



Watch Out!

Understanding geomorphology of the sea cliffs at the Scripps Coastal Reserve to make recommendations on erosion hazards to the community



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Introduction

The University of California Natural Reserve System manages the Scripps Coastal Reserve (SCR) located in La Jolla associated with the University of California San Diego (UCSD). The SCR is a conservation area servicing different biohabitats, researchers, students and public users.

A common problem the SCR faces are people going off trail and being at the edge or base of the cliff which are locations where the cliff is less stable. For people to understand why these actions are life threatening or harmful they need to have a base knowledge of the geology and erosion mechanisms controlling the bluffs.

Since the University of Regents obtained the land in 1987, there were invasive species eradications, closing off Sumner trail due to trampling and failed efforts of back filling the trail to prevent cliff face erosion. The SCR has experienced landslides and mass wasting events that are very likely to persist in the future.

The main objective of this project is to make recommendations of areas in the reserve that should be more protected based on cliff retreat data and areas of the cliff prone to failure. In addition the reserve users will be educated about the geomorphology of its sea cliffs through developing new templates for signage and making this content available on the SCR's website to facilitate making reserve users aware of their actions and conscious about their safety when visiting.

Geology of the Reserve

Formation	General Description
Ardath Shale	<ul style="list-style-type: none"> ~50 Ma, deposited in deeper water on the continental slope Fine grained, fissile olive-gray silty sediment and sandy layers Hard layers of molluscan fossils on the beach (Kennedy and Moore, 1971)
Scripps	<ul style="list-style-type: none"> ~ 48 Ma, deposited on shallower continental slope Light tan-brownish medium-grained sandstone and sandy siltstone Poway cobble channels with clasts originating from Sonora, Mexico, vary in thickness and is a defining characteristic (Abbott, 1999). High energetic events (Kennedy and Moore, 1971)
Linda Vista	<ul style="list-style-type: none"> ~1.5 Ma, deposited in shallow marine environment, marine terrace Reddish brown sandstone, conglomerates, concretions and hard cap rocks Abbott, 1999).

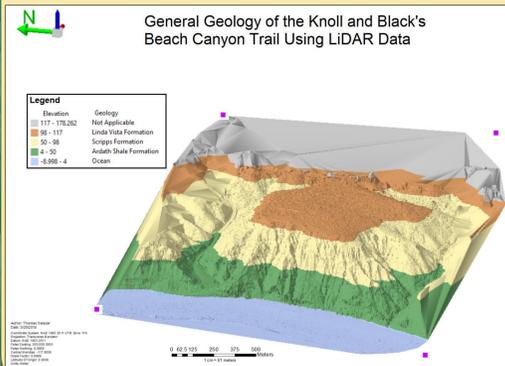


Figure 1: Geology of the reserve based on elevation. The gray color shows extrapolated data not considered geology.

Results

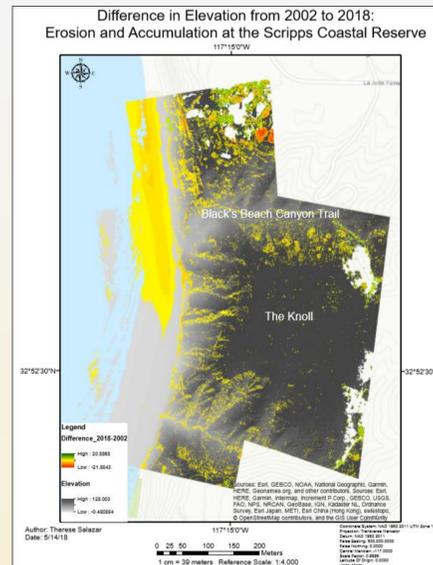


Figure 2: LiDAR data focusing on the Knoll and Black's Beach Canyon Trail demonstrate a general erosion rate occurring at about 0.16m/yr.

