WASHINGTON STATE DEPARTMENT OF
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MORPHOLOGY OF THE ALDERWOOD LANDSLIDE; A PROBABLE ORIGIN FOR TSUNAMI AT LYNCH COVE, PUGET SOUND, WASHINGTON

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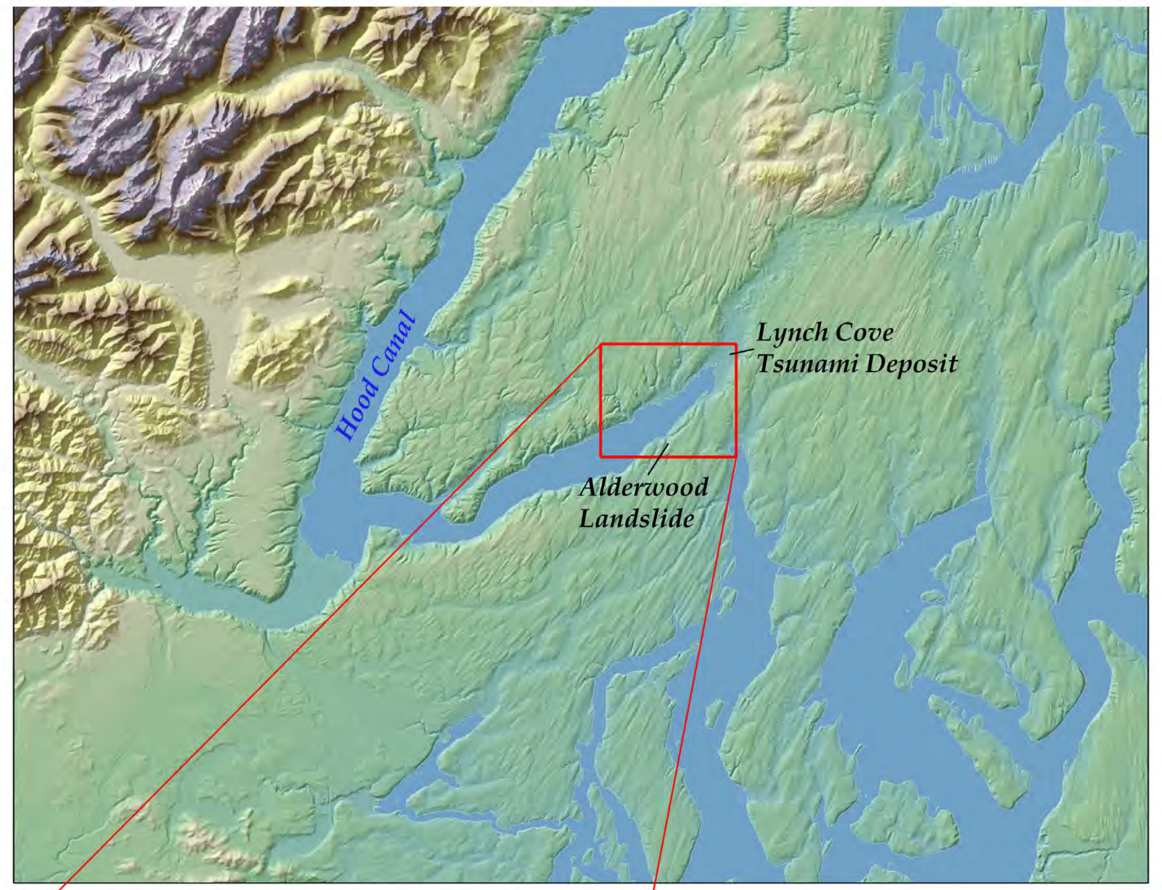
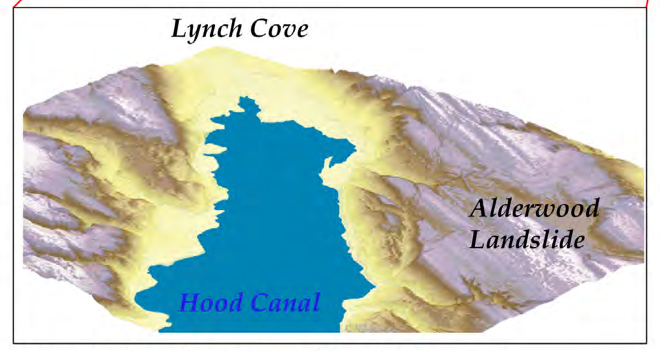
Abstract

