Desert Research Institute

Potential Sources of Sand for the Keeler Dunes

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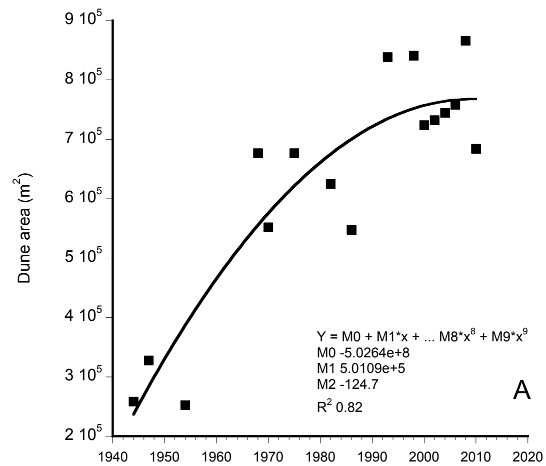
Introduction

The Keeler Dunefield is located in the Owens Valley of east-central California northeast of Owens (dry) Lake. The dunefield currently occupies an area of approximately 0.68 km^2, with a further 4 km^2 consisting of thin to discontinuous sand sheets. The estimated sand volume of the dunefield today is approximately 600,000 m^3. The dunes and sand sheets overlie Late Pleistocene and Holocene distal alluvial fan deposits, as well as lacustrine deposits and shoreline features associated with Late Holocene transgressions of Owens Lake to elevations of 1108 m asl.

Since 1944 (the date of the earliest aerial photographs available), the dunefield has undergone significant changes, including development of well-defined linear and crescentic dunes from an initial small area of partially vegetated dunes, resulting in an increase in the area of the dunes by a factor of 3 since 1944. Much of the increase in dunefield area and volume apparently occurred between 1954 and 1965, with further expansion in the 1980's (Lancaster and McCarley-Holder, 2012) (Fig 1). Identifying the source of sand required to sustain the expansion of the dunefield area and volume is important to understand how the expansion occurred and to constrain the boundary conditions associated with the expansion.

Wind regimes

The primary sand-transporting winds in the area of Owens Lake are from the northwest, with a secondary mode from the SSE to SSW; and a minor westerly mode. The energy of the wind regime, as measured by the sand drift potential (DP) (Fryberger, 1979) decreases from NW to SE, so that drift potential at Keeler is 18.71, or about one third of that on the (former) North Sand Sheet (A-Tower), where the average DP for the period 1991-2010 is 48.6. Sand transported by northwesterly winds is therefore deposited in the vicinity of Keeler Dunes, as the transport capacity of the wind declines. Given the dominance of northwesterly winds, the sand source area must therefore be located NW or W of the Keeler dunes



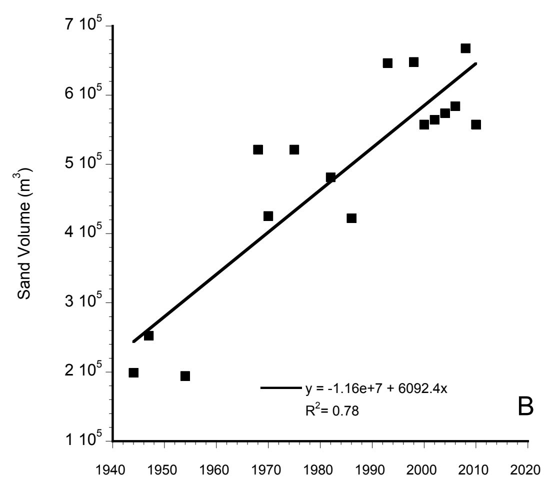


Fig 1. Changes in (A) area and (B) volume of Keeler Dunefield over time.

Potential sand sources

Several potential sources of sand exist to contribute to the formation and expansion of the Keeler Dunes. They are listed and described below.

(1) Alluvial fans derived from Inyo Mountains

The Keeler Dunefield is situated on the apex of the distal part of a large alluvial fan that leads in the Inyo Mountains to the east of the Owens Valley. Ephemeral flows of water and sediment derived from the headwaters of this fan system have been noted by observers in the Keeler area for many years. Flows generally follow localized heavy rains in summer or less frequently, winter seasons. Active channels on the fan lie to the south of the dunefield, where flow is directed towards Keeler.