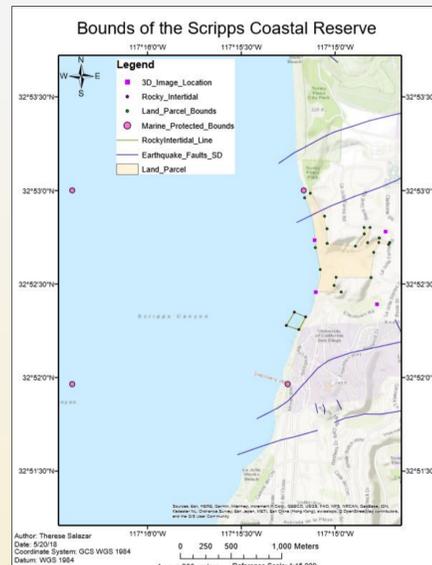


Figure 3: Whole view of Scripps Coastal Reserve- marine and land parcels.

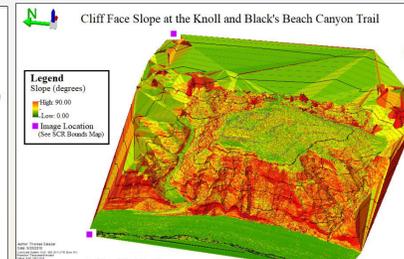


Figure 4: Cliff face slope calculated through ArcGIS. Steeper cliffs means more prone to failure and landslides.

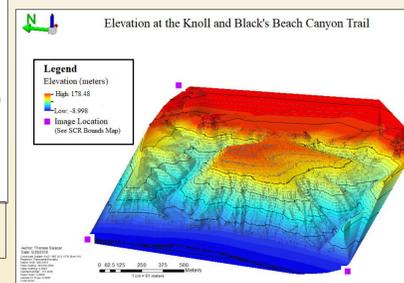


Figure 5: Elevation from airborne LiDAR.

Geologic Hazards at the Scripps Coastal Reserve

Weathering and Erosion
Weathering and erosion are two mechanisms that can cause cliff failure and make it more weak. Falling material or ways to make the cliff weak mean increases in landslides or rockfalls which may hurt patrons.

- Weathering definition:** breakdown of rocks and minerals (sediment)
 - Causes at the sea cliff:
 - Physical: thermal stress (rock affected by temperature change)
 - Tectonic (cracks in rocks)
 - Wedging (salt or frost layers breaking rock)
 - Chemical: acid (dissolving minerals)
 - Hydrolysis (uses hydrons in water to break rock)
 - Salt crystallization (forms crystals)
 - Biological: organisms burrowing or roots growing thicker
 - Subaerial: precipitation, runoff, sapping (water coming out of cliff)
 - Marine: undercutting (waves carve out bottom of cliff)
 - Wave driven impact (pressure of water hitting cliff)
 - Abrasion (water carries sediment, hits cliff)
- Erosion definition:** movement weathered material by wind, water, gravity
 - Types for sea cliffs:
 - Subaerial: makes cliffs broader and more gentle
 - Marine: undercutting, makes cliff have sharp edges at the bottom

Landslides
The reserve has experienced multiple episodes of landslides which makes this area sensitive and likely to occur in the future. To ensure your safety, please beware of where you stand and not be at the base of the cliff or go off of the trail.

Examples of Unstable Geology
Unstable geology can be defined as any structure likely to fall or break at any given time. Makes the cliff prone to failure.

- Cracks
 - tectonic: rock is at least partially broken, ready to be eroded
 - drying: if rock dry, easier to erode
- Undercut platforms
 - Carved out by waves leaving rock sticking out of the side of the cliff
 - Can fall at any moment
- Concretions
 - Definition: Hard compact mass formed by liquid mineral solution hardening into a solid
 - If they are sticking out of the cliff surrounded by weaker rock, may fall at any time. If they are incorporated into the cliff then it works to make the cliff stronger
- Sapping
 - Water coming outside of the cliff because it cannot go through a rock layer
 - Causes different parts of the cliff to erode at different elevations

Figure 6: Template for Black's Beach Canyon Trail signs educating users about geologic hazards that exist in the cliffs and staying safe.

Materials and Methods

- Maps
- Maps were generated using ArcGIS with ArcMap or ArcScene or Google Earth
 - Airborne LiDAR from SIO researchers
- Geomorphology Information
- Read literature, compiled information from other classes
 - Go to site and observe features listed in template

Geology of Scripps Coastal Reserve

Geologic Formations
Knowing the geology of the reserve informs us on how the cliff will erode and fail and help manage safety precautions for its patrons. Please heed the our signage warning when enjoying your use. We can use LiDAR (Light Detection And Ranging) to measure the rate of erosion.