As part of a statewide effort to map unstable landforms in forested watersheds, landslides in the Mason Watershed Administrative Unit (WAU) were evaluated using lidar, orthophotographs, aerial photographs dating from the 1960's to 2000's and reconnaissance field work. During our landslide study, the Alderwood landslide was identified as a major complex in Hood Canal that may have been triggered by seismic shocks. The Sunset Beach fault runs parallel to the Alderwood landslide and intersects with the headscarp. Trench stratigraphy showed one surface displacement event, which is younger than 1.3 thousand years (personal communication, Alan Nelson, USGS).

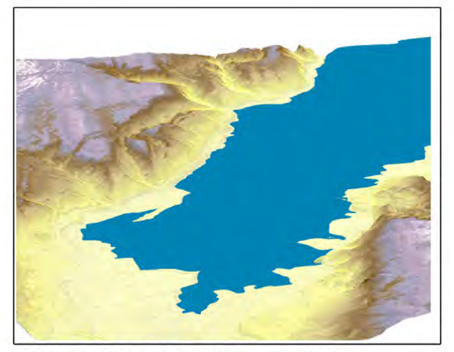
A tsunami deposit observed by Jovanelly and Moore, 2005, is located to the northeast of the Alderwood landslide. This study indicates that this deposit was correlated to a seismic event approximately 1,100 years ago. The correlation between the tsunami deposit and activity along the Sunset Beach fault make this landslide complex an ideal origin for the tsunami deposit in Lynch Cove. We plan to core sag ponds at the head of the landslide to attempt to confirm this correlation.

Historical aerial photographs document modern movement of the Alderwood landslide as well. Movement was determined by observing head and internal scarp position changes through four flight years at approximately 10 year intervals. Remote sensing, using orthophotos and lidar, was used to map structures and movement within the study time horizon. Water well logs were studied to determine geologic structures and possible failure planes within the landslide and to construct cross sections and evaluate internal structure.





View of Lynch Cove and the Alderwood Landslide from the SW to NE.



View of Lynch Cove and the Alderwood Landslide from NE to SW.

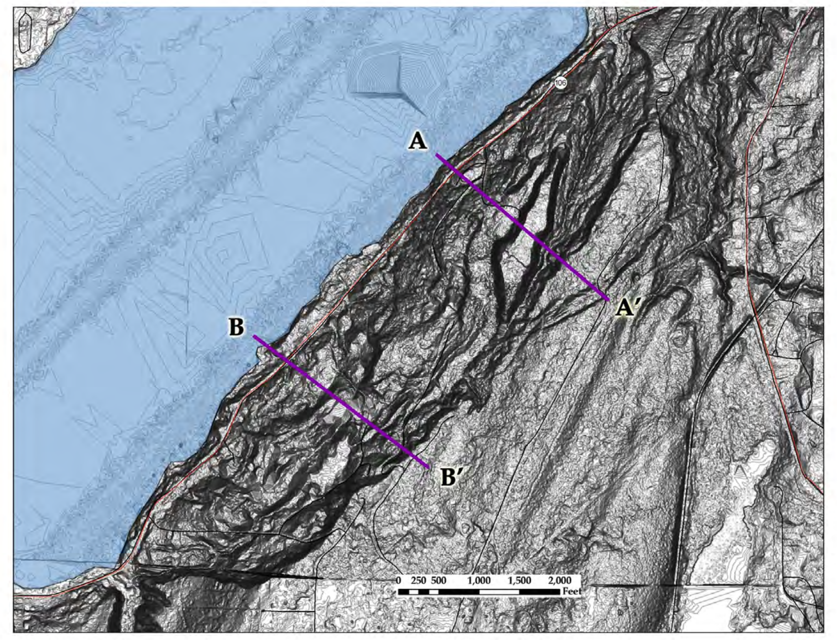
The Alderwood Landslide is located near the end of Hood Canal, southwest of Lynch Cove.

