WATER-TABLE FLUCTUATIONS IN THE AMARGOSA DESERT, NYE COUNTY, NEVADA.

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ABSTRACT

Pleistocene ground-water discharge deposits approximately 20 km southwest of Yucca Mountain were previously thought to represent pluvial water-table rises of 80 to 120 m. Data from new boreholes at two of the three discharge sites indicate that the modern water-table is at depths of only 17 to 30 m and that this shallow water is part of the regional ground-water flow system rather than being perched. Calcite in equilibrium with this modern ground water would have isotopic compositions similar to those in Pleistocene calcite associated with the discharge deposits. Carbon and uranium isotopes in both ground water and discharge deposits imply that past discharge consisted of a mixture of both shallow and deep ground water. These data limit Pleistocene water-table fluctuations at the specified Amargosa Desert discharge sites to between 17 and 30 m and eliminate the need to invoke large water-table rises.

I. INTRODUCTION

Ground-water discharge deposits are present throughout southern Nevada[1], including three sites in the north central Amargosa Desert approximately 20 km southwest of Yucca Mountain (fig. 1), site of a potential high-level radioactive waste repository. Radiometric ages between 15 ka to more than 200 ka determined from these deposits indicate that discharge was active during at least the last two pluvial cycles[2] (J.B. Paces and others, USGS written communication, 1996, 1997). Isotope compositions (initial $^{234}U/^{238}U$, $\delta^{87}Sr$, and $\delta^{13}C$) of authigenic components in these deposits were interpreted to reflect a ground-water source associated with regional flow systems rather than perched-water or runoff sources (J.B. Paces and others, USGS written communication, 1996, 1997). The depth of the modern regional water table beneath the discharge sites previously was estimated at 80 to 120 m, assuming uniform hydraulic gradients between widely dispersed boreholes[2] (J.B. Paces and others, USGS written communication, 1996). As a result, a 100-m water-table rise during the last two pluvial cycles was postulated at the discharge sites and, by inference, upgradient at Yucca Mountain. If true, similar water-table rises in the future could impact the potential repository by reducing unsaturated-zone thickness, shortening unsaturated-zone ground-water travel times, and decreasing the effectiveness of radionuclide absorption in unsaturated zeolitized tuffs above the modern water table.

New boreholes in the Nye County Early Warning Drilling Program[3] (NC-EWDP) provide the first opportunity to sample ground water and measure the depths to water at two of these discharge sites. The purpose of this paper is to summarize the new data, evaluate the source of the shallower-than-expected ground water in the boreholes, compare water and mineral isotope data, and provide a more accurate estimate of pluvial water-table rises.

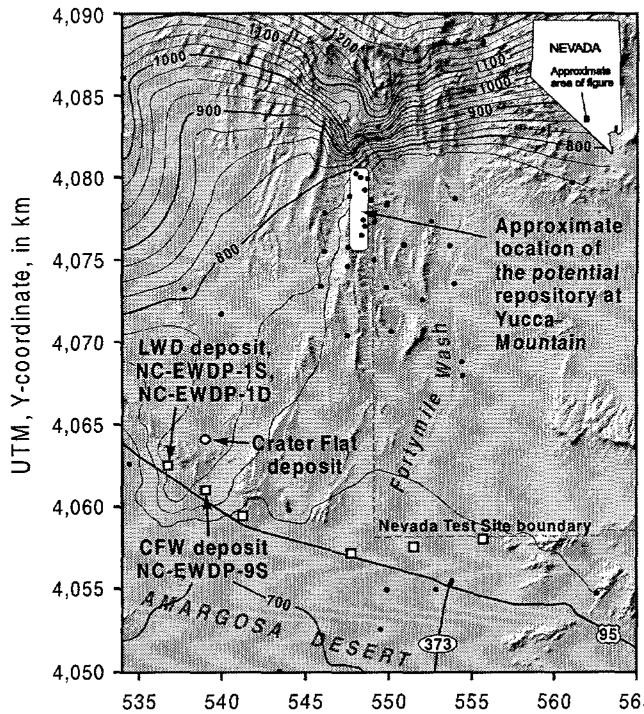

Fig.1 *Location of ground-water discharge deposits, Nye County* Early Warning Drilling Program boreholes (white squares), and other boreholes with water table elevations (black circles). *Potentiometric surface elevations are given in meters above* mean sea level with 25-m contours (modified from C.C. Faunt, USGS, 2000, written communication).