The active channel from Slate Canyon discharges onto the Owens playa immediately northwest of Keeler Dunes. There is evidence for flooding onto this area on August 1968 aerial photographs (see Figure in Lancaster and Bacon 2012). Other significant flood events in the area occurred in 1979, 1982, and other years, including August 2012

The mineral composition of sand derived from this potential source area is however incompatible with that of the Keeler Dunes, based on bulk XRD mineralogy (Lancaster et al, 2012). In addition, the potential volume of material derived from these ephemeral flood events is estimated to be low, based on the small area flooded in each event and the limited extent of the active channels and depositional areas (Unit Qf6 of Bacon and Lancaster, 2012).

(2) Erosion of pre-existing aeolian sands in the vicinity of the present Keeler Dunefield

Parts of the area on the western edge of the present Keeler Dunefield are underlain by aeolian sands deposited in prior episodes of accumulation as documented by Lancaster and Bacon (2012). The composition of these sands is identical to that of the modern dunes. The sands are preserved below thin layers of flood silts and are estimated to cover an area of 100,000 m^2. The maximum measured thickness of these deposits is 1.5m, giving a maximum estimated volume of 150,000 m^3. Reworking of portions of these deposits could provide material for the expansion of the Keeler Dune field.

However, the volume of material contain is not consistent with the volume of sand estimated to be involved in the expansion of the Keeler dunes. Expansion of the dunefield between 1954 and 1975 involved an additional 327,000 m^3 of sand. If all the pre-existing sands were eroded, they would only provide about 50% of the needed sand volume. Many of the outcrops of the older aeolian sands are however not eroded as they capped by flood silt deposits and therefore unavailable for reworking. Most of the older flood silt units were, in addition, buried by the modern active dunes until 2000, based on examination of aerial photographs.

(3) Swansea Dunes area

Undulating sand sheets, with a variable vegetation cover and development of coppice dunes comprise an area extending northwest and west from the vicinity of the site of the Swansea settlement. These dunes have a composition similar to the Keeler Dunes, but there is no geomorphic evidence for transfer of sand from these dunes to the Keeler Dunefield. These dunes appear to have been largely stable in area for the period of aerial photograph and satellite records, although changes in vegetation cover have occurred.

In addition, evidence from OSL dating of dunes in the western part of this area (the Lizard Tail Dunes) suggests that these dunes have been stable for past 300-400 years (Lancaster and Bacon, 2012).

(4) Owens Lake bed and delta

The composition of the Keeler and Swansea dunes determined by bulk XRD mineralogy is identical to sand from the Owens River delta and fluvial deposits. (Lancaster et al., 2012). This suggests strongly that the Keeler Dunes are derived from this source, either directly by deflation and wind transport of sand deposited by major flood events in the Owens River (e.g. 1939, 1969, 1982), or by wind erosion and deflation of sandy lacustrine and deltaic sediments deposited prior to the lowering of Owens Lake by water diversions.

Measurements of winds and sand flux on the northern part of the lakebed and sand sheets by GBUAPCD indicate that sand is transported by winds from the W-NNW and SSW-SSW sectors (Fig. 2). In any year, sand is transported back and forth by the wind, but with a net (or vector) movement towards the east (082° azimuth). The sand flux measurements indicate that large quantities of sand are transported in this manner (Cox and Holder, 1997).

An estimate of the amount of erosion of surface sediments that has taken place in the northern part of the Owens Lake playa and delta can be derived from reconstructions of the extent of exposed deltaic, lacustrine, aeolian, and playa deposits in historic (1920) and modern times (Fig. 3; and Plate 1). Figure 3A shows the reconstructed extent of lake plain and deltaic sediments as they would have been in 1920, following drying of the lake to the elevation of the brine pool (1085 m); Fig. 3B shows the extent of the same geomorphic units as well as areas of the exposed playa in the area of the delta and lake plain unit, in 1998, immediately prior to the construction of dust control measures on the lake floor. The maps indicate that only 6.1% of the original lake plain still remained in small areas along the north shore of the playa. In the area of the delta that was exposed by reduction in the lake level from 1096 to 1085 m, some 2 km^2 or 13% of the original extent of deposits had been eroded by the wind to expose underlying playa sediments. If the deltaic deposits consisted of 100% sand sized material and only a 0.5 m thickness of material had been removed in this way, it would have generated 1 million cubic meters of sand for transport downwind to form other deposits, such as the North Sand Sheet (10.7 km^2) and the Keeler Dunes.