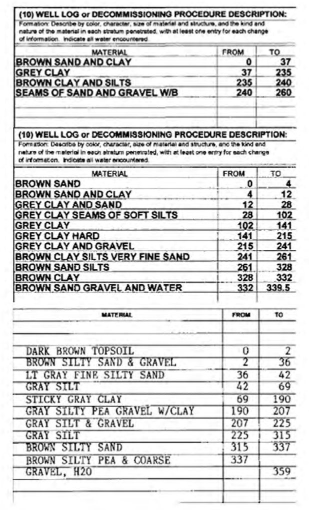
Introduction

The Alderwood Landslide was identified by the Landslide Hazard Zonation Project in the Mason Watershed Administrative Unit (WAU). It was quickly recognized as an anomalous feature from other climatic induced landslides found along the coastline and a more in depth study was conducted to determine the trigger of the landslide. Because of its size and low angle of failure, seismic shaking was first thought to have triggered the landslide. Tidal flats in Lynch Cove, interpreted by Buchnam in 1992, were determined to have sudden uplift about 1,100 years ago. A surge of water (tsunami) followed the uplift, depositing a discontinuous layer of fine-grained sand. As the flats became reestablished, fresh water peat replaced the salt water bog.

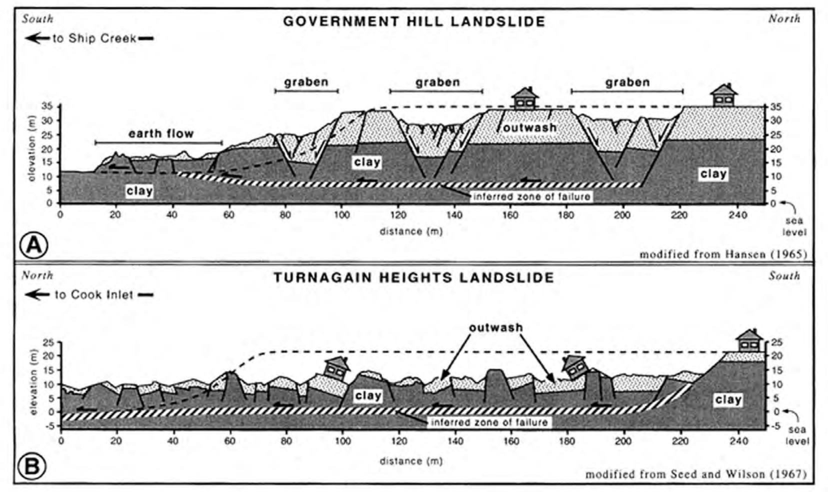
The discovery of uplift and tsunami deposits in Lynch Cove stirred interest in the area. A regional event around 1,100 years ago (900 AD) was suggested to have triggered at least one tsunami in the Puget Sound. Moore (1999) and others studying Cultus Bay (Whidbey Island) discovered a tsunami deposit that match the date and uplift of Lynch Cove. Jovanelly and Moore (2005) studied the Lynch Cove tsunami deposit, confirming the event at around 1,100 years ago. They suggested that the tsunami was probably triggered by fault rupture, but also suggested that a landslide was also possible.

