Late Pleistocene wetland deposits at Valley Wells, eastern Mojave Desert, California: initial results

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1. Introduction

Ground-water discharge (GWD) deposits form in arid environments when water tables approach or breach the ground surface during periods of enhanced effective precipitation. When active, desert springs and wetlands provide an important water source for local fauna, support hydrophilic vegetation, and act as a catchment system for eolian sediments. The interplay between emergent water tables, ecological and biological systems, and wind-blown sediments results in a complex depositional environment that contains information on the timing and magnitude of past changes in local or regional hydrologic budgets. GWD deposits, which are also called “spring” or “wetland” deposits, also clearly demarcate the position of past ground-water highstands and, therefore, can be used to constrain changes in climate for a given area.

GWD deposits are common in arid environments but are often misidentified as lake deposits because of their similar appearance and position on the landscape (Forester et al., 2003). They typically consist of fine-grained sediments that are commonly positioned at or near valley bottoms or other topographic lows. When eroded, they may

exhibit a badland appearance similar to lake deposits, and may contain gastropod and bivalve shells that are similar to lacustrine taxa. GWD deposits have been identified in all four deserts of the American Southwest (Chihuahuan, Great Basin, Mojave, and Sonoran), but have been thoroughly investigated at only a handful of sites (Quade, 1986; Quade and Pratt, 1989; Haynes, 1991; Quade et al., 1995; Quade et al., 1998; Kaufman et al., 2002; Pedone and Rivera, 2003; Quade et al., 2003; Pigati et al., 2004; Mahan et al., 2007). Recent geologic mapping of surficial deposits in the Mojave Desert has identified more than 130 localities that exhibit evidence of past ground-water discharge (e.g., Bedford et al., 2006; Schmidt and McMackin, 2006). Of these, GWD deposits identified at Valley Wells, located in Shadow Valley in the eastern Mojave Desert (Fig. 1), are among the most spatially and stratigraphically extensive and contain evidence for multiple episodes of high water-table conditions that can be dated using several chronometric techniques. Our preliminary results suggest that there were at least two distinct ground-water highstands at Valley Wells that supported complex spring and wetland systems during the late Pleistocene.

2. Valley Wells setting

Shadow Valley is located in the eastern Mojave Desert between the Clark Mountains and Mescal Range to the east and the Halloran Hills to the west, approximately 40 km northeast of Baker, California (Fig. 1). The valley lowlands are largely covered by alluvial fan deposits that consist of rocky detritus from a number of sources: Proterozoic quartzites and Paleozoic carbonates from the Clark Mountains and Mescal Range, arkosic sediments from granites underlying Cima Dome and Halloran

Summit to the south and west, respectively, and a few local basalt flows (Hewett, 1956; Reynolds et al., 1991). The mountains east of the valley are higher than other nearby mountains, consist primarily of carbonate rocks, and thus are efficient at intercepting moisture and are highly permeable. The southeastern part of Shadow Valley includes the Valley Wells basin, which contains a distinct set of light-colored deposits that are positioned near the valley floor and are bisected by Interstate 15 and Cima Road (Fig. 2). These sediments were first interpreted as Pleistocene lake deposits by Hewett (1956) and later mapped as such by Evans (1971). Additional investigations recovered a suite of terrestrial and freshwater gastropod shells, as well as a number of terrestrial fauna, including rodents, small invertebrates, ungulates, and megafauna (mammoth and mastodon), but the lacustrine interpretation for the origin of the sediments remained the same (Reynolds and Jefferson, 1971; Reynolds et al., 1991).

The light-colored deposits at Valley Wells are present in three separate locations in the basin, which we refer to as the east, north, and west flanks, respectively (Fig. 2). There are significant differences in the physical characteristics of the sediments between the three flanks that we suspect reflect differences in the mineralogical composition of the sediments, their ages, spatial relationship to past spring orifices, and position on the current landscape. In this paper, we concentrate our discussion on the sediments in the east flank for several reasons: (1) they are well preserved, (2) they contain abundant macrofossils (ostracodes and gastropods) that can be used to reconstruct past environmental conditions, (3) they contain material suitable for dating by radiocarbon, uranium series, and luminescence methods, and (4) they exhibit evidence of multiple ground-water highstands. Sediments in the west flank are largely deflated, and we have

not found any ostracodes, gastropods (except for a few fragments), or material suitable for radiocarbon dating from either the north or west flank.