The area northeast of the exposed delta and the historic shoreline is today comprised of areas of eroded lake plain that expose underlying playa sediments (1.64 km^2), together with areas of sand sheets (Qe (ss)) with an area of 3.20 km^2. The eroded lake plain is considered to be a likely source area for the Keeler Dunefield. If this part of the original lake plain was covered with the equivalent of 0.50 m thickness of sand, the eroded material would comprise 820,000 m^3 of sand. The estimated mean volume of the Keeler Dunefield has ranged from 200,000 m^3 in the 1940s-1950s to 500,000 m^3 in the 1970s and 600,000 m^3 in the period 1990-2010. It is therefore quite feasible to generate sufficient sand to increase the area and volume of the Keeler dunes since the 1950s by erosion of sandy lake plain deposits exposed by lowering of lake levels. Although variable image quality makes definitive determinations of sand sheet extent and characteristics, is noteworthy that aerial photographs of the area in the 1940s and early 1950s show an extensive sand sheet between the delta and the shoreline in the vicinity of the Keeler dunes (Fig. 4). This sand sheet was progressively eroded from the west by 1970. 1986 photographs also appear to show a relatively extensive sand sheet, which had largely been eroded in its western parts by the late 1990s (1998 image).

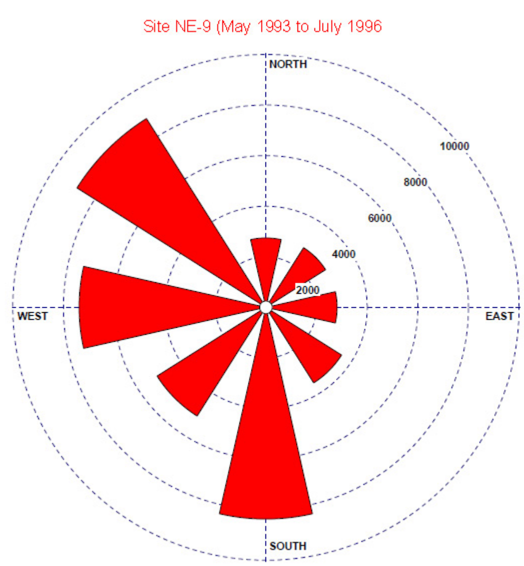


Fig. 2. Summary of sand transport in the area between the North Sand Sheet and the Keeler Dunes. Net sand transport is towards 82°. From data in Cox and Holder (1997).

