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Estimating Sand Loss: Using Eolian Sand Ramps as a Proxy for Estimating Past Erosion within the Lincoln City Dune Sheet; Lincoln City, Oregon

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Estimating Sand Loss:

Using eolian sand ramps as a proxy for estimating past erosion within the Lincoln City Dune Sheet; Lincoln City, Oregon

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ABSTRACT

Eolian sand ramps are features that are sculpted from beach sand blowing up against sea cliffs or bluffs. In some coastal areas, sand ramp deposits only appear as the erosional remnants of pre-existing ramps that have been truncated at eroded shorelines, separating them from their previous sediment supply. Although sand ramp features have been observed in other areas on the western coast of the United States , they had not been studied or documented within the Lincoln City Dune Sheet (LINC) prior to this study – which documents the existence of truncated eolian sand ramps in LINC and uses them to estimate both a volume and rate of erosion since their initial deposition. The eroded volume was estimated to be $1.17X10^6 \pm 4.4X10^5$ m^3; based on cross-sectional sand ramp areas calculated using the height of the eroded sea cliff, the slope of the sea cliff, the mid-beach slope, and an estimated pre-erosional sand ramp slope. Using radiometric dating, the beginning of sand ramp deposition was dated as 1,160 cal BP. Given that erosion must have occurred some time after the onset of deposition, this date was used to create as average rate of erosion of $1.47X10^3 \pm 3.78X10^2$ m^3/yr, or $1.47X10^6 \pm 3.78X10^5$ per m of sea level rise (SLR), given 1 m SLR per ka for the last 3 ka within LINC.

