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Letter to the Editor

Are the benches at Mormon Point, Death Valley, California, USA, scarps or strandlines?

Through mapping of deposits underlying the alluvial surfaces at Mormon Point and studies of the stratigraphy in the walls of Mormon Point Canyon, Knott et al. (2002) have made a valuable contribution to our understanding of the Quaternary history of Death Valley. However, two points in their paper (OIS-2 water levels and confusion over the No. 2 gravel of Hunt and Mabey (1966)) merit discussion, and I disagree with their conclusion that many of the strandlines on Mormon Point are eroded fault scarps.

OIS-2 water levels

Knott et al. (2002, pp. 358–359) cite Hooke (1972) in support of their contention that the OIS-2 stage of Lake Manly "was ~2 m deep after 17,000 yr B.P." and "receded below −89[1] m by 17,440 ^{14}C yr B.P." These interpretations are not consistent with my core data. A date of 12,980 ^{14}C yr B.P. was obtained from black lacustrine sediment at a depth of ~8 m, or at ~−90 m (elevation), in my core 68-7. Comparing this with the stratigraphy and date in my core 68-10 demonstrates that the maximum depth of the lake at that time was *at least* 10 m. Secondly, the black lacustrine sediment was overlain by a meter or two of olive–green silt and clay that is probably lacustrine (Hooke, 1972, Fig. 2 and p. 2087). Thus, a substantial lake existed in the valley until well after 12,980 ^{14}C yr B.P.

Stratigraphy in Li et al.'s (1996) core DV93-1 from Badwater indicates that there was a perennial saline lake in the valley from ~35,000 to ~10,000 yr ago. During most of its history, this lake must have been significantly deeper than 10 m, as otherwise it would not have persisted for 25,000 yr. Indeed, from tufas on the Black Mountains, Ku et al. (1998, p. 261) obtained dates of 25 ka from −22 m and 18 ka from −30 m, indicating lake depths of 64 and 56 m, respectively, using the present elevation of Badwater of −86 m. Furthermore, although the stratigraphy in Anderson's (1998) core DVDP96-6 suggests that the lake may not have been much deeper than 15 m for much of this time, that in her cores DVDP96-6, -9 and -10 does not preclude a late OIS-2 high stand, lasting a few centuries, with a surface elevation near sea level. In the absence of differential tectonic movements, however, her core DVDP96-2 suggests that OIS-2 lake levels may not have exceeded −9 m.

In short, more core data and better dates on possibly correlative shorelines are needed to resolve the question of the depth of the OIS-2 lake.

No. 2 gravel

Knott et al. bring up, once again, Hunt and Mabey's (1966, p. A69, A71) confusion over the fact that Blackwelder-stand strandlines are cut into only some of the surfaces, at appropriate elevations, underlain by their No. 2 gravel (designated Qg_2 by Knott et al.). This also puzzled Blackwelder (1933). Knott et al. "solve" this paradox at Mormon Point by noting that their Qg_2 unit is younger than the surface into which the shorelines are cut, implying that all surfaces mapped as No. 2 gravel by Hunt and Mabey are younger than OIS-5e/6.

Hooke (1972, pp. 2092–2093) noted that Hunt and Mabey did not recognize that their No. 2 gravel on the west side of the valley included three distinct ages of gravel, designated Q1, Q2, and Q3 by Hooke and Dorn (1992). Q1 is everywhere higher than the maximum stage of the Blackwelder stand, which, owing to tectonic tilting, is at ~+60 m on the west side of the valley. Blackwelder stand strandlines are cut into the Q2 surface in the few locations where it extends below +60 m. The Q3 surface is, indeed, younger than OIS-6.

Strandlines or fault scarps?

Knott et al. hypothesized that all of the lines on Mormon Point, save the highest one, are fault scarps. In contrast, all previous workers have identified them as strandlines. Anyone who studies John Shelton's photograph in Knott et al. (2002, Fig. 2) will find their conclusion a hard sell.

On Mormon Point, most of the horizontal or nearly horizontal lines that one sees from a distance (Fig. 1) are subtle, though readily detectable, when one is standing on them. In profile, they consist of a convex-upward segment between two longer concave segments (Fig. 2b). The crests

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[1] All elevations herein are relative to current sea level.

