THE ORPHAN TSUNAMI OF 1700

By:
Brian F. Atwater, Musumi-Rokkaku Satoko, Satake Kenji, Tsuji Yoshinobu, Ueda Kazue and David K. Yamaguchi , **ISBN 0-295-98535-6, U.S. Geological Survery, UW Press (2005)**

A REVIEW

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REVIEW SUMMARY

"Orphan Tsunami of 1700" is a beautifully illustrated book which - in addition to very useful reference material - provides a wealth of diverse geologic data as evidence that mega thrust earthquakes of magnitude 8 or 9 in the Cascadia region may have generated major tsunamis along the Pacific Northwest and possibly elsewhere in the Pacific Ocean.

A section of the book summarizes and interprets the significance of extensive geological findings and purported paleotsunami deposits (sand layers covering peaty soils) found by geological investigations along the shores of northern California, Oregon, Washington and British Columbia, as evidence that tsunamigenic earthquakes have occurred throughout geologic time along the Cascade Subduction Zone. Based on the stratigraphic layering of the deposits, their extensive geographical distribution, and their dendrochronological and radiocarbon dating - as previously reported in the literature - the authors establish a relative chronology of at least three mega thrust events for the Cascadia region – the latest about 300 years ago (AD 1710 +/- 10 years). Lore of early natives pertaining to cataclysmic flooding and other unusual phenomena in the Pacific Northwest is provided as additional forensic evidence.

Subsequent sections of the book provide a comprehensive historical account of a destructive tsunami of unknown origin that struck Japan on January 26, 1700, and the results of a numerical modeling study of the tsunami, postulating the latest Cascadia mega thrust earthquake as its source - since it occurred around the same time.

Based on the dating of the ostensible paleotsunami deposits, the numerical tsunami simulation, the native accounts, and by a process of "elimination" - since no other great earthquakes occurred that year - the authors conclude that the missing parent source of "The Orphan Tsunami of 1700" observed in Japan (but nowhere else in the Pacific), must have been the megathrust earthquake in the Cascade region. To this earthquake an estimated moment magnitude range of 8.7 to 9.2 is assigned (which is almost as great as the December 26, 2004 tsunamigenic earthquake along the Great Sunda Trench), and a rupture zone of more than 1,000 Km (600 miles) – thus suggesting a continuous break of all fault segments along the entire length of the Cascadia subduction zone on the eastern side of both the Juan De Fuca and Gorda tectonic plates. Furthermore, based on the tsunami travel time to Japan as determined by the numerical simulation, the authors refine the radioactive carbon dating of the Cascade megathrust event as having occurred around 9 PM on January 26, 1700.

In summary, the book represents a dissection of the two disasters on opposite sides of the Pacific and is jam-packed with beautiful graphics and interesting views as to the Pacific Northwest's earthquake and tsunami vulnerability. However, no conclusive evidence is presented that moment magnitude 8 and 9 earthquakes can indeed occur along the Cascadia mega thrust, or that the earthquake of 1700 had such a high magnitude (8.7 to 9.2), or that it was indeed the source of the tsunami observed in Japan. Connecting the two events is an interesting scenario that is plausible, but the forensic geologic evidence on which it is based is largely circumstantial.

Although the book does not provide all the answers, nonetheless it is a valuable contribution that helps understand better the vulnerability of the Pacific Northwest and offers a strange sort of comfort in the knowledge that if a major or great earthquake occurs in the future, there will be additional vigilance and tsunami preparedness in the region. Thus, the purpose of the book to provide an overview of potential future risk factors for disaster assessment and mitigation is partially achieved. However, as the chosen title connotes, "The Orphan Tsunami of 1700" in Japan, may still remain a partial mystery, at least until additional geologic or tsunami run-up evidence elsewhere in the Pacific, ties it together conclusively to an earthquake in the Cascadia region.

