

Preliminary Field Report

Liquefaction and deformation near Lake Iliamna may be evidence of recent earthquakes on the Lake Clark Fault

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ABSTRACT

We used aerial imagery analysis, precision GPS field surveys, and outcrop investigation to characterize possible evidence of past earthquakes along Lake Iliamna. Deformed sediment and warped paleo-shorelines along Lake Iliamna are likely evidence of seismic activity since glaciers retreated from Lake Iliamna. The deformed sediment – a series of liquefaction features in beach-bluffs – most likely resulted from repeated episodes of strong shaking. Variation in the elevation of surveyed shorelines formed after glaciers retreated from Lake Iliamna about 12,600 years ago shows probable tectonic deformation since that time. Both types of deformation could have been caused by earthquakes on the Lake Clark Fault southwest of its mapped limit near Lake Clark, or by activity on some other unmapped fault. There are other possible sources of sediment deformation besides earthquakes, but none match the particular features we observed. Strong seismic activity in the Lake Iliamna region is a potential threat to communities and infrastructure, and particularly to the tailings dams that may be constructed as part of the proposed Pebble Mine. Further investigation of the seismic history of the region is needed to characterize this threat.

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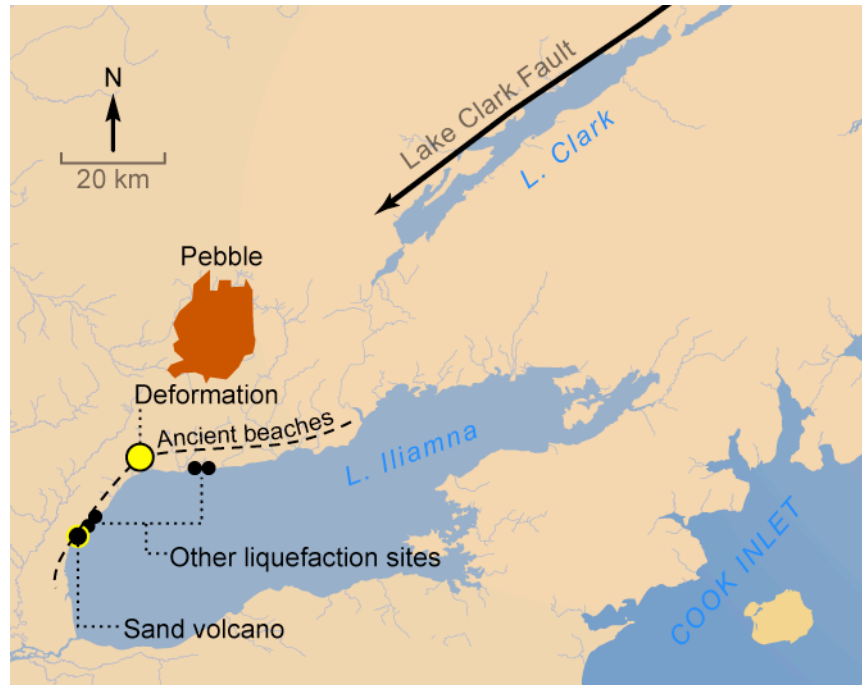


Figure 1. Map of the region, and locations of field sites.

LIQUEFACTION FEATURES

We documented small-scale liquefaction of post-glacial lake sediments spread over multiple kilometers of L. Iliamna coastline, and extensive "sand volcano" deposits including liquefied source sediment, sand dykes, sills, and surface deposits, revealed along a 50 meter long section of lakeshore bluff (Fig. 2.)

