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LETTER TO THE EDITOR

Is There Any Evidence of Mega-Lake Manly in the Eastern Mojave Desert during Oxygen Isotope Stage 5e/6? A Comment on Hooke, R. L. (1999). Lake Manly(?) Shorelines in the Eastern Mojave Desert, California, *Quaternary Research* **52,** 328–336

Hooke (1999) rekindled the hypothesis that a large lake (mega-Lake Manly) filled Death Valley and the adjoining Silver/Soda Lake during pluvial periods (e.g., Hale, 1985). Like Hooke, we also have been investigating lake deposits, strandline features, and Quaternary tectonics in the Death Valley, Silurian Valley, and the Silver/Soda Lake areas for more than a decade (e.g., Wells *et al.*, 1989; Brown *et al.*, 1990; Enzel, 1990; Anderson and Wells, 1996; Knott *et al.*, 1996, 1999; Enzel and Wells, 1997; Knott, 1997, 1998; Anderson, 1998, 1999). On the basis of drill cores, detailed geologic mapping, survey data, ^{14}C dates, luminescence dating, soil descriptions, and tephrochronology, we strongly disagree with both Hooke's large-lake hypothesis and his tectonic reconstruction. We believe there are sufficient data to conclude that, contrary to Hooke's claims, (1) the pluvial features and deposits at Silver Lake and Salt Spring Hills represent lakes formed in different terminal playas between 30,000 and 9000 yr ago and thus are not coeval with the ∼186,000–120,000 yr B.P. Blackwelder strandline of Death Valley (Wells *et al.*, 1989; Brown *et al.*, 1990; Anderson and Wells, 1997; Ku *et al.*, 1998), (2) the Blackwelder strandline deposits are on the footwall block of the Black Mountains and thus have either been uplifted or, at the very least, unchanged relative to the region to the south; and (3) the Salt Spring Hills and Silver Lake shorelines are not tilted (Wells *et al.*, 1989; Brown *et al.*, 1990; Anderson, 1999), suggesting that they have only minimally been affected, if at all, by tectonic activity. Below, we review both the data presented by Hooke in support of his hypothesis and the data from studies that preceded Hooke (1999), data that we argue contradict Hooke's findings.

Hooke (1999) could have addressed the problem (reconstructing the mega-lake or its deformed shorelines) from at least two logical perspectives: if he had tectonic data (rates of relative movement from Shoreline Butte to Mesquite Hills) he could have tried to correlate the shorelines using the elevations and rates of movement; or, if he had age control on the shorelines, he could have reconstructed the rates of tectonic movement. Instead, Hooke—with neither age control on the shorelines nor independent control on the tectonic activity—treated all shorelines to be of similar age, correlated them over a distance of ∼200 km, and proposed a major tectonic warping in the Mojave Desert.

Age of the Blackwelder shoreline. Hooke (1999, p. 328) debated whether the Blackwelder shoreline is ∼186,000 to ∼120,000 yr old or ∼1.3 to ∼1.0 myr old as suggested to him by G. I. Smith in 1998. Hooke concluded that, because the preponderance of U/Th and rock-varnish cation-ratio ages on shoreline features are within the range of 186,000 to 120,000 yr (oxygen isotope stage [OIS] 6/5e), this must be the age of the Blackwelder stand. This conclusion was reached despite the possibly spurious U/Th dates (Hooke, 1999, p. 328) and known problems with rock-varnish cation-ratio dating (see Watchman, 2000, for a review). We agree that the Blackwelder stand deposits are younger than ∼1 myr B.P., although for reasons different from Hooke's (1999). At Mormon Point, Blackwelder gravels overlie the ∼510,000 yr B.P. Dibekulewe ash bed (Knott *et al.*, 1996, 1999; Knott, 1997, 1998). Thus, the Blackwelder gravels and shoreline are clearly younger than that. Consistent with this result, the U-series ages of Ku *et al.* (1998), measured on tufa near the elevation of Blackwelder strandline, range from 216,000 to 81,000 yr B.P.

Salt Springs Hill shoreline. Shorelines and greenish-gray silts and clays are evidence for late Pleistocene Lake Dumont in the basin just east of the Salt Spring Hills (Anderson and Wells, 1996, 1997; Anderson, 1999). Field mapping shows the horizontal bench is cut into colluvium at the base of the southern Salt Spring Hills and alluvial fan deposits to the southeast at 176–177 m above mean sea level (masl). The bench is not associated with any underlying fault; thus Anderson (1999) concluded that it is a shoreline.

