Front cover

A simulated tsunami reaches Japan ten hours after its start along the Pacific coast of North America (p. 74-75).

Back cover

Sailboats skirt a pine-covered spit where Japanese villagers puzzled over a tsunami of remote origin in 1700 (p. 76-79). At the nearby castle, the word *tsunami* received its earliest known use in 1612 (p. 41). Map, from 1687, courtesy of East Asian Library, University of California, Berkeley.

The Orphan Tsunami of 1700

みなしご元禄津波

A merchant's notebook, in an entry for January 1700, tells of a tsunami that lacked an associated earthquake in Japan. The shaking occurred instead along the northwest coast of North America. A French map compiled in 1720 shows what Europeans then knew of those shores.

jishin nite mo
earthquake

tsukamatsurazu
did not occur

Quote from Moriai-ke "Nikki kakitome chō" (p. 50-52). Map by Guillaume Del'Isle, from University of Washington Libraries, Special Collections Division (p. 2, 5).

The Orphan Tsunami of 1700
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Japanese clues to a parent earthquake in North America
親地震は北米西海岸にいた

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LANGUAGE NOTES

みなしご	元禄	津波
minashigo	*Genroku*	*tsunami*

THE BOOK'S TITLE in Japanese, "Minashigo Genroku tsunami," means "The orphan tsunami of the Genroku era." In western calendars, the Genroku era began in 1688 and ended in 1704. Japanese written records tell of but one Genroku tsunami of remote origin. It dates to the year 1700 (p. 42).

親地震	は	北米	西海岸	に	いた
oya-jishin	*wa*	*Hokubei*	*nishi kaigan*	*ni*	*ita*

THE SUBTITLE, "Oya-jishin wa Hokubei nishi kaigan ni ita," means, "The parent earthquake was along the west coast of North America."

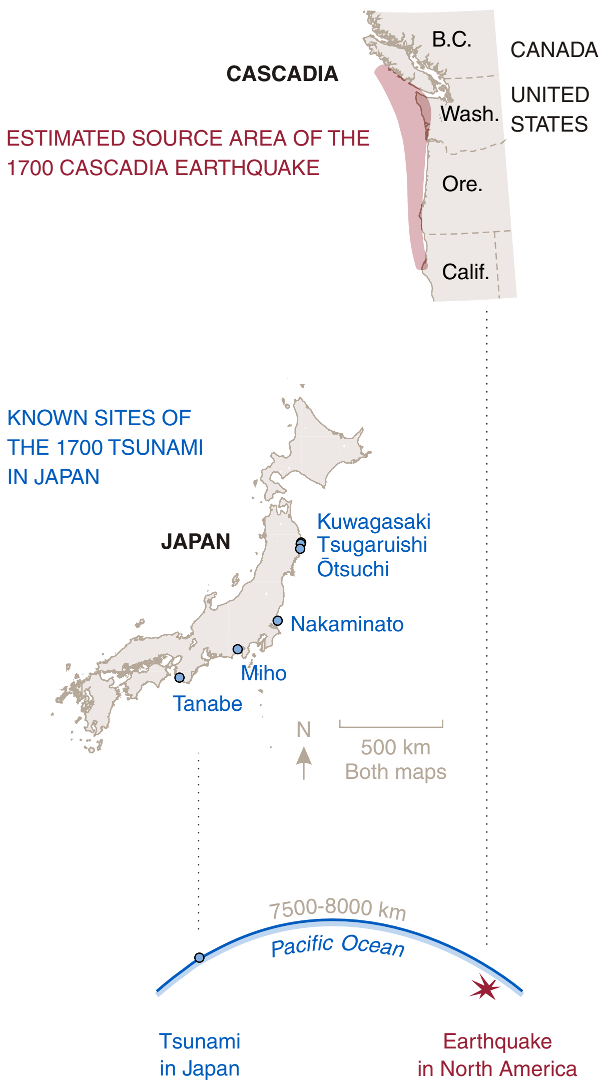
JAPANESE CITIZENS' NAMES appear in customary order, family name first. For clarity, the authors' family names contain small capital letters on the title page, pages 110-111, and the back cover.

