Observations of Past Megathrust Events Along the Cascadia Subduction Zone: Insight into Earthquake Event Forecasting

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Abstract

Understanding past megathrust earthquake events along the Cascadia subduction zone (*Figures 1 & 2)* through analysis of the stratigraphic record provides accurate information about the size of past events, rates of reoccurrence and time since the last event. Reliable indicators in the stratigraphic record include both paleotsunami and turbidite sediments. The research findings show that these indicators can be linked to the last megathrust event that occurred on January 26, 1700. Further evidence supports six such events in the last 2,000 years, with as many as 18 events recorded in a single location. If these events occur in regular intervals, then there should be a megathrust event roughly every 330 years.

Introduction

On January 26, 1700 an enormous earthquake occurred off the coast of the Pacific Northwest causing 600-1,000 km of the coast to drop 1-2 m below the sea level (Goldfinger, 2003). This earthquake generated local tsunamis that were 10-12 m high, and were recorded in Japan. Paleoseismic data indicates that this event was a magnitude (M_w) 9-subduction type earthquake. Earthquake prediction has been the Holy Grail of seismology, but before we can begin to forecast earthquakes (probabilistic assessment of earthquake hazard as far as frequency and magnitude in a given area) we need a model for the area of interest.

The Cascadia subduction zone (boundary between two tectonic plates, one riding over the other) stretches roughly 1,000 kilometers in length from Vancouver Island to Northern California. The zone is characterized as the boundary between the subducting Juan de Fuca plate and overlying North American plate. This boundary lies 60-130 km offshore.

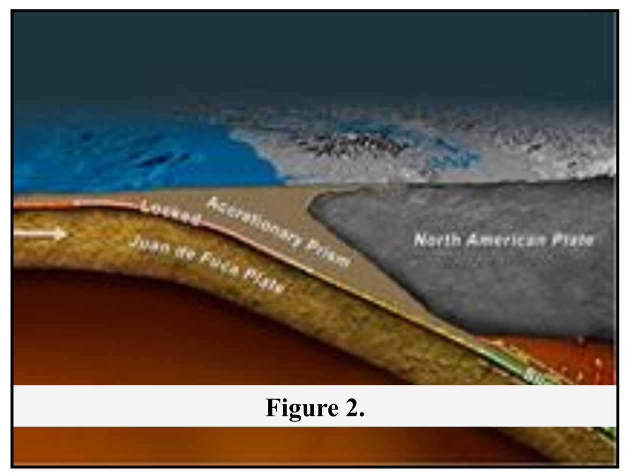

Figure 2.

Sudden releases of compressional stresses along this boundary lead to large megathrust (magnitude 8 to 9) earthquakes *(Figure 3.)*. Subsided tidal wetlands (*Figure 4 & 5*) overlaid by tsunami related sands in North America were the first substantial evidence for megathrust earthquakes (Atwater, 1987). In order to accurately model earthquake events forecasts require fundamental information about the event size, rates of reoccurrence and time since the last event.

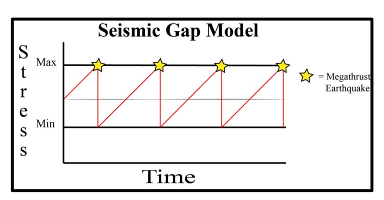

Figure 3.

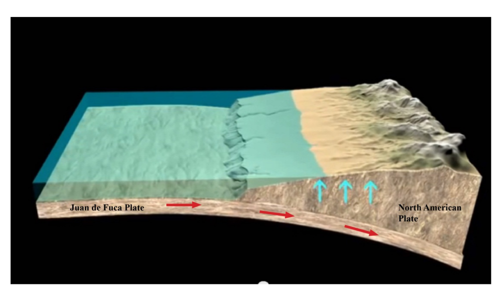

Figure 4.

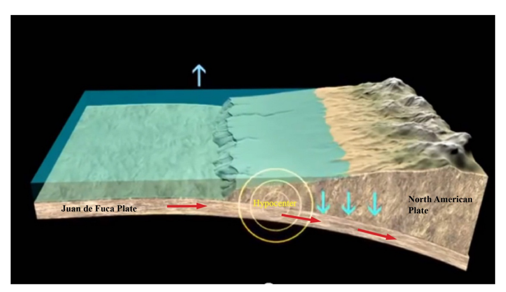

Figure 5.