Internal Structure and Geology

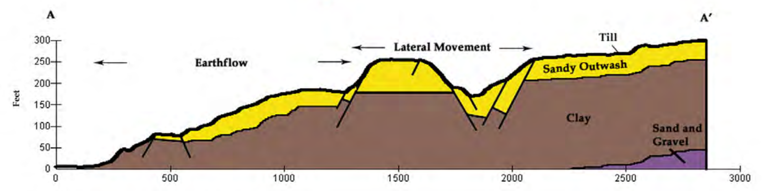




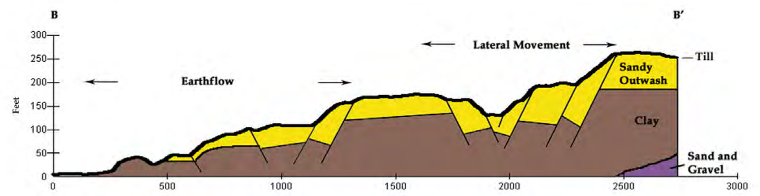
Well log data from the Washington Department of Ecology was examined to determine internal structure of the landslide as well as the stratigraphy.



The Turnagain Heights landslide and Government Hill landslide failed during the Good Friday Earthquake on March 27, 1964. Both of these landslides have striking similarities to the Alderwood landslide, both in structure and stratigraphy. Image from Barnhardt and Kayen, 2000

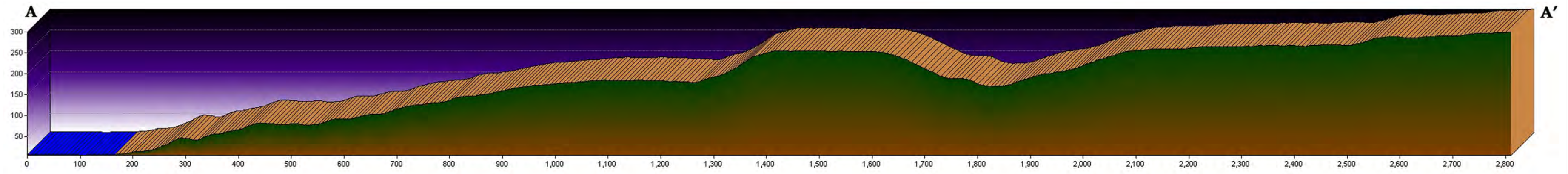


Cross section A to A'

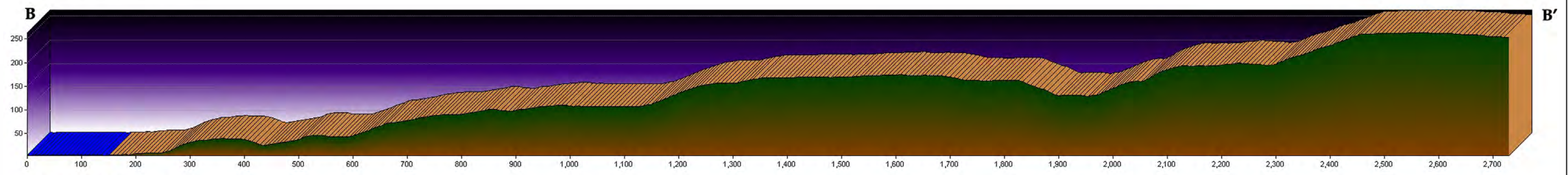


Cross section B to B'

Profile A and B (below) show the lateral displacement and earthflow movement within the Alderwood Landslide. Cross section A and B (above) show the inferred geologic stratigraphy and structure.



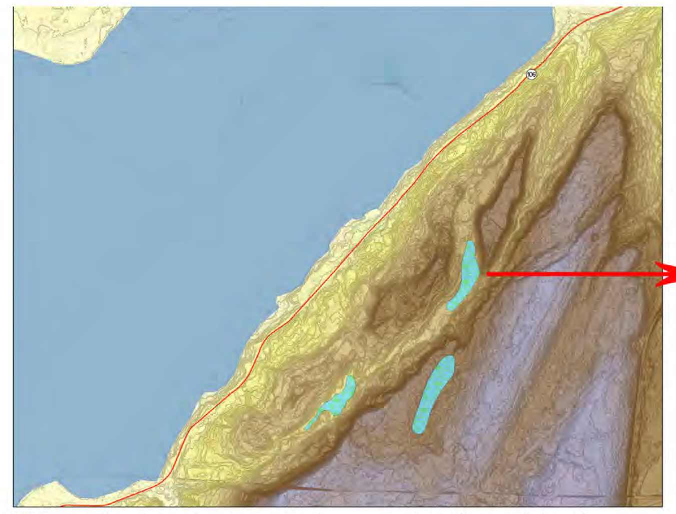
Profile A to A'