TO WRITE JAPANESE WORDS in Roman letters we use a variant of the Hepburn system. The vowel sounds resemble those in Spanish: *a* resembles the first vowel in "mama," *e* the final vowel in "Santa Fé," *i* the second vowel in "police," *o* the first vowel in "José," and *u* the first vowel in "uno." The combination *ei* prolongs the *e* sound, as does *ii* for *i*. Prolonged *o* and *u* take macrons (*ō*, *ū*) except in internationalized words (Tokyo = Tōkyō). The *n* is pronounced *m* before *b* or *p* (Nambu, Sumpu) as it is in English (imbalance, empower). Additional changes in sound at the junctures between syllables or words are footnoted on pages 38, 52, 60, 68, and 78. A slight pause precedes a doubled consonant (*yokka*).

JAMES CURTIS HEPBURN (1815-1911), an American missionary, devised the system now employed widely, in modified form, to transcribe Japanese sounds into Roman letters. The standard dictionary by Nelson and Haig (1997) uses the Hepburn system. We hyphenate most counters (as in *niji-kken*, p. 39) but follow Nelson and Haig in closing compounds for the day counter *ka* (*yōka, yokka*).

Contents 目次

This book tells the scientific detective story of a giant earthquake and its trans-Pacific tsunami.



Part 1 illustrates geologic signs of enormous earthquakes and tsunamis at Cascadia, along the Pacific coast of North America from British Columbia to California.

Part 2 presents old Japanese writings about a tsunami of mysterious origin that caused flooding and damage in January 1700 from Kuwagasaki in the north to Tanabe in the south.

Part 3 links this orphan tsunami to a Cascadia earthquake and to seismic hazards in the western United States and Canada.

PAGE

The Orphan Tsunami of 1700

みなしご元禄津波

Still-uncharted shores in North America were home to a giant earthquake and its tsunami in the year 1700, two decades before France's royal geographer compiled this map. In North America, the catastrophe left traces on the landscape and probably in the oral histories of native people. Across the Pacific, the tsunami entered Japan's written history as a sea flood without local cause. Three centuries later, the combined clues would reveal that the North American earthquake probably attained magnitude 9.

Introduction はじめに

OUTSIDERS SCARCELY KNEW of northwestern North America in the year 1700. Leading European geographers of the time left that part of the map blank. Not until 1741 would Russians land in Alaska. From there to Oregon's Cape Blanco, the coast would remain uncharted until Spanish and English expeditions of the 1770s.

Across the Pacific Ocean in Japan, unusual seas ran ashore in 1700. People wrote of the effects: flooded fields, wrecked houses, a fire, a shipwreck, evacuation, fright. Having felt no earthquake beforehand, some writers called the flooding a “high tide” and most resisted calling it a tsunami. None could have known that a seismic shift on a North American fault had set off a train of trans-Pacific waves. Far from its parent earthquake, the tsunami of 1700 was an orphan.

The 1700 tsunami in Japan would remain an orphan for nearly three hundred years. The North American fault at its source would go unnoticed until the last decades of the 20th century. Today the fault is charted, and an earthquake on it is regarded as the orphan’s parent. This kinship gives the earthquake an exact date (January 26, 1700) and an estimated size (magnitude 8.7-9.2) that spur precautions against future earthquakes and tsunamis in the United States and Canada.

THE INDIAN OCEAN TSUNAMI of December 26, 2004, reminded the world of what an earthquake of magnitude 9 can do. Earth rarely provides such reminders; only three 20th-century earthquakes reached or exceeded magnitude 9.0 worldwide.

