<u>Seamounts on the Juan de Fuca</u>

By: Alexander Wilson

Nyack high school

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Abstract

Sedimentation on the Juan de Fuca plate located off the West coast of North America has affected the amount of visible seamounts immensely throughout history. Seamounts are commonly known as extinct volcanoes that don't break the surface of the water; therefore they are not considered islands. Sedimentation is carried out through underwater current systems and coastal waterways that carry and drop dirt, sand, and many other sedimentary objects on to the Juan de Fuca plate. The result of this can cause seamounts 500 meters in height to be buried and unseen. By using sound waves and thermal imaging the ocean floor is deterred as a plain ground near the coast, where it becomes rocky and mountainous away from the coast and closer to the ridge. The lack of sedimentation near the Juan de Fuca plate creates a more visible area allowing for seamounts to be seen. The Juan de Fuca plate is slowly subducting underneath the North American plate. By using sonar technology the sediment thickness is acquired and can determine the true height of the seamounts. The data also helps in finding the depth of the basement below the sediment.

Introduction

Seamounts are volcanoes that rise up from the ocean floor and sometimes reach the sea surface. Seamounts are active or extinct volcanoes with heights exceeding 100 meters (Wessel, 2010). They usually have their own magma sources and have a large range of heights and widths. Seamounts are important for several reasons. Because the rocks that make seamounts have more pores than the surrounding sediments, seamounts can provide pathways for ocean crust fluid to circulate (Fisher, 2010). For active seamounts, their extra heat in comparison to the generally cold seafloor makes them an oasis for deep ocean biological communities. Also when seamounts enter subduction zones, they sometimes trigger earthquakes (Staudigel, 2010).

The Juan de Fuca plate is a small plate located offshore of the west coast of the United States. It is bounded by the Juan de Fuca Ridge to the east, the Cascadia subduction zone to the west and the Blanco Transform Faults to the south. The Juan de Fuca plate was located in 1986 when a hydrothermal vent was discovered on the ridge, it's known that the Juan de Fuca plate is subducting underneath the North American plate. By studying the magnetic anomalies recorded in the seafloor rock, scientists have discovered that the Juan de Fuca plate is one of the remnants of the ancient "Farallon Plate" (McKenzie and Morgan, 1969; Atwater, 1970).

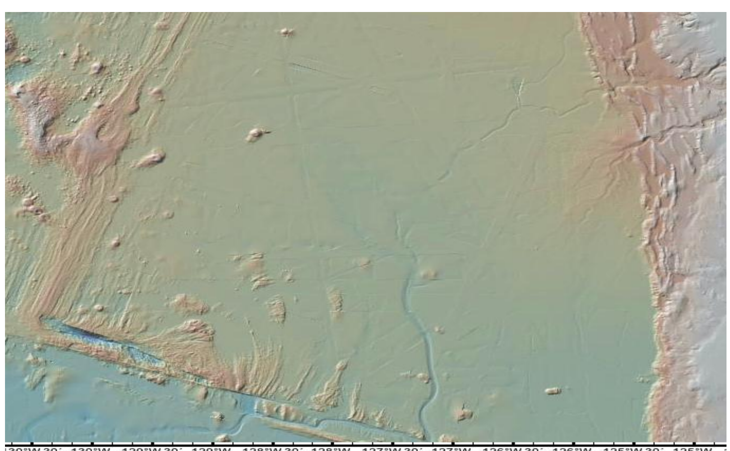


Figure 1, Bythymetry map of Juan de fuca plate.
(GeoMapApp.Com)

Seamounts on the Juan de Fuca plate are rare. As shown in figure 1, only a handful of seamounts can be identified from the bathymetry map, whereas there are abundant seamounts on the Pacific plate to the west of the Juan de Fuca Ridge. One possibility for the small number of seamounts on the Juan de Fuca Ridge is that this plate is covered by thick sediments. Underwater current systems and coastal waterways carry and drop mud, sand and pebbles on to the Juan de Fuca plate. In some places, the sediment is as thick as 2 km. It is possible that there are abundant seamounts on Juan de Fuca plate but they are not visible because they are buried by the sediments.

