500,000-Year Temperature Record Challenges Ice Age Theory

Just outside the searing heat of Death Valley lies Devils Hole (fig. 1), a fault-created cave that harbors two remnants of the Earth's great ice ages. The endangered desert pupfish (*Cyprinodon diabolis*) has long made its home in the cave. A 500,000-year record of the planet's climate that challenges a widely accepted theory explaining the ice ages also has been preserved in Devils Hole.

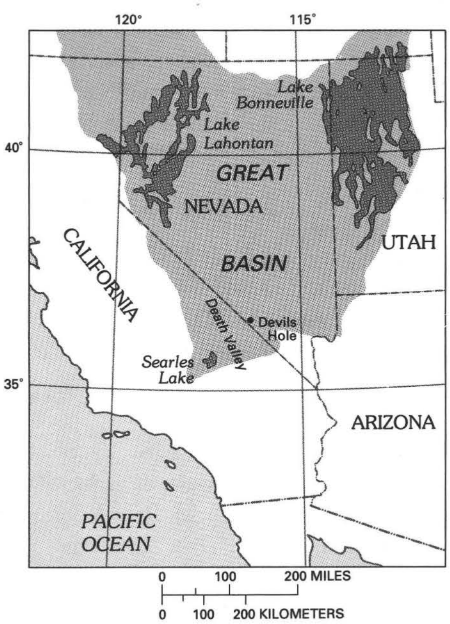

Figure 1. Devils Hole and other features in the Southwestern United States.

The Devils Hole temperature record is preserved in calcite, a common mineral. The calcite was deposited from ground water moving through this desert cave for hundreds of thousands of years. Variations in oxygen isotopes in the calcite are linked to variations in air temperature when the water in Devils Hole fell as rain or snow on the surrounding mountains. Changes in the abundance of carbon–13, a nonradioactive isotope of carbon also preserved in the calcite, provide a second record of climate change. The calendar used to date these two climate records was developed by age-dating sections of a 36-centimeter (14.2-inch)-long calcite core taken from Devils Hole.

The temperature variations indicated by the oxygen isotopes in calcite at Devils Hole match all the major patterns displayed by oxygen isotopes in other well-known global climate records—ocean sediments that record the extent of global ice sheets and the Vostok ice core from Antarctica that records air temperature.

Because the Devils Hole record has been carefully dated by using uranium and thorium isotopes, it can be used to test the hypothesis that ice age glacial cycles were caused by cyclical variations in the Earth's orbit.

Ice Ages and the Milankovitch Theory

The Pleistocene Epoch, popularly known as the ice age, was marked by several periods of long, gradual buildup of massive ice sheets in Europe and North America. These glacial buildups were punctuated by sudden episodes of rapid melting that led to warm interglacial periods much like the present. The reasons for these abrupt climate changes have interested scientists for more than 150 years. Identifying the causes of these sudden warming periods is of particular interest now as scientists try to determine how much global warming is natural and how much is manmade.

The commonly accepted explanation for planetary warming and cooling was first offered in 1920 by the Serbian mathematician Milutin Milankovitch, who attributed these changes to variations in the tilt and wobble of the Earth's axis and to the eccentricity of the planet's orbit around the Sun. These variations lead to cyclical changes in incoming solar radiation, or insolation, received at the Earth's surface.

Milankovitch cycles of 20-, 40- and 100-thousand-year duration are well known in the geologic record and also appear in the Devils Hole calcite. However, when the age of a prominent warming indicated by the Devils hole record as already being underway about 140,000 years ago is compared with reconstructions of insolation caused by Milankovitch cycles, very little emerges in the way of a cause-and-effect relation. Additionally, between 350,000 and 450,000 years ago, when there was little change in insolation in either hemisphere, the Devils Hole and the marine records show a prominent glacial-interglacial cycle.

Even before study of the Devils Hole record was complete, some evidence suggested that the Milankovitch climate-change hypothesis was incomplete. For example, cycles with lengths similar to those projected to have occurred during the Pleistocene also have been reported in strata from periods of geologic time that preceded the onset of Northern Hemisphere glaciation by millions of years. The Devils Hole record strongly supports a competing climate-change concept that attributes the Pleistocene ice age to complex, internal, nonlinear feedbacks among the oceans, ice sheets, and atmospheric carbon dioxide. This concept suggests that the timing of major climate shifts is unpredictable.