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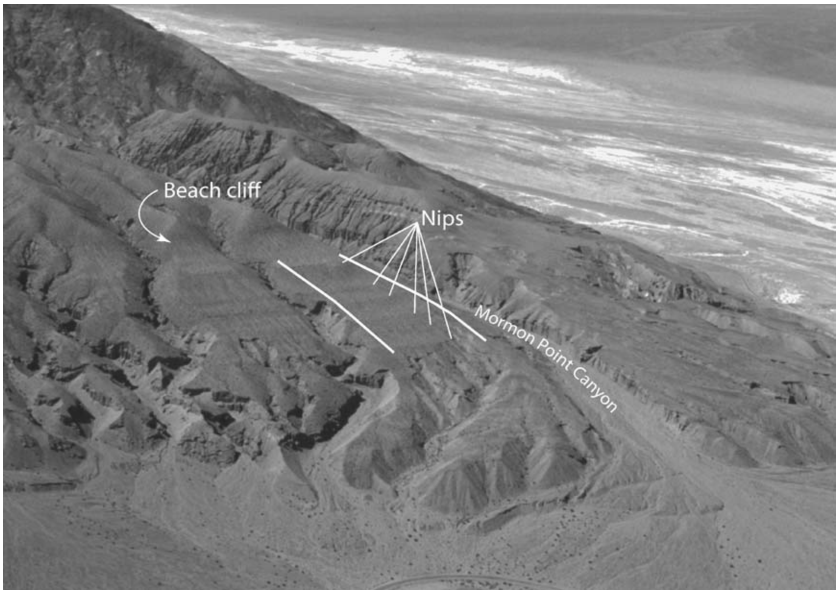

Fig. 1. Oblique aerial photograph of Mormon Point. White lines are ~200 m apart and show approximate locations of hand-leveled profiles. View is to south. (Photo by R. I. Dorn).

of the convex segments, called nips hereinafter to avoid genetic connotation, are commonly marked by a line of cobbles and small boulders. Above the highest of these nips on Mormon Point there is a steeper, higher riser that, owing to the spacing of gullies, gives rise to triangular facets (Fig. 1).

Field observations on modern coasts and model studies in a sand box equipped with a wave generator led Hooke (1972, p. 2089) to conclude that the nips were formed just below water level at the point where swash from an incoming wave interrupts down-beach transport of sediment by backwash from the preceding wave. Strahler (1966) called these common features of beach profiles *steps*. Knott et al. and I agree that the steep high riser above the highest nip is an eroded beach cliff, but they maintain that the nips are fault or fault-line scarps, not steps.

Knott et al. advance two lines of evidence in support of their hypothesis: (1) there are no bars or spits associated with the nips; and (2) they have found faults in the wall of Mormon Point Canyon at the points where the nips intersect the canyon wall. They claim that local erosion and deposi-

