Devils Hole, Nevada—A Primer

This fact sheet summarizes the multifaceted research of the U.S. Geological Survey—published in diverse outlets—that focuses on the subaqueous cavern Devils Hole in Nevada.

What is Devils Hole?

Devils Hole is a subaqueous cavern in south-central Nevada within a geographically detached unit of Death Valley National Park (fig. 1). The cavern is tectonic in origin and has developed in Cambrian carbonate rocks bordering the Ash Meadows oasis (Carr, 1988). The open fault zone comprising the cave extends to a depth of at least 130 meters below the water table, which is about 15 meters below land surface (Riggs and others, 1994). The primary source of groundwater flowing through Devils Hole, and discharging from the major springs within the oasis, is precipitation on the Spring Mountains to the east of the cavern. The Spring Mountains are the highest mountain range in southern Nevada (altitude 3,630 meters) (Winograd and Thordarson, 1975; Winograd and others, 1998).

Why is Devils Hole of interest to paleoclimatologists?

The importance of Devils Hole to paleoclimatologists is twofold. Below the water table, the near-vertical walls of Devils Hole are coated with up to 40 centimeters of vein calcite that precipitated from groundwater moving through the cavern (fig. 2). The calcite can be accurately and precisely dated with radiometric methods, such that the depth-varying sequences of oxygen and carbon stable isotopes in the calcite provide a record of climatic variations spanning more than 500,000 years (Winograd and others, 1988, 1992, 2006). Additionally, subhorizontal cave deposits, called folia, record variations of the water table during the past 120,000 years (Szabo and others, 1994).

How was the isotopic record from the Devils Hole vein calcite dated?

Since 1992, vein calcite samples have been uranium-series dated using thermal ionization mass spectrometric (TIMS) methodology (Ludwig and others, 1992). In 1997, the Devils Hole thorium-230 ages were independently confirmed by non-U.S. Geological Survey (USGS) investigators using protactinium-231 (Edwards and others, 1997).
What paleoclimate phenomena are recorded by the Devils Hole stable isotopic time series?

The Devils Hole oxygen-18 ($\delta^{18}$O) time series (fig. 3) is primarily a proxy indicator of paleotemperatures. Unlike oxygen isotopes in deep-sea cores, it is not a record of past global ice accumulation in terrestrial systems. Rather, the time series appears to correspond, both in timing and relative magnitude, to variations in paleo-sea-surface temperature (SST) recorded in Pacific Ocean sediments off the west coast of North America, from Oregon to California, and as far south as the equatorial eastern Pacific (fig. 4) (Winograd and others, 1996, 1997, 2006; Lea and others, 2000; Herbert and others, 2001; Winograd, 2002). The Devils Hole $\delta^{18}$O record is also highly correlated with major variations in paleotemperatures recorded in the Vostok ice core from the East Antarctic Plateau (Landwehr and Winograd, 2001; Landwehr, 2002). The Devils Hole carbon-13 ($\delta^{13}$C) time series is thought to reflect changes in global variations in the ratio of stable carbon isotopes of atmospheric carbon dioxide (CO$_2$) and (or) changes in the density of vegetation in the groundwater-recharge areas tributary to Devils Hole (Coplen and others, 1994).

Figure 3 (top right). The Devils Hole $\delta^{18}$O time series from 4,500 to 567,700 years before present, with data as given in Landwehr and others (2011).

Figure 4 (right). The Devils Hole $\delta^{18}$O (in blue) and sea-surface temperature (in red) time series from marine cores TR163-19 retrieved in the east equatorial Pacific at 2°N and 91°W (Lea and others, 2000) and ODP1020 retrieved off the Oregon-California border at 41°N and 126°W (Herbert and others, 2001). The linear correlation coefficient “$r$” between records is shown for the period from 4,500 to 360,000 years before present (Winograd and others, 2006).

Where can one find the isotopic records?

The $\delta^{18}$O and $\delta^{13}$C time series from ~560,000 to 60,000 years before present are provided in USGS Open-File Report 97–792 [http://pubs.usgs.gov/of/1997/ofr97-792/] (Landwehr and others, 1997). The $\delta^{18}$O record for Devils Hole was extended into the mid-Holocene (up to ~4,500 years before present) and is provided in USGS Open-File Report 2011–1082 [http://pubs.usgs.gov/of/2011/1082/] (Landwehr and others, 2011).

