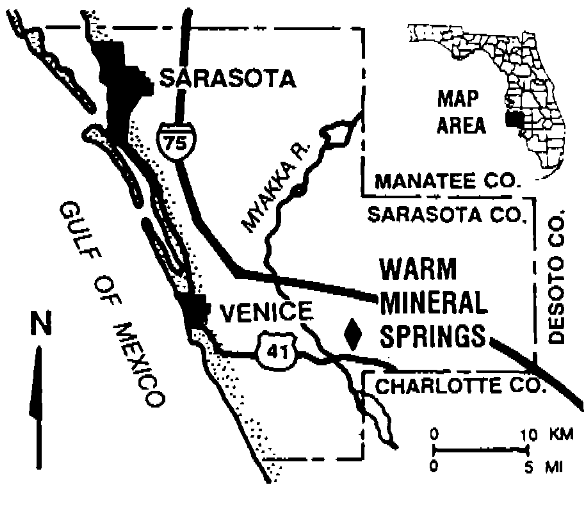

Figure 1. Location Map.

The spring pool is a large, circular, cover-collapse sink, formed in the Miocene age carbonates which underlie the area. It measures 72 meters in diameter at the water surface, along its north-south axis. In cross section (Figure 2), the spring's profile resembles an hour glass. At a water depth of 3 to 5 meters below the spring pool surface (bps), the pool narrows to 48 meters in diameter, followed by a vertical drop-off down to 10 meters bps. Below this, the cavity widens again, attaining a diameter of about 55 meters at a depth of 13 meters bps. Here, the walls constrict, forming a distinct ledge. This ledge apparently accumulated Pleistocene fossil material which fell into the sink; it also served as a paleoindian burial site during lower sealevel stands (Cockrell, 1990).

Below the ledge, the sink walls gradually converge to a throat with minimum diameter of 36 meters at a depth of 30 meters bps. At 30 meters the cavity widens again, broadening to a width of 72 meters at the sink's maximum depth of 70 meters bps. A large debris cone, consisting of material which has slumped or fallen into the sink, rises from the spring floor to a depth of 38 meters. This cone may offer