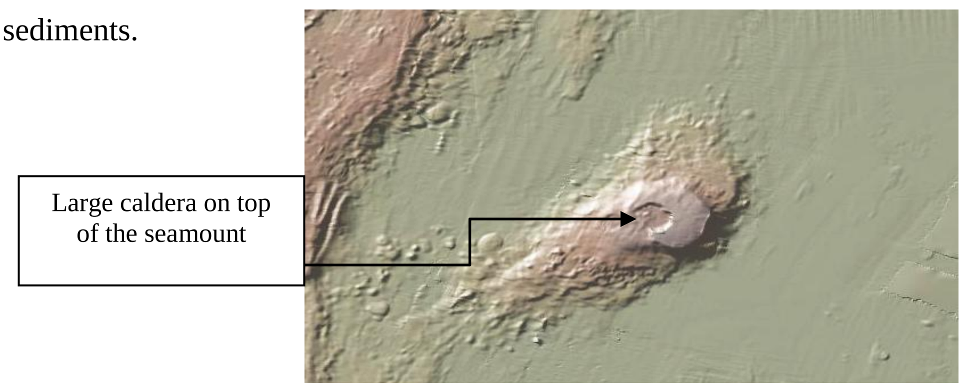


Figure 2 shows a large caldera on top of an elongated seamount. The caldera is the result of an extinct volcano erupting at one point in time and leaving a whole at the top where the magma exploded out of (Geomappapp.org).

Figure 3 is another example of a close-up view of a seamount on the Juan de Fuca plate. This seamount is circular and has two calderas on top of it. One of the calderas is directly in the center of the seamount and is perfectly circular. This means when the seamount was an active volcano the eruption happened directly at the top of the structure. The second caldera is much larger and slightly deformed but has a circular shape (Geomappapp.org).

The topography of the basement is composed of bed rock and has a very rocky surface. It is much different from the sea floor because the seafloor is mostly flat and is composed of sedimentary objects. The topography of the seafloor becomes rockier and more jagged when closer to the ridge. This is due to the lack of sedimentation which exposes the basement and the bed rock that is normally covered by sediment when closer to the coast. There are some topographical structures that rise above the seafloor, these are called seamounts. As shown in figure 2 seamounts protrude off the seafloor and above the sediment. Some topographical characteristics of seamounts include their calderas and elongated or circular shape. A caldera is a volcanic feature that is usually formed by the collapse of land following a volcanic eruption, most calderas are circular and deformed but they range in sizes depending on how devastating the eruption was. The shape of the seamount is also a very important in the biological aspect of seamounts. Circular seamounts create water currents that affect the biological ecosystems around it. Some seamounts have an elongated shape in which the seamount is long and affects the ocean in different ways.

Purpose

The purpose of this study is to take a census of the seamounts on the Juan de Fuca Plate that can be identified from the bathymetry map. Because most seamounts are buried partly by sediments, we looked at multichannel seismic images to estimate their height beneath the sediments, and therefore get their true heights. We also make estimations about how many seamounts might be buried by the sediments on the Juan de Fuca Plate. This study provides new information on the geological processes taking place on of the Juan de Fuca Plate.

Methods and Materials

Bathymetry is the study of the underwater depth of the ocean floor. The bathymetry data used for this study were analyzed using an Earth science exploration and visualization program called GeoMapApp (geomapapp.org). The software was created by scientists at Lamont Doherty Earth Observatory and is continuously updated with measurements from marine explorations that they conduct. GeoMapApp is a very helpful tool in researching the geological features of the planet and more. The program allows for the visualization of ocean structures deep beneath the ocean surface. It uses bathymetry data collected from satellite as well as acoustic bathymetry measurements from research cruises.