Profile B to B'

Our assumption was that the Alderwood Landslide was triggered during the seismic event that uplifted Lynch Cove and was the probably origin for the tsunami in Hood Canal. The run-out toe of the Alderwood Landslide is submerged in Hood Canal and although it is difficult to determine its exact extent, a rough estimate determined at least 100 feet of the landslide slide into Hood Canal. Large sag ponds near the scarp of the landslide were determined to be ideal locations to core to obtain a date of initial movement of the landslide.

Sag Pond Coring



We looked at the two major sag ponds within the landslide and determined that the northern sag pond was the most ideal to sample.

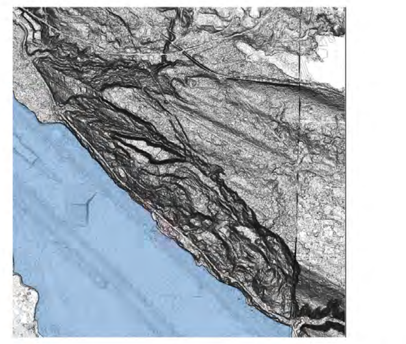
After walking the sag pond, we found an ideal location.

We examined our recovery and sent two samples to be dated

We cored to shattered till below the peat

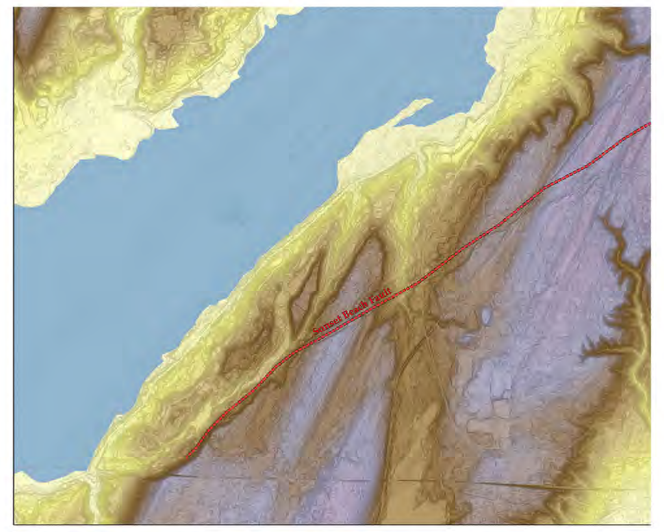
Sample Data	Measured Radiocarbon Age	13C/12C Ratio	Conventional Radiocarbon Age(*)
Beta - 229237 SAMPLE : ALSP 1 ANALYSIS : AMS-ADVANCE delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal AD 1310 to 1360 (Cal BP 640 to 590) AND Cal AD 1390 to 1440 (Cal BP 560 to 510)	520 +/- 40 BP	-24.0 o/oo	540 +/- 40 BP
Beta - 229238 SAMPLE : ALSP 2 ANALYSIS : AMS-ADVANCE delivery MATERIAL/PRETREATMENT : (wood): acid/alkali/acid 2 SIGMA CALIBRATION : Cal AD 900 to 920 (Cal BP 1050 to 1030) AND Cal AD 950 to 1040 (Cal BP 1000 to 920)	1050 +/- 40 BP	-25.5 o/oo	1040 +/- 40 BP

Two samples collected were sent for AMS data, giving two dates, 540 BP and 1040 BP (approx. 900AD). The first sample we recovered was charred material, but the sample also contained rootlets that probably skewed the age. The second sample we recovered was wood and was free of rootlets.