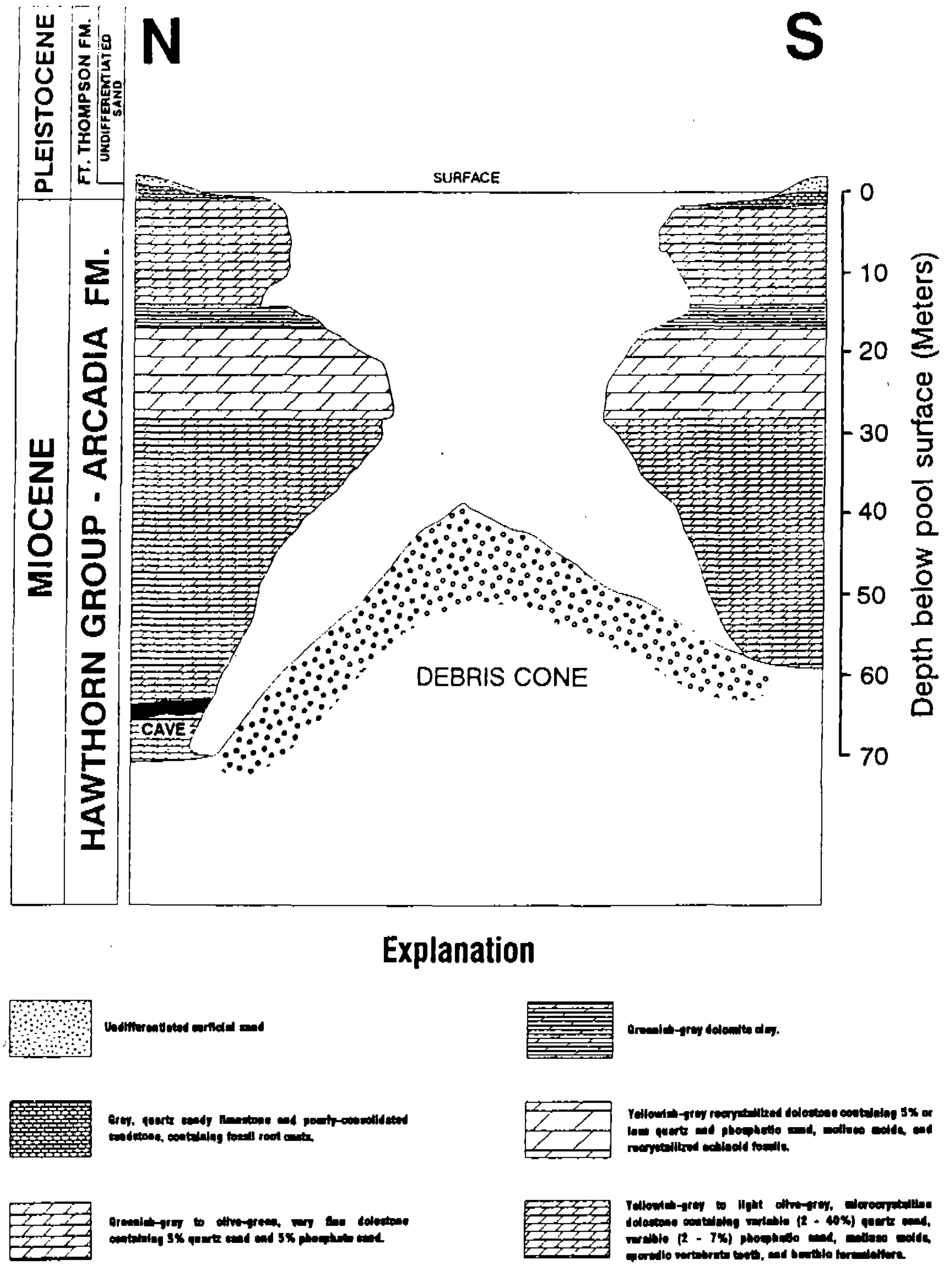

Figure 2. Geologic section in Warm Mineral Springs.

a potentially undisturbed stratigraphic record of the events since formation of the sink.

Dripstone, in the form of stalactites and stalagmites, rims the walls of the sink at a depth of 30 meters bps. Such dripstone formations are indicative of subaerial exposure during Pleistocene water table lowstands (Cockrell, 1990). Tufa deposits, formed from the precipitation of calcium carbonate, occur on the ledge at 13 meters bps.

Numerous small freshwater springs and seeps occur around the periphery of the sink. The principal water source for Warm Mineral Springs is a vent in the north wall of the sink, at a depth of 63 meters bps. An estimated 20 million gallons per day issue from this vent (Cockrell and Murphy, 1978). This water is warm, averaging about 30 degrees C, anaerobic, and has a high chloride and hydrogen sulfide content. Rosenau et al. (1977) reported sulfate (SO_4) concentrations ranging from 1,600 to 1,700 mg/l and chloride concentrations ranging from 9,200 to 9,600 mg/l for spring water samples taken during the period 1927 to 1972. The warm, mineralized nature of the water has long been an attraction to humans, and the spring has functioned as a bathing spa for much of the past century.

The source of this heated, mineralized water is uncertain. Two primary theories have been advanced to explain its unique nature. Stringfield (1966) theorized that the spring is an emergence of pre-Miocene seawater, which was trapped beneath the Miocene sediments over 30 million years ago.

More recently, Kohout et al. (1977) believed the water source to be deep, geothermally-heated seawater. These authors hypothesized that seawater from the Gulf of Mexico and Atlantic Ocean seeps under the Florida Platform, to depths approaching 1,000 meters below mean sea level. Here it is geothermally heated, and some rises to the near-surface through natural fractures in the overlying carbonates. The rising water may be cooled and diluted in part as it percolates through the overlying freshwater-bearing carbonates of the Floridan aquifer system. Warm Mineral Springs likely represents a point where this deep geothermal water discharges to the surface.

The anaerobic nature of the spring water is largely responsible for the excellent preservation of paleoenvironmental and archeological remains in the sink. Well preserved human bones and artifacts and Pleistocene vertebrate bones have been recovered from the 13 meter ledge in the sink. Faunal remains from the spring include species of Pleistocene birds, fox, sabercat, llama, proboscideans (mastodons and mammoths), wolf, deer, giant ground sloth and numerous rodents, as well as reptiles, amphibians, and molluscs (McDonald, 1990). Leaves and pollen from a number of tree and plant species have also been found in the spring (McDonald, 1990).