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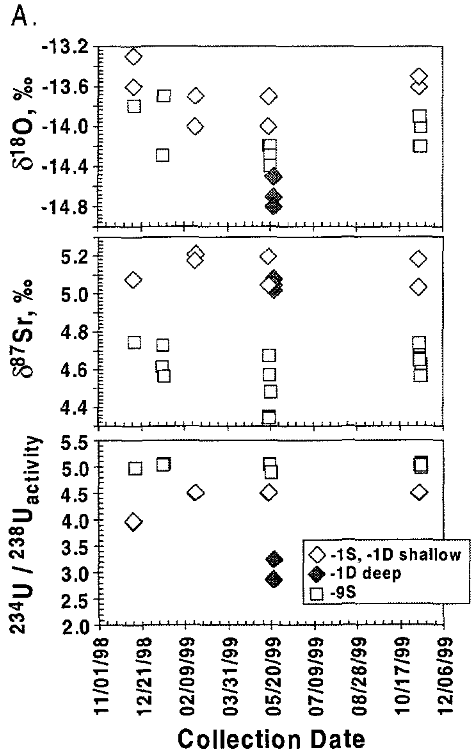

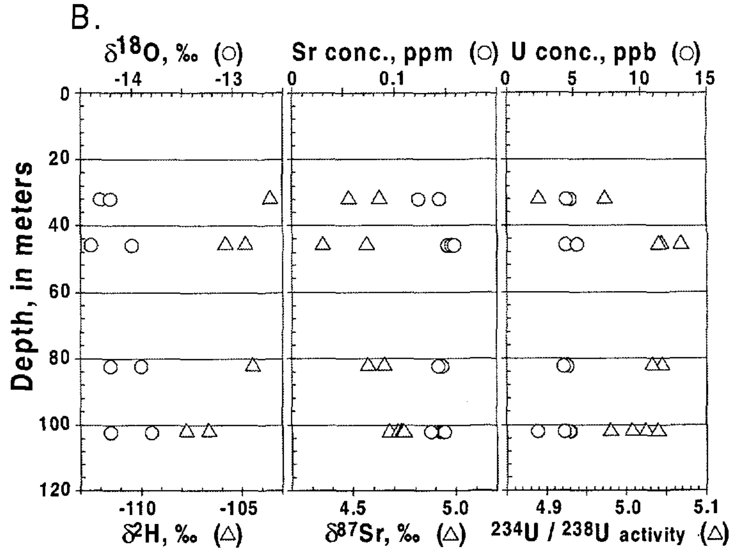

Fig. 2 A) Isotopic compositions of ground water from wells NC-EWDP-1S, -1D, and -9S versus time. B) Isotopic compositions and Sr and U concentrations from discrete zones in well NC-EWDP-9S.

II. NEW GROUND-WATER DATA

Boreholes at the Lathrop Wells Diatomite (LWD, fig. 1) deposit (NC–EWDP–1S; land surface altitude of 803 m above sea level, msl) and Crater Flat Wash (CFW) deposit (NC–EWDP–9S; land surface altitude of 797 m above msl) penetrate the shallow volcanic-rock aquifer to depths of about 130 m.[3] In addition, a deep borehole (NC–EWDP–1D) drilled next to NC-EWDP-1S to a total depth of 762 m is screened at several discrete depths including a deep zone between 658 and 683 m.[3] The unsaturated portions of the boreholes were dry-drilled, and the first water encountered was sampled by bailing when the boreholes were still only several meters deeper than the water table. After boreholes were drilled to their total depths, a large volume pump was used to clean the open bore prior to completion.[3] Pumped samples were collected from both the open bore and from discrete zones isolated using a packer system.

Water was first encountered at a depth of about 17 m in NC-EWDP-1D and NC-EWDP-1S. Static water levels in borehole NC-EWDP-1S, screened at depths of about 50 and 70 m,[3] have remained at approximately this depth (786 m above msl). A lower water level in NC-EWDP-1D (749 m above msl) reflects the lower hydraulic head in the deeper volcaniclastic-rock aquifer. Static water levels in NC–EWDP–9S are at a depth of about 30 m (767 m above msl).[3] Water-table altitudes in these boreholes are substantially higher than in nearby boreholes towards the south and east as indicated by the potentiometric-surface map shown in (fig. 1).