DETAILED REVIEW OF THE ORPHAN TSUNAMI OF 1700

PART 1

In summary, Part 1 of the book, titled "Unearthed earthquakes", provides a cursory review of past historical earthquakes in the Cascadia region, speculates on their magnitudes and tsunamigenic potential on the basis of recently found paleotsunami deposits, makes comparisons with other known seismically active subduction regions of the world where large megathrust tsunamigenic earthquakes have occurred – claiming that they are analogous - and concludes that great earthquakes of magnitude 8 or 9 can occur also along the Cascadia Subduction Zone (CSZ).

More specifically, this section addresses the potential of tsunami generation in the region from megathrust earthquakes, and presents excerpts from diaries of early explorers which elicit lore of native tribes about flooding from the sea and recessions – one lasting for as much as four days - but not associated with any earth shaking motions.

Subsequently presented is an overview of the effects of extensive subsidence along Cascadia's Pacific coast, which has resulted in ghost forests inside areas that are now tidal marshes. Analogies are drawn from the 1964 Alaska earthquake, which caused extensive land subsidence, tidal incursions and depositions of sand and silt, thus burying preexisting surface soils. Examples are given of tree ring analysis as clues that the shoreline subsidence was sudden, following earthquake events on the megathrust. Associated geological evidence is presented that tsunamis must have overran the subsided areas, since sand sheets were found on top of previous soil surfaces – as with tsunami action in Chile, Japan and Alaska. Additional geologic evidence is provided that earthquake-induced subsidence was the cause of destruction of native campsites along the coast of Washington State. Also, examples are given which illustrate that strong shaking from earthquakes must have caused the filling of cracks and of other geological intrusions and the geomorphologic features found during surveys of shorelines along the Pacific Northwest.

Finally, based on this geologic evidence, this section of the book poses the question on whether the Cascadia region has the potential for earthquakes of moment magnitude 9, admitting to an existing impasse in reaching scientific consensus on this matter. However, claims are made that the geologic deposits and the dead trees that are separated by great distances - but linked as concurrent in time by radiocarbon dating and dendrochronology - indicate that the Cascadia earthquake of AD 1700 had a great rupture. On the basis of the purported long rupture of 1,000 Km or more, a final claim is presented that the earthquake had moment magnitude that could have ranged from 8.7 to 9.2.

Comments for Part 1

Although brief, the discussion in Part one of the book is informative and well presented but leaves a number of questions unanswered while raising new ones. The discussion does not extent to the specific seismogenic parts of the Cascadia megathrust – an analysis of which could improve the understanding of the mechanics of this important fault zone or why and how it could be considered analogous to other subduction zones where large earthquakes have occurred and destructive tsunamis have been generated. For example, there is no discussion of the state or origin of the N-S compressive stress field along the Cascadia Subduction Zone (CSZ). Is the stress field really analogous to that of other subduction zones and can the region indeed generate earthquakes with an upper range moment magnitude of as much as 9.2? Furthermore, is such large magnitude possible along the CSZ in view of the fact that there have been few, if any, earthquakes recorded instrumentally?

An earthquake of such magnitude would require a continuous rupture from the Mendocino fracture zone in the south to the Queen Charlotte Fault in the north. We know from recent geophysical and geological investigations that the rupture-zone geometry of the CSZ has potential constrains that could prevent such long crustal fracturing. Therefore, how can the unusual aspects of this region be mechanically similar to other major plate boundary faults around the world, given the additional fact that the seismogenic part of the Cascadia megathrust appears to be located offshore and west of the CSZ? Two major earthquakes with magnitudes of 7.2 in June 14, 2005 and in November 8, 1980 occurred west of the CSZ and did not generate tsunamis. The April 25, 1992, Cape Mendocino earthquake (M=7.2), at the southernmost part of the subduction zone, generated a relatively small tsunami. Maximum tsunami wave height (peak-to-trough) was 1.1 meters at Crescent City, and 0.2 meters at Point Arena, California, and only 0.1 meters in the Hawaiian Islands.