Mapping and Geologic Sampling

In the summer of 1991, cave divers from the Florida State University (FSU) Academic Diving Program, working in conjunction with the Warm Mineral Springs Archaeological Project members, recovered rock specimens from the sink walls and surveyed and mapped the 53 meter-long primary conduit feeding the spring. At the request of the Florida Geological Survey (FGS), rock specimens were collected by divers at three meter (10 feet) water depth intervals, from the pool surface down to the sinkhole's maximum depth of 70 meters (230 feet) bps. Approximately fist-size rock samples were removed from the north wall of the sink, bagged, and sent to the FGS in Tallahassee for analysis. The samples were lithologically described and a lithologic column for Warm Mineral Springs constructed (Figure 2).

The divers also explored the main conduit feeding the sink and produced the map shown in Figure 3. This exploration dive, at depths in excess of 62 meters, required the breathing of special mixed gases. It is probably the first documented use of mixed gas in scientific diving below 62 meters (Gregg Stanton, FSU Academic Diving Program, personal communication, 1992).

The cave originates at a flattened, elliptical vent, measuring about three meters wide and one meter high. This vent is situated 63 meters bps near the base of the north wall of the spring sink (Figure 2). The first segment of cave has a clay bottom, and extends east-northeast from the vent a distance of approximately 8 meters. In cross section, the cave is an elliptical tube, typical of subaqueous phreatic caves in Florida. About halfway along this first segment, the floor drops from 63 to 65 meters in depth. At 8 meters into the cave, the conduit then turns abruptly, trending north-northeastward for 9 meters. Here, the bottom sediments become predominantly quartz sand.

The conduit turns northwestward at a distance of approximately 17 meters in from the vent. From this turn, it extends as a linear tube a distance of about 20 meters. Then, at 37 meters in from the vent, the conduit abruptly turns east-northeast again, and opens into a cavern room about 10 meters long and 3.5

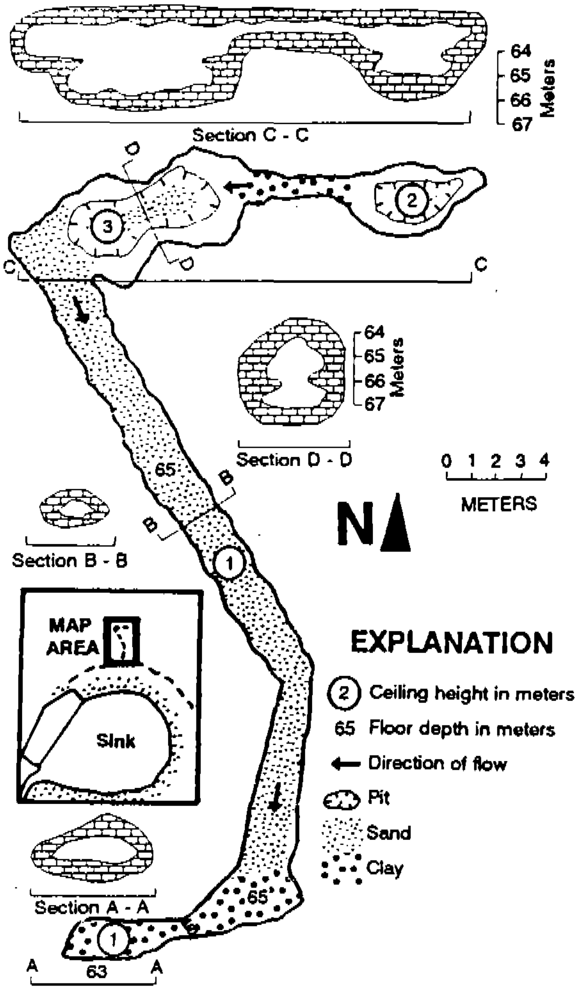

Figure 3. Map of main conduit feeding Warm Mineral Springs (modified from Irving and Wood, 1991).

meters wide. The cavern assumes a keyhole shape in cross section, with upper and lower portions delineated by a horizontal constriction around the perimeter of the cavern. The floor of the cavern lies at about 67 meters bps. A short, 4-meter long conduit, trending due east, connects the east end of the cavern with a second smaller cavern, which forms the terminus of the cave system, 53 meters in from the vent. This cavern measures approximately 5 meters long and 2.5 meters wide and has a "keyhole" shape similar to the first cavern. Diver Steve Irving, who explored the last segment of cave, reported that the water flow was barely perceptible, and the warm, saline, anaerobic water appears to issue from the floor of this small cavern (S. Irving, personal communication, 1992).