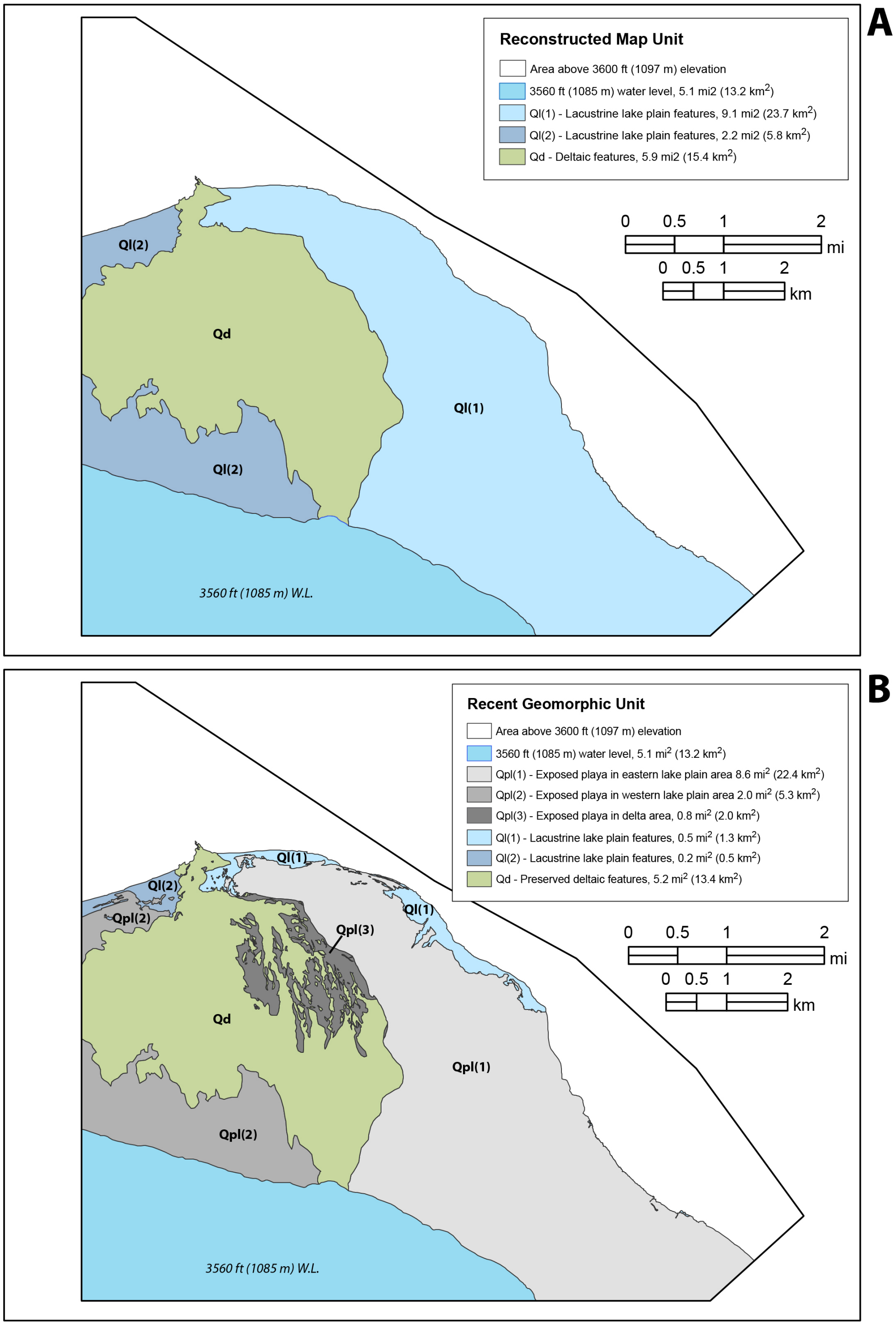


Fig. 3. A: Reconstructed geomorphic units as they would have appeared in 1920; B: extent of the same geomorphic units in 1998. Data from Bacon and Lancaster, 2012.