Depositional evidence of turbidites (submarine debris slides) tells of 18 events over the past 9,850 years (Goldfinger, 2003). More recently, cored samples of paleotsunami sands over the last 3,000 years demonstrate 450-540 year intervals (Peterson, 2013). However, the tsunami records at Bradley Lake in southern Oregon shows contrary evidence of six tsunamis over the past 200 years (Nelson, 2006). An accurate understanding of the Cascadia subduction zone is of particular interest to residents of Vancouver Island and the Pacific Northwest of the United States.

Research Question

Can our understanding of past megathrust earthquake events along the Cascadia subduction zone be used to predict similar earthquake events in the future?

Methods

- Field mapping and sediment analysis from drill core
- Tree ring analysis
- Lake and lagoon sediment analysis
- ^{14}C radiometric age dating of sediments
- Turbidite analysis
- Seismic Reflection
- Historical eye witness accounts of tsunamis

Research Findings Timeline

(Atwater, 1987)

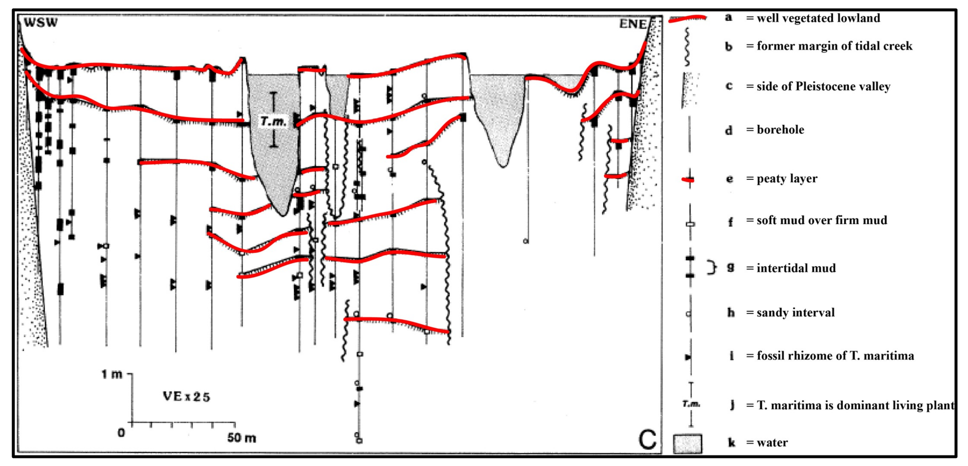

Figure 6.
Modified from (Atwater, 1987)

(Goldfinger, 2000)