3. Stratigraphic units

We used field mapping, detailed sedimentological descriptions, and stratigraphic relations to identify at least two distinct sediment packages in the east flank of Valley Wells. Our unit terminology largely follows Haynes (1967), but we refer to the older, more extensive deposits at Valley Wells as Unit X because we cannot definitively correlate it with a specific unit in southern Nevada due to unresolved geochronologic questions. A brief summary of Haynes' unit terminology is given in Table 1.

3.1. Unit X

Unit X is more than ~5-6 m thick (the base of the unit is not exposed) and comprises nearly all of the stratigraphic section in the east flank. The top of Unit X decreases in altitude ~6-8 meters from east to west and is essentially continuous except where it has been eroded either by headcutting or local slumping that occurred after spring discharge ceased. Near the western margin of the east flank, basal sediments of Unit X range from a light-purple silty clay to fine sands and silts. These sediments are overlain by light-brown silt that typically contains numerous root casts that are oxidized and easily identified. Above this silt, there is a thin (20-40 cm) olive-green clay containing abundant ostracodes and gastropod shells that is overlain by 30-50 cm of white silt to silty clay. This series of fine-grained units is capped by a thick (up to ~1 m), extremely hard and well-cemented, whitish-grey deposit that contains abundant calcium

carbonate (hereafter referred to as the carbonate cap; shown at the top of the section in Fig. 3a). In a few places, the surface of the carbonate cap has been locally shattered by a combination of freeze-thaw, salt accumulation, and bioturbation processes, and is exposed as small areas of desert pavement that are composed almost entirely of carbonate rubble. We did not find any evidence of microfauna, pollen, or plant macrofossils within the cap.

The fine-grained Unit X deposits progressively grade to the east into coarse-grained materials ranging from silt and sand (Fig. 3b) to gravel (Fig. 3c). The hard carbonate cap also changes character to the east, grading into a fairly soft unit that is interbedded with alluvial sand and gravel near the eastern margin. We did not find evidence of microfauna or plant macrofossils in any of the units in this area.

3.2. Unit E_2

Unit E_2 at Valley Wells consists of a package of olive-green clay overlain by a dark-brown to black, organic-rich clay, which is locally capped by a thin (20-30 cm) light-brown silt. Unit E_2 is typically 2-3 m thick, is inset into the older Unit X deposits in the east flank (the top of Unit E_2 is 4-6 m below the top of Unit X), and is relatively soft and easily eroded. Locally, Unit E_2 exhibits a badland appearance (Fig. 3d), but the unit is expressed as subdued topography elsewhere in the east flank. Unit E_2 deposits are also exposed in a small arroyo between Cima Road and the west flank deposits, where they are capped by Holocene alluvium (Fig. 2).

4. Habitat reconstruction

We used sedimentological data and the presence/absence of microfauna to reconstruct the paleoenvironmental conditions represented by Units X and E_2 at Valley Wells. First, we used the relations between hydrologic regime, plants, and sediments deposited within wetland systems established by Quade *et al* (1995) to differentiate between areas of maximum ground-water discharge (wetland facies), areas that once supported phreatophytic plants (phreatophyte flat), and areas lacking shallow groundwater that were largely covered by xerophytic plants even when wetlands were present nearby. We then sampled sediments along several transects across the wetland facies to determine the presence/absence of ostracodes and gastropods to verify our interpretations based on the sedimentological evidence. We also attempted to verify our interpretation using pollen analysis, but pollen was not recovered in any of the Unit X deposits that we studied at Valley Wells (D. Wahl, pers. comm., 2007).

