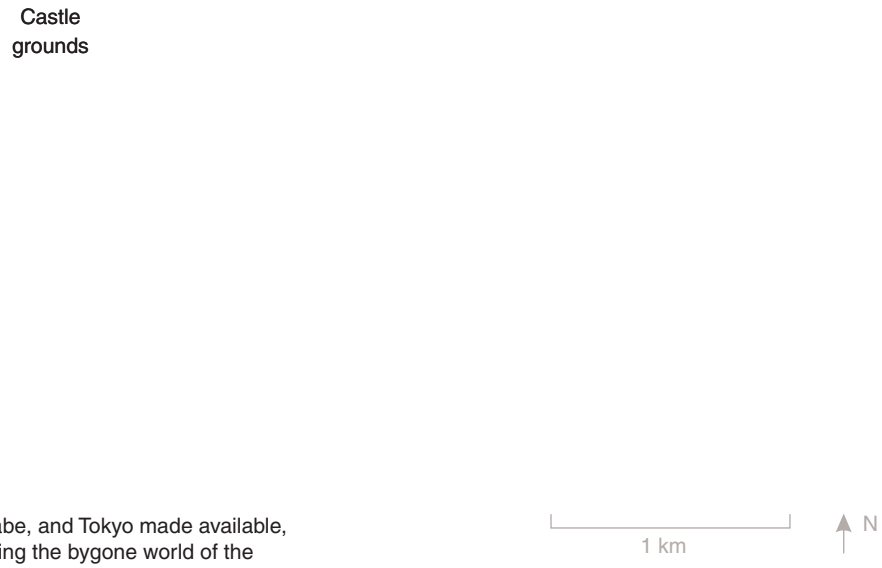
Acknowledgments 謝辞



Libraries in Berkeley, Morioka, Seattle, Tanabe, and Tokyo made available, for use in this book, maps that aid in visualizing the bygone world of the orphan tsunami of 1700. The example above—from the collection of the East Asian Library of the University of California, Berkeley—shows moats and samurai neighborhoods spiraling around the castle grounds of Edo in 1684. The white box outlines an area of daimyo mansions (enlarged view, p. 61).

The Berkeley collection can be viewed at http://www.davidrumsey.com/japan/. The image above is excerpted from "Eiri Edo ōezu," published in Ten'na 4 by Hyōshiya Ichirōbe'e. Courtesy of East Asian Library, University of California, Berkeley.

WHERE JAPANESE WRITERS recorded the 1700 tsunami, dozens of people helped us explore questions central to this book: Who wrote the original accounts of the flooding and damage? Why were these accounts written and how were they preserved? Which passages contain errors in copying? Where are the places described as flooded? Were these same places reached by the 1960 tsunami as well?

In Morioka, Konishi Hiroaki granted access to the Morioka-han documents reproduced on pages 36, 38-39, 44-45, 58, and 60. He provided clues on how Morioka-han "Zassho" was compiled, documentation on senior ministers named there, and likely dates for the early 18th-century maps of Miyako-dōri and Ōtsuchi-dōri (p. 36, 44, 58). He serves as librarian of the Documents Office, Morioka City Central Community Center (Kyōdo Shiryō Shitsu, Morioka-shi Chūō Kōminkan).

On the coast in modern Miyako city, Yamazaki Toshio and Sasaki Tsutomu identified places inundated by the 1960 tsunami in Kuwagasaki and Tsugaruishi (photos, p. 49 and 51). In 1999, Mr. Yamazaki was fire chief and Mr. Sasaki one of his deputies at the Central Fire Station of the Miyako Unified Fire District (Miyako-chiku Kōiki Kumiai Gyōsei, Shōbōsho Honbu). Shuto Nobuo of Iwate Prefectural University provided an introduction to Mr. Yamazaki and a walking tour of Kuwagasaki's tsunami-prone districts. Kishi Shōichi, a historian for Miyako city, shared his knowledge of Miyako's Edo-period governance. His successor, Kariya Yūichirō, helped us interpret and photograph Moriai-ke "Nikki kakitome chō."