For the acoustic bathymetry measurement, the sound waves are sent down to the bottom of the ocean and bounce back up, and the two-way travel time for the sound wave is measured. The two-way travel time is the time it takes for the sound waves to hit a solid object on the ocean floor, or in this case, a seamount, and bounce back to the surface. This is measured in seconds. Knowing the speed of sound, the ocean floor depth can be determined from the two-way travel time. Acoustic bathymetry cannot be used to determine the depth of the basement because it is buried beneath the sediment. The depth of the sediment is measure by active source seismic data. It does not directly measure the thickness, but measures the two-way travel time of the seismic wave. This is then divided by the distance from the ridge and the result is the sediment thickness. By measuring the thickness of the sediment, the depth of the basement can be determined. By using this strategy, the ocean surface and basement which is the bedrock underneath the sediment, can be viewed by plotting the data available on the GeoMapApp database.

This experiment gathered data from expedition MGL1211 which took place in 2012, the expedition mapped basement and seafloor, and it stretched from the spreading ridge of the Juan de Fuca towards the coast line of California. The coordinates, depth and height of any structure lying on the ocean floor were all organized in a spreadsheet. A table was created with the number of each seamount along with its, latitude, longitude, height, width, distance from the ridge, and a general description of the seamount. The height and width were measured from the east and west sides of the seamount, and then measured again from the north and south. The general description included the shape of the seamount, whether it is circular or elongated, the shape of its caldera, and the number of calderas if it has more than one. The data was then plotted.

