Project Description - Thermal Structure of the Cascadia Subduction Zone on the Washington Margin, NSF Grant 1144164 – H. Paul Johnson and Evan Solomon, PI's.

Grant Period: 07/01/2012 to - 6/30/2017

Major goals of the project?

The primary goal of the project is to determine the thermal structure of the Cascadia Subduction Zone off the Washington margin.

The recent occurrence of large subduction earthquakes and their associated tsunamis have demonstrated their capability for destruction, including the 2011 Magnitude 9.0 Tohoku Japan earthquake-induced tsunami that killed an estimated 16,000 people. This demonstration of the destructive capability of great subduction earthquakes has heightened the awareness of Pacific Northwest communities to the inevitability of a similar event happening locally within the Cascadia Subduction Zone. The last large megathrust earthquake on the Washington, Oregon and British Columbian coasts occurred over 300 years ago and the statistical odds of another 'big one' increase with each passing year. Understanding the mechanisms that underlie this active subduction zone is essential for evaluating the potential shaking hazards and local tsunami inundation maps for the entire west coast of the U.S. Any earthquake movement on a subduction zone fault is temporarily blocked by only a very small portion of this plate interface - where friction temporarily prevents relative plate motion and where tectonic stress from the massive collision is stored. This 'locked zone' on a fault is similar to the brakes on a bicycle wheel, where the very small caliper pads arrest the motion of the entire wheel.

Identification of the specific off-shore location of the 'locked zone' of the contact fault between the North America and Juan de Fuca plates determines if an individual megathrust earthquake will produce largely terrestrial damage to infrastructure from shaking but only a small tsunami. In contrast, if this critical 'locked zone' where plate tectonic energy storage is located lies instead beneath the submerged portion of the outer continental margin, only a small amount of terrestrial damage from earthquake shaking will result, but can produce very large tsunamis that can inundate the coast communities. Because of this dramatic difference in possible types of impact resulting from a megathrust earthquake, it is critical to locate the exact position off-shore of the portion of the subduction zone fault that is locked where these massive amounts of energy will be released when an earthquake occurs.

Impact of NSF Grant

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Mapping of the specific off-shore distance where the locked zone is located was accomplished by modeling the thermal environment of the entire subduction zone, including the fault-damaged rocks on both of the colliding tectonic plates. This is possible since both the upper and lower boundaries of the locked portion of the plate interface are determined by the temperature of the rocks that surround the subduction fault zone. The current published study used heat flux calculations obtained from data that were obtained from a 2012 multi-channel seismic research cruise aboard the R/V Langseth. This research cruise used a large array of airguns and hydrophone streamers to map the sub-seafloor structure of the Cascadia Subduction Zone along a 60 mile North-South distance lying offshore Southern Washington State.

In order to test the newly published thermal model that is based primarily on data from the Langseth seismic cruise, in August, 2013, we conducted an additional 30-day detailed heat flow and fluid flux survey along a single across-strike profile of the Washington margin, from the abyssal plain west of the deformation front of the accretionary wedge at 3000 meters depth to the continental shelf at 160 meters water depth - using the R/V ATLANTIS and the ROV JASON II. This survey area was specifically chosen to exactly overlie the previous LANGSETH cruise survey lines on the Washington margin in order to test our previous interpretations using traditional heat flow probes and seafloor thermal blankets to measure the temperature of the Cascadia Subduction Zone. Although the two manuscripts reporting the results of this 2013 cruise are in the final preparation stages for publication, the results show a dramatic confirmation of the interpretations listed above.

What is the impact on other disciplines?

The recently published results from this new thermal model clearly predicts the location of fault breakage and movement during a large subduction earthquake is likely to occur fully offshore the Washington coast. This new location places the earthquake motion further from large population centers such Seattle and Portland, but shows there is a higher chance of the fault movement reaching all the way to the seafloor at the western edge of the margin. This type of fault movement dramatically increases the risk for the production of a very large tsunami on the Washington coast, similar to what occurred during the 2011 Tohoku Japan earthquake. An additional important result of the new published thermal model is that the rocks that form the Cascadia Subduction Zone are uniquely hot compared to most other subduction zones. These elevated temperatures could potentially play a role in explaining the reduced number of smaller earthquakes observed within the Cascadia Subduction Zone when compared other subduction zones worldwide.

What is the impact on the development of human resources?

The cruise on the R/V Atlantis using the ROV Jason II provided opportunities for research, teaching and mentoring in science and engineering - including an extremely valuable 'at sea' experience for a large number of students, both graduate and undergraduate, and from the University of Washington, Oregon State University and other academic institutions. In addition to the at-sea experience, the project provided data used for student research projects (Salmi, Miller, Homola) which were processed into publications in reviewed scientific journals.

What is the impact on physical resources that form infrastructure?

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What is the impact on institutional resources that form infrastructure?

This project has impact on the geohazard assessment of the Cascadia Subduction Zone including such as policies, practices, programs, or establishment or sustenance of national

geophysical societies and federal organizations. The recent paper on remotely triggered turbidites (partially supported by this grant) will also have an impact on the placement of communication and research cables, which can be destroyed by slope failures on the active Cascadia margin.

What is the impact on information resources that form infrastructure?

The impact of the study supported by this grant will impact the policies, practices, programs of the US Geological Survey, including the Salmi et al (2017) paper that located the Cascadia Margin seismogenic zone completely off-shore and the impact this will have on the geohazard assessment analysis made regarding coastal infrastructure.

What is the impact on technology transfer?

As above, the new location of the Cascadia seismogenic zone completely off-shore, and therefore likely to generate a large tsunami during the next megathrust earthquake will have a major impact on the geohazard assessment for the Washington and Oregon coastal zones.