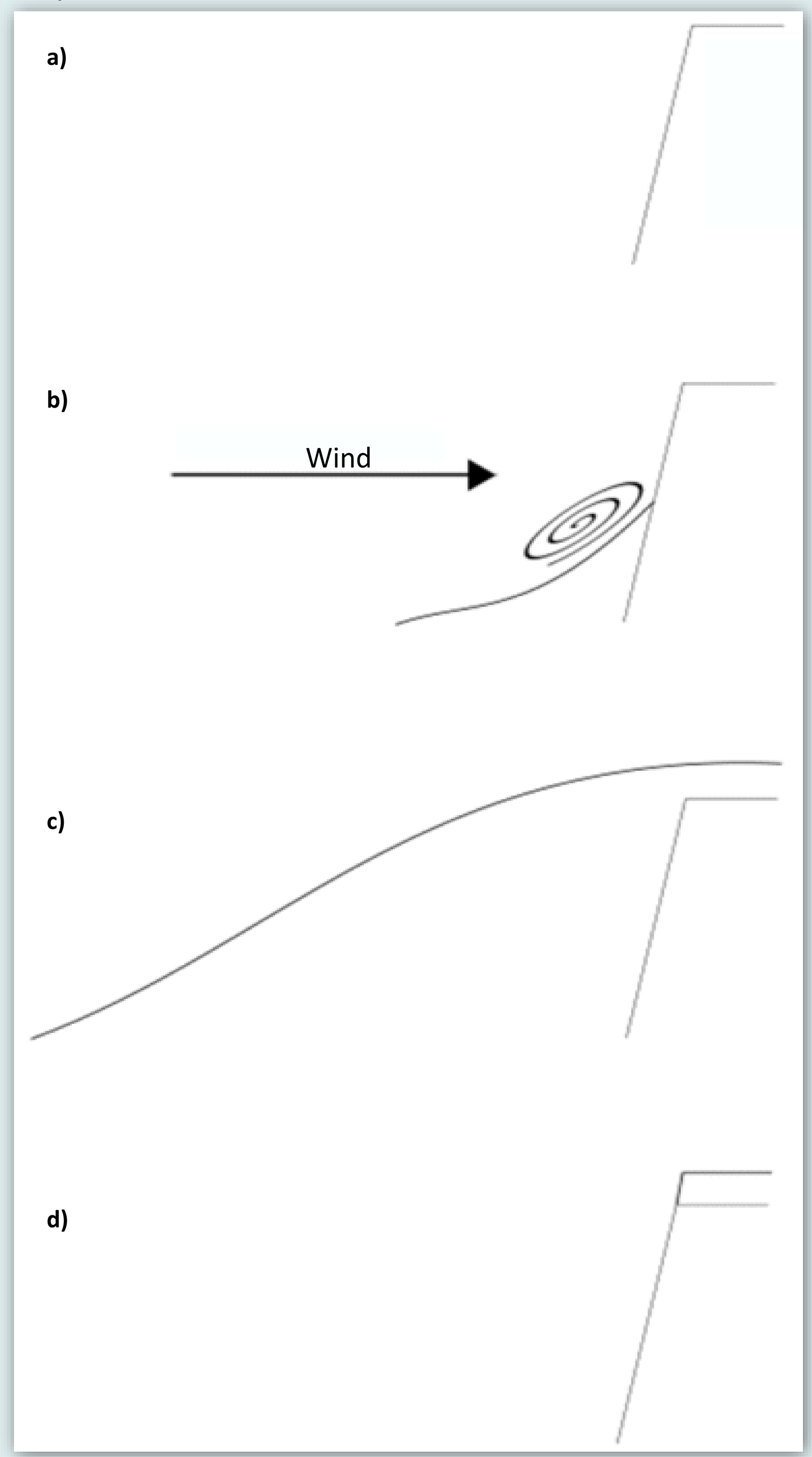


Figure 1: Diagram of development of truncated eolian sand ramps; a) an obstruction is established during non-depositional period (eg: sea cliff or bluff), b) sand blows in and begins to pile up against the obstruction, c) sand piles high enough that it overtops the obstruction and begins to form what looks like the stoss side of a sand dune, d) sediment supply is cut off and ramp is eroded away.