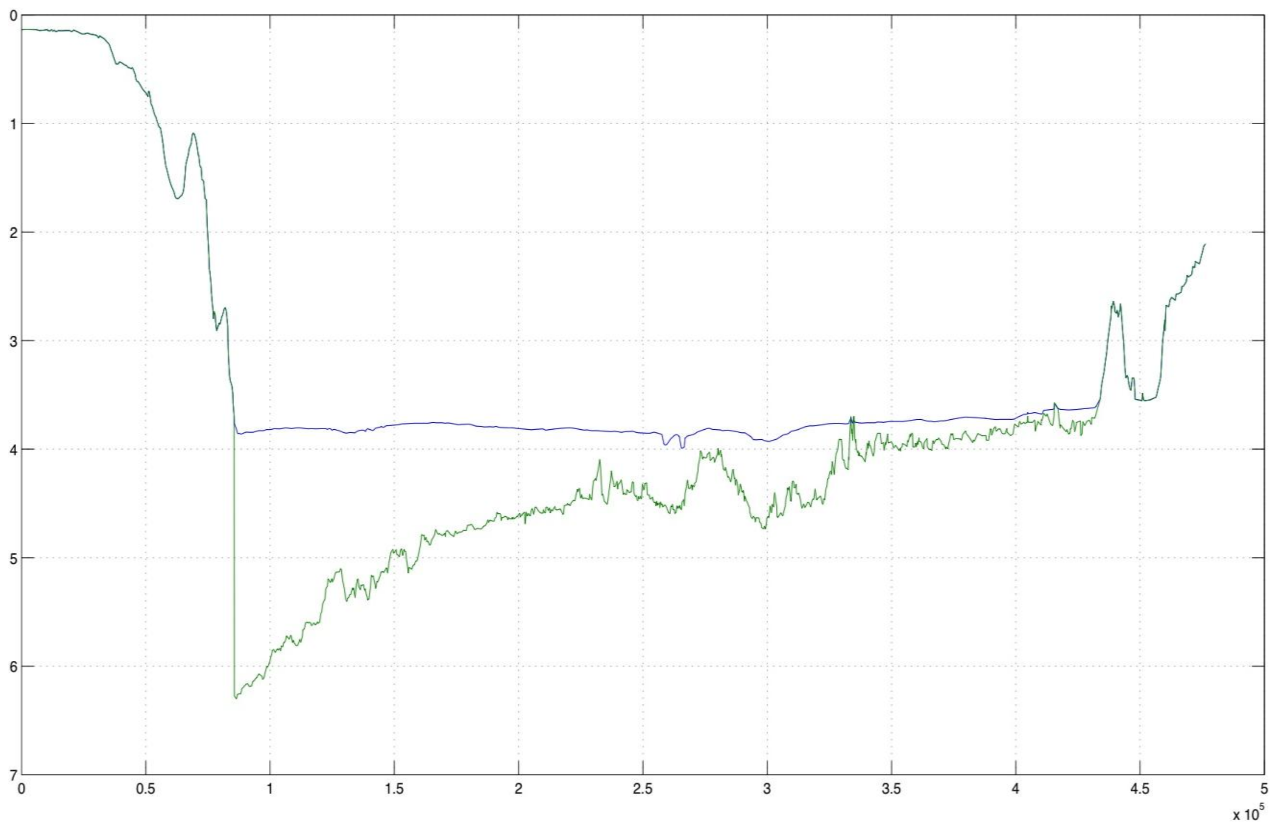
Results

Table 1 shows the sediment thickness data acquired from figure 4. By measuring the two-way travel time and distance from the ridge, the sediment thickness was found. There were 14 different measurements that took place; at each place the sediment thickness was different. This is because there was a decrease in sediment as the measurement got closer to the ridge

Table 1: The table shows the data collected from measuring the sediment thickness. The sediment thickness was determined by retrieving the two-way travel time and dividing it by the distance to get the sediment thickness.

Distance from Ridge (Kilometers)	1	1.25	1.5	1.75	2	2.25	2.5	2.75	3	3.25	3.5	3.75	4	4.25
Two-way Travel Time (Seconds)	2.12	1.30	1.18	0.94	0.76	0.59	0.47	0.24	0.76	0.4	0.24	0.18	0.06	0.118
Sediment Thickness (Kilometers)	3.18	1.94	1.77	1.41	1.15	0.88	0.7	0.35	1.14	0.62	0.35	0.26	0.09	0.177

Figure 4 shows a relationship between the seafloor, basement and sediment thickness. The seafloor is represented by the upper-most line and is relatively flat; it begins at about four second on the two-way travel time axis. The basement is represented by the bottom line that is very deformed and not flat like the seafloor line. Between these lines lies sediment that has been deposited from the coast onto the Juan de Fuca plate. There is less sediment closer to the ridge which is located at approximately 4.5 kilometers on the distance from ridge axis.



Distance from Coast (Km)

Figure 4: The graph shows a relationship between the seafloor, basement and sediment thickness. The green line represents the basement. The blue line represents the seafloor; everything between these lines is sediment.

Seamounts	Latitude	Longitude	EW Height (m)	EW Width (km)	NS Height (m)	NS Width (km)	Average Height (m)	Distance from ridge (km)	Corresponding Sediment Thickness	True Height (m)	Description of seamounts