The Devils Hole record also indicates that the last four interglacial periods lasted about 20,000 years—twice as long as commonly believed. In other words, the current interglacial climate, which has lasted about 10,000 years, is not necessarily about to end.

Ground-Water Questions and Ecological Insights

The carbon–13 record at Devils Hole complements the oxygen isotope record, although its peaks occurred as much as 7,000 years earlier. The reasons behind this difference lie in the different physical and chemical reactions that cause these fluctuations.

The carbon–13 record raised new and interesting questions about ground-water chemistry and ice-age ecology. The Devils Hole carbon–13 record shows that the water chemistry of the aquifer is not as well understood as scientists once thought. U.S. Geological Survey scientists are trying to understand how the carbon–13 variations survived their 80-kilometer (49.7-mile) trip through the carbonate rock aquifer without being chemically obliterated. The answer to this scientific puzzle may provide a better understanding of water chemistry issues in other carbonate aquifers. The fact that the carbon–13 variations survived in the aquifer when they would not be expected to do so also raises some doubts about the use of carbon–14 to date ancient ground waters. Carbon–14 ground-water dates from the southern Nevada aquifer are probably thousands of years too old.

The cause of the carbon–13 fluctuations in the Devils Hole record is not yet fully understood. Two potential explanations seem most plausible: the record may represent local variations in the density and extent of vegetation in the neighboring mountains and ridges or it may reflect global changes in the carbon–13 content of atmospheric carbon dioxide. If it is a local vegetation record, then it is one of the longest such registers in existence. Well-dated paleoecological records end at 30,000 years. The Devils Hole record would add another 500,000 years to southern Nevada's ecological history. It suggests that what had been documented by paleoecologists for the past 20,000 years probably also occurred during earlier times; as the climate changed from frigid glacial to warm interglacial, the tree line moved hundreds of meters up the mountains surrounding Devils Hole. Subsequently, vegetative density dramatically decreased, presumably due to high interglacial temperature. The carbon–13 record, by itself, is not a record of how moist the climate was. Even though the now dry lake beds in the Southwestern United States, such as Searles Lake, California, were filled to high levels during the glacial periods, the surrounding highest mountains were not necessarily covered by greenery as might be expected.

Alternatively, the geometric similarity between the Devils Hole and marine carbon–13 records suggests that Devils Hole may be recording global changes in atmospheric carbon–13. However, the atmospheric connections necessary to link the oceans with the precipitation that once fell over southern Nevada have not yet been identified. The level of carbon–13 in the atmosphere is one of several critical unknowns in current climate models that are being used to forecast potential climate change. Thus, Devils Hole may contain still another important piece of information relating to global climate.

In addition to its global climate records, the Devils Hole calcite deposits also have tracked fluctuations in the area's ground-water levels for the past 100,000 years. The calcite formations along the walls of Browns Room, one of the chambers in Devils Hole, show that between about 120,000 to 20,000 years ago, ground-water levels stood from 5 meters (16.4 feet) to as much as 9 meters (29.5 feet) higher than they do today. The water table has declined 9 meters in the past 20,000 years. Because these water-table fluctuations generally correspond with other regional paleoclimate indicators, including the levels of Lake Bonneville and Lake Lahontan, they probably also reflect variations in the climate of the Great Basin.

—Mitch Snow

References

Coplen, T.B., Winograd, I.J., Landwehr, J.M., and Riggs, A.C., 1994, 500,000-year stable carbon isotopic record from Devils Hole, NV: Science, v. 263, p. 361–365.

Szabo, B.J., Kolesar, P.T., Riggs, A.C., Winograd, I.J., and Ludwig, K.R., 1994, Paleoclimatic inferences from a 120,000-yr. calcite record of water-rable fluctuation in Brown's Room of Devils Hole, Nevada: Quartrnary Research, v. 41, p. 59–69.

Winograd, I.J., Coplen, B.J., Landwehr, J.M., Riggs, A.C., Ludwig, K.R., Szabo, B.J., Kolesar, P.T., and Revesz, K.M., 1992, Continuous 500,000-year climate record from vein calcite in Devils Hole, Nevada: Science, v. 258, p. 255–260.

Ludwig, K.R., Simmons, K.R., Szabo, B.J., Winograd, I.J., Landwehr, J.M., Riggs, A.C., and Hoffman, R.J., 1992, Mass-specometric ^{230}Th-^{234}U dating of the Devils Hole calcite vein: Science, v. 258, p. 284–287 (Discussion in v. 259, p. 1626–1627).

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