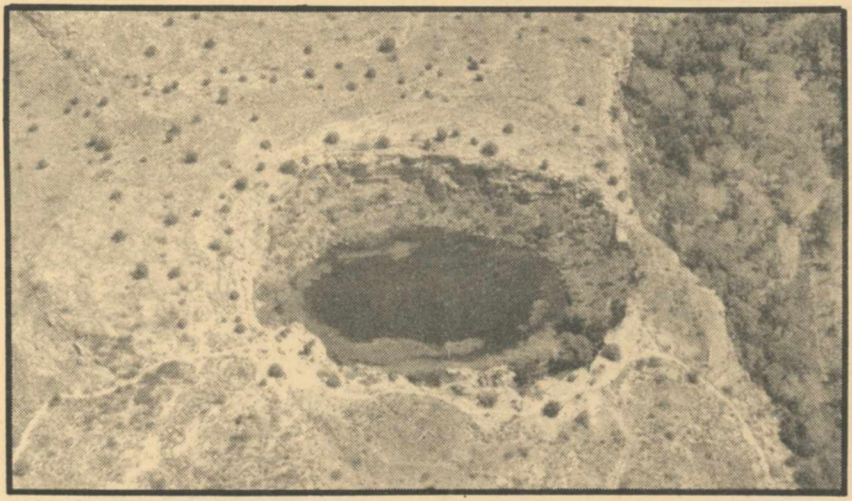
MONTEZUMA WELL: THE LIVING DESERT OASIS



Prepared for

NATIONAL PARK SERVICE

By

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Montezuma Well contains several forms of plants and animals not found in any other waters in the world. In part, this may be due to the constant input of large quantities of warm water that enter the Well through underground springs which keeps the environment within the Well very stable. Also, there are *NO FISH* in the Well, due to concentrations of dissolved carbon dioxide that are nearly 600 times higher than other natural aquatic environments. These unusual conditions have allowed the aquatic organisms in the Well to look and act differently than they do in other ponds and lakes. Therefore, Montezuma Well provides an opportunity for scientists to carefully study the interactions between these unique plants and animals.

THE BIRTH OF THE WELL

The story of Montezuma Well starts about 12 million years ago when the Verde Valley was covered by a large shallow lake 27 miles long and 15 miles wide. Lake Verde was full of tiny floating plants which, while they produced food, caused dissolved limestone to form minute crystals. These crystals slowly sank to the bottom of the lake and over several million years accumulated into thick layers of limestone rock. About 2 million years ago Lake Verde eroded away the volcanic dam at its southern end and the gigantic lake dried up.

Scientists think that an underground stream dissolved away some of the softer limestone deep under the ground and formed caverns below the surface of the Verde Valley. Over the years, churning water carved these underground caves larger and larger. Along various points of the underground stream, water would come to the surface and form a spring. Over several million years these springs deposited large quantities of salts, called travertine, around their openings. As the salts accumulated, large circular mounds were formed like the one surrounding the Well (see photograph on cover). As recently as 11,000 years ago, the roof of one of the underground caverns supporting a heavy travertine spring mound may have gradually crumbled into a sunken pool and hence MONTEZUMA WELL was formed!

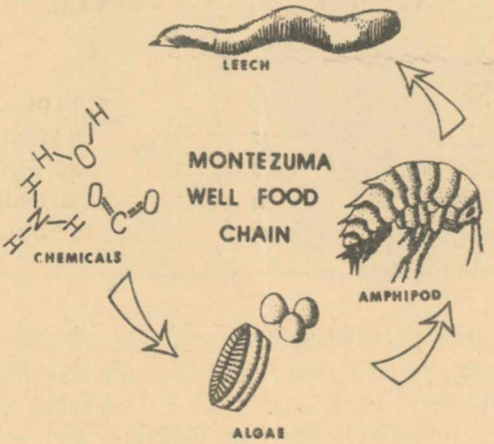
Presently, Montezuma Well is located at an elevation of 3,681 ft. (1,122 m) in the Upper Sonoran desert of Arizona. The terrestrial vegetation on the outside rim of the Well is adapted to the dry climate of the Verde Valley and includes juniper and acacia trees as well as assorted grasses, hedgehog and prickly pear cactus plants, and the exotic joint-fir, *Ephedra*, from which the nerve stimulant ephedrine is extracted.