1	129°57’W	044°36’N	738	10	775	10	756.5	38	252.5	1009	One large caldera with a little cone in the middle. Large circular seamount.
2	127°17.3’W	044°41.6’N	531	8	484	7	507.5	250	1176.5	1684	Flattened out seamount, has a deformed circular shape. Two calderas one small and one large.
3	126°55.3’W	043°41.6’N	848	14	779	10	813.5	300	1744.5	2558	Deformed base, circular top with one faded caldera on the top.
4	126°11.4’W	043°53.9N	724	11	700	6	712	340	2888	3600	Two small calderas or divits on a very elongated shaped seamount
5	127°06.6’W	044°23.8’N	393	7	392	8	392.5	250	1099.5	1492	Very faded seamount, it is flat and doesn’t seem to have any calderas.
6	127°11.7’W	044°52.2’N	405	16	277 & 329	12 & 12	341 & 367	230	896	1250	Rounded seamount with a circular shape
7	129°42.4’W	045°08.0’N	722	8	843	12	782.5	25	204.5	987	Rounded seamount with one caldera on top also has a rounded base.
8	129°22.0’W	045°22.1’N	400	7	325	9	362.5	50	137.5	500	Flat seamount with no calderas, has a deformed circular shape
9	129°29.4’W	045°50.59’N	850	12	900	20	875	40	255	1130	One large caldera atop a cone shaped seamount with a flat top
10	128°37.9’W	046°02.2N	1200	8	1700	15	1450	86	574	2024	Multiple calderas some larger than others
11	128°22.7’W	046°51.3’N	350	6	425	8	387.5	90	375.5	763	Rounded seamount with a caldera to the north side
12	128°00.31’ W	047°56.53’N	225	1	177	1.7	201	80	314	515	Elongated outcrop with no calderas.
13	127°43.9’W	047°50.17’N	130	0.8	100	1.8	115	100	355	470	Elongated outcrop with no calderas.
14	127°37.05’ W	047°51.57’N	253	1.6	285	3	269	105	389	658	Very long elongated outcrop with no calderas
15	127°47.14’ W	047°42.46’N	51	0.6	35	0.8	43	95	352	395	Very small elongated outcrop with no calderas
16	126°18.15’ W	045°05.43’N	190	1	170	3	180	77	305	485	Elongated seamount; looks like two seamounts together, no calderas.
17	128°03.9’W	047°16.6’N	455	4	400	4	427.5	82	310.5	738	Two equally sized calderas on top of a nearly perfectly circular seamount

