USGS
science for a changing world

The Chronology for the $\delta^{18}O$ Record from Devils Hole, Nevada, Extended Into the Mid-Holocene

By Jurate M. Landwehr, Warren D. Sharp, Tyler B. Coplen, Kenneth R. Ludwig, and Isaac J. Winograd

USGS Open File Report 2011–1082

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2011

For product and ordering information:
World Wide Web: http://www.usgs.gov/pubprod
Telephone: 1–888–ASK–USGS

For more information on the USGS—the Federal source for science about the Earth,
its natural and living resources, natural hazards, and the environment—
World Wide Web: http://www.usgs.gov
Telephone: 1–888–ASK–USGS

Suggested citation:
Landwehr, J.M., Sharp, W.D., Coplen, T.B., Ludwig, K.R., and Winograd, I.J., 2011, The chronology for the $\delta^{18}O$ record from Devils Hole, Nevada, extended into the mid-Holocene: U.S. Geological Survey Open-File Report 2011–1082, 5 p. (Available online only.)

Contents

Abstract 1
Introduction 1
Description of Analyzed Material 1
Devils Hole $\delta^{18}O$ Chronology 2
Summary 5
References Cited 5

Table

1. The Devils Hole chronology extended into the mid-Holocene 3

Conversion Factors

Multiply	By	To obtain
millimeter (mm)	0.03937	inch (in.)
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)

The Chronology for the δ^{18}O Record from Devils Hole, Nevada, Extended Into the Mid-Holocene

By Jurate M. Landwehr,[1] Warren D. Sharp,[2] Tyler B. Coplen,[1] Kenneth R. Ludwig,[2] and Isaac J. Winograd[1]

Abstract

This report presents the numeric values for the chronology of the paleoclimatically relevant mid-to-late Pleistocene record of the ratios of stable oxygen isotopes (δ^{18}O) in vein calcite from Devils Hole, Nev., which recently had been extended into the mid-Holocene. Dating was obtained using thorium 230-uranium 234-uranium 238 (^{230}Th-^{234}U-^{238}U) thermal ionization mass spectrometry.

Introduction

Devils Hole is a subaqueous cave of tectonic origin, which developed in the discharge zone of a regional aquifer in south-central Nevada (Riggs and others, 1994). The primary groundwater recharge source area is the Spring Mountains, the highest mountain range in southern Nevada [altitude 3,630 meters (m)], approximately 80 kilometers to the east of the cavern. The walls of the open fault zone comprising the cave system are coated with dense vein calcite precipitated from the through-flowing groundwater. The calcite, up to 40 centimeters (cm) thick, contains a continuous record of the sequential variation of the composition of stable oxygen isotopes in the ground water over time. The vein calcite has also proven to be a suitable material for precise uranium-series dating via thermal ionization mass spectrometry (TIMS) utilizing the thorium 230 (^{230}Th)-uranium 234 (^{234}U)-uranium 238 (^{238}U) decay clock. Earlier work (Ludwig and others, 1992; Winograd and others, 1992, 1997; Landwehr and others, 1997) has presented data from the Devils Hole core DH–11, a 36-cm-long core of vein calcite recovered from a depth of about 30 m below the water table (about 45 m beneath the ground surface). The DH–11 core provided a continuous record of isotopic oxygen variation from 567,700 to 59,800 years before present. Recent work has extended this record into the mid-Holocene epoch.

Description of Analyzed Material

As discussed in Winograd and others (2006), after the DH–11 analysis had been published (Winograd and others, 1992), two additional calcite specimens were obtained from Devils Hole Cave no. 2 (DHC2), a similar cave approximately 200 m north of Devils Hole, but in portions of DHC2 that are up the hydraulic gradient (that is, upstream in the aquifer) from the near-surface DH–11 core site. Specimen DHC2–3, which was precipitated from 80,000 to 19,000 years before present, provided 41,000 years of new record plus a 20,000-year overlap with core DH–11 (Winograd and others, 1996). Specimen DHC2–8, which precipitated between 30,000 and 4,500 years before present, provided 14,500 years of new record plus an 11,000-year overlap with specimen DHC2–3 (Winograd and others, 2006). The overlapping DH–11, DHC2–3, and DHC2–8 time series of the ratios of stable oxygen isotopes (δ^{18}O) were spliced together at 78,500 years before present (for the overlap between DH–11

[1]U.S. Geological Survey.
[2]Berkeley Geochronology Center.

and DHC2–3) and 24,500 years before present (for the overlap between DHC2–3 and DHC2–8), at points chosen to minimize any small chronological offsets in the overlapping time series.