Discussion

The configuration of the primary conduit feeding Warm Mineral Springs is characteristic of subaqueous cave systems in Florida (FGS unpublished cave data). Previous workers, such as Vernon (1951) and Windham and Spoul (1965), have hypothesized the existence of linear regional fracture systems in the bedrock underlying Florida. These fractures trend in two primary directions, generally northwest-southeast and northeast-southwest, with considerable variation in the bearings of individual fractures. Flowing water tends to exploit fractures as paths of least flow resistance. The linear alignment of many sinkhole systems, some river and stream course segments, and segments of both coasts in Florida commonly parallel these primary fracture directions, and may be controlled by local fracture systems.

The linear conduit segments in the Warm Mineral Springs cave correspond to the general statewide fracture directions. If the cave was continuous across the cavern which originally collapsed to form the sink, the continuation of the conduit in the opposite (south) wall of the sink is now plugged and obscured by the debris cone.

The depth of the conduit, varying between 63 and 67 meters bps, may be largely bedding-plane controlled. Like fractures, softer, less resistant strata in the bedrock offer paths of least resistance to erosion by flowing water.

Analyses of the rock specimens reveal that the bulk of the sink is developed in Miocene carbonates of the Hawthorn Group (Scott, 1988). The lithology for most of the sampled section is comprised of phosphatic, fossiliferous, microcrystalline dolomite. The entire sink section is developed in the Arcadia Formation of the Hawthorn Group, a Late Oligocene to Early Miocene, Chattian to Burdigalian stage unit (Scott, 1988, and T. Scott, personal communication, 1993).

At the base of the sink (64 to 52 meters bps), this unit is a yellowish-gray to light olive-gray, microcrystalline, phosphatic, dolostone, containing fossil pelecypod molds and approximately two percent phosphate sand. Interbedded strata of soft, clay-like dolostone, boulders of which were observed by divers (Steve Irving, personal communication, 1992) in the spring cave, may have provided a less resistant bedding plane for development of the spring conduit.

The Arcadia Formation in the interval 52 to 49 meters bps is a yellowish-gray dolostone containing about seven percent subrounded quartz sand and five percent phosphate sand. Recrystallization has destroyed most of the invertebrate fossils, but small mollusc impressions are common. Some of the phosphatic grains resemble vertebrate fossil fragments, possibly pieces of fish teeth.

Above 49 meters bps, the Arcadia Formation is comprised of yellowish-gray, variably quartz sandy and phosphatic microcrystalline dolomite. The quartz sand content increases upward from less than five percent at 49 meters bps to nearly 20 percent at 33 meters bps. Phosphate sand increases from about one percent at 49 meters bps to approximately seven percent at 33 meters bps. Impressions of molluscs and vertebrate teeth fragments, particularly shark and teleost fish teeth, are the dominant fossils in the interval 49 to 33 meters bps.

Between 33 and 30 meters bps, the Arcadia Formation is a very quartz sandy, phosphatic, microfossiliferous, microcrystalline dolostone. Quartz sand comprises approximately 30 to 40 percent of the sample. Rounded phosphate sand comprises about five percent of the rock. Highly recrystallized, unidentifiable benthic foraminifera and other microfossil fragments are the dominant fossils. Perhaps due to the high sand content, the rock in this interval is friable, crumbling easily under pressure.

The four samples in the interval 27 to 18 meters bps are comprised of more indurated, less sandy, recrystallized, yellowish-gray dolostone and microcrystalline dolostone. Quartz sand and phosphate sand comprise five percent or less of the samples. Mollusc molds and recrystallized echinoids are the predominant fossils present. These samples, taken at 27.4, 24.4, 21.3 and 18.3 meters bps, correspond to the position of the throat or constriction encircling the sink and giving it the hour-glass shape. The more resistant nature of the strata in this interval may, at least in part, be responsible for formation of the ledge-like constriction at the time the sink originally developed.