Table 2 is a seamount description table that shows the latitude and longitude of each individual seamount. It also has the heights and widths from the north, south, west and east sides of the seamount. The distance from the Juan de Fuca ridge to each seamount specifically is also included in the chart. Also a detailed description of each seamount which states the unique characteristics ranging from the number of calderas, to the shape of each caldera is included. The height of each seamount from the basement to the top of the seamount above the seamount is recorded on the description table.

Figure 5 portrays a relationship between the seamounts and sedimentation. Sediment thickness increases closer to the shore. As the seafloor elevation increases, closer to the shore, the seamounts must be taller to break the surface of the sediment. The black line represents the seamounts and the red line represents the sedimentation as it gradually gets closer to the coast. By measuring the length between each thickness interval the height above the sediment and below is able to be found. By measuring the thickness of the sediment and dividing that length by 1.5cm the height of the seamount in meters is found. The graph starts at the ridge and moves east towards the coast. It shows an increase in the height of sediment in the west, away from the coast.

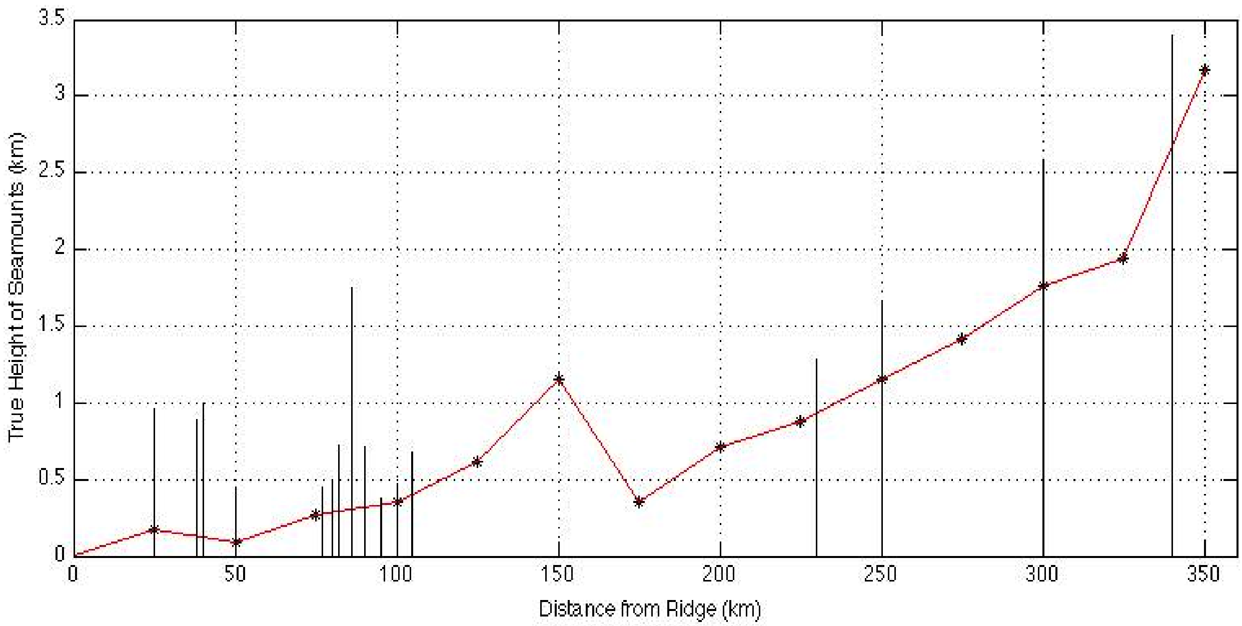


Figure 5: This seamount chart shows the relationship between the seamounts height and the sediment thickness. The true height of the seamount which originates in the basement is portrayed.

Discussion/Conclusion

Figure 5 shows the affect of sedimentation on the seamounts of the Juan de Fuca plate. As sedimentation occurs, seamounts are buried which affect the visibility of the seamount when using seismic imaging. As the Juan de Fuca plate subducts underneath the North American plate the seamounts are getting closer to the coast where the sedimentation is occurring the most. The main question asked relating sedimentation to seamounts is, what affect does sedimentation have on the census of seamounts on the Juan de Fuca plate? Figure 5 proves that the seamounts are buried extensively when close to the coast. Therefore, the census of seamounts decreases because the visibility of such seamounts is impaired due to the burying of the seamount as they continuously get closer to the coast. There are 17 seamounts that are being affected my sedimentation on the Juan de Fuca plate which is shown in table 2. The shapes of these seamounts vary from elongated to perfectly circular. The heights of these seamounts range from 43 meters to 1420 meters. The widths of these seamounts range from 13m to 1700m. This is a large variation in heights and widths of the seamounts. The height and widths are affected by sediment deposits and as they get closer to the coast the height and widths of these seamounts will continue to decrease above the seafloor. This implies that the motion of the Juan de Fuca is a factor in the process of the seamounts being buried.

Future study of the Juan de Fuca plate should include thermal imaging to provide a heat signature rather than a topographical view. This could be used to identify areas of high thermal activity, which could indicate active volcanoes and hotspots. If the experiment was to be repeated again, there would be some slight improvement that could be made, for example using a program that includes thermal data. This will allow for the availability of heat flow data and to check whether these seamounts are correlated with heat flow hotspot or cold spot, in this way, it can be assessed what roles these seamount plate in plate scale hydrothermal circulation. There are still questions that remain involving the sedimentation of the Juan de Fuca plate. Some of these questions include when will the seamounts that are visible now be buried by sediment? Another question would be will the rate of sedimentation on the plate be consistent or will it increase or decrease over time? These questions can be answered by the continuation of experiments and scientific studies on the plate. More cruises and measurements will be analyzed and will determine the sea floor and basement depths as the plate subducts underneath the North American plate.

Bibliography

Watts, A. B. (2010, March 10). Seamount Subduction and Earthquakes.

Atwater, T. (1969). Implications of Plate Tectonics for the Cenozoic Tectonic Evolution of Western North America. San Diego, California/U.S.: Institution of Oceanography.

B.F, R. W., & Goodwillie, A. (2009, March 25). Global Multi-Resolution Topography. Retrieved October 2, 2013, from Geomapapp website: http://www.geomapapp.org/

Wessel, P., Sandwell, D. T., & Kim, S.-S. (2010, March 25). The Global Seamount Census. Oceanography: Mountains in the Sea, 23(1).

Fisher, A. T., & Wheat, C. G. (2010, March 25). Seamounts as Conduits for Massive Fluid, Heat, and Solute Fluxes on Ridge Flanks. Oceanography: Mountains in the Sea, 23(1).