In modern wetland systems, Quade *et al* (1995) found clear relations between the hydrologic regime, floral assemblages, and the types of sediments deposited. For example, areas of active ground-water discharge that support dense stands of hydrophilic plants are represented by fine-grained sediments that commonly exhibit a high organic content. In the geologic record, these areas are represented by pale-green to white mudstones and dark-colored organic mats. Phreatophytic plants dominate the landscape upslope of areas of active ground-water discharge where water tables do not reach the surface but are still close enough to be tapped by plants. These plants, which in southern Nevada include rabbitbrush, sagebrush, and greasewood, efficiently capture wind-blown material and, as a result, the “phreatophyte flat” zone is represented in both modern settings and the geologic record as eolian silt and fine sand interbedded with alluvial

sediment. Alluvial fan depositional environments outside the influence of wetland systems are typically rocky, poorly sorted, and vaguely bedded deposits and are dominated by xerophytic plants.

4.1 Unit X

We mapped the spatial extent of the olive-green clay unit within Unit X at Valley Wells which, according to the Quade *et al* model, represents the area of active discharge. The green clay deposits are largely confined to the western margins of the east flank, which we interpret as the likely home of active springs, seeps, wet meadows and marshes, or a mosaic of all of these (Fig. 2). Upgradient to the east, areas in Unit X that are dominated by brown silt and sand are interpreted as representing a phreatophyte flat when wetlands were active downslope. Alluvial sands and gravels in Unit X progressively increase in abundance to the east where they are overlain by the soft carbonate cap, which we interpret as representing areas of progressively deeper ground-water.

Terrestrial and semi-aquatic gastropod shells were abundant in the green clay unit, confirming our interpretation based on the sedimentology; that is, that this area once supported an active wetland system. Gastropods identified in the field included members of the semi-aquatic *Succineidae* family, several genera of the terrestrial *Pupillidae* family, and other taxa that we have not yet identified. We did not find gastropod shells in any other strata or locations within Unit X. Ongoing work with Jeff Nekola at the University of New Mexico in Albuquerque is aimed at identifying the suite of gastropods present in these deposits.

Similarly, we found a number of ground-water ostracode taxa (i.e., ostracodes that live near spring orifices or other wetland settings) in the green clay deposits in the western margin of the east flank, which lends further support to our paleoenvironmental interpretation. We did not find ostracodes in strata at any other location within Unit X. Ongoing work with Jordon Bright at Northern Arizona University in Flagstaff is aimed at identifying the full range of ostracodes present in the deposits and reconstructing local environmental habitats and chemical properties of the water that discharged at these locations.

4.2 Unit E_2

Exposures of Unit E_2 are limited to a few small areas in the east flank and in a small arroyo between Cima Road and the west flank deposits (Fig. 2). Based on the presence of the organic-rich clay and green clay deposits, we interpret Unit E_2 as representing relatively modest areas of past ground-water discharge. These systems were not as extensive as those represented by Unit X, and we did not find sedimentary units or macrofossils associated with either phreatophytic or xerophytic vegetation that may have been supported by high water table conditions in the past. We conclude that high-water table conditions represented by Unit E_2 were not extensive and/or pervasive enough to support a phreatophytic flat adjacent to the area of active ground-water discharge. We did find a few scattered gastropod shells (*Succineidae*, *Pupillidae*, etc.) in the thin brown silt near the top of Unit E_2, but ostracodes were not present in these sediments.

5. Chronology

Reynolds *et al* (1971) recovered the remains of a number of mammals from Unit E_2 in the east flank, including *Symmetrodontomys* n. sp. (cricetid rodent) and *Onychomys* n. sp. (grasshopper mouse). The presence of these fauna suggests that the age of the base of Unit E_2 is late Blancan Land Mammal Age (2.6-1.8 Ma, Savage and Russell 1983). In contrast, Quade *et al* obtained radiocarbon dates of 10,250±160 ^{14}C yrs (Quade et al., 1995) and 11,600±120 ^{14}C yrs (Quade et al., 1998) from organic-rich clay in Unit E_2. There have not been any reported ages for Unit X at Valley Wells.