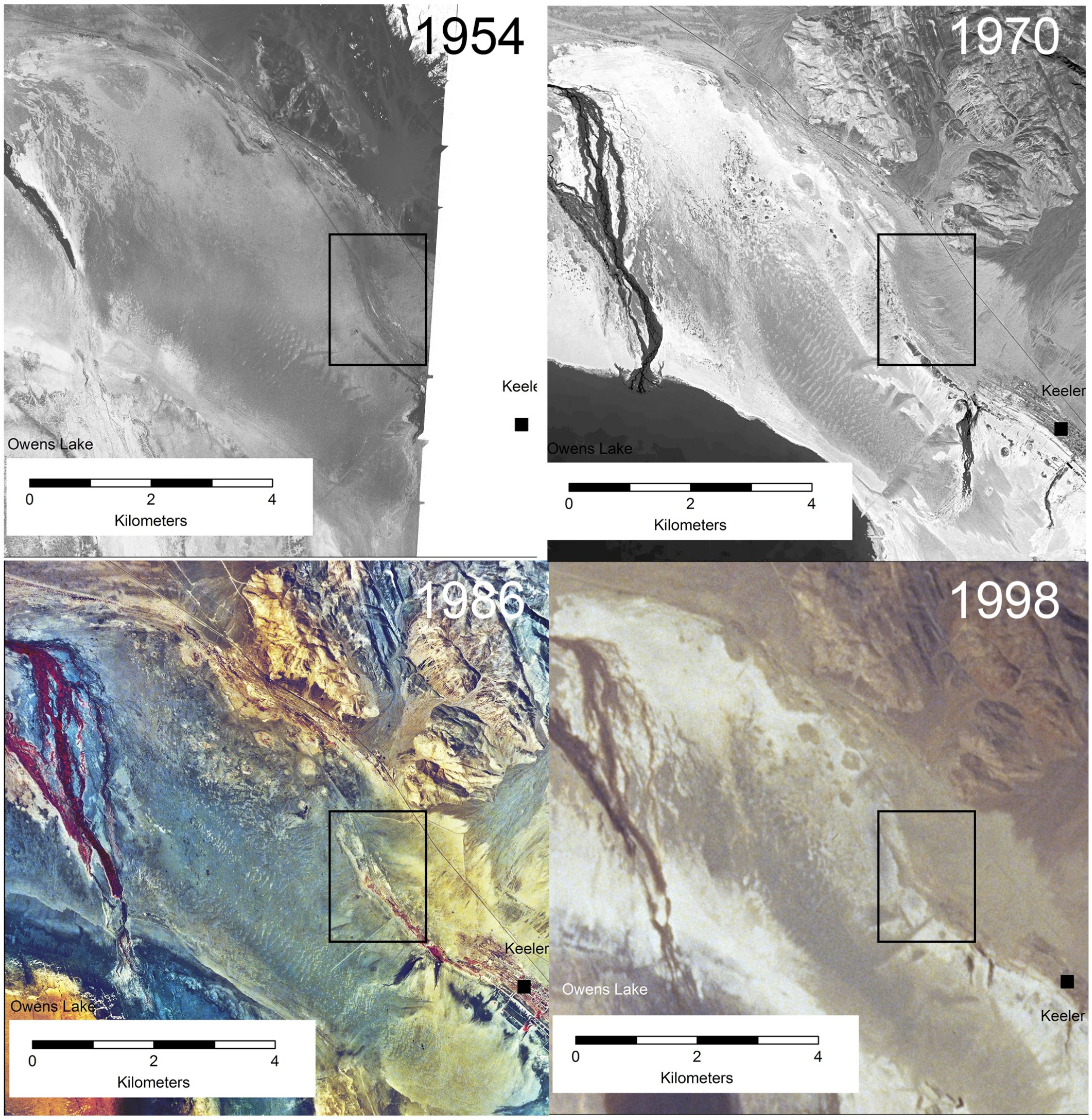


Fig. 4: Views of the northern part of Owens Lake and delta region in 1954, 1970, 1986, and 1998. Compare extent of sand sheets and exposed playa (light tones) at different times. Box indicates area of Keeler Dunefield.

Conclusions

Determinations of sand mineralogy and reconstructions of former deposit extent strongly indicate that the Owens River delta and/or adjacent sandy lake plain sediments exposed by low lake levels provided the major source of sand for the Keeler Dunefield as a result of progressive or episodic erosion of these materials by winds and transport of this material by NW and S winds in an net easterly direction towards the area of Keeler dunefield, where it was deposited as a result of reduced wind energy. Additional contributions may have come from sands deposited in the delta region by large flood events in the Owens River.

References Cited

Bacon, S. N. and Lancaster, N., 2012. *Geomorphic Mapping of the Keeler Dunefield and Surrounding Areas.* Report submitted to GBUAPCD, September 2012**.**

Cox, W. and McCarley-Holder, G., 1997. Owens Lake Aeolian Report. GBUAPCD Unpublished report.

Fryberger, S.G., 1979. Dune forms and wind regimes. In: E.D. McKee (Ed.), A Study of Global Sand Seas: United States Geological Survey, Professional Paper. U.S.G.S. Professional Paper, pp. 137-140.

Lancaster, N. and Bacon, S.N., 2012. *Late Holocene stratigraphy and chronology of Keeler Dunes area*. Report submitted to GBUAPCD, November 2012.

Lancaster, N.,., 2012. Decadal-scale evolution of a small dune field: Keeler Dunes, California 1944,Äì2010. Geomorphology(0).

Lancaster, N., Baker, S., Pepe, N., 2012. *Keeler Dunes - Mineralogical Analyses to determine sand source(s)*. Report submitted to GBUAPCD, November 2012.