In Tsugaruishi, Moriai Mitsunori granted access to his family's notebook, Moriai-ke "Nikki kakitome chō." He and his mother welcomed three of us into the family home (p. 53). Iwamoto Yoshiteru, an authority on the area's Edo-period economy (books, p. 116), provided guidance on obscure place names of Tsugaruishi (p. 50, 51, 56).

Morikoshi Ryō of Hachinohe helped Ueda identify copyist's errors in Moriai-ke "Nikki kakitome chō" by providing a transcription, in printed Japanese, of official records of Hachinohe-han, its "Han nikki" (footnoted, p. 52). Mr. Morikoshi leads Hachinohe Komonjo Benkyō-kai, a group that studies historical documents and which made the transcription of Hachinohe "Han nikki."

Moriai Mutsuharu, a retired schoolteacher in Tsugaruishi, adopted Atwater and Yamaguchi for a day of interviewing his fellow villagers about the 1960 tsunami (sites marked by blue and yellow dots, p. 56). Those who identified inundation limits include Yonezawa Takuji (in color photo, p. 57, upper right) and Moriai Miya (photo, below).

In Ōtsuchi, Maeda Zenji, Fujimoto Toshiaki, and Kamata Seizō provided guidance on Edo-period neighborhoods. They also shared the town's collection of photographs and maps showing sites inundated by the 1960 tsunami. When interviewed in 1999, Mr. Maeda headed Ōtsuchi's Historical Preservation Council (Ōtsuchi-chō Bunkazai Hogo Shingikai), while Messrs. Fujimoto and Kamata served as assistant director and archaeologist, respectively, in the town's office of continuing education (Ōtsuchi-chō Kyōiku I'inkai, Shakai Kyōikuka).

Ogawa Kaori journeyed to Ōfunato to learn about that city's devastation by the 1960 tsunami and its lack of writings on the 1700 tsunami (p. 81). She also checked for written records in Sendai. In Ōfunato she received help from Satō Etsuro of Ōfunato city, Shirato Yutaka and Kin'no Ryōichi of Ōfunato Museum, and Honda Fumito of nearby Rikuzentakada city.

Town officials, local historians, and private citizens of Hitachinaka (formerly Nakaminato) twice received visitors interested in tsunami evidence from Ōuchi-ke "Go-yōdome." The hosts included Kawasaki Osamu, Onizawa Yōichi, Onizawa Yasuhiko, Saitō Arata, Satō Tsugio, and, from the family that conserves the document, Ōuchi Yoshikuni. Town officials permitted photographs of the volume and of a picture map (p. 66-70).

In Miho, Endō Kunio kindly met with three North Americans to share with them "Miho yōji oboe" and how he came to possess it (p. 76). Mr. Endō's daughter, Mayumi, arranged a later gathering with two local historians, Endō Shōji and Watanabe Yasuhiro. She also provided copies of books on "Oboe" by Endō Shōji and others (p. 115).

Nagao Toshiyasu of Tokai University joined two of us in Miho for interviews of witnesses to the 1960 tsunami and 1974 storm: Shiba Tsune, Mizuno Teruko, and a lady in the Ishino family (p. 82-83). Moriguchi Osamu, of the central fire office of Shimizu city, arranged for an interview with another witness to the 1960 tsunami, Aoki Yukio.

Officials and residents of Tanabe welcomed us repeatedly for visits that included informative discussions with Kishi Akinori, a local historian, and field trips guided by

Shuto Nobuo at a memorial stone for the 1960 Chile tsunami near Miyako (map, p. 49). The inscription warns that even without an earthquake, a change in water level can mean a tsunami.

Moriai Miya of Tsugaruishi fields questions about flooding of her home by the 1960 Chile tsunami (p. 57, footnote). **Moriai Mutsuharu**, her neighbor, stands at right.

members of the city's general affairs office: its directors, Yamasaki Kiyohiro and Okamoto Yoshihiko, and staffers Urabe Shunji and Shin'ya Jun. Ōta Yūji, librarian with the municipal library, granted access to Tadokoro documents and shared his views of their history (p. 84-87). Hashimoto Kuniko and Minakata Fumie provided a tour of a Tanabe storehouse (photo, below left). In Shinjō, Matsuzaki Tomiji welcomed visitors to a storehouse site (p. 88) and Kashiwagi Tomio provided photos of the 1960 tsunami (p. 89).