We obtained preliminary radiocarbon dates from organic material and minute terrestrial gastropod shells recovered from Units E_2 and X to constrain the timing of ground-water highstands at Valley Wells. All samples were pretreated using standard procedures, which will be outlined in a forthcoming paper.

Preliminary ^{14}C ages for the organic-rich clay deposit in Unit E_2 range from 9,650±50 to 10,780±40 ^{14}C yrs, depending on the component of the material dated (e.g., base-soluble humic acids compared to base-insoluble humin residue). Additional ^{14}C ages on gastropod shell carbonate for shells recovered from the light brown silt unit that caps Unit E_2 ranged from 7,930±50 to 8,630±60 ^{14}C yrs. Unit E_2 deposits are common features of GWD in valleys in the southern Great Basin Desert and have been interpreted to represent a brief period of high water tables that peaked during the Younger Dryas (YD) cold event and continued into the early Holocene (Quade et al., 1998). Our dates are consistent with this interpretation.

Preliminary ^{14}C ages obtained from gastropod shells recovered from the green clay deposit in Unit X ranged from 30,280±210 to 33,770±220 ^{14}C yrs. For now, we assume that these ages should be taken at face value (i.e., they are not compromised by

small amounts of contaminant carbon). If so, then Unit X at Valley Wells may correlate with Unit D deposits in southern Nevada (Table 2) (Haynes, 1967; Quade, 1986; Quade and Pratt, 1989) that are interpreted to represent an extensive resurgence in ground-water tables that occurred during oxygen isotope stage (OIS) 2. However, we cannot rule out the possibility that our preliminary ages for Unit X are the result of older shells that are slightly contaminated with younger carbon. If so, then Unit X at Valley Wells may correlate with Unit B deposits in southern Nevada, which are interpreted to represent an earlier discharge event that likely occurred during OIS 6. But we have not found evidence for a major unconformity, soil development, or other indications that a significant time break lies between Units E_2 and X. We are currently employing alternative methods, including uranium-series and luminescence dating techniques, to evaluate the veracity of our radiocarbon chronology for this unit.

6. Conclusions

We used sedimentological evidence, microfaunal assemblages (gastropods and ostracodes), and radiocarbon dating to define the spatial extent and timing of high water-table conditions at Valley Wells during the late Quaternary. Our initial results suggest that active springs and wetlands occupied the western margin of the east flank of deposits at least twice during the late Pleistocene. The most recent episode of high water-table conditions occurred during the YD cold event and continued into the early Holocene. The earlier and more extensive event occurred either during OIS 3-2 or perhaps prior to that, possibly during OIS 6.

Investigation of the GWD deposits at Valley Wells is ongoing. Future work will include additional dating of Unit X using uranium-series and luminescence methods to secure the timing of the deposits, the use of stable isotopes (oxygen, hydrogen, uranium and strontium) to define the composition of source waters that fed the Pleistocene wetland systems, and measurement of modern water tables to determine the magnitude of hydrologic change in the area. We are also investigating GWD deposits at other sites in the Mojave Desert to determine whether hydrologic systems represented by GWD deposits responded to climate change synchronously across the desert, or if their response was more fragmented and influenced by local or regional factors. The results of this work will have significance for rural populations and agricultural communities that depend on shallow aquifers for their water supply and agricultural needs, and will allow us to better understand the potential response of shallow hydrologic systems to future climate change.

Acknowledgements

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Figure captions

Figure 1. Locations of Shadow Valley and Valley Wells in the Mojave Desert of eastern California.

Figure 2. Map of GWD deposits at Valley Wells. Unit X deposits are separated into three areas, the east, north, and west flanks, respectively, based on differences in sedimentology, preservation, and position on the landscape. Wetland facies in the east flank are inferred using sedimentological properties and the presence/absence of microfauna (ostracodes, gastropods): W = wetland or marsh, P = phreatophyte flat, A = alluvial setting. Unit E_2 deposits are inset within the older, more extensive deposits of Unit X in at least two areas in the east flank and in a small arroyo between Cima Road and the west flank.