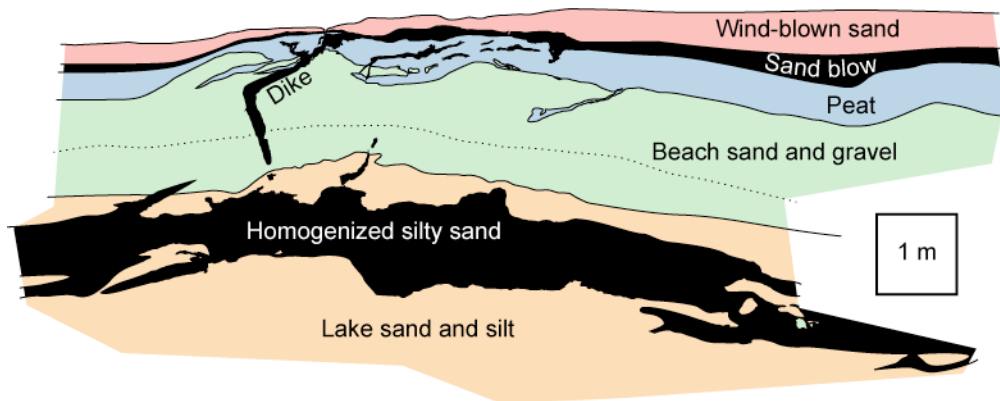


Figure 2. Sketch of a sand volcano deposit: Saturated lake-bottom sediment liquefied and injected upward through sand and gravel deposits then erupted onto a peat marsh. Sand poured out onto the surface as a "sand blow" that covered the peat for tens of meters in either direction.

Liquefaction features similar to this large sand volcano are rare, and are typically associated with very strong shaking (e.g. Martin & Bourgeois, 2012; Waller, 1966). There are other possible sources of sediment deformation besides earthquakes, but none match the particular features we observed. As part of our investigation, we assessed shoreline sediments for cryoturbation (ice-process deformation), deformation from glacial overriding, landslide or wave induced liquefaction, and other possible sources of sediment deformation. Cryoturbation and glacial deformation are extensive in the Lake Iliamna bluffs, but could be ruled out as explanations for the features we documented. We have tentatively ruled out landslides, wave action, and other possible mechanisms that might have induced liquefaction. We will provide our complete reasoning in an upcoming paper.

The sand volcano occurred late in the stratigraphic sequence recorded in the Lake Iliamna bluffs – after lake level subsided, and peat formed (Fig. 3). Most of the sediment overlying it are dune sands that are part of an active dune system. Pending radiocarbon dating and tephra identification (in progress), our interpretation is that this deposit is mid to late Holocene in age, likely within the past few thousand years.

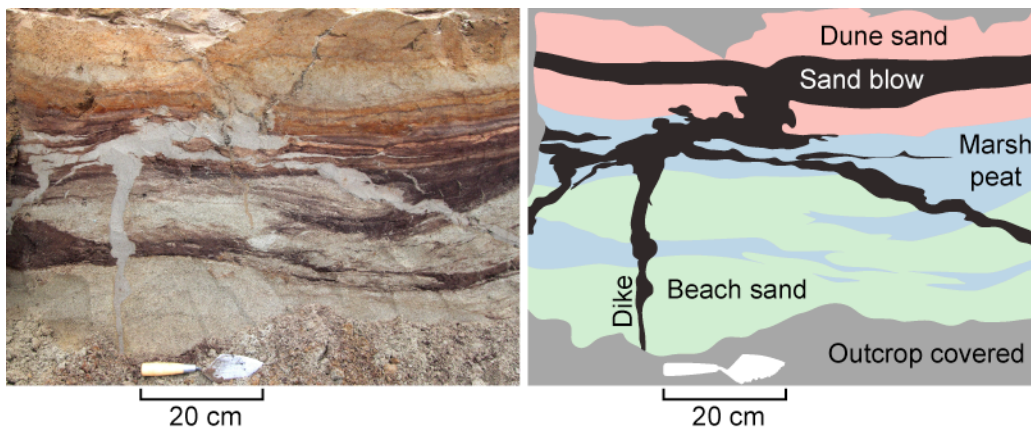


Figure 3: Photo of upper part of a sand volcano. This site sits about 5 meters southwest (left) of the site shown in Fig. 1. Sand forced upward from below penetrates beach deposits and peat to erupt onto wind-blown sand atop the peat.

Additionally, we found smaller-scale liquefaction evidence in multiple widely-spaced locations, including at least one event that must have preceded the major event described above. The predating event was several meters below the base of the sand volcano's origin, in the same lake sediment.