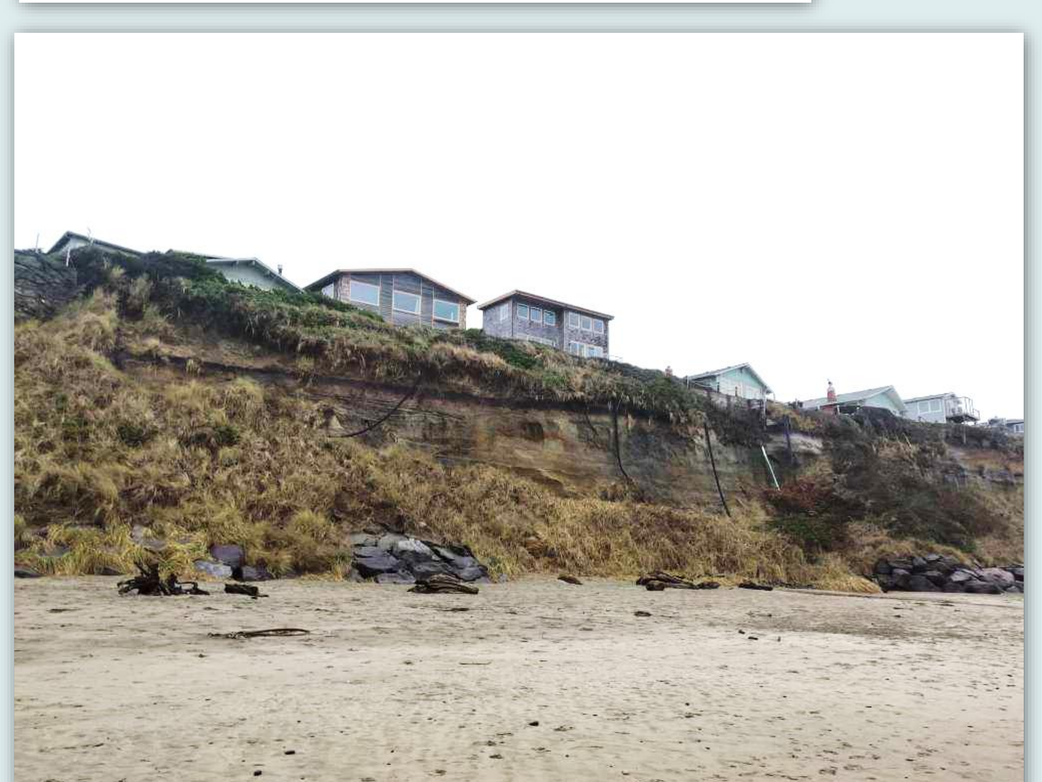
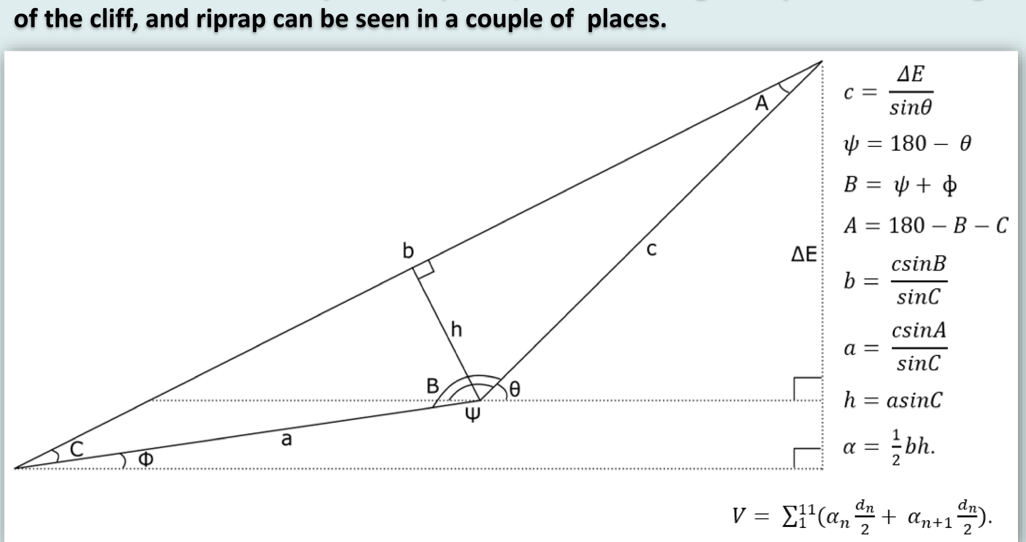


Figure 3: Photo from Road's End, Lincoln City showing signs of erosion. The sandstone sea cliff is visibly oversteepened, houses sit dangerously close to the edge of the cliff, and riprap can be seen in a couple of places.



INTRODUCTION

Background

- Population densities in coastal areas are increasing faster than any other areas in the world, thus increasing risk from future sea level rise (Appendini et al., 2012; Kopp et al., 2014; Mengel et al., 2016; DeConto & Pollard, 2016).
- Eustatic sea level is predicted to rise 1 to 2 meters over the next century (Vermeer and Rahmstorf, 2009).
- Based on current local geomorphology, this is estimated to result in at least 50 m of landward shoreline retreat within the Lincoln City (LINC) area (Peterson, 2012).
- Given this predicted shoreline retreat, the impacted beaches would not recover from the future erosion (Peterson, 2012).

HYPOTHESES

- While evidence of eolian sand ramps has not been documented in LINC, there is evidence of their existence in this area. I have tested this hypothesis by documenting features in the LINC site to see if they are morphologically similar to sand ramp deposits previously identified by Peterson, et al. (2017).
- If evidence of eolian sand ramps is present, these features continued to erode after they were formed, due to an increase in relative sea level, storm severity, and the lack of significant sediment supply. I have tested this by documenting signs of past erosion, such as oversteepened slopes, slope failures, or eolian deflation.
- Past erosion has been significant. In this case, significance is defined as an eroded volume equal to or greater than 10% of the modern beach sand.