Figure 3. Photographs of Unit X deposits in the east flank that were likely associated with (a) areas of active ground-water discharge, (b) the adjacent phreatophyte flat, and (c) areas that were not influenced by the presence of active wetlands. Deposits shown in each of these photographs are ~4-5 m thick. Local badland topography exhibited by Unit E_2 deposits in the east flank is shown in (d).

References

Bedford, D. R., Miller, D. M., and Phelps, G., 2006, Preliminary surficial geologic map database of the Amboy 30' x 60' quadrangle, California (1:100,000 scale), U.S. Geological Survey Open File Report 2006-1165, 28 p.

Evans, J. R., 1971, Geology and mineral deposits of the Mescal Range quadrangle, San Bernardino County, California (1:62,500 scale): Map Sheet 17, California Division of Mines and Geology.

Forester, R. M., Miller, D. M., and Pedone, V., 2003, Ground water and ground-water discharge carbonate: deposits in warm deserts, *in* Reynolds, R. E., ed., Land of Lost Lakes: the 2003 Desert Symposium Field Trip, California State University, Desert Studies Consortium, p. 27-36.

Haynes, C. V., 1991, Geoarchaeological and paleohydrological evidence for a Clovis-age drought in North America and its bearing on extinction: Quaternary Research, v. 35, no. 3, p. 438-450.

Haynes, C. V., Jr., 1967, Quaternary geology of the Tule Springs Area, Clark County, Nevada, *in* Wormington, H. M., and Ellis, D., eds., Pleistocene studies in southern Nevada: Carson City, NV, Nevada State Museum of Anthropology, p. 128.

Hewett, D. F., 1956, Geology and mineral resources of the Ivanpah Quadrangle, California and Nevada: U.S. Geological Survey Professional Paper 275, p. 172 p.

Kaufman, D. S., O'Brien, G., Mead, J. I., Bright, J., and Umhoefer, P., 2002, Late Quaternary spring-fed deposits of the Grand Canyon and their implication for deep lava-dammed lakes: Quaternary Research, v. 58, p. 329-340.

Mahan, S. A., Miller, D. M., Menges, C. M., and Yount, J. C., 2007, Late Quaternary stratigraphy and luminescence geochronology of the northeastern Mojave Desert: Quaternary International, v. 166, no. 1, p. 61-78.

Pedone, V., and Rivera, K., 2003, Groundwater-discharge deposits in Fenner Wash, eastern Mojave Desert: Geological Society of America Abstracts with Programs, v. 35, p. 257.

Pigati, J. S., Quade, J., Shanahan, T. M., and Haynes, C. V. J., 2004, Radiocarbon dating of minute gastropods and new constraints on the timing of spring-discharge deposits in southern Arizona, USA: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 204, p. 33-45.

Quade, J., 1986, Late Quaternary environmental changes in the upper Las Vegas Valley, Nevada: Quaternary Research, v. 26, p. 340-357.

Quade, J., Forester, R. M., Pratt, W. L., and Carter, C., 1998, Black mats, spring-fed streams, and late-glacial-age recharge in the southern Great Basin: Quaternary Research, v. 49, p. 129-148.

Quade, J., Forester, R. M., and Whelan, J. F., 2003, Late Quaternary paleohydrologic and paleotemperature change in southern Nevada, *in* Enzel, Y., Wells, S. G., and Lancaster, N., eds., Paleoenvironments and paleohydrology of the Mojave and southern Great Basin Deserts, Geological Society of America Bulletin Special Paper 368, p. 165-188.

Quade, J., Mifflin, M. D., Pratt, W. L., McCoy, W. D., and Burckle, L., 1995, Fossil spring deposits in the southern Great Basin and their implications for changes in water-table levels near Yucca Mountain, Nevada, during Quaternary time: Geological Society of America Bulletin, v. 107, no. 2, p. 213-230.

Quade, J., and Pratt, W. L., 1989, Late Wisconsin groundwater discharge environments of the Southwestern Indian Springs Valley, southern Nevada: Quaternary Research, v. 31, p. 351-370.

Reynolds, R. E., and Jefferson, G. T., 1971, Late Pleistocene vertebrates from Valley Wells, Mojave Desert, California: Geological Society of America Abstracts with Programs, v. 3, p. 183.