PALEO-SHORE DEFORMATION

Our survey along Lake Iliamna traces a series of ancient beaches that now run along the edges of the lake, high above the current beach (Fig. 4). These beaches formed earlier in the history of Lake Iliamna, after glaciers retreated after 12,600 C^{14} years ago (Stilwell and Kaufman, 1996, Detterman and Reed, 1973). As the outlet of the lake gradually cut downward, new shorelines formed below the oldest, highest shore. This high shore is no

longer horizontal, indicating deformation of the crust has occurred (similar work: e.g. Pedoja et al., 2006; Kelsey, 1990)

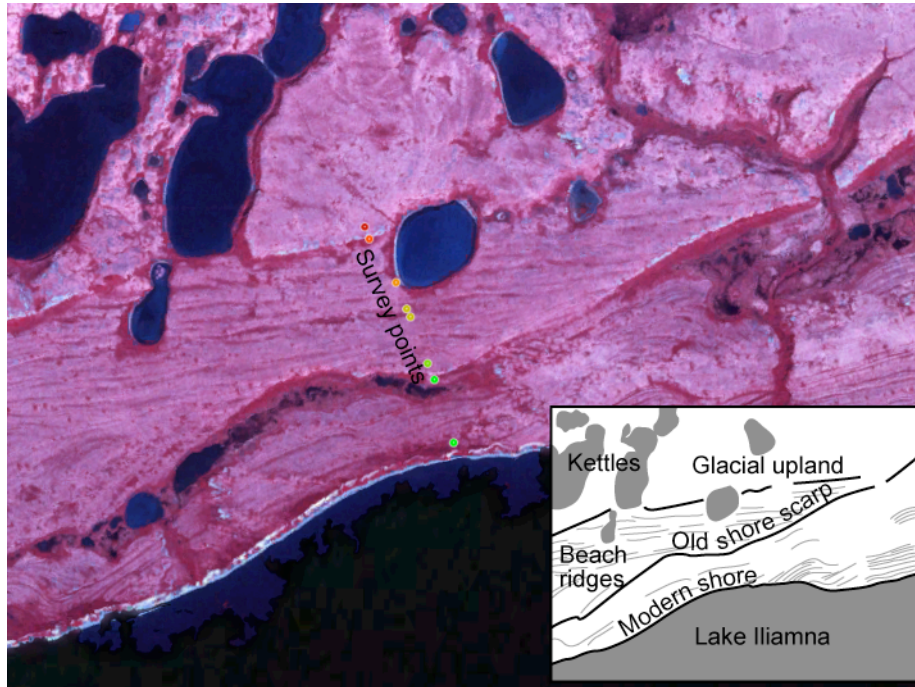


Figure 4: False-color infrared photo of the shoreline of Lake Iliamna. Ancient beaches stranded as the lake level declined over time leave beach ridges and long scarps running roughly parallel to the modern shore. In glacial uplands, and extending across the uppermost scarp and beach ridges, are glacial kettle lakes, showing that the upper shore formed when fragments of glacial ice still lay stranded in moraine and outwash. Interpreted map shown at lower right.

Between about the village of Iliamna and Lower Talarik Creek, there is little change in the elevation of the highest, oldest beach, but just west of Lower Talarik Creek the elevation of the shore drops by about 5 meters (Fig. 5). This lower elevation then extends further west all the way to the end of the lake.

This deformation is spread over about 5 kilometers. If it is a result of motion on a fault, the fault does not break the surface, but is buried at some depth.

If this deformation is related to movement on the Lake Clark fault, it would indicate that the fault extends southwest beyond its mapped extent near Lake Clark (Haeussler and Saltus, 2004) at least to Lake Iliamna, and passes within a few kilometers of the Pebble prospect. Additionally this would imply that the Lake Clark Fault is active. If so, this would provide a straightforward explanation for the evidence of liquefaction we observed only a few kilometers from this inferred fault trace. However, it is also possible this deformation results from tectonic activity on a previously unidentified structure.