Montezuma Well is 368 ft. (112 m) across and the water is 55 ft. (17 m) deep. The Well is still an active spring with a constant flow of 1,100 gallons of water entering at the bottom every minute (4,164 l per min). The water exits through a side cave and empties into an irrigation ditch outside the Well; the water level in the Well rarely changes! Because the water of Montezuma Well comes from an underground stream, it has a constant temperature of 76 °F (25 °C). High concentrations of the odorless gas, carbon dioxide, are dissolved into the water as it passes through the miles of undergound limestone deposits before entering the Well. As the water enters the Well, the limestone falls out of solution and the carbon dioxide is released as a dissolved gas into the water. The rich supply of dissolved carbon dioxide has apparently prevented many aquatic animals, especially fish, from living in these waters.

THE LIFE IN THE WELL

Montezuma Well contains several plants and animals that are only found in its unique environment. Scientists think that birds and possibly flying insects brought some of these small creatures, or at least their ancestors, to the Well. As the waterfowl traveled across the desert, they would stop at various water spots to drink and eat. At each stop the birds would deposit creatures and/or trap more new organisms in their feathers and webbed feet to be transported to their new destinations. Eventually, when the ducks visited Montezuma Well, some of the small creatures would be deposited in their new home. If they were tolerant of their new environment they would survive, if not, they would remain dormant or die! This dispersion process of aquatic organisms is still going on today in Montezuma Well with the annual visits of American widgeons, coots, mallards, ruddy ducks, cinnamon teal, gadwalls, and the occasional Canadian goose. These waterfowl make Montezuma Well their winter home between November and April of each year and then migrate to their summer home in the north.

Today in Montezuma Well we find several aquatic animals that have adapted to the unusual conditions of the Well. The proposed food chain in Montezuma Well is illustrated below.

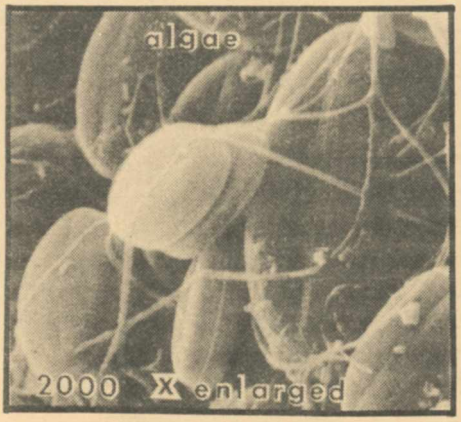


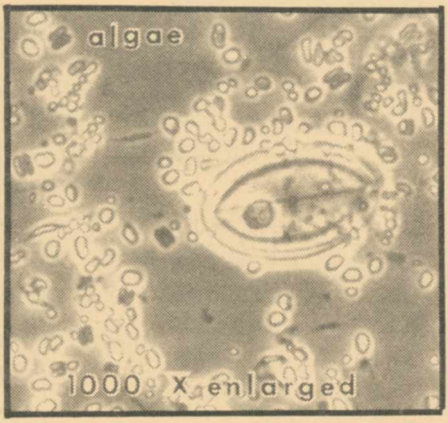
Some of the small aquatic plants (called algae), many of which could fit on the tip of a pin, float in the water and use light energy and the rich supply of dissolved carbon dioxide to manufacture food. These algae in turn serve as food for the numerous shrimp-like animals called amphipods that are less than one-eighth of an inch long. The unique amphipods have developed small food collecting hairs to trap the microscopic plants floating in the water.

Blood sucking leeches are also abundant in the aquatic vegetation. They probably feed on the turtles and muskrats in the Well. The most abundant species of leech in the Well does not suck blood, but has tiny sensory hairs all over their 2-inch long body which enable them to find, and in one big gulp, eat the amphipods in the total darkness of night. Occasionally, the always-hungry water scorpion will also creep out into the night to capture the shrimp-like creatures. There are no fish found in the Well because of the high concentration of carbon dioxide released from bottom springs, however, turtles seem to thrive in the environment.

A DAY IN THE WELL

During the day, the algae are found floating at all depths, but tend to concentrate as a glistening film at the water surface during calm periods, especially during the summer when light is plentiful. The two photographs below illustrate the variety of sizes and shapes of these tiny plants.