Ages for the intervals sampled for oxygen isotope measurements in all three specimens were estimated by linear interpolation between age control points obtained with ^{230}Th-^{234}U-^{238}U TIMS dating. Errors in the interpolated age estimates are bounded by the errors in the relevant control points for each interval (Ludwig and others, 1992; Winograd and others, 1997, 2006).

Oxygen isotope measurements are reported as $\delta^{18}O$, that is, the relative difference of the oxygen isotope ratios in the calcite and in the Vienna Standard Mean Ocean Water (VSMOW) reference water on a scale normalized such that Standard Light Antarctic Precipitation (SLAP) reference water is -55.5 per mil (‰) relative to the VSMOW reference water. The oxygen isotopic fractionation factors employed in this determination are listed in Coplen (2007). The $\delta^{18}O$ value of the isotopic reference material NBS 19 on this scale is +28.65‰. The one-standard-deviation error for the laboratory analysis of $\delta^{18}O$ is 0.07‰.

Devils Hole $\delta^{18}O$ Chronology

The $\delta^{18}O$ time series for the extended Devils Hole chronology up to 160,000 years before present was illustrated in figure 2 of Winograd and others (2006). Note that because the specimens DHC2–3 and DHC2–8 were micromilled to obtain samples every 0.25 millimeter, the time intervals are finer in the more recent portion of the chronology (younger than 78,500 years before present) than in the older portions of Devils Hole core DH–11. Table 1 presents the values for the full record of the Devils Hole $\delta^{18}O$ chronology, that is, from 567,700 to 4,500 years before present.

Table 1. The Devils Hole chronology extended into the mid-Holocene.

[As discussed in Winograd and others (2006), with interpolated uranium-series ages expressed as thousands of years before present (ka), and stable oxygen isotope ratios ($\delta^{18}O$), as per mil (‰)]

Age, ka	$\delta^{18}O$, ‰	Age, ka	$\delta^{18}O$, ‰	Age, ka	$\delta^{18}O$, ‰
4.5	14.55	71.2	13.93	330.5	15.15
5.2	14.61	71.5	13.88	332.6	15.10
5.8	14.59	71.9	13.92	334.6	15.15
6.5	14.59	72.2	13.88	336.7	14.50
7.2	14.57	72.6	13.96	338.7	14.15
9.5	14.64	72.9	14.08	340.8	13.90
12.0	14.62	73.3	14.07	342.8	13.80
14.5	14.68	73.6	14.11	344.8	13.65
16.9	14.69	74.0	14.11	346.9	13.55
17.8	14.57	74.3	14.07	348.9	13.45
18.3	14.27	74.7	14.10	351.0	13.35
18.9	14.09	75.0	14.10	353.0	13.15
19.4	14.05	75.4	14.09	354.9	13.05
20.0	14.02	75.7	14.06	356.6	13.10
20.5	13.98	76.1	14.06	358.3	13.20
21.0	14.01	76.4	14.09	359.9	13.40
21.5	13.95	76.8	14.13	361.6	13.45
22.0	13.97	77.1	14.15	363.3	13.50
22.5	13.97	77.5	14.20	365.0	13.65
23.1	13.93	77.8	14.25	366.6	13.70
23.6	13.88	78.2	14.22	368.3	13.80
24.1	13.88	78.5	14.28	370.0	14.00
24.5	13.82	78.6	14.31	371.7	13.85
24.6	13.83	78.7	14.35	373.3	13.85
24.7	13.84	80.4	14.70	375.0	13.80