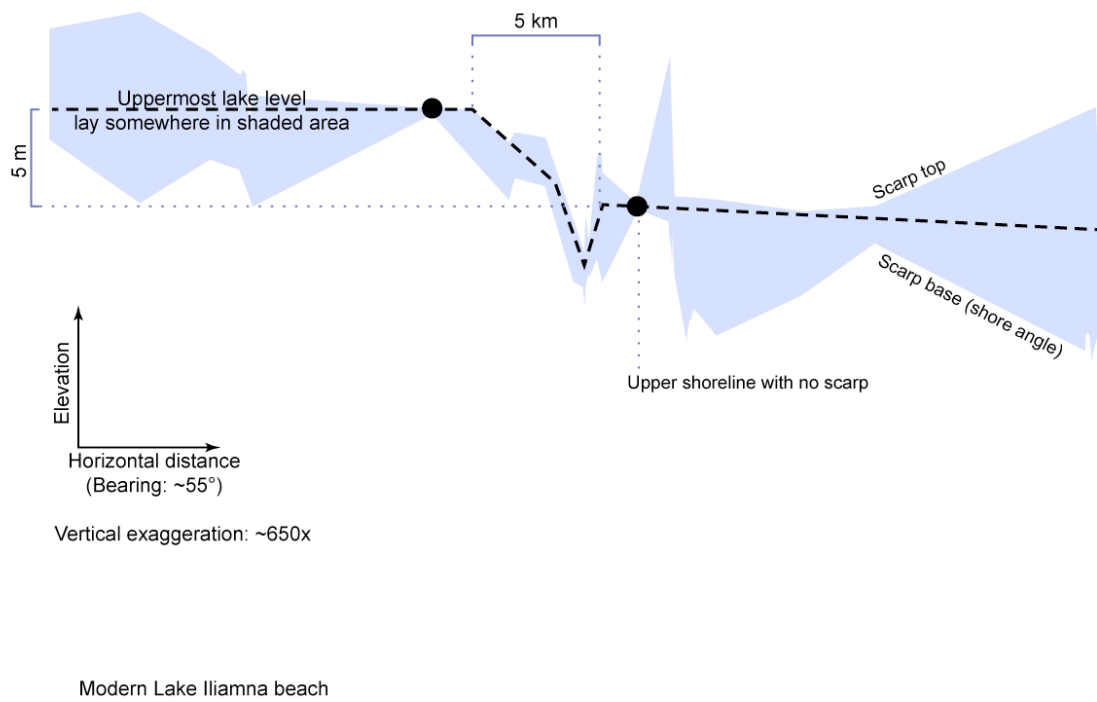


Figure 5: Ancient beaches running parallel to Lake Iliamna vary in elevation along their length, possibly as a result of tectonic deformation. The precise location of the highest, oldest shore can't be determined at most points, but it must lie between the highest erosional scarp base (shore angle) and the lowest surface unmodified by any shore action. At two points (black circles) the upper shore was preserved, forming a beach ridge. A lower, younger beach also appears to vary in elevation, though possibly to a lesser extent.

CONCLUSIONS

Widespread liquefaction, along with multiple liquefaction events, is consistent with recurring strong shaking in the area along some unmapped fault. Other common sources of liquefaction, such as landslides and storm waves, are unlikely to have generated all of these features. There is no previously published investigation of liquefaction features along the shore of Lake Iliamna. Further study is warranted to establish the distribution and nature of this liquefaction.

Our preliminary analysis of deformed sediments and abandoned lake terraces along shores of Lake Iliamna suggest a history of repeated strong shaking and tectonic deformation. This deformation and shaking likely occurred within the past few thousand years, or at least since deglaciation of Lake Iliamna 12,600 years ago (Stilwell and Kaufman, 1996). Our data are consistent with activity on the Lake Clark Fault, likely on a trace that does not break the surface. Alternately, earthquakes may originate on some other, currently unidentified tectonic structure.

FURTHER RESEARCH

This preliminary report was prepared for the EPA for the July 23, 2012, Watershed Assessment comments deadline, and includes results from fieldwork as recent as June 2012.

Our research is ongoing. We will be continuing our analysis and data collection in the coming year. Until our full paper is submitted for peer review, additional preliminary analysis and data will be available, as appropriate, here:

<http://www.groundtruthtrekking.org/pebble-mine-seismology-earthquake-science/>

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