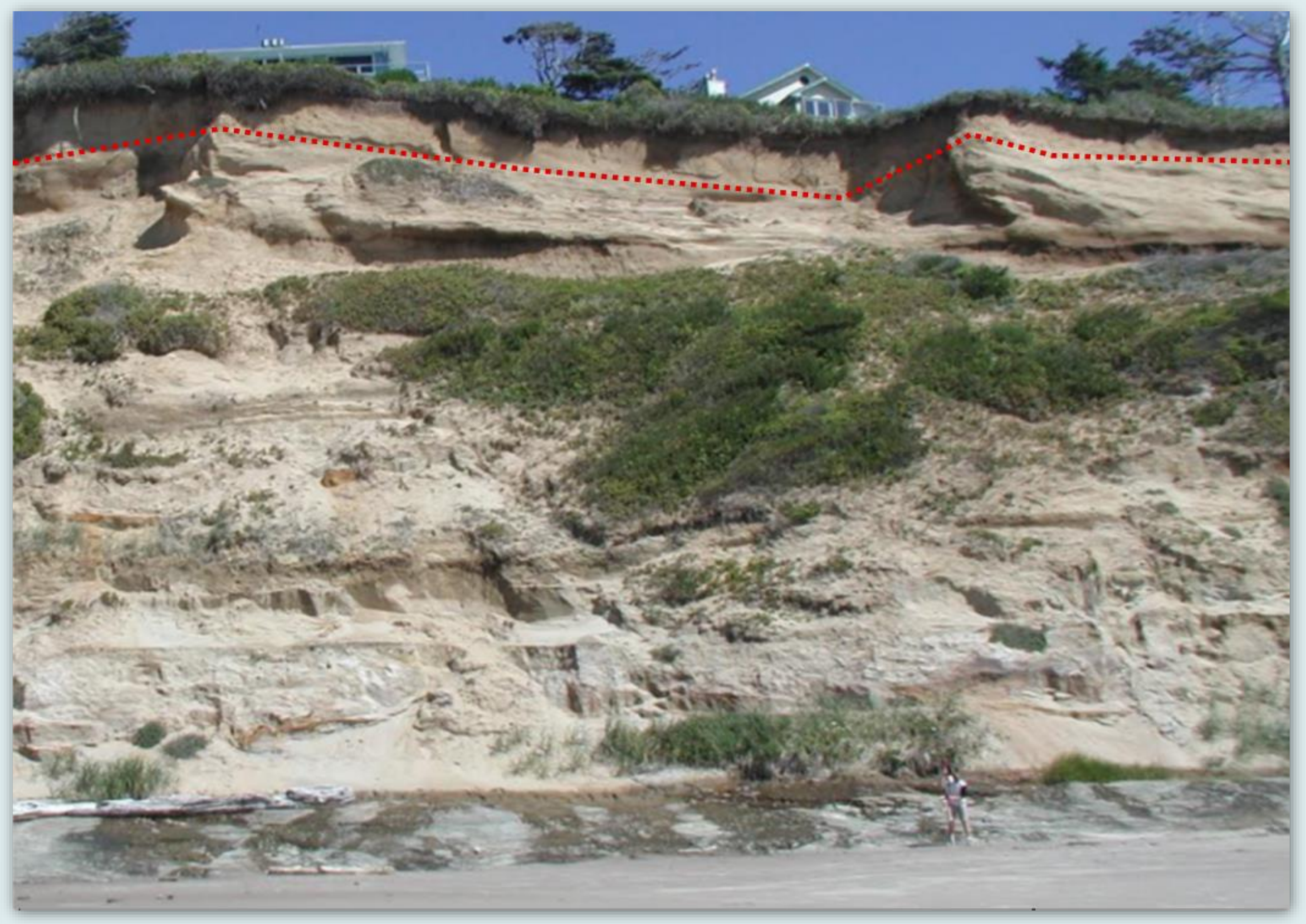


Figure 2: Photo of possible truncated eolian sand ramp (provided by Curt Peterson). The sea cliff appears predominately lithified, and well bedded; with exposed horizontal bedding, indicating that these beds were eroded back after deposition. However, the upper bed of sand above the dotted line, appears much younger, much more friable, and appears misplaced as compared to the rest of the sea cliff. Due to the elevation difference between the beach and the top of the sea cliff, there must have been a ramp in place, allowing younger sand to be deposited overlying older sand.

METHODS

- A profile of the sea cliffs was created using GPS, unit thicknesses, Munsel color, grain size, and penetrometer readings.
- 12 locations were selected which best represented the morphology of the sea cliff running parallel to the shoreline to calculate the estimated cross-sectional areas of the sand ramp, as shown in Figure 4.
- To get a sense of the magnitude of the amount of sand lost from this site, the estimated eroded volume was compared to both the modern beach sand volume and the total sand volume (modern + eroded). For these calculations, cross-sectional areas of the modern beach to Mean Higher High (MHHW) and Mean Lower Low (MLLW) depth were used from Peterson et al. (2004).
- Samples were also taken from a 7.5-meter core into the dune sheet at site 14C-2 (Figure 5). From those core samples, two were submitted to for radiocarbon dating (shown in Figure 6). The dates obtained from DirectAMS were calibrated using the IntCal13 Calibration Curve version 7.1 software (Reimer et al). Assuming a period of erosion bracketed by these two dates, along with the calculated volume, I was able to find and average rate of erosion for each of our estimated slopes . Based on a relative sea-level rise of approximately one meter per thousand years for the last 3 ka (Peterson et al., 2012), I used these dates to convert from volume of erosion per unit time, to volume of erosion per meter of sea level rise.

Figure 4: Representational triangle used for estimation of area of eroded dune slope cross sections. Elevation difference between the height of the sea cliff and the modern beach (ΔE), the slope of the sea cliff (θ), and the slope of the modern beach (ϕ) were obtained from lidar; and the pre-erosional sand ramp slope (C) is estimated based on examples from Alpha et al. (1998). All other variables are calculated geometrically as shown to find cross-sectional area (α), which along with the distances between points (d) was used to find the volume of the eroded sand ramp (V).