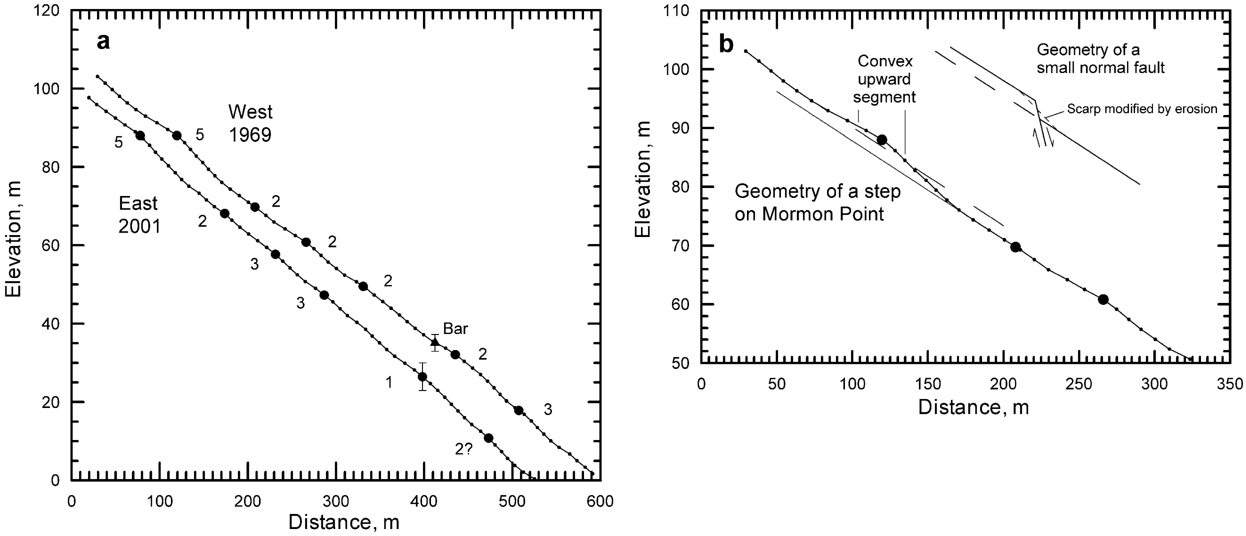

Fig. 2. (a) Profiles on wave-cut platform east of Mormon Point Canyon. For location, see Figure 1. Profiles are ~200 m apart. Dots indicate crests of nips. Numbers beside dots indicate degree of development of nip relative to top nip (compare with Fig. 1). The latter is arbitrarily given a rank of 5. Profiles do not extend up to beach cliff above highest nip. (b) Detail of top three nips from 1969 profile (Fig. 1). Line below top nip is a least squares fit to the four survey points just above the middle nip. Line through top nip is parallel to line below it. Inset shows geometry one would expect in a fault scarp.

Fig. 3. Photograph of a lacustrine gravel bar, interpreted to be a storm berm, at an elevation of ∼+32 m on the wave-cut platform east of Mormon Point Canyon. Note bedding dipping shoreward at depth. Notebook at far right gives scale.

tion have modified the nips sufficiently that one cannot determine whether or not they are horizontal (or parallel if tectonically tilted). Evidence presented below is either at odds with Knott et al's. observations or inconsistent with a fault origin.

Horizontality

In 1969 I hand-leveled a profile along the abrasion platform immediately east of Mormon Point Canyon (Figs. 1 and 2a). The survey yielded the relative elevations of the nips, and specifically of the difference in elevation between the lowest and highest nips in Fig. 2a. The elevations of these two nips were also surveyed with the use of a Kern DKM-1 theodolite from two bench marks at known elevations on the west side of the valley, yielding two additional independent estimates of the difference in elevation. Analysis of the resulting three measurements suggests an uncertainty in the hand leveling of about ±3 m over a horizontal distance of 394 m. In 2001 I surveyed a similar profile up the east side of this abrasion platform, about 200 m east of the 1969 profile (Fig. 1). In all but one case (Fig. 2a), the crest of a nip could be located to within ±1 m vertically, and in all but this one case, there is little difficulty tracing the nips across the abrasion platform (Fig. 1). Hand leveling across the platform suggests that the highest nip varies from horizontal by less than 3 m in 200 m. Accordingly, the profiles in Figure 2a were plotted with the highest nip at 88 m, the elevation determined from the theodolite surveys (Hooke, 1972, Table 4). It is clear from Fig. 2a that the vertical spacing of the lower nips is essentially the same on the two profiles, indicating that the nips are either all horizontal or, if slightly tilted tectonically, they deviate from horizontal by the same

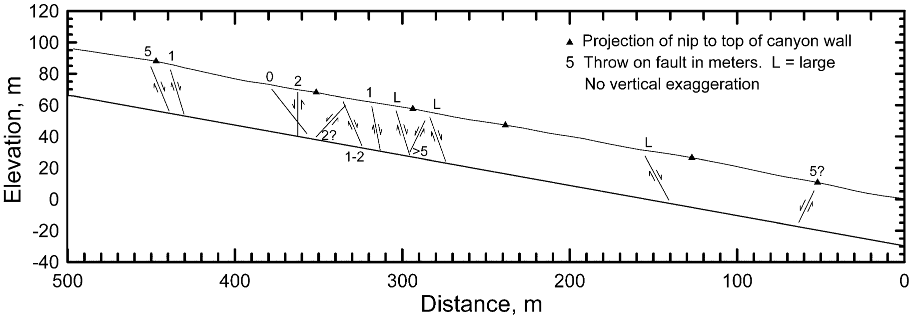

Fig. 4. Wall of wash east of 2001 profile (Fig. 1). Surface profile and locations of nips are taken from Fig. 2. Depth of canyon is schematic. Strike and dip of faults were measured and apparent dip in canyon wall is plotted. Sense and magnitude of throw are based on drag indicators and on strata that could be identified on both sides of fault. "L" indicates throw sufficiently large that bedding could not be correlated across fault; in these cases, a significant gouge zone was commonly present. Intersections of faults were not observed; intersections shown are a consequence of assigning an arbitrary depth to the canyon.