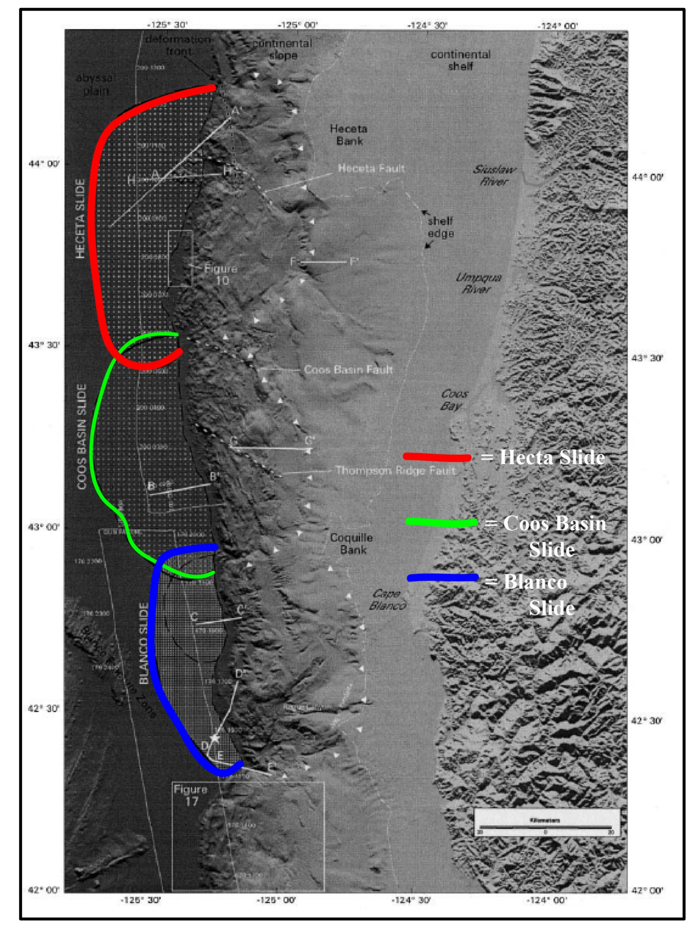

Figure 7.
Modified from (Goldfinger, 2000)

(Goldfinger, 2003)

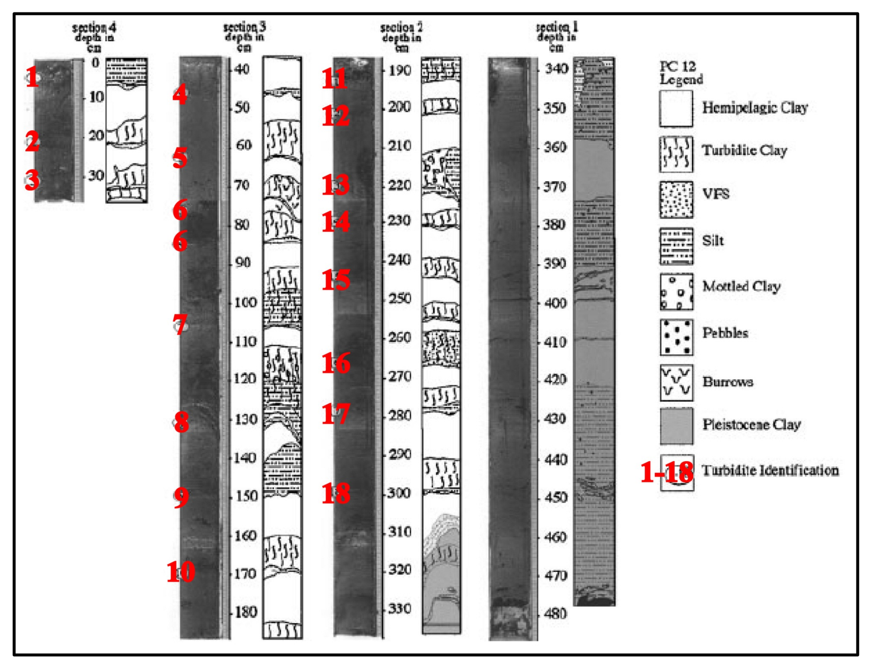

Figure 8.
Modified from (Goldfinger, 2003)

(Wang, 2003)

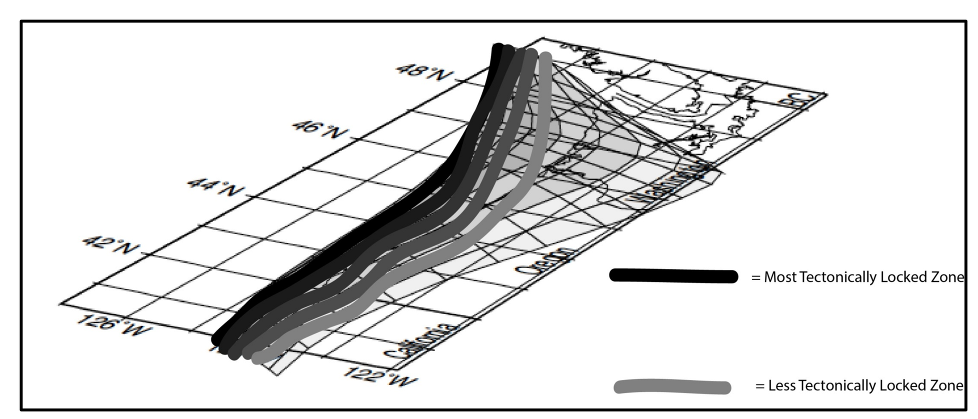

Figure 9.
Modified from (Goldfinger, 2003)