Not far from Tanabe, in Hirogawa, Shimizu Isao gave three North Americans an enthusiastic, full-day field trip on Hamaguchi Goryō and his response to the 1854 tsunami that devastated Hiro-mura (photo, below right). At the time of that field trip, Mr. Shimizu was continuing education specialist at the town's community center, Hirogawa-chō Chūō Kōminkan. Tsumura Kenshiro, formerly of Hirogawa, further advised us on Goryō and "Inamura no hi." The picture on page 47 was taken by him and is reproduced with permission of the painting's owner, Yōgen Temple.

IN FORMER EDO, Watanabe Tokie of the Earthquake Research Institute (ERI), University of Tokyo, set up some of the rural visits. Murakami Yoshikane, while a graduate student at ERI, provided a speedy drive to northeast Japan. Katō Teruyuki of ERI advised us on tide-gauge data. Hirata Sakura and Kikuchi Ryōichi of Meiji University allowed us to examine maps of Japan and Suruga province from 1702 (p. 32, 76). Ota Yoko, formerly of Yokohama National University, helped us interpret the picture maps of Morioka-han (p. 36, 44, 58), the inland waterways between Nakaminato and Edo (p. 67), and land-level changes in northeast Japan (p. 65). She also arranged for an Edo mansion for Atwater and his family; and Joel Muraoka provided Tokyo lodging for Yamaguchi.

In nearby Tsukuba, Okada Masami and Tanioka Yūichirō of the Meteorological Research Institute, Japan Meteorological Agency, checked tidal measurements and datums. Odagiri Satoko, of the Geographical Survey Institute, provided old topographic maps. Staff of the Active Fault Research Center, a part of the National Institute of Advanced Industrial Science and Technology, extended countless courtesies to Atwater. These included telephone interviews and trip planning by Isoda Hisako, guidance on Japanese history and language from Horikawa Haruo and Nanayama Futoshi, and bibliographic work by Satō Nobue. Dr. Horikawa photographed the monument on page 45; Ms. Satō, the anthologies on pages 62 and 123. Azuma Takashi led the visits to Hitachinaka and to the shogunal maps at Meiji University (p. 32, 76).

Atwater's contributions to the book were made possible, in part, by several visits to Japan. During the longest of these, for nearly a year, his travel and living expenses were covered by Japanese government fellowships from the Center for Global Partnership, ERI, the Science and Technology Agency, and the Geological Survey of Japan. Persons who made these fellowships possible include Usui Akira and Ozaki Hiromi of the Geological Survey of Japan; Satō Hiroshi, Shimazaki Kunihiko, and Murakami Tomoko of ERI; and Ruth Reid and Rebecca Barnhart, and Jack Medlin of the U.S. Geological Survey (USGS).

Matsuda Izumi welcomed Atwater to her first-year Japanese language course at the University of Washington. Yamaguchi drew on Japanese language training that includes a summer program in 1976 (sponsored by Sumitomo Bank) and immersion during an appointment at the Hokkaido Research Center of the Forestry and Forest Products Research Institute from 1994 to 1996 (supported by Japan's Science and Technology Agency).

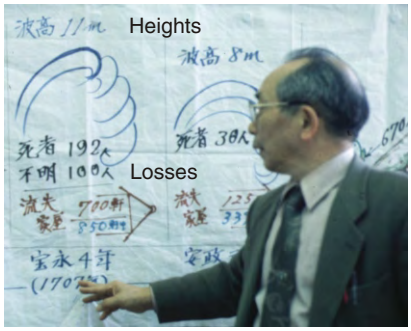
THE NORTH AMERICAN PARENT for Japan's orphan tsunami of 1700 became known through the work of a great many people. The principals include Hiroo Kanamori of the California Institute of Technology; Tom Heaton and Alan Nelson of the USGS; and Minze Stuiver of the University of Washington.

The Nuclear Regulatory Commission underwrote the radiocarbon dating of trees and herbs killed by tidal submergence from the 1700 earthquake (p. 24-25). In Minze Stuiver's lab, Philip Wilkinson analyzed the spruce samples.