The Indian Ocean disaster, by affecting areas from southeast Asia to Africa, raised concern about earthquake and tsunami hazards around the planet. The disaster reminded North Americans of such hazards not only in Alaska, struck in 1964 by an earthquake of magnitude 9.2, but also at Cascadia—the region west of the Cascade Range from southern British Columbia to northern California.

Cascadia is home to a gently inclined boundary between two of the moving tectonic plates that make up Earth’s outer shell. The shallow, mostly offshore part of the boundary is the fault that ruptured in 1700. What losses will Cascadia sustain the next time it breaks? A scenario printed in 2005, several months after the Indian Ocean disaster, gives an idea of what to expect.

The scenario begins with an earthquake of magnitude 9.0. Strong shaking lasts for minutes along the Pacific coast in British Columbia, Washington, Oregon, and California. The main coastal highway, U.S. 101, becomes largely impassable, and landslides “sever highway travel between the coast and inland areas.” Thus isolated, coastal residents “have to do much of the work of rescuing those trapped in the rubble.”

The expected damage extends inland to Vancouver, Seattle, and Portland. In this urban corridor, "utilities and transportation lines in some areas could be disrupted, perhaps for months." Damage to tall buildings "could lead to significant fatalities in downtown areas."

These risks used to be unthinkable. Cascadia has no written records of homemade earthquakes larger than magnitude 7.5, nor of trans-oceanic tsunamis generated in its backyard. However, the region does have geologic records of great earthquakes—shocks of magnitude 8 or larger—and of tsunamis they spawned. It is the most recent of these Cascadia tsunamis that entered written history in Japan.

RECOGNIZING A HAZARD is just the first step toward dealing with it. Next, the hazard must be defined well enough for practical precautions to be devised and put into effect.

Discoveries about the orphan tsunami of 1700 helped drive this process at Cascadia. Earth science in North America revealed earthquake and tsunami hazards that Japanese history sharply defined. The findings spurred precautionary steps like the mapping of areas that future Cascadia tsunamis may flood and the posting of evacuation signs. The safeguards also include teaching schoolchildren the basics of tsunami survival: If you feel a strong earthquake, run to high ground. If the sea recedes strangely, run to high ground. If a tsunami ensues, stay on high ground; its first wave probably won't be the last—or the highest.

If only such precautions could have been taken around the Indian Ocean before its 2004 disaster. Most of the victims experienced the earthquake, which was felt even in Thailand and Sri Lanka. Many saw the sea withdraw before the first damaging wave. Some thought the first wave would be the last. Almost everyone was surprised by the earthquake's magnitude and by the tsunami's height and reach. The 2004 earthquake and tsunami were outsize events with hardly any known precedent in the Indian Ocean's past.

IN THIS BOOK we use the past to help warn of outsize earthquakes and tsunamis of the future. We assemble clues from both sides of the Pacific to establish precedent for a giant Cascadia earthquake and its tsunami. We tell the detective story behind some of the recent precautions against earthquakes and tsunamis in western North America.

Five of us were among the detectives. Ueda and Tsuji identified, verified, and correlated several of the Japanese accounts of an orphan tsunami from 1700. Satake recognized this tsunami's probable link to North American geology and estimated the parent earthquake's size. Atwater discovered some of that geology and Yamaguchi led in dating it, with tree rings, to a 10-month window that contains the orphan tsunami's time.

The discoveries thrilled and astonished us—and they still do. But they also bring to mind the Indian Ocean disaster. How many actual orphans did the tsunami of 1700 create?

SIGNS OF CATASTROPHE in 1700 can still be seen in sediments and trees of northwestern North America and in archives of shogunal Japan. Having been privileged to examine these clues, we try to tell the story through them.

The Japanese archives tell of the 1700 tsunami in the words of magistrates, merchants, and peasants. We reproduce each account in full and, guided by linguist Musumi-Rokkaku, state its literal meaning in English. We also explore how each account came to be written and preserved, and how earthquake historians learned of it. Today's North American precautions against earthquakes and tsunamis are founded, in part, on these minutiae of Japanese history.