(Nelson, 2006)

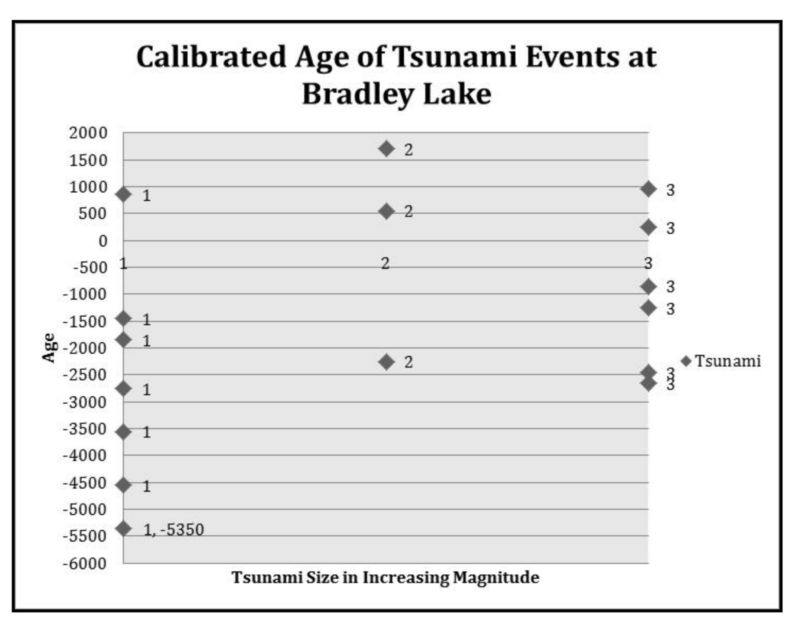

Figure 10.
Modified from (Nelson, 2006)