PART 2

The more extensive Part 2 of the book provides a great historical account of a destructive tsunami of unknown origin - “The Orphan Tsunami of 1700” - that struck nearly 1,000 km of the Pacific coast of Japan, in the evening of January 27/28, 1700.

The primary sources of the historical information are listed and beautifully illustrated with copies of original accounts and old maps of ports and coastlines of Honshu and Hokkaido Islands. According to the old Japanese government manuscripts, tsunami waves as high as 15 feet inundated several coastal towns and villages along a 500-mile stretch of the Island of Honshu in northern Japan. Waves up to 10 feet high damaged 20 homes in the town of Miyako and further south rice paddies and storehouses were flooded.

Additional information is provided on even earlier destructive historical tsunamis and further correlated with Samurai scribes and records. Specific tsunami amplification factors for certain regions of Japan are discussed and the heights of the 1700 tsunami are estimated – for some areas - based on recorded losses of human lives. The chronology of recorded events in the Japanese calendar is then correlated and converted to times and dates in the Gregorian calendar, in an effort to link in time a possible distant origin source for "the orphan tsunami". Subsequently presented are the results of a numerical simulation study that postulates the tsunami's source to be a large megathrust earthquake off the Pacific Northwest. Based on the tsunami travel time from the Pacific Northwest to Japan, it is subsequently deduced that the Cascadia earthquake must have occurred at about 9 p.m. on January 26, 1700.

Comments for Part 2

The entire part 2 section of the book is an outstanding work of scholarship with the usual perfection and thoroughness that characterizes Japanese record keeping and their pioneering tsunami research work. The numerical study is valid but it should be pointed out that the earthquake source parameters are primarily based on conjecture. However, the exactness of the dating of the Cascadia event and the reconciliation of chronologies and calendars are addressed in the commentary for Part 3.

PART 3

The third part of the Book entitled "The orphan's parent" is an effort to further document a dogmatic opinion originally expressed at the 1996 meeting of the Trans-Pacific Reunion that the "parent" event that caused the tsunami in Japan was the postulated magnitude 9 Cascadia megathrust earthquake. On the basis of subsequent geologic findings and through a process of "elimination" – since no other great earthquake occurred elsewhere in the Pacific - this section refocuses on a Cascadia source earthquake. Correlation to the Cascadia "parent" event is further advocated on the basis of earlier work on tree-ring tests and dendrochronology, which placed the approximate window of time for the megathrust earthquake to be - for a certain area only - in the range of August 1699 and May 1700. From this evidence, and radiocarbon dating of "paleotsunami" deposits that give a time range of about 1700 -1710 (+/- 10 years), a conclusion is provided that large earthquakes had struck the Pacific Northwest repeatedly in the past several thousand years and - as previously stated - the latest Cascade megathrust event purportedly occurred in the evening (9 P.M) of January 26, 1700.

Subsequently, based on the geographical spread of the observations, this section reiterates that the rupture of the Cascadia megathrust earthquake was at least 1,000 km long and, thus, the moment magnitude in the range of 8.7 to 9.2 – as much or even more than that of other great tsunamigenic earthquakes in other subduction zones. Furthermore, in an attempt to establish a recurrence frequency of megathrust earthquakes, the subsequent section presents data and illustrations identifying episodes of subsidence along the Pacific Northwest. These episodes are then correlated to megathrust earthquakes, the relative chronology of occurrences is established and an estimate of 10% probability of recurrence in the next 50 years is assigned to the next great Cascadia earthquake.

The final section of Part 3 concludes with some useful information on preparedness and disaster mitigation measures. It includes a cursory discussion of disaster preparedness issues from a repeat of the great Cascadia earthquake and tsunami and provides some general guidelines for hazard zones and safe areas – as obtained from tsunami hazard modeling studies.

Comments on Part 3

The conclusions of Part 3 of the book linking the "orphan" tsunami in Japan to the purportedly contemporaneous, great Cascadia megathrust earthquake of 1700 are based on postulations which appear to be reasonable but which, however, lack definitive confirmation. They are based on conjecture and are somewhat contradicted by current geological and geophysical findings. The analysis and conclusions linking the two events together in Part 3 raise questions as pointed previously, but also invoke the need for additional commentary.