DATA/RESULTS

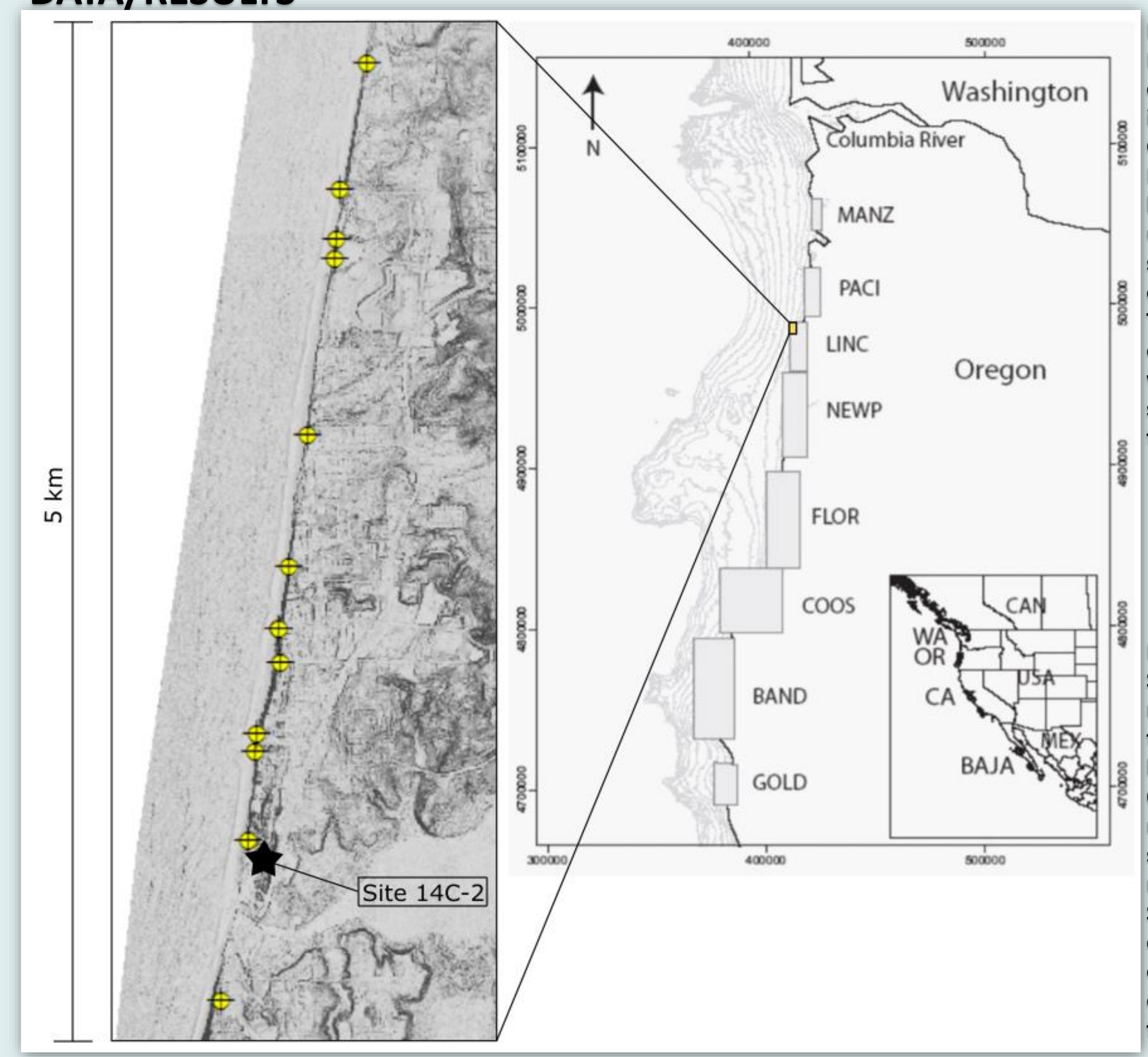


Figure 5 (left): Map of Oregon dune sheets (right) including Lincoln City, labelled LINC); with locations of points used in estimate sand ramp volume calculations (left). The star marks a coring site from which radiocarbon samples were taken.