- Geologic definition:** rock layer has similar properties of rock type and structure
- Geology presents and their general descriptions**
 - Ardath Shale**
 - About 50 million years old (Ma), is the base of the cliff
 - deposited in deeper water on the continental slope
 - Fine grained, fissile olive-gray silty sediment and sandy siltstone
 - Green gray hard layers of molluscan fossils on the beach
 - Scripps**
 - About 48 Ma, deposited on shallower continental slope on top of the Ardath
 - Light tan-brownish medium-grained sandstone and sandy siltstone
 - Poway cobble channels with clasts originating from Sonora, Mexico, vary in thickness and is a defining characteristic
 - High energetic events
 - Has some honeycomb erosion (caves on side of cliff, honeycomb shape like)
 - Linda Vista**
 - About 1.5 Ma, deposited in shallow marine environment, marine terrace
 - Marine terrace- preserved rock formation from a past sea level
 - Reddish brown sandstone, conglomerates, concretions and hard cap rocks
 - Conglomerate- rock has other rocks in it, varies size
 - Concretions- hard compact mass formed by liquid mineral solution hardening into a solid
 - Caprock- more resistant to weathering, hard rock formed over a less erosion resistant rock

Can you spot these units at the reserve? Here are some examples of their main features!

- Figure 1: Find the Ardath Shale at the bottom in gray. Trace up the cliff and where the clear layers stop is where the Scripps contains the thin the Ardath Shale.
- Figure 2: This is characteristic of the Scripps. It has flat layers of sand, concretions, caves (are they are small) and signs of erosion features.
- Figure 3: Characteristics of the Linda Vista. It has reddish brown sandstone, conglomerates, concretions and hard cap rock (right).
- Figure 4: Example of cobble channels in the Scripps.
- Figure 5: Map of formation contacts and hazardous areas on the reserve for the Knoll and Black's Beach Canyon.

LiDAR
LiDAR is a remote sensing technique that records elevation measurements by having a laser light beam bounce off of a terrestrial surface and return. Calculating the difference in elevation between two different time periods for LiDAR data sets can demonstrate a loss in surface (erosion) or gain in surface (accumulation). Areas with more erosion that are inside the canyons and on the sides of the Knoll are hazardous areas not meant for use.

Figure 6: The LiDAR data focusing on the Knoll and Black's Beach Canyon Trail demonstrate a general erosion rate occurring at about 0.16m/yr.

Figure 7: Template for Black's Beach Canyon Trail signs educating users about the importance of geology and LiDAR.

Conclusions

- Standing directly at the base of the cliff, going off trails or sitting on edge of cliffs:
 - dangerous due to erosional processes, landslide susceptibility and cliff failure mechanisms.
 - Protect failure prone areas
- The beach and the sub canyons have shown the most change throughout the reserve.
- The trails, being away from the base of the bluffs and interbedded stable geology help support the SCR's access
 - Harder layers to erode- Scripps and Linda Vista
 - Linda Vista is generally the most resistant
 - Easiest to erode- Ardath Shale



Figure 8: Rocky intertidal cliffs are relatively stable because the Miocene dike, concretions and left over block failures act as a natural blockage.

- Not all erosion is bad.
 - Acceptable cliff retreat delivers sand to the beach
 - Dissipate wave energy preventing further cliff retreat.
- Landslides have occurred in the past and are to be considered in the future
 - Influenced by the Rose Canyon fault and precipitation or irrigation addition.
- Change and erosion at the reserve is inevitable but understanding possible future effect of cliff retreat can better prepare management of areas and efforts made at the reserve.
- Sea level rising based on climate predictions
 - Significant amounts of the cliff face are predicted.

References

- Abbott, P. (1999). Rise and Fall of San Diego: 150 Million Years of History Recorded in Sedimentary Rocks. Sunbelt Publications.
- Kennedy, M., Moore, G. (1971). Stratigraphic Relations of Upper Cretaceous and Eocene Formations, San Diego Coastal Area, California. *American Association of Petroleum Geologists*, 55(1971) p. 709-922.

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