ACTIVE HYPOGENE SPELEOGENESIS IN A REGIONAL KARST AQUIFER: AYYALON CAVE, ISRAEL

Israel Naaman[1,3], Chanan Dimentman[2], and Amos Frumkin[3]

Ayyalon Cave is the longest (2.7 km) and most important known cave in the Ayyalon Saline Anomaly (ASA), Israel (Frumkin and Gvirtzman 2006; Naaman 2011). Located in the inner costal plane of Israel, 21 km from the Mediterranean Sea, it has been truncated by an open quarry in the center of ASA.

The cave comprises two levels of horizontal passages, each with distinct characteristics. The upper level is a network maze cave. The passages have well rounded smooth walls and the ceiling is rich with cupolas and rising cupolas chains. The cave morphology and water properties show that the cave was formed by hypogenic flow of aggressive water that penetrated upwards through vertical shafts and fractures in the bottom of the passages. The findings suggest that the cave was formed in the phreatic zone, beneath the water table, by slow water flow from a deep source into the cave formation zone.

Wall etching is common in the cave, particularly observed around silicified concretions and fossils, which protrude from the etched wall. The etching is often associated with soft, fluffy weathered walls. The soft weathered rock walls and secondary gypsum and calcite deposits in the upper levels indicate condensation corrosion and associated deposition. These processes are attributed to air convection that took place under vadose conditions, after the water table dropped. The nature and distribution of these deposits allowed us to estimate the tracks of the air convection currents. These currents of air convection supplied oxygen to and received heat from the surface of the groundwater and were associated with convection in the groundwater and distinctive dissolution pattern of vertical water flow.

No clear hydrologic connection was observed between the voids and the surface. The observed shafts are completely smooth and rounded. They terminate upward in round cupolas or chert beds, where horizontal galleries are commonly developed. The only clastic sediments within the cave passages are fine clays (apart from breakdown debris).

The largest chamber in the cave is roughly circular in plan, ~40 m in diameter. At the bottom of the cave we have reached the water table of a warm, H_2S-rich aquifer, associated with modern dissolution features. The most notable dissolution features are underwater karren resembling subaerial rillenkarren. These are attributed to the downward part of convective aggressive water flow, descending along the walls

Deformation and collapse features are common in the larger voids of the cave. These include post-cavity movements along bedding planes and fractures, as well as chambers whose ceiling has partly collapsed. Some cave voids have been blocked by collapse and deformation.

In this location, the groundwater of the Yarkon-Taninim Aquifer is warmer and more brackish than the surrounding groundwater, has reduced conditions, and contains hydrogen sulfide.

The surrounding Yarkon-Taninim Aquifer, the western part of Israel's Judea Group aquifer supplies annual average of 360 million cubic meters. Today, this aquifer is endangered due to intensive pumping. The fall of the water table in Ayyalon Cave impacts the cave and particularly its ecosystem (below). The replenishment zone of the aquifer extends along the western slopes of Judea and Samaria mountains, while most pumping wells spread along the western foothills of the Shefela region, where the aquifer is commonly confined. The aquifer rocks are predominantly Cretaceous carbonates interbedded with thin marl layers, with a total thickness of about 800 m. Most wells pump from its shallow part, termed the "upper sub-aquifer," consisting of late-Cenomanian and Turonian rocks, while the Albian and lower-Cenomanian rocks, the "lower sub-aquifer," have been hardly drilled, so its properties are less known. Ayyalon Cave is developed in the upper sub-aquifer within Turonian limestone of Bi'na Formation.

The groundwater exposed in the cave is highly representative of the ASA, with chloride concentration of 524 mg/l and total dissolved solids of 1371 mg/l. The sulfide concentration is 5 mg/l and the water temperature (29°C) is 5°C higher than the average temperature in the aquifer. In some measurements we did not identify presence of dissolved oxygen in the water, but its long-term presence is obvious, possibly at the uppermost water layer, as it is crucial for the aquatic organisms. The water table in the area dropped by 13 m since 1951. However, there were no significant changes in the water chemical composition, and no significant correlation between the water properties and the groundwater level. Comparison of ionic ratios of the water in the cave and water wells in the vicinity reveals a mixture of two different salinity sources of water, and shows that the water in the Ayyalon Cave is closest to the saline end-member.

The lower level is characterized by large collapse halls and debris piles covering the bottom of the passages and halls. The

[1]The Hermann Institute of Earth Sciences, The Hebrew University of Jerusalem, Jerusalem, Israel
[2]Department of Ecology, Evolution and Behavior, The Hebrew University of Jerusalem, Jerusalem, Israel
[3]Cave Research Center, Geography Department, The Hebrew University, Jerusalem, Israel

morphology of this level indicates speleogenesis under phreatic conditions. Until recently, speleogenesis activity occurred on most of this level surface, but anthropogenic over-use of the regional aquifer since mid 20th century lowered the water-table to the point that this level has almost dried out. Consequently, the "wetland" was reduced to a fraction of its original size.

The Ayyalon Cave has unique ecosystem. Lacking sunlight and a constant supply of organic material, the ecosystem is based on chemoautotrophic primary production, by *Beggiatoa-like* bacteria that create a bacterial mat on the water surface. The isotopic composition of carbon and oxygen in the fauna and the bacteria shows that the latter are the energy source for the system. The cave groundwater contains new species of eyeless, pigmentless stygobitic crustaceans. Troglobitic terrestrial arthropods were found in the adjacent area within the cave.

The faunistic assemblage consists of six endemic stygobiont and troglobiont crustaceans and other arthropods. Two species are still under unclear status (Por et al., 2013). Some species, such as the scorpion *Akrav israchanani* apparently became extinct, probably due to the massive drop of water level in the cave and resulting reduction in primary production at the water surface.

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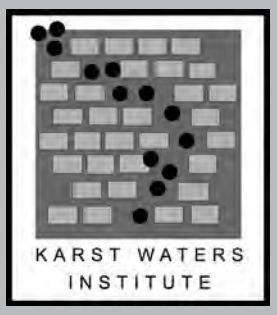

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Edited by
Alexander Klimchouk
Ira D. Sasowsky
John Mylroie
Scott A. Engel
Annette Summers Engel

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