Unsung heroes of the earthquake's tree-ring dating include Boyd Benson, Lori Davis, John Shulene, Karl Wegmann, and Marco Cisternas, all of whom helped dig out and sample the stumps of earthquake-killed red cedar.

Pierre Saint-Amand provided sharp prints of the Chilean photos on pages 10 and 11. The Alaskan airphoto on page 14 comes from the collection of A. Thomas Ovenshine and Susan Bartsch-Winkler, formerly of the USGS. Ian Shennan supplied one of the more recent Alaskan images on page 95.

Hashimoto Kuniko leafs through a book from the collection of Minakata Kumagusu (1867-1941), a mycologist and folklorist. She stands in a traditional Tanabe storehouse on a floor 0.4-0.5 m above the ground. The 1700 tsunami may have flooded such a raised floor (**B**, p. 88).



Shimizu Isao of Hirogawa enumerates losses of life and property from the 1707 and 1854 tsunamis in Hiro village (p. 47).

THIS BOOK began in 1999 as a manuscript too large for its intially intended outlet, a volume of papers on subduction zones. Andō Masataka—who twenty years earlier published a seminal paper on Cascadia's great-earthquake potential—released Atwater from a promise to contribute to that volume.

Critical review began that year with Andrew Moore, then at Tohoku University, and Ruth Ludwin, University of Washington. Ebara Masaharu of the Historiographical Institute, University of Tokyo, corrected subsequent transliterations and translations of the Edo-period documents.

Later drafts were reviewed in full by Emile Okal of Northwestern University; Ruth Pelz of the Burke Museum, Seattle; Yoko Ota; and Ruth Kirk, Kip Ault, Eric Blackford, and an anonymous reader on behalf of University of Washington Press. Suggestions from the anonymous reader spurred reorganization of the book and expansion of its chapters on the Cascadia subduction zone. Additional reviews were provided by Patricia Atwater, Lori Dengler, Adriana Erickson, Ned Field, Harumi Kato, Hayakawa Yukio, Hal Mojfeld, Joel Muraoka, Yoshiko Sorensen, and Vasily Titov. Pauline Curiel and Satō Nobue printed and circulated the reviewers' copies.

The book's covers were developed at University of Washington Press with design by Ashley Saleeba (first edition) and Tom Eykemans (second edition). Sophia Smith and Pat Soden contributed to the book's English title. Jacqueline Volin, Sarah Nagorsen, and Larin McLaughlin edited additions to the second edition.

The reference list includes titles located by Keiko Yokota-Carter, the Japanese-language specialist at the East Asia Library, University of Washington. Inoue Megumi, Nakamura Noriyuki, and Ekida Fusae, bilingual graduate students from Japan, translated reference materials and romanized bibliographic citations. Additional translations were provided by Tajima Maiko and Harada Shino. Annaliese Eipert helped compile the references.

The book's design is based on a USGS pamphlet by Peter Ward, Robert Page, Laurie Hodgen, and Jeff Troll, and on examples presented by Edward Tufte. Susan Mayfield and Sara Boore of the USGS provided guidance on color, fonts, and layout; Boore also prepared the block diagrams adapted on page 10. Ed Mulligan and Lorien Freeman, University of Washington, helped us mock up pages by providing computer-network connections and maintaining a color printer.

The USGS granted Atwater freedom to devote several years to the book. Michael Blanpied, Nancy Rountree, Peter Stauffer, and Jane Ciener helped set aside USGS funds for editing and printing. Ruth Kirk initiated discussions, with Michael Duckworth and Pat Soden, that led to joint publication by University of Washington Press.

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Morioka City Central Community Center, Documents Office—p. 36, 44, 45, 49, 50, 58
Ōfunato city—p. 81, 133
Sendai Museum—p. 127
Shinjō Community Center—p. 85, 89
Tanabe Municipal Library—p. 84, 90
United States National Archives and Records Administration—p. 12
University of California, Berkeley, East Asian Library—p. 26, 30-31, 41, 43, 61, 70-72, 76, 106, back cover
University of California, Berkeley, National Information Service for Earthquake Engineering—p. 9
University of Washington Libraries, Special Collections—frontispiece and p. 2, 13, 104, 129
Yōgen temple, Hirogawa—p. 47

The paper by Andō Masataka, with Emery Balazs, initiated the study of cyclic land-level change at Cascadia (Ando and Balazs, 1979). We consulted Ward and others (1989) and Tufte (1990, 2001) on book design.