Overlying the constriction is the 13 meter ledge, upon which paleoindian remains have been found (Cockrell, 1990). A three meter thick, greenish-gray dolomitic clay bed occurs at 15 m, at the edge of the burial ledge encircling the sink. X-ray analysis of this layer revealed it to be nearly pure, clay-size dolomite (Meryl Enright and Dr. Ken Osmond, F.S.U., personal communication, 1992).

Above the clay layer, the Arcadia Formation continues upward to the top of the unit at three meters bps as a greenish-gray to olive-green, very fine dolostone, containing about 5% each of quartz sand and phosphate sand.

The Arcadia Formation is unconformably overlain by gray sandy limestone and poorly consolidated sandstone of the Pleistocene Ft. Thompson Formation. This unit contains what appear to be plant root casts, and medium sand-size phosphate grains possibly reworked from the underlying Arcadia Formation sediments. The Ft. Thompson is locally less than 3 meters thick, with its top obscured by an overlying surface veneer of undifferentiated Pleistocene sands and clayey sands.

Acknowledgements

The author wishes to thank a number of people for their contributions to this study. Dr. Wilburn Cockrell of the Warm Mineral Springs Archeological Project graciously provided access to the spring for the sampling and mapping efforts, and his cooperation is very much appreciated. The late Mr. Parker Turner was instrumental in coordinating the exploration dives and sample collecting at Warm Mineral Springs; his enthusiasm and dedication to his work, and his expertise in scientific cave diving were very much appreciated, and will be sorely missed. Special thanks are due Mr. Steve Irving and the late Mr. Sherwood Schile, of the Florida State University Academic Diving Program, and Mr. Skip Wood of the Warm Mineral Springs Archeological Project for collecting the geological samples, mapping the cave system, and providing the cave map for this report. Steve Irving also kindly reviewed the draft text. Drs. Tom Scott and Walt Schmidt, of the Florida Geological Survey, reviewed drafts of this report and provided many useful suggestions. Dr. Ken Osmond, F.S.U., and Meryl Enright of the F.G.S. kindly X-rayed the dolomitic clay sample and interpreted the results.

References

Cockrell, W.A., 1990, Archaeological research at Warm Mineral Springs, Florida: in: Diving for Science...'90, Proceedings of the American Academy of Underwater Sciences Tenth Annual Scientific Diving Symposium, St. Petersburg, Florida, October 4-7, 1990, p. 69-78.

Cockrell, W.A., and Murphy, L., 1978, Pleistocene man in Florida: Archaeology of eastern North America, Vol. 6, p. 1-13.

Irving, S., and Wood, S., 1991, Warm Mineral Springs Cave, Sarasota County, Florida: Unpublished map.

Kohout, F.A., Henry, H.R., and Banks, J.E., 1977, Hydrogeology related to geothermal conditions of the Floridan Plateau, in: Smith, D.L., and Griffin, G.M., eds., The geothermal nature of the Floridan Plateau: Florida Bureau of Geology Special Publication 21, p. 1-41.

McDonald, H.G., 1990, Understanding the paleoecology of fossil vertebrates: Contributions of submerged sites: Diving for Science...'90, Proceedings of the American Academy of Underwater Sciences Tenth Annual Scientific Diving Symposium, St. Petersburg, Florida, October 4-7, 1990, p. 273-291.

Rosenau, J.C., Faulkner, G.L., Hendry, C.W., and Hull, R.W., 1977, Springs of Florida: Florida Bureau of Geology Bulletin 31 (revised), 461 p.

Scott, T.M., 1988, The lithostratigraphy of the Hawthorn Group (Miocene) of Florida: Florida Geological Survey Bulletin 59, 148 p.

Stringfield, V.T., 1966, Artesian water in Tertiary limestone in the southeastern states, U.S. Geological Survey Professional Paper 517, 226 p.

Vernon, R.O., 1951, Geology of Citrus and Levy Counties, Florida: Florida Geological Survey Bulletin 33, 256 p.

White, W.A., 1970, Geomorphology of the Florida peninsula: Florida Geological Survey Bulletin 51, 164 p.

Windham, S., and Sproul, R., 1965, Unpublished surface lineament map derived from airphotos: Florida Geological Survey.