Age, ka	$\delta^{18}O$, ‰	Age, ka	$\delta^{18}O$, ‰	Age, ka	$\delta^{18}O$, ‰
25.1	13.81	82.4	14.25	376.7	13.80
25.6	13.73	84.4	14.35	378.4	14.05
26.0	13.69	86.4	14.20	380.0	13.95
26.4	13.64	88.4	14.00	381.7	14.10
26.8	13.66	90.3	14.10	383.4	14.10
27.3	13.60	92.3	14.25	385.1	14.15
27.7	13.57	94.3	14.10	386.7	14.00
28.1	13.67	96.3	14.35	388.4	14.05
28.6	13.62	98.3	14.45	390.1	14.15
29.0	13.61	100.3	14.45	391.8	14.15
29.4	13.66	102.2	14.60	393.4	14.10
29.8	13.55	104.2	14.55	395.1	14.25
30.3	13.68	106.2	14.50	396.2	14.45
30.7	13.64	108.2	14.45	397.3	14.75
31.1	13.58	110.2	14.30	398.4	14.90
31.5	13.62	112.2	14.30	399.5	14.90
31.8	13.61	114.2	14.35	400.6	14.90
32.2	13.53	116.2	14.55	401.7	14.95
32.6	13.54	118.1	14.75	403.5	14.85
32.9	13.64	119.9	15.05	405.4	14.80
33.3	13.56	120.9	15.25	407.3	14.90
33.6	13.72	121.8	15.35	409.2	14.85
34.0	13.73	123.7	15.55	411.1	14.80
34.4	13.77	126.7	15.75	413.0	14.70
34.7	13.78	129.8	15.60	414.9	14.50
35.1	13.77	133.5	15.60	416.8	14.05
35.5	13.74	138.5	15.15	418.7	13.95
35.8	13.75	143.6	14.45	420.6	14.00
36.2	13.80	146.7	14.10	422.5	13.90
36.6	13.78	149.7	13.85	424.4	13.80
36.9	13.80	151.5	13.75	426.3	13.75
37.3	13.77	153.4	13.75	428.2	13.65
37.6	13.76	155.2	13.65	430.0	13.65
38.0	13.78	157.0	13.65	431.9	13.70
38.4	13.79	158.7	13.90	433.8	13.45
38.7	13.70	160.4	13.95	435.7	13.80
39.1	13.74	162.2	13.90	437.6	13.55
39.5	13.79	163.9	13.85	438.8	13.55
39.8	13.75	165.7	13.85	439.9	13.55
40.3	13.78	167.4	13.85	440.9	13.55
40.7	13.79	169.1	13.90	442.0	13.50
41.1	13.84	170.9	13.70	443.1	13.50
41.5	13.85	172.6	13.55	444.1	13.55
41.9	13.93	174.4	13.75	445.2	13.55
42.3	13.89	176.1	13.85	446.3	13.50
42.7	13.80	177.8	13.95	447.4	13.45
43.1	13.93	179.6	13.95	448.5	13.50
43.6	13.86	181.3	13.95	449.5	13.65
44.0	13.84	183.1	13.95	450.6	13.80
44.4	13.83	184.8	14.10	451.7	14.10
44.8	13.86	186.5	14.15	452.8	14.10
45.2	13.88	188.3	14.20	453.9	14.25
45.6	13.92	190.0	14.35	455.0	14.30
46.0	13.93	191.8	14.35	456.0	14.20
46.4	13.88	193.5	14.50	457.1	14.40

Age, ka	$\delta^{18}O$, ‰	Age, ka	$\delta^{18}O$, ‰	Age, ka	$\delta^{18}O$, ‰
46.8	13.91	195.2	14.55	458.2	14.50
47.3	13.89	197.0	14.35	459.3	14.50
47.7	13.87	198.7	14.25	460.4	14.55
48.1	13.81	200.5	14.00	461.7	14.65
48.5	13.86	202.2	14.10	463.2	14.50
48.9	14.00	203.9	14.20	464.8	14.50
49.3	13.98	205.7	14.45	466.4	14.45
49.7	14.01	207.4	14.30	468.0	14.45
50.1	13.97	209.2	14.40	469.6	14.40
50.6	13.99	210.9	14.35	471.2	14.45
51.0	13.97	213.4	14.35	472.8	14.45
51.4	13.97	215.9	14.30	474.4	14.45
51.8	13.98	218.3	14.10	476.0	14.30
52.2	13.96	220.7	13.80	477.6	14.30
52.6	13.89	223.2	13.65	479.2	14.40
53.0	13.93	225.6	14.15	480.7	14.35
53.4	13.91	228.0	14.35	482.3	14.45
53.8	13.89	230.4	14.50	483.9	14.40
54.3	13.89	232.8	14.65	485.5	14.35
54.7	13.80	235.2	14.70	487.1	14.35
55.1	13.82	237.8	14.70	488.7	14.35
55.5	13.77	240.5	14.75	490.3	14.30
55.9	13.70	245.8	14.80	491.9	14.30
56.3	13.82	248.5	14.20	493.5	14.25
56.6	13.75	251.2	14.05	495.1	14.30
56.9	13.71	253.9	13.80	496.7	14.30
57.2	13.73	256.6	13.90	498.3	14.25
57.6	13.71	259.2	13.85	499.8	14.30
57.9	13.72	261.9	13.65	501.4	14.25
58.2	13.71	264.6	13.55	503.0	14.35
58.5	13.68	267.3	13.40	504.6	14.35
58.9	13.63	269.7	13.15	506.2	14.35
59.2	13.56	271.6	13.20	507.8	14.25
59.5	13.62	273.5	13.40	509.4	14.25
59.8	13.51	275.4	13.55	511.0	14.20
60.1	13.52	277.3	13.80	512.6	14.30
60.5	13.51	279.3	13.90	514.0	14.25
60.8	13.51	281.2	14.00	515.5	14.25
61.1	13.44	283.1	14.05	516.9	14.35
61.4	13.41	285.0	14.20	518.3	14.10
61.8	13.41	286.7	14.20	519.8	14.00
62.1	13.40	288.2	14.20	521.2	13.90
62.4	13.39	289.8	14.05	522.6	13.75
62.7	13.38	291.3	13.95	524.0	13.75
63.1	13.35	292.8	13.90	525.5	13.80
63.4	13.41	294.4	13.85	526.9	13.70
63.7	13.48	295.9	13.80	528.3	13.75
64.0	13.57	297.5	13.85	529.8	13.85
64.3	13.56	299.0	13.95	531.3	13.90
64.7	13.56	300.5	14.00	533.2	13.80
65.0	13.62	302.1	14.10	535.1	13.75
65.3	13.62	303.6	14.10	537.0	13.70
65.6	13.63	305.1	14.20	538.9	13.70
66.0	13.64	306.7	14.15	540.8	13.70
66.3	13.73	308.2	14.25	542.7	13.75