Plate 1. Geomorphic maps based on Bacon and Lancaster (2012) showing: (upper) reconstructed areas of exposed lake plain and deltaic deposits prior to 1924; and (lower) areas of exposed playa and recent aeolian deposits as of 1998.
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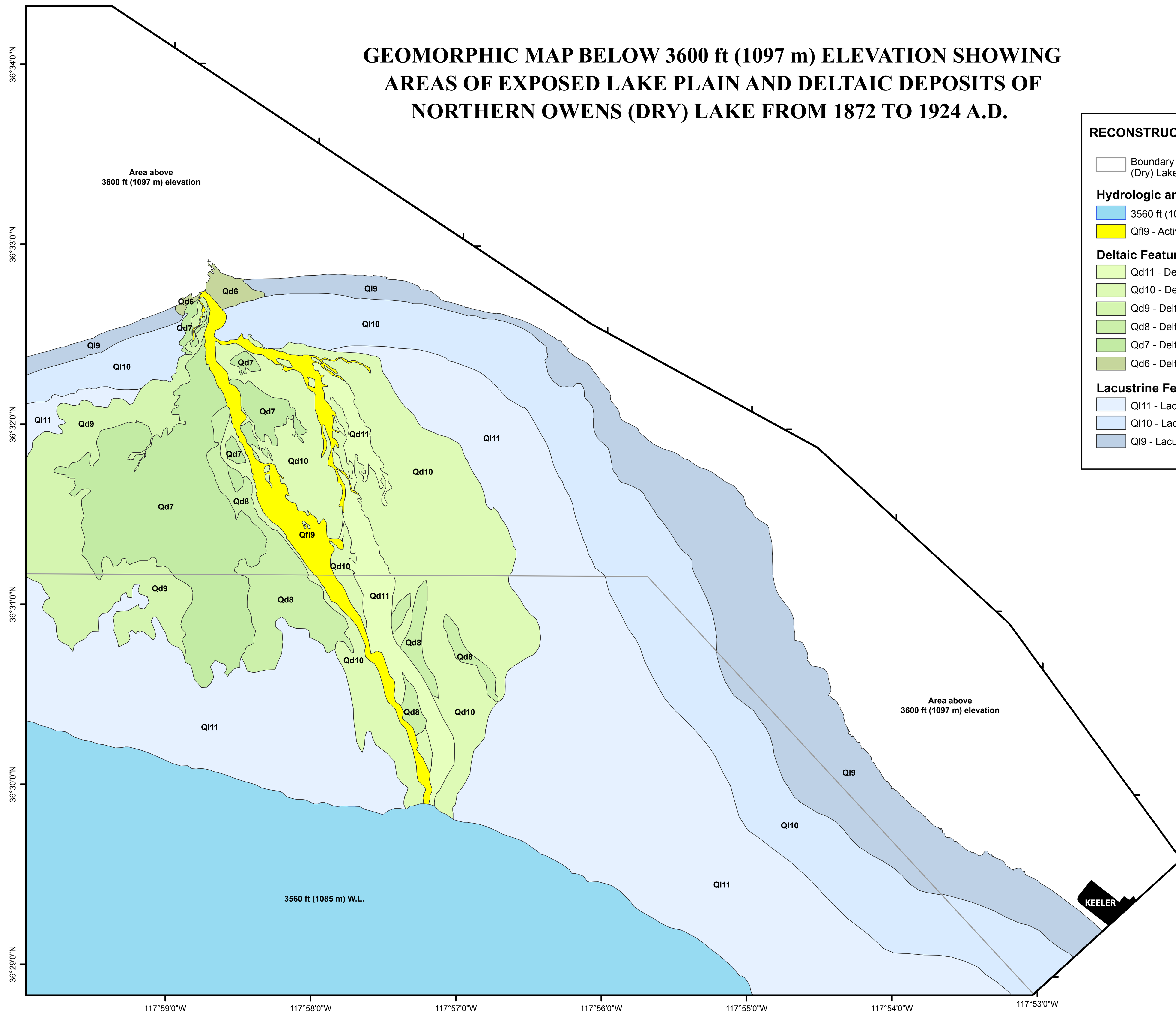
GEOMORPHIC MAP BELOW 3600 ft (1097 m) ELEVATION SHOWING AREAS OF EXPOSED LAKE PLAIN AND DELTAIC DEPOSITS OF NORTHERN OWENS (DRY) LAKE FROM 1872 TO 1924 A.D.