Field evidence indicates that this shoreline is closer in age to the latest Pleistocene (<30,000 yr B.P.) than to OIS 5e/6 (>120,000 yr B.P.) (Ritter, 1987; Anderson and Wells, 1996, 1997; Anderson, 1999). Based on relative-age dating, Ritter (1987) and McFadden *et al.* (1989) concluded that the alluvial fan into which the shoreline is incised formed during the latest Pleistocene. This age estimate is supported by the unvarnished clasts on the shoreline and the lack of significant erosion.

Anderson and Wells (1997), and later Hooke (1999), reasonably assumed that the shoreline is related to the lake deposits

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found just 4 m below (Fig. 1c of Hooke, 1999). Accelerator mass spectrometry–derived radiocarbon ages of the gray lacustrine clays range from 27,500 ± 360 to 18,150 ± 80 ^{14}C yr B.P. (Anderson and Wells, 1996, 1997). Ostracodes from the 18,150 ± 80 ^{14}C yr B.P. strata indicate freshwater lacustrine conditions (Anderson and Wells, 1997). Our interpretation of the data indicates that intermittent lake conditions began about 30,000 yr B.P. at Lake Dumont and lasted until the sill was breached sometime after 18,000 yr B.P., which corresponds well to other pluvial lakes found in the region (e.g., Hooke, 1972; Wells *et al.*, 1989; Anderson, 1998). Our interpretation also suggests that the dates of lake deposits are probably representative of the age of the lake that created the shoreline features nearby. Hooke himself stated that "the relation of the 178 m bench [in the Dumont basin] to Lake Manly is ambiguous; it could have been formed by Lake Dumont" as suggested by Anderson and Wells (1997). Hooke offered no new data (e.g., age determinations) to refute the latest Pleistocene age for this shoreline or to indicate that the shoreline or deposits are equivalent to the Blackwelder stand.

Saddle Peak Hills. Hooke (1999, p. 329) has found "possible delta foreset beds in deposits of the Amargosa River" and "benches in this area" that Butler and Mount (1986) "suspect may be shorelines." However, Hooke offered no age determinations on these deposits that would allow correlation to the Blackwelder stand.

Silver Lake shorelines. Hooke (1999) did not cite the ^{14}C-dated, unequivocal wave-cut shorelines near the Silver/Soda Lake basin overflow that have a 16,500 to 9000 ^{14}C yr age range (>20 ^{14}C ages) (Ore and Warren, 1971; Wells *et al.*, 1989; Brown *et al.*, 1990). At Silver Lake, soil development on alluvial fan surfaces, both older and younger than the shorelines, supports a latest Pleistocene age (Wells *et al.*, 1987; Reheis *et al.*, 1989).

Soda Lake core. Hooke (1999, p. 332) stated that sediments from drill cores recovered by Muessig *et al.* (1957) from the Soda Lake playa show perennial lake deposits at depths of ∼10 to 35 m that are "probably" correlative with an ∼30,000 to ∼10,000 yr B.P. stand of Lake Manly. On the basis of numerous radiocarbon ages between 20,320 ± 740 and 9330 ± 95 yr B.P., Wells *et al.* (1989; Smith, 1991a,b; Brown and Rosen, 1995) previously concluded that these deposits are equivalent in age to the OIS 2 stand of Lake Manly.

Hooke (1999, p. 332) suggested that coarse sand and granules at depths of ∼35–90 m in the Soda Lake cores (Muessig *et al.*, 1957) represent a playa or ephemeral-lake depositional environment and that deeper orange-brown clayey silts "may have been deposited in perennial lakes, possibly connected with the Blackwelder stand." We strongly disagree with this interpretation. Brown and Rosen (1995; see also Smith, 1991a,b) pointed out that 19 cores and 13 boreholes have been drilled into the Silver/Soda Lake playas since the Muessig *et al.* (1957) publication, and all have found only one basinwide lacustrine event between 3 and 36 m. This single, geologically recent lacustrine episode is also supported by Meek (1989), who showed that the Mojave River has discharged into the Silver/Soda Lake basin only since the latest Pleistocene. Hooke (1999) offered no data (e.g., ostracodes or age determinations) to refute the conclusions that only a late Pleistocene lake occupied the Silver/Soda basin, nor did he offer age control regarding the depth at which deposits equivalent to the Blackwelder stand are found in Silver/Soda Lake basin.