Although the origin of the "orphan" tsunami may have been unknown since there was no earthquakes recorded in Japan, Kamtchatka, Alaska, or South America that year (A.D. 1700), it is possible that a different source - such as a landslide or an unreported or unfelt earthquake - may have caused it. The 1992 earthquake in Nicaragua is an example of such a silent offshore earthquake. None of the people in Central America felt any strong earthquake motions before the tsunami struck. Therefore, it is possible that the "orphan" tsunami in Japan may have had a similar unknown local or distant origin source – and not necessarily from the Cascadia region. No paleotsunami deposits have been found in Hawaii or elsewhere in the Pacific that would support the generation of a Pacific-wide tsunami from a Cascadia earthquake. Furthermore, tsunamis from major earthquakes in Northern Japan in 1963 and 1994, or the great Kamchatka earthquake of 1952 – which had similar energy path orientation but from the opposite side of the Pacific – were not significant in the Pacific Northwest. Therefore, why should we assume that a Cascadia earthquake was the parent source event of the "orphan" tsunami in Japan, when the well-documented and more recent data for other events does not support major azimuthal focusing of tsunami energy?

Additionally, the postulated chronology of events on both sides of the Pacific could be incorrect given the differences of calendars, the limits of error in radiocarbon dating techniques (+/- 10 years), or the seasonal time window of dendrochronology. Even if we assume that all corrections reconciling calendars (Japanese, Julian and Gregorian) were made correctly – which is doubtful - to deduce that the Cascadia earthquake occurred at about 9 P.M. on January 26, 1700 based on the 10 hour tsunami travel time to Japan, as determined by the numerical modeling study which postulated such a source, is a self fulfilling prophesy. It is unwarranted accuracy based on compounded conjecture.

Even if we assume that the chronology is correct, can we really conclude that all of the purported paleotsunami sediments found over a large expanse of the Pacific Northwest were deposited by a single tsunami generated by a single Cascadia earthquake? Could there have been more than one event, perhaps closely spaced in time? Many subduction zones produce large earthquakes within days or weeks apart. The subduction zones in Japan and the Solomon islands have produced major or great earthquakes, days or weeks apart, as one segment of a fault stress loads another. The recent earthquake of December 26, 2004 in Sumatra is another example. Stress load transfer caused the great Nias island earthquake of March 28, 2005 in the adjacent southern segment of the Great Sunda Subduction Zone, three months later.

Additionally, could it be that some of the purported paleotsunami sediments and sand layering found in the Pacific Northwest were actually deposited by storm surge action, flash flooding, or some other rapid depositional mechanism that could also account for the random mix of sediment particle sizes?

Furthermore, can we reasonably conclude that one single megathrust earthquake in the Cascadia region in 1700 had a rupture of 1,000 or more km and a moment magnitude of as much as 9.2, based only on the presumption of widely scattered sediment layers believed to have been deposited by a single tsunami? Is such a long rupture possible on the CSZ given the fact that the Cascadia zone has not produced any earthquakes with magnitudes greater than 6 during the past 70 years? This fact alone has convinced many scientists that the region is relatively inactive – not necessarily because of locking - but because sediments from the Columbia River must constantly ``lubricate" the downward-thrusting oceanic plates so they never build up significant strain – thus believing that earthquakes with moment magnitude 9 are highly unlikely to occur in the future.