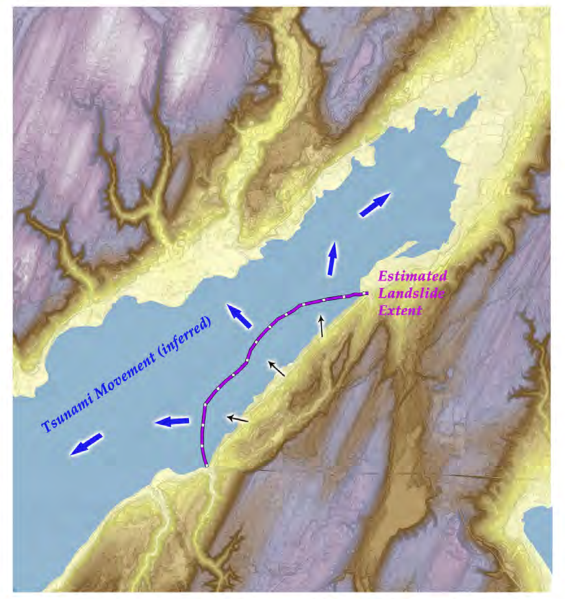


The Turnagain Heights landslide studied by Hansen, 1965 of the USGS shortly after the Good Friday earthquake. The deformation is in the picture is strikingly similar to the deformation on the lidar image of the Alderwood Landslide (right)

Fault, Tsunami, and Activity

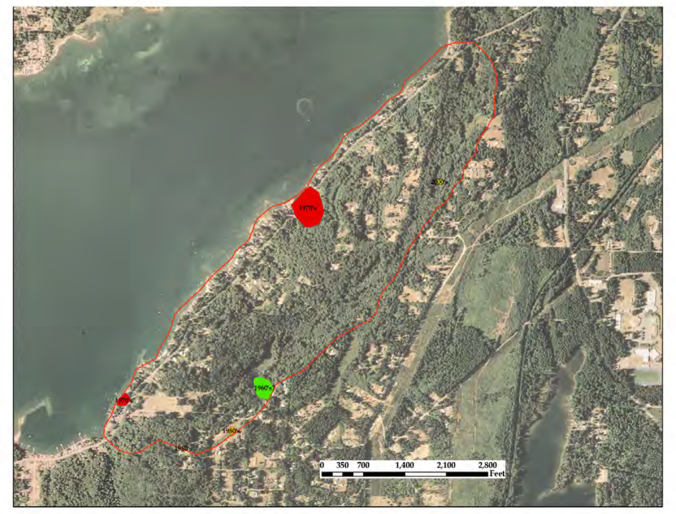


The Sunset Beach Fault intersects the Alderwood Landslide along the scarp. Trenching by the Alan Nelson of the USGS discovered one surface displacement younger than 1.3 thousand years ago.



The toe of the Alderwood Landslide is submerged in Hood Canal. The extent of movement is indicated above and the arrows mark the likely direction of water displacement.

Activity



Activity from the 1960's to present was located on aerial photos. The picture above indicates areas observed to be active and the decade observed.

Conclusion

Samples recovered and dated from the Alderwood Landslide suggest that landslide movement formed the sag ponds around 1,100 years ago. This movement correlates to the uplift and tsunami deposits discovered in Lynch Cove. The cause of this movement is not as clear. Trenching by Alan Nelson of the USGS determined that the Sunset Beach Fault surface rupture occurred earlier than 1,300 years ago. The discrepancy in age suggests that the Sunset Beach Fault may not have initiated the landslide; however, the date obtained is a limiting age and still suggests that the fault movement might be correlated to the Alderwood Landslide movement.

References

Barnhardt, W. A; Kayen, R. E., 2000, Radar Structure of Earthquake-Induced, Coastal Lansdlides in Anchorage, Alaska, Environmental Geosciences, Volume 7, Number 1, 2000 38-45

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