RECONSTRUCTED MAP UNIT

Boundary of geomorphic map of the northern and northeastern margins of Owens (Dry) Lake, California

Hydrologic and Fluvial Features

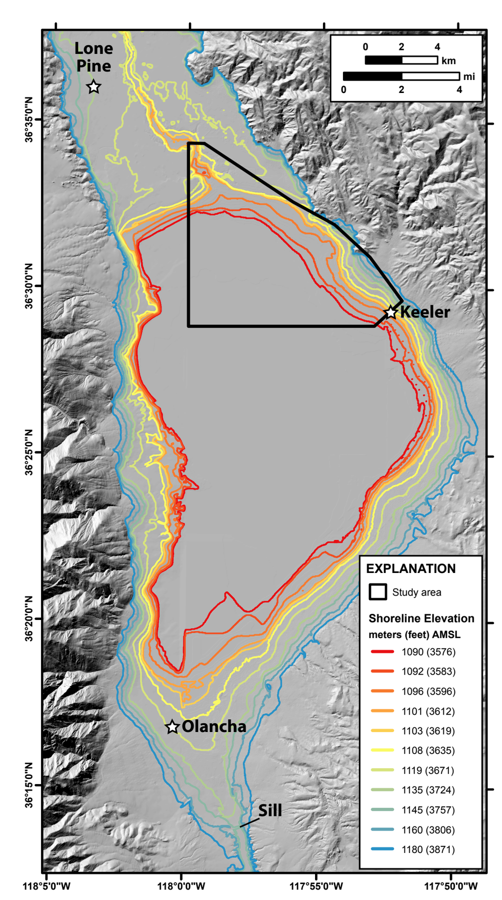
- 3560 ft (1085 m) water level after large flood events (e.g., 1938, 1969, 1983 A.D.)
- Qfl9 - Active channel Owens River (2005 to 2010 A.D.)

Deltaic Features

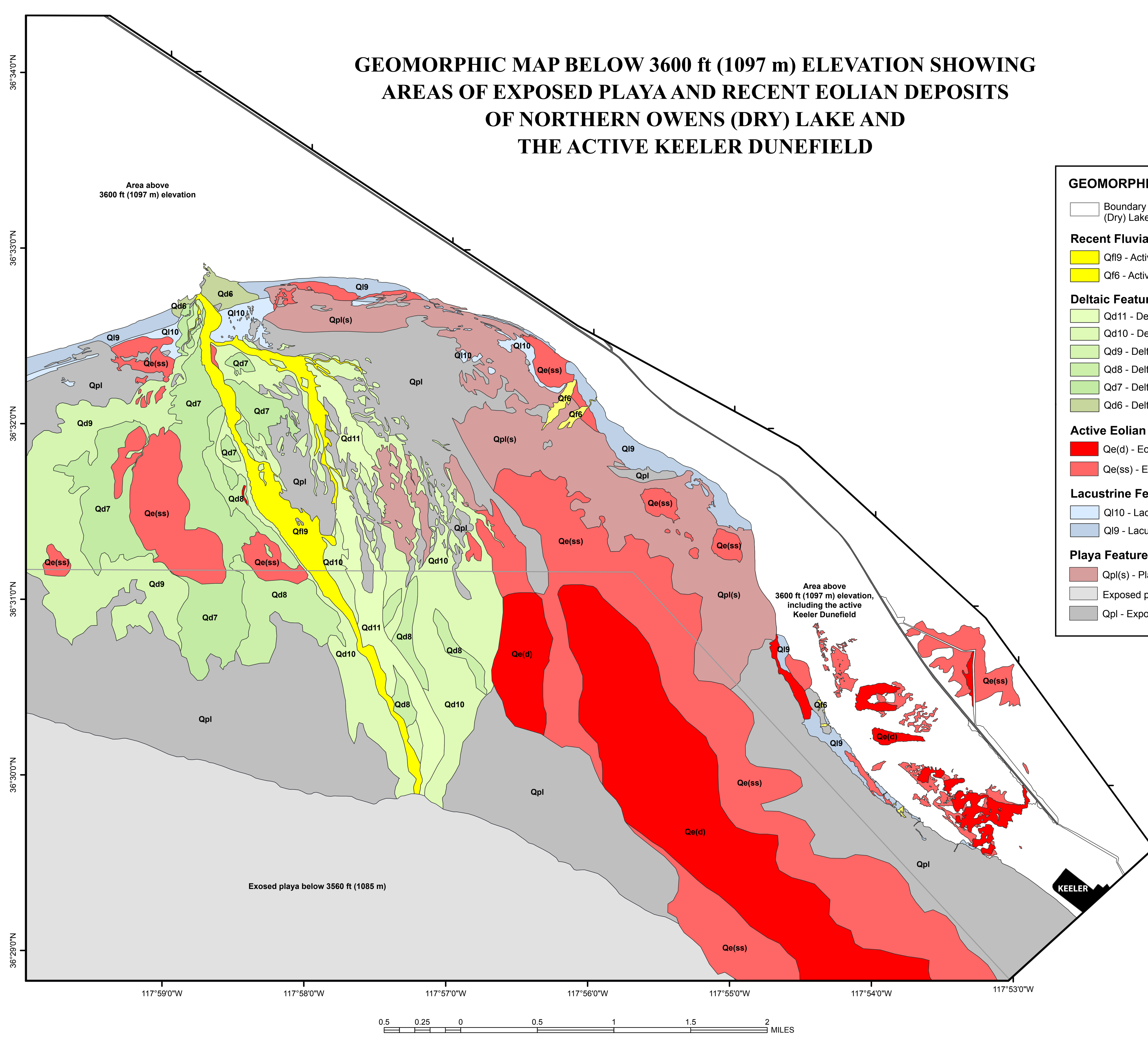
- Qd11 - Delta plain (post desiccation of lake)
- Qd10 - Delta plain (post desiccation of lake)
- Qd9 - Delta plain (post desiccation of lake)
- Qd8 - Delta plain (post desiccation of lake)
- Qd7 - Delta plain in 1884 to 1894 A.D.
- Qd6 - Delta bar and plain in 1872 to 1884 A.D.