The Nuclear Regulatory Commission, reviewing the design of this power plant, supported carbon-14 dating of Cascadia earthquakes (p. 25).

Satsop, Washington (location map, p. 96).

Boyd Benson, in an Oregon tidal swamp, checks the annual rings of a spruce survivor of the 1700 earthquake (p. 97).

Authors 著者紹介

Brian Atwater, Musumi-Rokkaku Satoko, Satake Kenji, Tsuji Yoshinobu, Ueda Kazue, and David Yamaguchi. Tokyo, 2004.

THE STORY OF THE 1700 TSUNAMI draws on human history interpreted from old Japanese documents, on natural history inferred from North American sediments, trees, and native legends, and on mathematical modeling of tsunamis. The authors pooled their backgrounds in these and other fields. Below, as on the cover and title page, their names appear alphabetically.

Brian F. ATWATER ブライアン・F・アトウォーター conceived of the book and led in its preparation. To this work he brought over a decade of experience with geologic records of the 1700 earthquake and tsunami in North America. Through field work in 1999 he also contributed to size estimates for the 1700 tsunami in Japan. He holds B.S. and M.S. degrees in geology from Stanford University and a Ph.D. in geology from the University of Delaware. In thirty years with the U.S. Geological Survey he has studied bay and river geology in California, ice-age floods in Washington, and geologic records of earthquakes and tsunamis in the United States, Chile, and Japan. He lives in Seattle and is based at the University of Washington.

MUSUMI-ROKKAKU Satoko 六角 聰子 guided the transliteration and translation of the tsunami accounts. She also contributed to interviews in northeast Japan and to historical background material. Her education includes a B.A. in Humanities at Tokyo's International Christian University and an ensuing year as a Fulbright Fellow at the University of Chicago, where she did graduate work in Islamic cultural history and Arabic language. Since 1979 she has coordinated the United Nations University fellowship program for Asian food scientists while teaching at Tokyo's Obirin University. She has served as an officer in the UNU Women's Association and holds an honorary professorship at the Mongolian University of Science and Technology. Her travels have taken her to 33 countries.

SATAKE Kenji 佐竹 健治 estimated sizes of the 1700 tsunami in Japan and the 1700 earthquake at Cascadia. He also tracked down primary sources for accounts of the 1700 tsunami in Tsugaruishi and Nakaminato. These contributions stem from his broad interest in subduction-zone earthquakes, which he studies with instrumental, written, and geological records, and with geophysical modeling. He holds B.S. and M.S. degrees in geophysics from Hokkaido University and a Ph.D. in geophysics from the University of Tokyo. He spent seven years in the United States, as a postdoctoral researcher at the California Institute of Technology and as an assistant professor at the University of Michigan. Since 1995 he has worked at the Geological Survey of Japan, where he is now deputy director of the Active Fault Research Center of the National Institute of Advanced Industrial Science and Technology. His field work in 2005 included post-tsunami surveys in Myanmar and Thailand. He chairs the tsunami commission of the International Union of Geodesy and Geophysics, serves on governmental committees that evaluate earthquake hazards in Japan, and edits "Rekishi Jishin," the journal of Japan's Society of Historical Earthquake Studies.

TSUJI Yoshinobu 都司 嘉宣 identified places reached by the 1700 tsunami, computed tides for estimates of the tsunami's height, and helped transliterate and translate the tsunami accounts. From the University of Tokyo he earned a B.S. in civil engineering, and M.S. and Ph.D. degrees in geophysics. His studies of Japan's historical earthquakes and tsunamis began in the 1970s, when he worked for the National Research Center for Disaster Prevention. In 1987 he joined the faculty of the University of Tokyo's Earthquake Research Institute. He subsequently participated in post-tsunami field surveys in Nicaragua and Papua New Guinea, and he led such surveys in 2005 in Aceh and Thailand. He has also investigated storm surges and tsunami-induced damage to buildings. His second languages include Korean, Chinese, Russian, English, and Fortran.