THE MAP on the frontispiece and page 2, "Hemisphere occidental," was compiled in 1720 and published in 1724 by Guillaume Del'Isle, then France's foremost cartographer (Portinaro and Knirsch, 1987, p. 314; French, 1999, p. 353-354). Del'Isle began publishing maps in 1700, gained a reputation for accuracy, and was appointed royal mapmaker—Premier Géographe du Roi—in 1718. University of Washington Libraries, Special Collections, UW23622z.

EARLIER MAPS that leave northwestern North America blank include "Nova totius terrarum orbis tabula" by Frederick de Wit, 1665; "Novissima totius terrarum orbis tabula" by John Seller, ca. 1673; de Wit's "Totius Americae descriptio," 1690, and "A new map of America" by Edgar Wells, 1700 (Portinaro and Knirsch, 1987, p. 186-209). Hayes (1999) chronicles the European discovery of northwestern North America by presenting the explorers' maps.

FAMILIAR WESTERNERS OF 1700 include Antonio Vivaldi, Johann Sebastian Bach, George Frideric Handel; Daniel Defoe, Jonathan Swift, Alexander Pope; Issac Newton, Gottfried Wilhelm von Leibniz, Jakob Bernoulli, Edmond Halley, Gabriel Daniel Farenheit; John Locke, Voltaire, Montesquieu; Rob Roy, William "Captain" Kidd; and Peter the Great. Charles Perrault's "Little Red Riding Hood" appeared in 1697. In 1700 London was Europe's largest city with a population of 550,000. In England's North American colonies, residents of Boston then numbered 7,000, and New York was a town of 5,000. The school later renamed Yale University opened in 1702. Benjamin Franklin was born six years after the 1700 earthquake. Sources: Pascoe (1991), Garruth (1993), and Williams (1999).

"A MAGNITUDE 9.0 EARTHQUAKE SCENARIO" was prepared by a panel of scientists, engineers, and officials from government and industry, the Cascadia Region Earthquake Workgroup (2005). The scenario does not include numerical estimates of losses of life or property.

THE 2004 SUMATRA-ANDAMAN EARTHQUAKE was felt, at low intensity, in Sri Lanka, peninsular India, Myanmar, Malaysia, and Thailand. Estimates of the earthquake's moment magnitude range from 9.0 (for seismic waves of 300-second period) to 9.3 (including waves of periods >500 seconds). By the criteria used to estimate the size of the 20th century's largest earthquakes (graph, p. 98), the 2004 Sumatra-Andaman earthquake attained magnitude 9.0 (Lay and others, 2005).

THE INDIAN OCEAN has a written history of dozens of tsunamis since the middle of the 18th century (http://www.ngdc.noaa.gov/spotlight/tsunami/tsunami.html). One of the largest of these was generated in 1833 during an earthquake of estimated magnitude 8.8-9.2 along the west coast of Sumatra (Zachariasen and others, 1999). Its rupture area lies a few hundred kilometers south of the southern end of the 2004 break. Northern parts of the 2004 rupture are the most likely sources of earthquakes of magnitude 8 in 1847, 1881, and 1941 (p. 101). A tsunami in the Bay of Bengal is known to have accompanied the earthquake of 1881 (Bilham and others, 2005, p. 304).

A TSUNAMI-SURVIVAL GUIDE by Atwater and others (1999) mentions Pacific and Atlantic hazards but not the Indian Ocean.

DOCUMENTARIES on findings central to this book include:
"The quake hunters"
http://www.films.com/id/10444
"Cascadia, the hidden fire"
http://www.globalnetproductions.com/products.html
"The next megaquake"
http://www.bbc.co.uk/sn/tvradio/programmes/horizon/megaquake_qa.shtml
"Unearthing proof of a tsunami in the Pacific Northwest"
http://www.npr.org/templates/story/story.php?storyid=4629401