Water temperature at the shallowest depths is between 27 and 30°C (P. Strifler, USGS, 2000, personal communication). These temperatures are substantially warmer than the mean annual surface temperature of about 18°C (data from the southwest corner of the Nevada Test Site at the Gate 510 station with a surface elevation of 838 m above msl[4]). Despite the shallow water table depths at these sites, water temperatures are similar to or only slightly cooler than much of the ground water beneath Yucca Mountain where the water table is at depths of 500 to 700 m below land surface.[5]

Strontium and uranium concentrations as well as $\delta^{18}O$, $\delta^{2}H$, $\delta^{13}C$, $\delta^{87}Sr$, and $^{234}U/^{238}U$ compositions have small but distinct differences between samples from the shallow zones in boreholes NC-EWDP-1S, -1D and borehole –9S (fig. 2a, for example). These differences have remained more-or-less constant over a sampling period of about a year. Furthermore, samples collected from discrete zones within the shallow parts of both NC-EWDP-1S and –9S have only minor variations within each borehole (fig. 2b, for example). In contrast, larger compositional differences are present between the shallow samples from all three boreholes and those from the deep zone in NC–EWDP–1D. Compared to samples from shallow zones, the deeper water contains heavier $\delta^{13}C$ values (about 0 per mil [‰] compared to –6 to –2‰ for shallow water), much smaller ^{14}C abundances (2 to 3 percent modern carbon versus 7 to 12 for shallow water), slightly lighter $\delta^{2}H$ and $\delta^{18}O$ values, larger Sr concentrations (0.1 ppm versus 0.1 to 0.6 ppm for shallow water), much smaller U concentrations (0.005 ppb versus 4 to 8 ppb), and lower $^{234}U/^{238}U$ activity ratios (2.9 to 3.2 versus 4.0 to 5.0 for shallow water). These isotopic differences are consistent with deep samples containing a larger component of water with isotopic characteristics similar to the Paleozoic-carbonate aquifer underlying Tertiary volcanic and volcaniclastic confining units.

III. DISCUSSION

A. Regional versus Perched Water

Results from the new boreholes indicate that ground water at the discharge sites is shallower than was originally expected, raising the question of whether the water is perched or part of the regional flow system. Hydrographs from 6-months to a year after drilling[3] indicate that water levels generally have remained constant within centimeters of the depths at which water was first encountered in dry-drill boreholes; even after substantial development. If the shallowest water was perched and of limited extent, water levels measured after major pump tests are not likely to have recovered rapidly to pre-test static levels. Also, local recharge to shallow perched horizons is not likely to have the warm temperatures observed in all three boreholes.

The overall compositional uniformity with depth in the two shallow boreholes also provides strong evidence against the water being perched. Samples of both the first water encountered and the uppermost discrete zones have similar or identical isotopic compositions to samples from open borehole pump tests or lower discrete zones. In contrast, perched water derived from local recharge would reflect modern precipitation and infiltration with much heavier values of $\delta^{18}O$ and $\delta^{2}H$ (values of –8 to –10‰ and –60 to –75‰)[6], and substantially lower $^{234}U/^{238}U$ (activity ratios near 1.6 ± 0.2).[7] Although the depth profiles may reflect minor amounts of local recharge in the uppermost zones (slightly heavier $\delta^{2}H$ and lower $^{234}U/^{238}U$ ratios, fig. 2b), hydraulic, temperature, and compositional data indicate that shallow water from boreholes NC-EWDP-1S and -9S is associated with the regional flow system.

B. Isotopic Comparisons between Modern Water and Pleistocene Deposits

Authigenic carbonate components of the Pleistocene discharge deposits contain $\delta^{13}C$, $\delta^{87}Sr$, and $^{234}U/^{238}U$ compositions that can be related to the isotopic compositions of modern ground water at the two sites. Calcite $\delta^{13}C$ values from nodules and ledges in the LWD deposits overlap those calculated for calcite in equilibrium with $\delta^{13}C$ values of water from NC-EWDP-1S and –1D at 25°C (fig. 3a). Late Pleistocene calcite (about 70 to 15 ka) has $\delta^{13}C$ values of about –2 to –3‰, similar to values for calcite in equilibrium with NC-EWDP-1S and shallow NC-EWDP-1D ground water. Middle Pleistocene calcite (about 180 to 120 ka) has heavier $\delta^{13}C$ values between –2 and +3‰, more similar to values calculated from deep NC-EWDP-1D ground water. These differences may reflect a larger component of deep ground water in the surface discharge during the penultimate pluvial episode than during the last discharge episode.

Radiogenic isotope compositions ($\delta^{87}Sr$ and $^{234}U/^{238}U$) also show similarities between modern ground water and calcite from discharge deposits (after age corrections are made to $^{234}U/^{238}U$). Both discharge calcite and ground water at the LWD deposit have $\delta^{87}Sr$ values that are slightly larger than those at the CFW deposit (fig. 3b). At both sites, $\delta^{87}Sr$ compositions of the discharge deposits extend to slightly larger values than those measured in modern ground water and may reflect a slightly soluble Rb-enriched silicate phase (clays) that was incorporated into HCl leachates during analysis. Ground water