UEDA Kazue 上田 和枝 discovered, transliterated, and translated accounts of the 1700 tsunami. She also confirmed the tsunami's misdating in Moriai-ke "Nikki Kakitome-chō" (p. 53), investigated the historical context of the tsunami's accounts, and interviewed witnesses to the 1960 tsunami. For over thirty years she has specialized in the written records of Japanese earthquakes. She entered that field eleven years after earning a B.A. in psychology at Tokyo Woman's Christian College and joining the Earthquake Research Institute, University of Tokyo. The 21-volume, 16,812-page earthquake anthology, "Shinshū Nihon jishin shiryō" (p. 123), resulted largely from her efforts. These included some 300 visits to libraries, prominent families, government offices, temples, and shrines where she searched thousands of pages daily for accounts of earthquakes and tsunamis. Since retiring from the Earthquake Research Institute in 1998 she has remained active in meetings and publications on Japan's historical earthquakes.

David K. YAMAGUCHI デイビッド・K・ヤマグチ relentlessly revised the entire book for presentation and content. He also contributed tree-ring dates, photographs, and bilingual interviews in Tsugaruishi, Miho, and Tanabe. A Seattle-born grandson of Japanese immigrants, he earned a B.S. in biology at Yale and a Ph.D. in forestry at the University of Washington. While a graduate student, he dated two eruptions of Mount St. Helens to 1479-1482 from the thin rings of trees damaged downwind. These findings led to a postdoctoral fellowship with the U.S. Geological Survey, where he dated volcanic debris flows by matching the ring-width patterns of entombed trees with those of living ones. During that fellowship he began the coastal tree-ring studies that helped identify Cascadia as the source of the orphan tsunami (p. 24, 96-97). Those studies progressed while he served on the research faculty of the University of Colorado and worked as a visiting scholar at the Forestry and Forest Products Research Institute, Hokkaido. Later he became a financial advisor at Merrill Lynch and a public-health statistician at the University of Washington's School of Dentistry. He now analyzes public-health data as a programmer at the Center for Health Studies, Group Health Cooperative, Seattle.

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A village elder saves his fellow villagers from a tsunami in a story that was introduced to Japanese school-children in the 1930s and 1940s (textbook cover, left). Inspired by real events in 1854 (p. 47), the plot runs through video frames on succeeding pages. Related references are listed under the author names Hearn, Hodges, Shimizu, and Tsumura.

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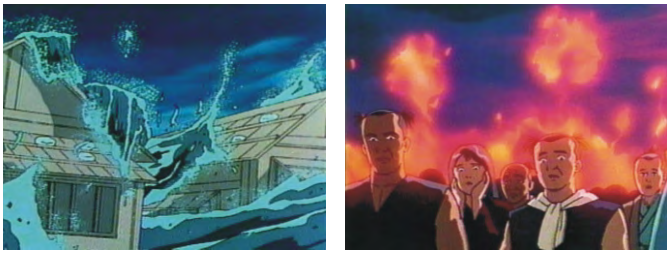
VIDEO FRAMES from "Inamura no hi" ["The rice-sheaf fire"], courtesy of Gakken Co., Tokyo.



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First volume, shelved at upper right, was published in 1981.

Fingered volume, published in 1993, contains accounts of the orphan tsunami of 1700.