Age, ka	$\delta^{18}O$, ‰	Age, ka	$\delta^{18}O$, ‰	Age, ka	$\delta^{18}O$, ‰
66.6	13.75	309.8	14.30	544.6	13.65
67.0	13.75	311.3	14.35	546.5	13.80
67.3	13.77	312.8	14.20	548.5	13.80
67.7	13.76	314.4	14.20	550.4	13.90
68.0	13.77	315.9	14.25	552.4	13.90
68.4	13.77	317.5	14.30	554.3	13.95
68.7	13.87	319.0	14.45	556.3	14.00
69.1	13.84	320.5	14.70	558.2	13.95
69.4	13.81	322.1	14.80	560.2	14.00
69.8	13.91	323.6	14.95	562.1	14.10
70.1	13.88	325.1	15.05	564.0	14.25
70.5	13.91	326.7	15.05	565.9	14.35
70.8	13.96	328.5	15.20	567.7	14.40

Summary

This report provides the full record for the stable oxygen isotope chronology from Devils Hole, Nev., from 567,700 years before present and extended to 4,500 years before present for use by the paleoclimatic community.

References Cited

Coplen, T.B., 2007, Calibration of the calcite-water oxygen-isotope geothermometer at Devils Hole, Nevada, a natural laboratory: Geochimica et Cosmochimica Acta, v. 71, p. 3948–3957.

Landwehr, J.M., Coplen T.B., Ludwig, K.R., Winograd, I.J., and Riggs, A.C., 1997, Data for Devils Hole core DH–11: U.S. Geological Survey Open File Report 97–792, 8 p.

Ludwig, K.R., Simmons, K.R., Szabo, B.J., Winograd, I.J., Landwehr, J.M., Riggs, A.C., and Hoffman, R.J., 1992, Mass-spectrometric ^{230}Th-^{234}U-^{238}U dating of the Devils Hole calcite vein: Science, v. 258, no. 5080, p. 284–287.

Riggs, A.C., Carr, W.J., Kolesar, P.T., and Hoffman, R.J., 1994, Tectonic speleogenesis of Devils Hole, Nevada, and implications for hydrogeology and the development of long, continuous paleoenvironmental records: Quaternary Research, v. 42, no. 3, p. 241–254.

Winograd, I.J., Coplen T.B., 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, no. 5080, p. 255–260.

Winograd, I.J., Coplen, T.B., Ludwig, K.R., Landwehr, J.M., and Riggs, A.C., 1996, High resolution $\delta^{18}O$ record from Devils Hole, Nevada, for the period 80 to 19 ka: EOS, v. 77, no. 17, p. S169.

Winograd, I.J., Landwehr, J.M., Coplen, T.B., Sharp, W.D., Riggs, A.C., Ludwig, K.R., and Kolesar, P.T., 2006, Devils Hole, Nevada, $\delta^{18}O$ record extended to the mid-Holocene: Quaternary Research, v. 66, no. 2, p. 202–212.

Winograd, I.J., Landwehr, J.M., Ludwig, K.R., Coplen, T.B., and Riggs, A.C, 1997, Duration and structure of the past four interglaciations: Quaternary Research, v. 48, no. 2, p. 141–154.