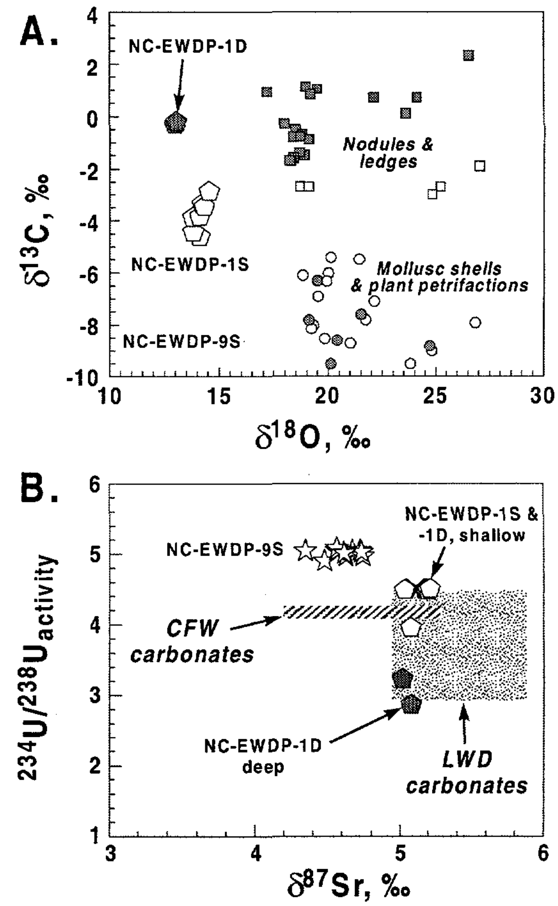

Fig. 3 Isotopic compositions of discharge deposits and modern ground water. A) $\delta^{13}C$ and $\delta^{18}O$ compositions of calcite from the LWD deposits (small symbols; late Pleistocene, open circles and squares; middle Pleistocene, filled circles and squares; data from Paces et al., 1996) and calcite in equilibrium with water from NC-EWDP-1S and -1D at 25°C (large symbols). B) $\delta^{87}Sr$ and $^{234}U/^{238}U$ compositions of water from NC-EWDP-1S, -1D, and -9S (symbols) and fields indicating the ranges of $\delta^{87}Sr$ and initial $^{234}U/^{238}U$ in Pleistocene LWD and CFW carbonates.

$^{234}U/^{238}U$ ratios from NC-EWDP-9S are slightly larger than initial $^{234}U/^{238}U$ from CFW deposits; however, a small surface-water component mixed into the discharge environment could explain the difference. Values of $^{234}U/^{238}U$ in ground water from NC-EWDP-1S and -1D overlap initial $^{234}U/^{238}U$ ratios calculated for discharge carbonates from the LWD deposit (fig. 3b). Like the $\delta^{13}C$ results, smaller initial $^{234}U/^{238}U$ values characteristic of the middle Pleistocene LWD deposits relative to late Pleistocene deposits are consistent with a larger component of water from the deeper aquifer during the penultimate discharge episode.

CONCLUSIONS

The similarities between isotope compositions in modern ground water and calcite in Pleistocene discharge deposits in the north central Amargosa Desert indicate a genetic link between the two and provide a record of water-table fluctuations between pluvial and interpluvial climates. A similar paleohydrographic record in the eastern Amargosa Desert indicates that the late-Pleistocene water table was 9 m higher than present based on subterranean calcite deposits associated with the separate regional carbonate-aquifer flow system discharging at Ash Meadows.[8] A somewhat higher rise in the water-table of about 17 m is required to activate surface discharge at the LWD deposit which in turn supported the flowing spring and wetland paleoenvironment that has been reconstructed on the basis of fossil mollusc, ostracode, and diatom data.[9] A similar rise at the CFW deposit would not result in surface discharge; however, evidence for Pleistocene flowing springs and standing water is not as obvious at this site. Nevertheless, shallow water tables (less than 10 m) are likely to have supported abundant phreatophyte vegetation along with the development of eolian and capillary-fringe deposits.[1] Therefore, Pleistocene water-table fluc-tuations at these Amargosa Desert discharge sites may be limited to between 17 and 30 m rather than the 80 to 120 m range as suggested previously[2] (J.B. Paces and others, USGS, written communication, 1996). Although the hydraulic, temperature, and compositional data indicate that the modern saturated-zone hydrology at these sites is complex, interpretations of these data support a regional ground-water source for the deposits without requiring large Pleistocene water-table fluctuations either locally or, by inference, upgradient at Yucca Mountain.

ACKOWLEDGEMENTS

Work was done in cooperation with the Nevada Operations Office, U.S. Department of Energy, under Interagency Agreement DE-AI08-97NV12033. Zell Peterman and Gary Patterson provided Sr and radiocarbon data, respectively. Dwight T. Hoxie and Edwin P Weeks provided thorough reviews of this manuscript.

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