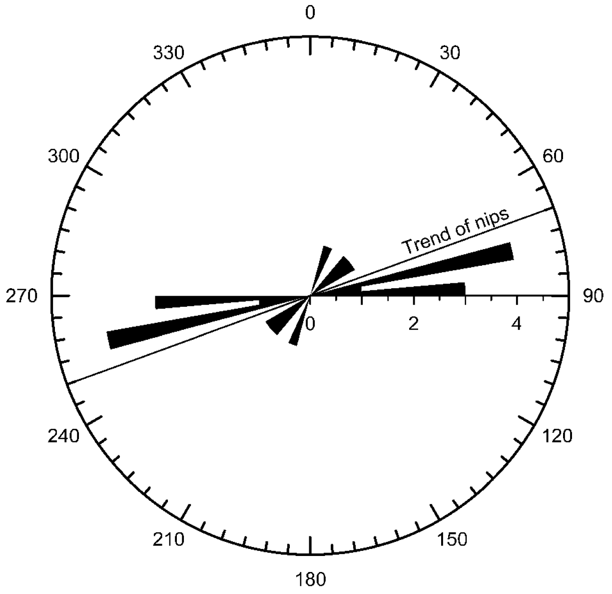

Fig. 5. Rose diagram comparing trends of faults in Figure 4 with trend of nips.

amount. This would be unlikely if the nips resulted from faulting.

Spacing

The second nip from the top is 18 m vertically below the top one. The third is 27 m below the top. Similar nips occur at these vertical spacings at four other locations in southern Death Valley (Hooke, 1972, Table 4). In all cases the top nip is the most prominent, and in most cases a steep riser, interpreted to be a beach cliff, rises above the highest nip. This coincidence in spacing and degree of development at five locations in the valley would be highly unlikely if the nips were fault controlled.

Shape

The shape of the nips is not consistent with a fault origin. In faulting on this horizontal scale, the surfaces above and below the scarp remain parallel to one another (Fig. 2b, inset). In contrast, the profile upslope from a step is concave upward, so the crest of the step rises above the extrapolated plane (Strahler, 1966, Fig. 8). In this respect, the nips on Mormon Point resemble steps, not fault scarps.

Lack of bars and spits

Bars and spits form where indentations in the topography result in shallow bays. Waves feel bottom and break near the mouths of such bays, resulting in bar formation. In several places where bays were present in the shore of Lake Manly, bars did form (Hunt and Mabey, 1966, p. A69; Hooke, 1972, pp. 2091–2092). Any such indentations that were present on Mormon Point probably became the deep, steep-sided washes that now dissect Mormon Point. Such dissection is not conducive to preservation of bars or spits.

Despite these qualifications, there is a gravel bar associated with the second nip on the 1969 profile (Fig. 2a). The bar (Fig. 3) is composed of granule to pebble gravel that is more rounded and better sorted than typical fan gravel. Bedding near the surface dips 5° to the south, into the slope. At a depth of a few decimeters, these upper beds lie with angular unconformity on beds that dip 25° to the south. This is a typical geometry for bedding in a storm berm. Thus, there is at least one bar associated with the nips.

Faults in canyon east of 2001 profile

After hand-leveling the 2001 profile, I built cairns in line with the nips but close enough to the wall of the adjacent canyon so they could be seen from the canyon floor. Only slight uncertainty is introduced by the need to extrapolate the trend of the nips across the colluvial slope at the top of the canyon wall to a point visible from the canyon floor. I then mapped all faults visible in the canyon wall (Fig. 4), noting strike, dip, sense of displacement (using offset strata or drag indicators), and throw where determinate.

Two relevant characteristics emerged: (1) faults trend in a variety of directions, and most are not parallel to the nips (Fig. 5); and (2) while some faults appear to be associated with nips, most do not. Note also that the throw on the lowest fault is north-side up, which would result in a scarp facing the mountains. In this canyon there is not the one-to-one correspondence between nips and faults that Knott et al. (p. 357) say occurs in Mormon Point Canyon.

Slopes of faults and nips

The slope of a fresh fault scarp should lie between the angle of repose and the angle of dip of the fault, with steeper slopes in more cohesive material. The average dip of the faults I measured (Fig. 4) is 70°. The average slope of the downslope face of the nips is ~0.4°. If we assume that the slope of a scarp would decrease to the angle of repose in 100 years, a crude calculation, based on an equation given by Bucknam and Anderson (1979), suggests that it would take over a million years for the slope to then decrease from 35° to 0.4°. Although the uncertainties in this calculation are quite large, it seems unlikely that the gentle distal slopes of the nips could have evolved from fault scarps in $<10^5$ years.

Conclusion

The evidence relating the nips to faults is weak, and that relating nips to some type of shoreline process is strong. The best explanation, so far, is that the nips are (Strahler) steps, formed slightly below water level by interaction between wave swash and backwash.

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