Mesquite Spring. Hooke (1999, p. 331) cited Bassett and Muessig's (1957) reluctant interpretation that two benches and fine-grained sediments at Mesquite Spring are lacustrine (Fig. 1f of Hooke, 1999). They actually describe the origins of these features with question marks as "wave-cut (?) benches and green lacustrine (?) sediments." Thompson (1929), who preceded Bassett and Muessig, described the Mesquite Spring deposits as a combination of aeolian and spring-related salts with many springs discharging in the surrounding area. Since Bassett and Muessig's writings, studies have shown that spring deposits had, in the past, been confused with lacustrine deposits (e.g., Quade *et al.*, 1995). Thus, there are at least two disparate interpretations of the deposits at Mesquite Spring and general questions regarding earlier interpretations of lake deposits in the Mojave. Hooke offered no new data (e.g., ostracodes or other paleoenvironmental indicators) to clearly resolve these issues, and we think the information presented by Hooke to support a lacustrine interpretation is insufficient.

The benches near Mesquite Spring, which Hooke (1999) stated "appear to be wave-cut," are incised into at least three different substrates (Kupfer and Bassett, 1962) and are not within a continuous line of sight of each other. Thus, it is difficult, at best, to follow Hooke's arguments in the field by leveling or to eliminate alternative interpretations for the benches (e.g., differential erosion). In any case, Hooke (1999) offered no data regarding the age of the Mesquite Spring benches and deposits; therefore correlating these features with the Blackwelder stand is speculative.

Tectonic warping of Death Valley–Soda Lake region. Hooke's tectonic reconstruction was based on several "known and suspected Blackwelder-stand shorelines" along a cross section from Death Valley extending ∼120 km south to Mesquite Spring in the Mojave Desert (Fig. 4; Hooke, 1999). Hooke (1999, p. 333) indicated that, in the last 120,000 yr, Blackwelder shorelines in Death Valley have been down-dropped at least 88 and 290 m relative to the Salt Spring Hills and Silver Lake shorelines, respectively.

We think this interpretation is not feasible and strongly disagree with it for several reasons. First, according to the discussion above, of the known or suspected shorelines used in the reconstruction of the 186,000–120,000 yr B.P. Blackwelder shoreline, one is younger (Salt Spring), two others are undated (Saddle Peak Hills and Mesquite Spring), and the most continuous (Soda/Silver Lake) is 22,000–8000 yr and therefore not related to the Blackwelder shoreline. Second, the tectonic framework south of Shoreline Butte is predominantly strike-slip, dominated by the right-lateral Southern Death Valley fault zone with only localized regions of vertical uplift, exclusive of Salt Spring Hills and Silver Lake. This lack of vertical tectonic activity is clearly shown by regional tectonic geomorphic studies (e.g., Bull and McFadden, 1977). Third, the Blackwelder shorelines at +90 m described by Hooke (1999) are on the Black Mountains footwall or Confidence Hills block, both of which are composed of tilted and uplifted Quaternary rocks. Thus, shorelines in these areas should be moving relatively upward or be stationary, rather than moving down as Hooke postulated.

Hooke (1999, p. 333) proposed a relative rate of vertical displacement of ∼2 mm/yr for the Silver/Soda Lake basin, necessary to level the putative Mesquite Spring shorelines (342 and 338 masl) in the south with the shorelines at the north (287.5 and 285.5 masl; Wells *et al.*, 1989), all relative to Shoreline Butte (Figs. 4a and 4c of Hooke, 1999). However, Wells *et al.* (1989) completed a Total Station survey that included thousands of points along the Silver/Soda Lake shorelines, a length of 35–40 km. The survey, conducted at a level of precision that would detect tectonic activity and shoreline deformation, indicated that the two most continuous shorelines (287 and 285.5 masl which are latest Pleistocene in age) are remarkably level (10–20 cm). Neither higher nor older shorelines exist in that basin and therefore no correlation with the Blackwelder stand is possible. Tilting or any other deformation, as postulated by Hooke (1999), was not observed, nor are there continuous Quaternary fault scarps between Mesquite Spring and Silver/Soda Lake to accommodate movements of discrete blocks.

How is the lake surface stabilized in Death Valley without a sill? Hooke asked a similar question as the motivation for his study (p. 328) and speculated that sills must have been present to prevent expansion of the lake and to produce a clear shoreline. There is no conclusive evidence of sills within Death Valley and we would therefore like to offer the simple alternative hypothesis to the sill: Lake Manly stabilized at that elevation as a result of a balance between inflow and evaporation. No sill is needed to form a pronounced shoreline because there is no lower basin for the water to spill into. Other true terminal basins in the world, such as the Dead Sea and its late Pleistocene precursor, Lake Lisan, have very pronounced shorelines without the stabilization at overflowing sills observed in other types of pluvial lake basins.

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