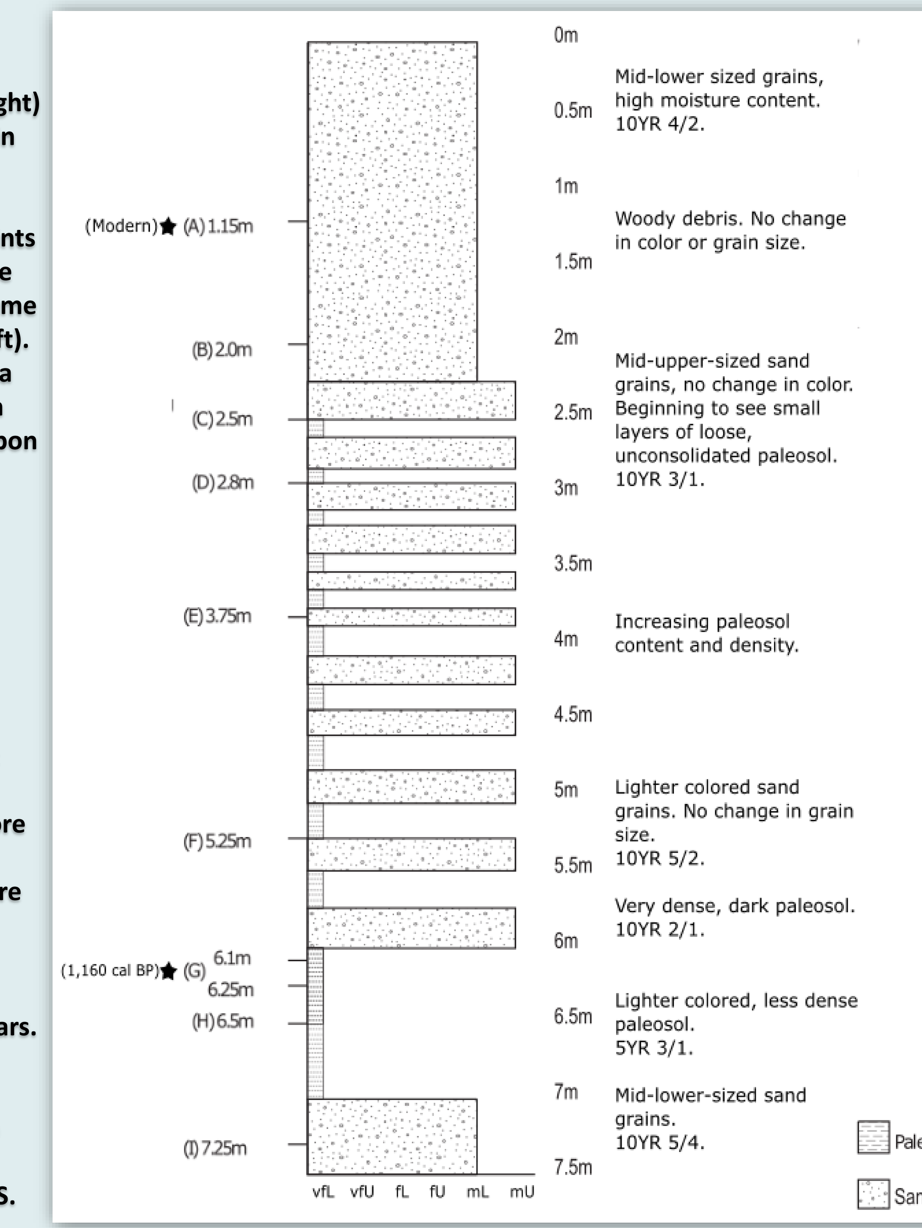


Figure 6 (right): Strat column representing core taken from location in Figure 6. Locations of radiocarbon samples are marked with stars. Sample dates displayed are calibrated from data obtained from DirectAMS.

Slope (degrees)	Volume (m^3)	% of Modern (MHHW)	% of Modern (MLLW)	% of Total (MHHW)	% of Total (MLLW)	Rate (m^3/yr)	Rate (m^3/m)
10	$2.15X10^6$	308	168	75	63	$1.85X10^3$	$1.85X10^6$
15	$1.27X10^6$	182	100	64	50	$1.1X10^3$	$1.1X10^6$

Table 1: Table of predicted eroded sand volumes based on pre-erosional sand ramp slopes of 10 and 15 degrees. The third and fourth columns show the eroded volume as a percentage of the volume of the modern beach sand to both MHHW and MLLW depth respectively. The first and sixth columns show the eroded volume as a percentage of the total volume (eroded + modern) of sand to both MHHW and MLLW depth respectively. The seventh column shows an estimated rate of erosion in terms of volume per year, based on a radiocarbon age of 1,160 cal BP. The final column shows the same rate of erosion in terms of volume per meter of sea level rise, given a local sea level rise of one meter per ka for the last 3 ka (Peterson et al., 2012).