Reynolds, R. E., Jefferson, G. T., and Reynolds, R. L., 1991, The sequence of vertebrates from Plio-Pleistocene sediments at Valley Wells, San Bernardino County, California, *in* Mojave Desert Quaternary Research Center Symposium, Zzyzx, CA, p. 72-77.

Savage, D. E., and Russell, D. E., 1983, Mammalian paleofaunas of the world: Reading, PA, Addison-Wesley, 432 p.

Schmidt, K. M., and McMackin, M., 2006, Preliminary surficial geologic map of the Mesquite Lake 30' X 60' Quadrangle, California and Nevada (1:100,000 scale), U.S. Geological Survey Open-File Report 2006-1035, 89 p.

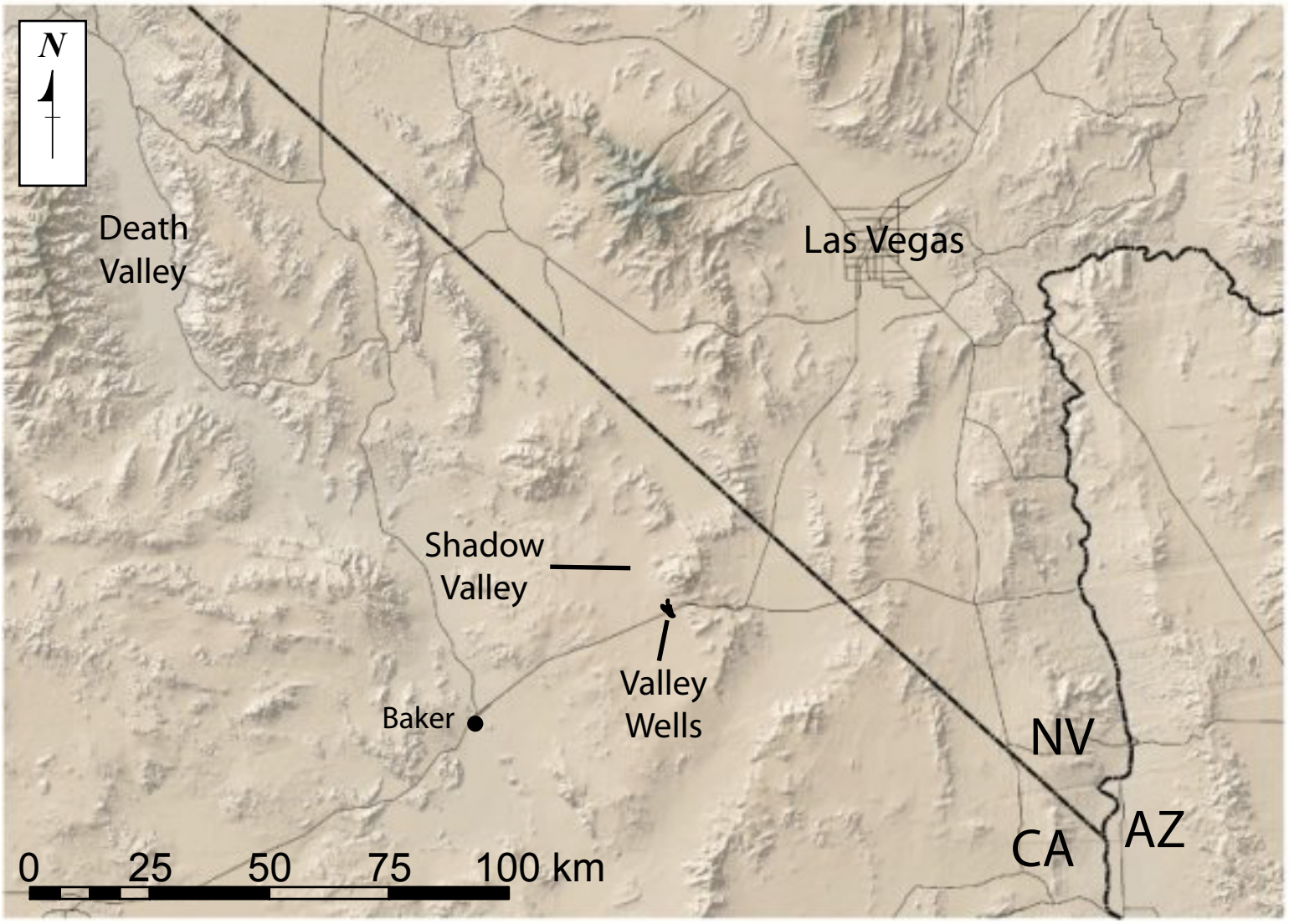

Figure 1
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Late Pleistocene wetland deposits at...