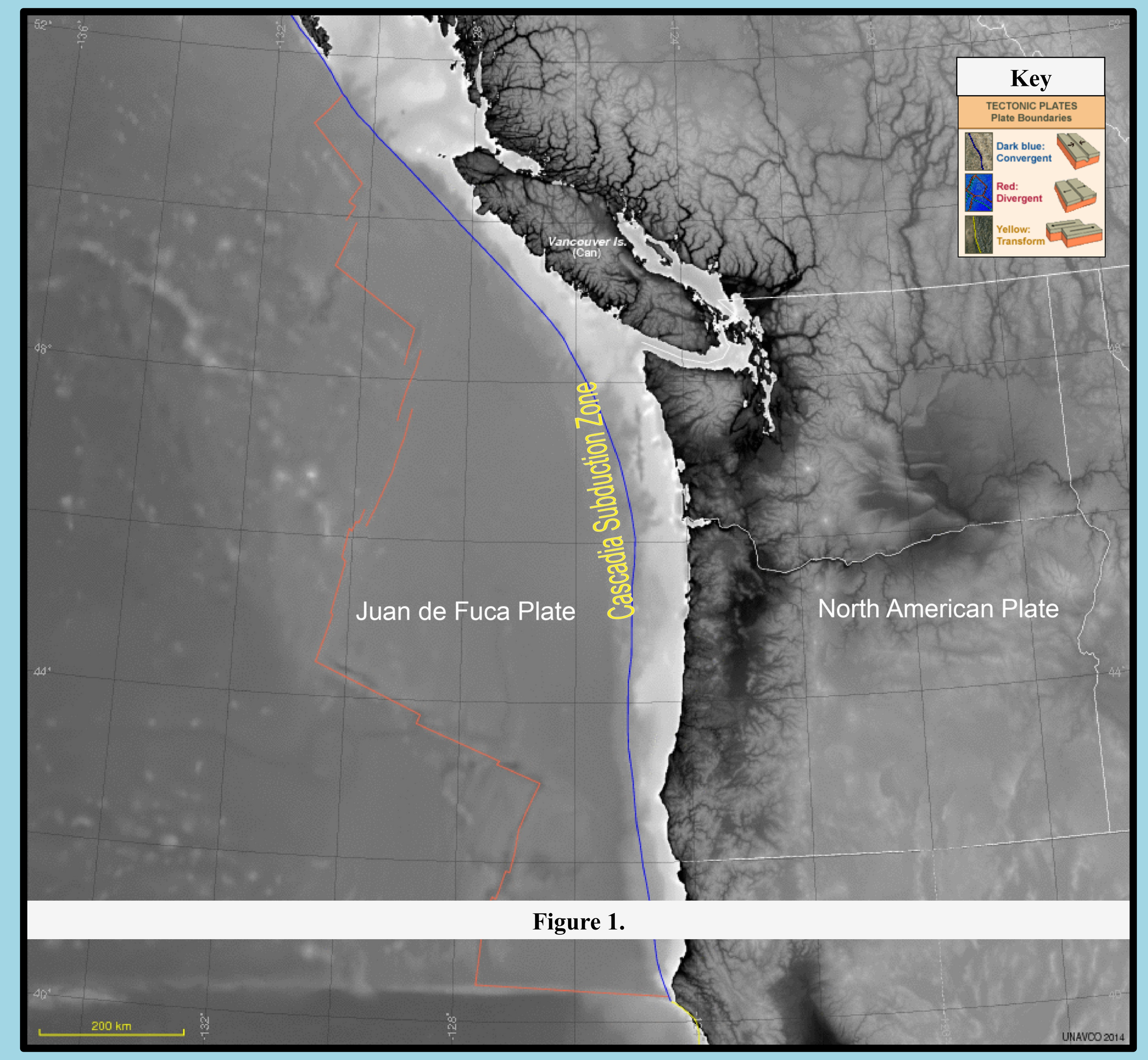

Figure 1.

Discussion & Conclusions

The present understanding of the Cascadia subduction zone does not allow us to predict earthquakes, however, the research done by Atwater, Goldfinger, Nelson and Peterson has revealed valuable insight needed for an earthquake forecasting model.

It was not thought that the Cascadia subduction zone was capable of producing magnitude (M_w) 9-subduction type earthquakes until Atwater observed subsequent layering of buried vegetation along the coast of the Pacific Northwest. He explains that the burial of peaty layers must be a result of rapid tectonic subsidence (*Figure 6*).

Goldfinger showed that turbidite analysis in the forearc basin can be correlated to both large seismic events along the subduction zone and paleotsunami sediments on the coast (*Figure 7).*

Evidence for a repeating pattern of events along the Cascadia subduction zone is seen in the stratigraphy. Using core data, Goldfinger was able to identify 18 separate turbidite events (*Figure 8.*).

Wang's revised dislocation model of interseismic deformation of the region provides a 3-D view of the locked zone along the subduction fault. This model provides further constraints for possible origins of megathrust-type events (*Figure 9*).

Stratigraphic evidence from core data at Bradley Lake in Southern Oregon tells of six large tsunamis in the past 2,000 years. This is contrary to the previously believed four events over the past 2,000 years. Looking at the column in its entirety reveals 12 separate tsunamis over the past 5,000 years (*Figure 10*).

The findings show that the most recent megathrust event occurred on January 26, 1700. This event is recorded in the stratigraphic record by both paleotsunami sediments and turbidite sediments. If these sediments are true indicators of a megathrust event then there is stratigraphic evidence supporting six such events in the last 2,000 years. Assuming these events occur in regular intervals, then there should be a megathrust event roughly every 330 years. These findings provide accurate information about the size of past events, rates of reoccurrence and time since the last event. All of which is essential for a probabilistic assessment of modern day earthquake hazards in the Cascadia subduction zone.

New Insights & Implications for Future Studies

- Further drill core analysis of paleotsunami sediment
- Further drill core analysis of turbidite sediment from the forearc basin
- Age date constraints from ash layers
- Subsea radon emissions
- Seismic gap correlation
- Turbidite analysis from seismic reflection data
- Short-term event series analysis