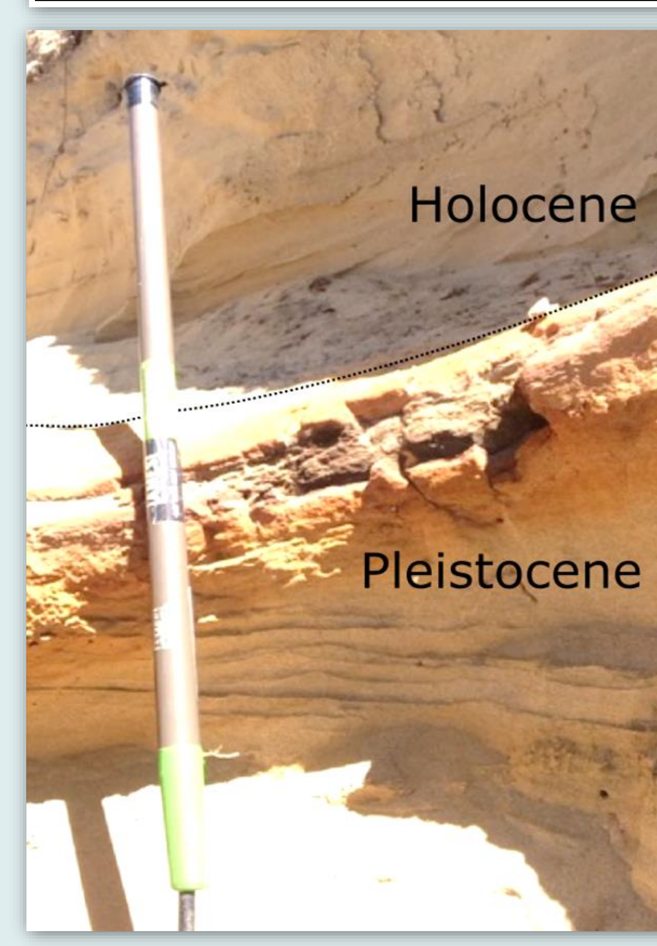


Figure 7: Photo showing boundary between Holocene and Pleistocene sand (dotted curve). This boundary represents an unconformity established during a nondepositional period between the Pleistocene and the Holocene. For the younger Holocene sand to have been deposited overlying the older Pleistocene sand, there must have been some sort of sand ramp in place. The length of the hoe handle is one meter.

Figure 8: A patch of Holocene sand is shown on top of a Pleistocene sand unconformity; one of many similar sites in the area. After being cut off from the original sediment supply, the more vulnerable portions of the Holocene sand ramp were likely eroded away – possibly by ocean waves at the base, eolian deflation above, and eventual slope failure, to leave the remnant or perched sand deposit at the sea cliff top edge.

SUMMARY/ CONCLUSIONS

- The observed morphology matches the definition of truncated eolian sand ramps (Peterson et al. 2017), indicating that eolian sand ramps previously existed within LINC.
- In Figure 9, a patch of Holocene sand is shown on top of a Pleistocene sand unconformity. After being cut off from their sediment supply, more vulnerable portions of the Holocene sand ramp were eroded, leaving the remnant or perched sand deposit at the sea cliff top edge. Thus it appears that the sand ramps within the LINC site have continued to erode until present time.
- The amount of sand I estimate to have eroded since 1,160 cal BP is significant, surpassing my benchmark of 10% of the volume of sand present on the modern beach. For both 10 and 15 degree slopes, I calculate eroded volumes between one and three times more than the modern beach volume (Table 1). Put another way, the eroded volume is between ~50% and 75% of the total sand volume (combined modern and eroded).
- This large volume of erosion may have implications for the rest of the littoral cell, which is roughly seven times longer than the LINC sand ramp area (33.7 km and 5 km respectively). No evidence of eolian sand ramps has been found anywhere else within the littoral cell. Although this does not mean they were never present, it does mean that we cannot use this erosion rate to make any certain conclusions about erosion in any other part of the littoral cell.

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