What contributions has Devils Hole research made to the fields of paleoclimatology, paleohydrology, and geochemistry?

Publication of the half-million-year-long Devils Hole $\delta^{18}$O time series in 1992 initiated a decades-long discussion regarding the capability of the Milankovitch hypothesis (also referred to as orbital or astronomical theory) to predict the onset and duration of Pleistocene ice ages, a discussion that continues to this day (Wunsch, 2004; Henderson and others, 2006; Lourens and others, 2010). The radiometrically dated Devils Hole time series indicates an atmospheric warming beginning more than 10,000 years earlier than the timing of the penultimate major deglaciation (also referred to as Termination II) as predicted on
What does Devils Hole reveal about how long we can expect the present interglaciation to last?

No one knows for sure how long the present interglacial will last. Any estimate depends on several factors: the paleoclimatic archive and proxy record(s) utilized; the degree to which these records reflect global conditions; the theory invoked; and current potential climatic influences, such as anthropogenically generated greenhouse gases. The Devils Hole δ¹⁸O record indicates that the last four interglaciations each lasted over ~20,000 years, with the warmest portion being a relatively stable period of 10,000 to 15,000 years duration (Winograd and others, 1997). The most recent portion of the Devils Hole record suggests—as do SST records off California—that the warmest portion of the current interglaciation began by 17,000 years before present (Winograd and others, 2006). From these data one might infer that in the absence of any mitigating conditions, such as anthropogenically induced climate warming, the onset of a period of global cooling is imminent or even overdue on a geologic time scale (Ruddiman, 2007). However, some researchers have suggested that the current interglaciation might continue for tens of thousands of years (Berger and Loutre, 2002).
What are some practical applications of the Devils Hole findings?

In addition to providing information about the possible duration of our present interglacial climate (discussed above), research in Devils Hole has been a source of valuable information for water managers. Devils Hole cave provides hydrologists with direct access for making hydraulic measurements and collecting chemical samples of the regional carbonate-rock aquifer underlying much of south-central Nevada and which supplies the groundwater that is discharging within the Ash Meadows oasis. Meaningful estimates of the sustainable use of this aquifer hinge on knowing the age of the groundwater. Estimates of the groundwater age inferred from carbon-14 dating of dissolved inorganic carbon in the groundwater have yielded an age in the range of 13,000 to 25,000 years (Anderson, 2002), whereas carbon-14 dating of dissolved organic carbon has yielded ages on the order of 3,000 to 7,000 years (Thomas, 1996; Morse, 2002). However, several lines of evidence derived from Devils Hole indicate a groundwater age of 2,000 years or less (as discussed in appendix A in Winograd and others, 2006). The evaluation of Yucca Mountain, which is about 45 kilometers north-northwest of Devils Hole, for the geologic disposal of spent nuclear fuel has required estimation of past and future climates over time frames of hundreds of thousands of years. The paleoclimatologic and paleohydrologic information gleaned from Devils Hole has provided the foundation for such estimates (Forester and others, 1999; Sharpe, 2007; Paces and others, 2010).

Why is Devils Hole of interest to zoologists?

The endangered species of pupfish *Cyprinodon diabolis* is endemic to Devils Hole, with a habitat dependent on stable groundwater-table levels (Dudley and Larson, 1976). Concern for the protection of this unique species’ habitat provided the first test of the Endangered Species Act and resulted in the unanimous affirmative landmark decision by the U.S. Supreme Court in 1976 (Cappaert v. United States, 426 U.S. 128). This pupfish species has been studied by zoologists for decades, not only because of its unusual habitat, but also because of speciation-process debates concerning the length of its isolation from other members of its genus (Riggs and Deacon, 2004). Estimates of the length of its isolation range from tens of thousands of years (Riggs, 1991) to perhaps hundreds of thousands of years (Winograd, 1991; based on data in Winograd and Szabo, 1988).

References Cited


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