Lacustrine Features

- Ql11 - Lacustrine lake plain in 1912 to 1924 A.D., 3579 to 3560 ft [1091 to 1085 m]
- Ql10 - Lacustrine shore lands in 1884 to 1912 A.D., 3584 to 3579 ft [1092 to 1091 m]
- Ql9 - Lacustrine shore lands in 1872 to 1884 A.D., 3600 to 3584 ft [1097 to 1092 m]



GEOMORPHIC MAP BELOW 3600 ft (1097 m) ELEVATION SHOWING AREAS OF EXPOSED PLAYA AND RECENT EOLIAN DEPOSITS OF NORTHERN OWENS (DRY) LAKE AND THE ACTIVE KEELER DUNEFIELD



GEOMORPHIC MAP UNIT

Boundary of geomorphic map of the northern and northeastern margins of Owens (Dry) Lake, California

Recent Fluvial and Alluvial Features

- Qfl9 - Active channel Owens River (2005 to 2010 A.D.)
- Qf6 - Active channel, alluvial fan (2005 to 2010 A.D.)

Deltaic Features

- Qd11 - Delta plain (post desiccation of lake)
- Qd10 - Delta plain (post desiccation of lake)
- Qd9 - Delta plain (post desiccation of lake)
- Qd8 - Delta plain (post desiccation of lake)
- Qd7 - Delta plain in 1884 to 1894 A.D.
- Qd6 - Delta bar and plain in 1872 to 1884 A.D.

Active Eolian Features on Playa Floor and Keeler Dunefield

- Qe(d) - Eolian active dune and mega-ripples on floor of playa
- Qe(ss) - Eolian active sand sheet

Lacustrine Features

- Ql10 - Lacustrine shore lands in 1884 to 1912 A.D., 3584 to 3579 ft [1092 to 1091 m]
- Ql9 - Lacustrine shore lands in 1872 to 1884 A.D., 3600 to 3584 ft [1097 to 1092 m]

Playa Features

- Qpl(s) - Playa with sandy surface
- Exposed playa below 3560 ft (1085 m) elevation that is frequently inundated
- Qpl - Exposed playa (salt and silt crust surfaces)

Geomorphology mapped by Steven Bacon, P.G., C.E.G., and field checked by Nicholas Lancaster, Ph.D. and Scott Stine, Ph.D.

Reconstructed map units based on new mapping at a scale 1:5000 to 1:10,000 using 2-, 18-, and 1-meter resolution imagery aquired in 1970, 1998, and 2005, respectively. Spatial distribution of reconstructed map units based on initial mapping from the Geomorphic Map of the Northern and Northeastern Margins of Owens (Dry) Lake, California by Bacon and Lancaster (2012). Reconstructed deltaic and eolian map units in the area of the "northern sand sheet" are based on 1970 and 1998 imagery.

Geographic coordinate system WGS 1984

Final Version: November 2012

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