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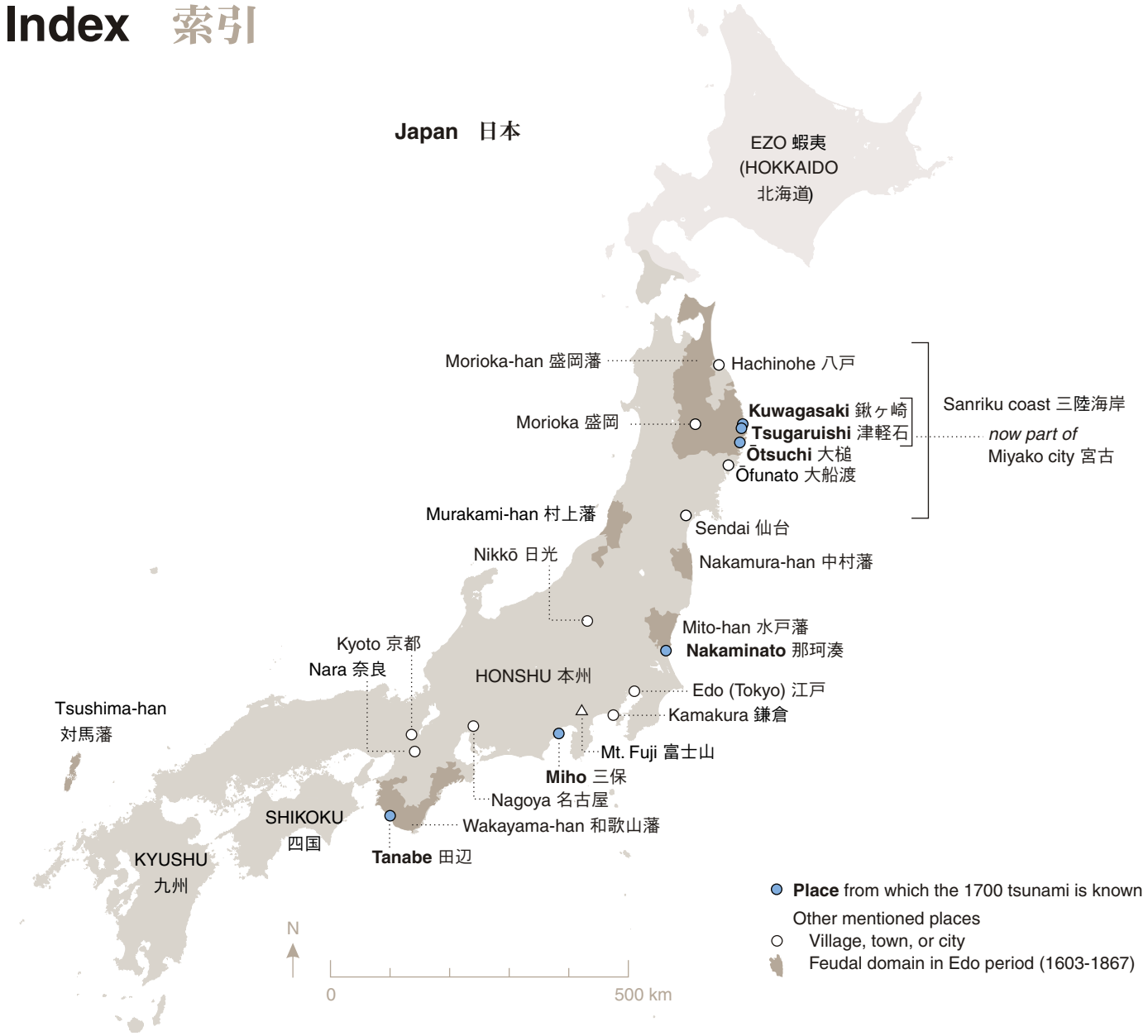
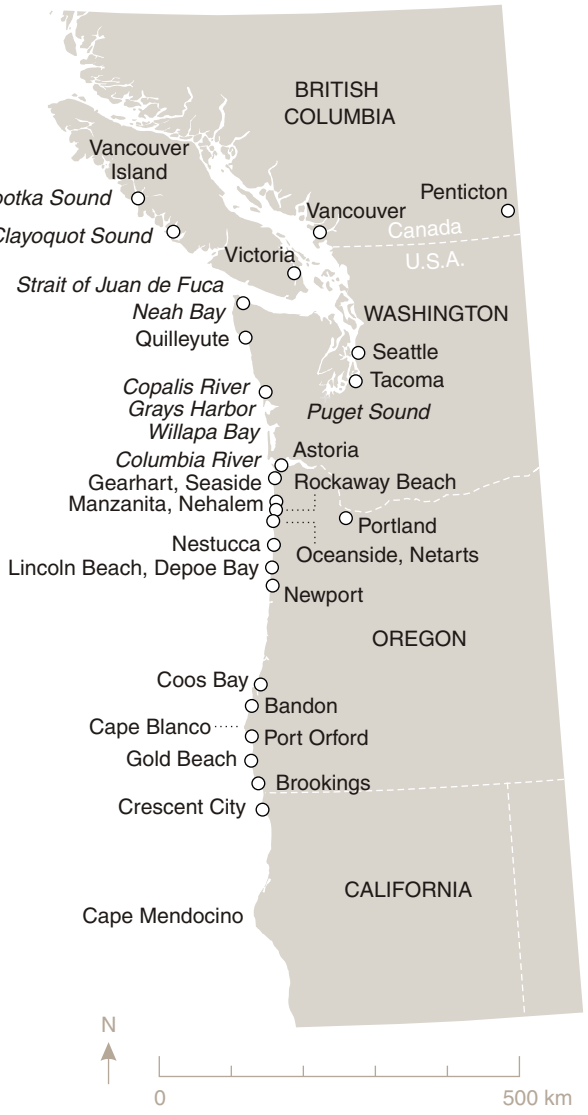