Unfortunately, the book “The Orphan Tsunami’ had already been written when the 7.2 magnitude earthquake of June 14, 2005 occurred off the coast of Northern California. An analysis of this event, if included in the book, would have been useful in the assessment of potential megathrust tsunamigenic earthquakes near the Cascadia Subduction Zone. Only a sensitive tide gauge recorded a 3 cm tsunami. This latest earthquake occurred inside the highly deformed southernmost portion of the Juan de Fuca plate, known as the Gorda plate. In spite of the earthquake’s proximity to the subduction zone, its crustal displacements resulted from slip on a NE striking, left-lateral, strike-slip fault on the seismogenic portion of the Gorda plate - which we know to be highly deformed. In fact the epicenter of this quake was about 67 miles west of the epicenter of the November 8, 1980, where a 7.2M earthquake, which had been even closer to the CSZ, but did not generate a tsunami.

This latest earthquake event of June 14, 2005, raises several additional questions that create doubt as to some of the conclusions provided in the “Orphan Tsunami”. The length of the rupture has been previously addressed but must be questioned again. Could all segments of the CSZ from the Mendocino fracture boundary plate to the Queen Charlotte fault break in sequence for a length of 1,000 km to generate a 9.2 earthquake? Where would the rupture originate? Would it originate near the Nootka fracture zone of the central Juan de Fuca plate, which separates it from the northern Explorer segment, and, if so, how could it be 1,000 km long? Would it originate near the Blanco Fracture Zone close to the northern boundary of the Gorda plate and extend north? Or would perhaps originate at the southeastern most corner of the Gorda plate near the triple junction where the CSZ joins the Mendocino Fracture Zone and the San Andreas fault? The 7.2 magnitude Cape Mendocino earthquake in 1992 occurred near the triple junction but no great rupture occurred. The tsunami was relatively small in Crescent City and elsewhere. There was no significant tsunami along the Pacific Northwest.

Also, additional questions arise from the conclusions of "The Orphan Tsunami" about Cascade earthquakes with moment magnitude 9 - given the complexity of Cascadia's stress provinces. For example, both the Pacific Northwest Province and the Cascade Convergence Province have compressive stresses but one has a N-S orientation while the other has a NNE-SSW orientation. This could be a limiting factor in rupturing. Therefore, are the apparently different types of compression geometry and segmentation along the CSZ, limiting factors as to the size of earthquakes that can occur and the length of potential ruptures? Should we perhaps accept that the CSZ has different geometry and stresses than the subduction zone along the Great Sunda Trench? Can we reasonably categorize the two regions and their tectonics as being analogous? Would a segmentation and fragmentation analysis of the Juan de Fuca or Gorda plates show that such a long break might not be possible? Shall we perhaps reexamine the tectonic plate motions in the entire Pacific Northwest? We have divergence on the western boundary of the Juan De Fuca tectonic plate and convergence along the eastern boundary. We have rotation along the southern boundary. Could perhaps large earthquakes in Cascadia involve blocks with maximum rupture lengths of only 200 – 250 km as those along the Japanese subduction zone? Finally, can indeed tsunamis be generated in the Cascadia region that can have destructive far field effects as far away as Hawaii or Japan? Finally, shall we perhaps look somewhere else for the parent event of the "Orphan Tsunami" rather than in the Cascade region?

CONCLUSIONS

"The Orphan Tsunami" is a great book with very useful information in assessing the tsunami risk of the Pacific Northwest, but does not provide all the answers. The authors do a magnificent job of documenting the historical information of the tsunami in Japan and in outlining potential tsunami risks of the Pacific Northwest from major earthquakes that can indeed occur along the Cascadia Subduction zone – although potential magnitudes may have been overstated. The major conclusion linking the "orphan" tsunami in Japan to a Cascade megathrust, magnitude 9 earthquake is based primarily on conjecture and peripheral circumstantial evidence. Thus, the title "The Orphan Tsunami" was properly chosen for the book, which, in spite of its wealth of data, elaborate detective work, and seemingly persuasive arguments – still leaves us with the uncertainty of what really was the parent event that resulted in the destructive tsunami of 1700 in Japan. What is presented in the book is a possible scenario but not necessarily what actually happened. However, this should not detract from the value of the book as an outstanding work of scholarship and documentation, even in the absence of adequate historical or geological data to work with and sufficiently link the two disaster events.