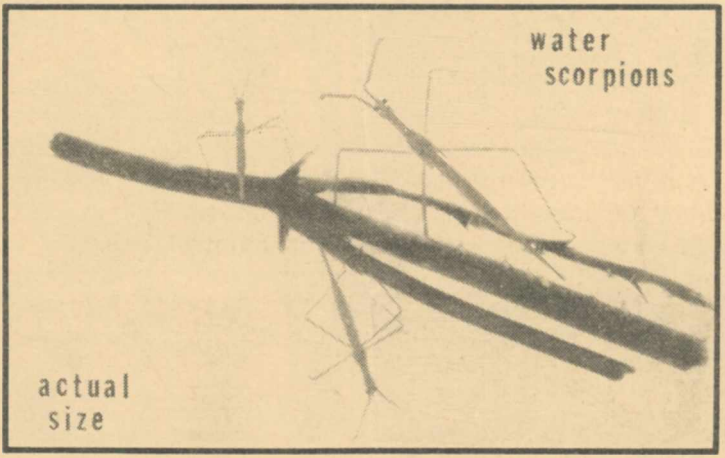




Without concern for predators, the amphipods swim freely throughout the water except in the top 3-5 ft (1-1.5 m). Oddly enough, scientists have discovered these amphipods prefer to swim 8-12 ft (2.5-3.5 m) below the surface during the day. As many as 100 animals per quart (0.95 l) of Well water may be found at this layer, while substantially fewer amphipods are found deeper. Perhaps they are escaping from the bright sunlight as well as the hungry waterfowl and turtles from above and yet maintaining a safe distance above the ravenous leeches located near the bottom of the Well.

SCUBA divers have witnessed the entire bottom waving with slimy leeches protruding from soft mud tunnels during the day. Biologists think the leeches remain near the dimly lit bottom to avoid being seen and eaten by the turtles that are often basking in the sun on logs and dense aquatic plants. Some also think that the leeches may feed on the tiny worms that slither through the soft bottom mud.

Within the dense aquatic vegetation around the Well, the highly camouflaged stick-like water scorpion (pictured below) awaits quietly on stems and foliage and occasionally grabs an unsuspecting insect or amphipod that ventures too close to its claw-like legs. Female water scorpions also use the stems of aquatic plants to deposit their eggs. These cylindrical eggs with two air-breathing appendages can be seen in the stem in the picture below.



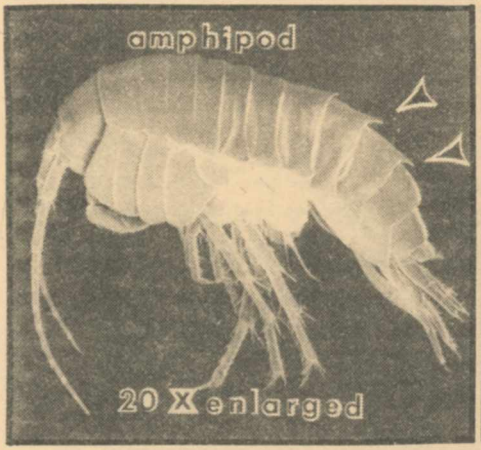
The leeches wait for the amphipods for their dinner, and the amphipods in turn, remain at subsurface depths in expectation of the tasty algae, while the always ravenous water scorpion awaits quietly in the vegetation for its evening meal, but all remain stationary until the protection of darkness.

Along the pathways around the Well, especially during the summer and fall, visitors will frequently encounter the beetles searching for food and, when harrassed, these insects will take a protective stance with their posterior ends pointed upward ready to release a pungent spray to ward off potential enemies. Numerous damselfly and dragonfly adults will also be seen flying along the shoreline of the Well in search of unsuspecting smaller aquatic insect prey.

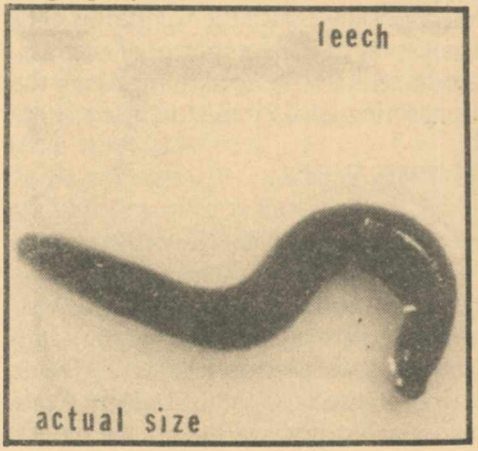
A NIGHT IN THE WELL

Once the protection of darkness sets in, the disadvantages of being seen by a hungry predator are reduced, at least so it seems! As the sun sets, an exciting sequence of biological events begins. Around the margins of the Well, hungry daddy long leg spiders and assorted tarantulas scamper over the damp soil in search of food. Numerous bats and swallows leave the crevices and caves in the surrounding cliffs to feast on a variety of insects. Even the resident Great Horned Owl takes advantage of the many small mammals that use the protection of darkness to feed and hopefully reduce their chances of being seen by a hungry predator.