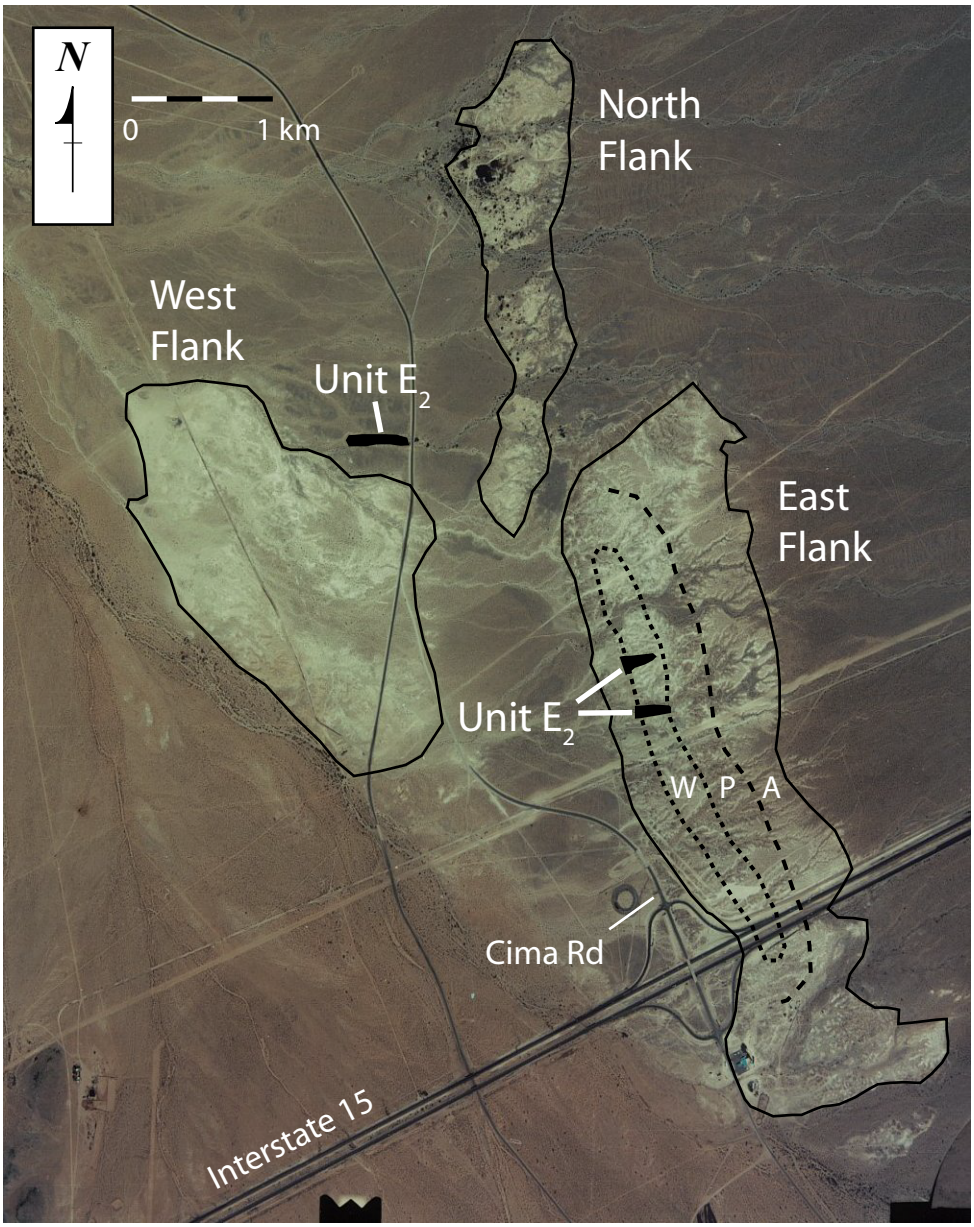

Figure 2
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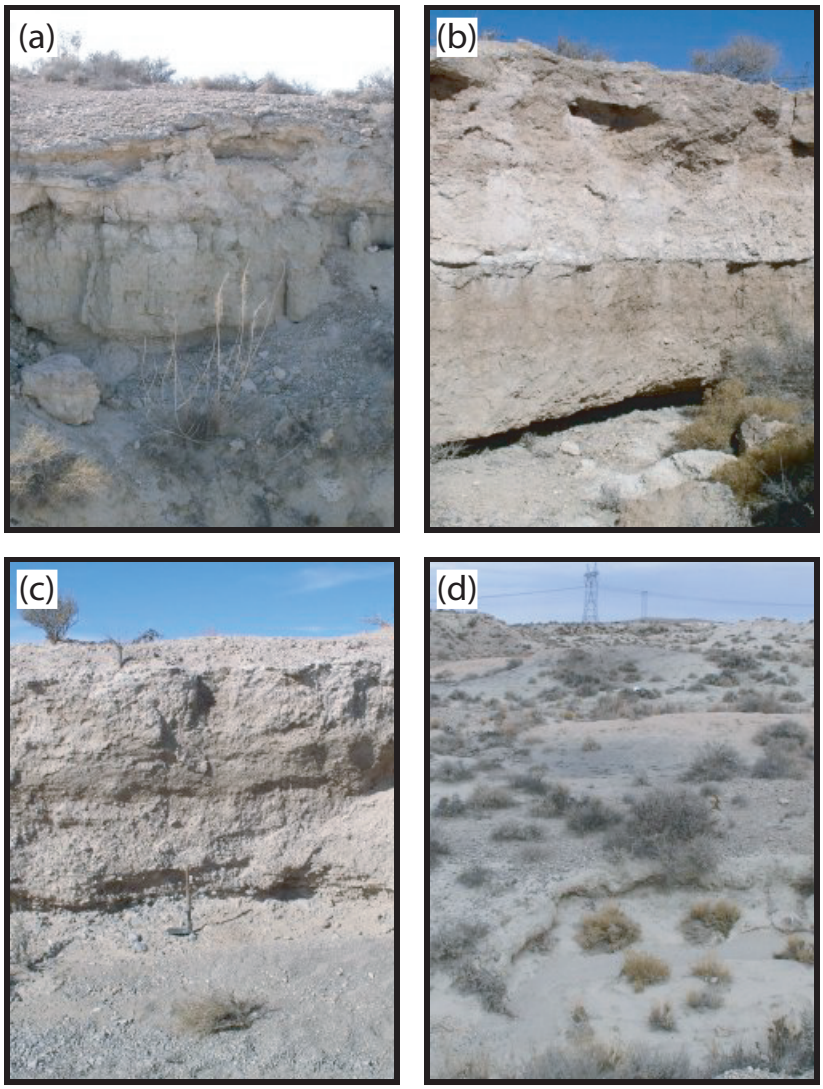

Figure 3
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Table 1: Summary of units in Southern Nevada

Unit	Oxygen Isotope Stage	Approximate age range (^{14}C yrs BP)	Environment
A	>6	--	fluvial
B	6?	--	extensive (?) wetlands
C	3-4?	--	fluvial/alluvial
D	2	14,000-30,000	extensive wetlands
E_1	late 2	11,800-13,500	modest wetlands
E_2	early 1, late 2	7,200-11,200	waning wetlands
F	1	4,000-7,000	dessication

[1] Age range as defined in Haynes (1967) and Quade (1986)