A number of similar events also occur in the water. First, the resident muskrats leave their mud burrows along the shore of the Well and swim into the aquatic plants to feed. Also, many of the amphipods swim to the surface of the open water and gorge themselves on algae by trapping these tiny plants in specialized feeding hairs near their mouth (see illustration below). The amphipods can no longer be fed upon by ducks and turtles because they can't be seen, but they must escape from a new predator. . . .the leech.



Soon after sunset, the leeches leave their soft mud tunnels and slowly swim to the surface and feed on the abundant amphipods near the water surface. Fortunately, the leeches do not need to see the tasty amphipods, but instead hunt their food by using tiny sensory hairs (pictured below) to detect the water vibrations produced by the swimming amphipods. The amphipod's only defense is to curl up and expose the spines found on their backs (see above picture of amphipod).



Once the amphipods have collected the algae on their feeding hairs and have filled their guts, they disperse into deeper water and also into the aquatic plants located around the margin of the Well. This movement usually occurs several hours after sunset; the leeches follow in pursuit! Hungry leeches may track down additional amphipods in the vegetation, while leeches that are full probably return to their soft mud tunnels at the bottom to conserve energy and digest their evening meal. A typical evening meal for each leech consists of about 14-20 amphipods.

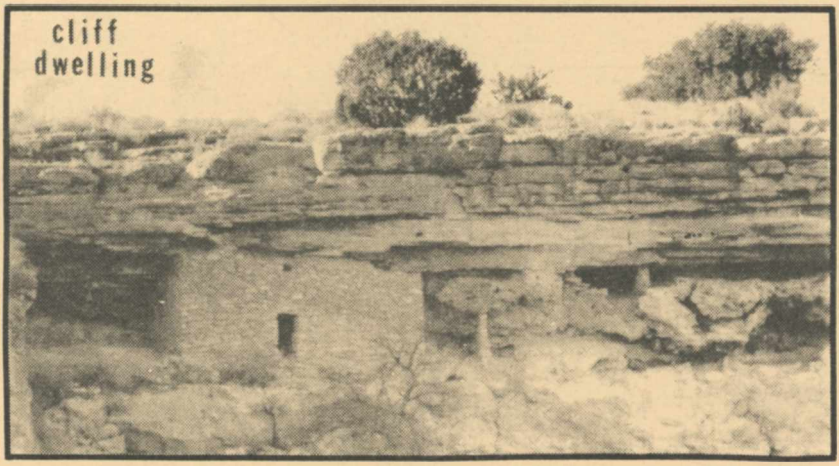
Not only do the amphipods need to be aware of leeches sneaking up from below, but they also need to be concerned about the water scorpions that swim out from the vegetation. These water scorpions swim near the surface and feed on the amphipods with their piercing beaks. This cat-and-mouse game between prey and predator is most active around twilight but continues until sunrise afterwhich all is calm in the surface waters of Montezuma Well.

MAN AT THE WELL

Man first came to the Well around 11,000 years ago, just after its formation according to some scientists. Large groups of wandering hunters would stop at the Well to drink and rest while tracking down wild game such as elephants, horses, and camels. For the next 9,000 years the Well was used as a resting spot, but no permanent settlements were built. Before the time of Christ, groups of wandering Indians first decided to live in the area around the Well, hunting small game (deer, ducks, and turtles) and gathering wild plants.

Around the year 600 A. D., another group of Indians called the Hohokam, (an Indian word meaning "those who have gone") moved in from southern Arizona. Archeologists think that they may have moved north due to the lack of water and overpopulation. These people lived in primitive pithouses around the Well and started to grow their own food. They diverted water from the constantly flowing Well and used it for irrigating their crops of corn, beans, and squash.

Around the year 1125 A. D., another group of Native Americans came from the northern part of Arizona (Walnut Canyon and Wupatki settlements). Scientists think these Sinagua Indians (Spanish for "no water") may have moved down to the Verde Valley because of the cold winters, disease, and overpopulation experienced at higher northern elevations. Their impact on the village is reflected by slow replacement of the pithouses with cliff dwellings, differences in pottery, and changes in burials. They did however continue to irrigate crops.



Soon the community grew and the cliff dwellings expanded to consist of as many as 50-60 rooms. Sometime in the early 1400's the village was abandoned. It has been theorized that fear of war, crop failures, intra-village rivalry, and/or disease made them leave. In 1853, the first white men saw Montezuma Well. These early Spanish explorers found only the abandoned pueblos and some local Indians living in primitive huts. These Native Americans were not the irrigation farmers or the cliff dwellers of the past, but were gatherers, hunters, and stream-bank farmers. The people of this once large village were now gone, never to return. Montezuma Well became a National Monument on April 1, 1947. Its lands are now protected so our children will be able to enjoy its very special natural beauty.

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