m, on map only; n, in footnote only
Italicized entries are Japanese terms other than place names

Cascadia



D

E

* MAJOR JAPANESE EARTHQUAKES are known in Japan by their era name and region; the 1611 event, for instance, is the Keichō Sanriku earthquake. The 1854 events, though traditionally assigned to the Ansei era, predated the start of that era by three weeks.

Date Masamune, daimyo of Sendai-han, is associated with the earliest known writing of 津波 (p. 41).

Courtesy of Sendai Museum

N

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Makah Indians sit for a portrait by J.G. Swan, probably in the 1860s. In 1864, another Makah told Swan a sea-flood legend the 1700 tsunami may have inspired (p. 12-13).

O

P

Q

R

Ōuchi-family compound in Nakaminato, 1842. The storehouse may have then held Ōuchi-ke "Go-yōdome," the collection of shipwreck documents that refers to the 1700 tsunami (p. 66).

Courtesy of Hitachinaka City

U

V

W

* Like the associated earthquakes (footnote, p. 126), these tsunamis are known by era and region. Complications: Hakuhō is obsolete as an era name, and the 1854 tsunamis predate the Ansei era but are customarily assigned to it.

Z

A wave from Chile in 1960 approaches roofs of Ōfunato, Japan (p. 81).

Courtesy of Ōfunato city

Afterword, 2015　2015年の後書き

A SIMULATED TSUNAMI modeled on the one in 1700 floods nearly all of the peninsular town of Westport, Washington (p. 103). The area mapped as tsunami-prone includes the grounds of the town's public schools, which stand on a low sandy plain between the Pacific Ocean and Grays Harbor.

A partial remedy was rising from that plain in 2015, as this book approached reprinting. Two years earlier, voters in Grays Harbor and Pacific Counties had approved a $13.8 million bond issue for school reconstruction. The measure provided for a tsunami haven—a rooftop platform with space for as many as a thousand persons.

The platform design combines resistance to earthquake shaking, safeguards against tsunami scour, and ample height. Reinforced concrete towers support the flat roof at its four corners. Piles are driven fifteen meters into the sand. The platform stands nine meters above ground, well above simulated water levels in an extreme scenario (diagrams, opposite).

This engineered refuge, North America's first for tsunamis, has roots across the Pacific. Its design incorporates lessons from the catastrophic tsunami of March 2011. Its funding came about while memories of that disaster were fresh. Its necessity came to light, in large part, through matching of North American and Japanese clues to the transpacific tsunami of January 1700.

—Prepared by Brian Atwater and David Yamaguchi from information provided by *Paula Akerlund*, superintendent, Ocosta School District; *Cale Ash*, associate principal with Degenkolb Engineers in Seattle and engineer of record for the Ocosta project described here; *Robert Butler*, professor, University of Portland, and founder, Cascadia Earthscope Earthquake and Tsunami Education Program (CEETEP); *Jon Harwood*, science and math teacher, Ocosta secondary schools; *John Schelling*, earthquake, tsunami, and volcano programs manager, Emergency Management Division, Washington State Military Department; *Beth Pratt-Sitaula*, CEETEP program director; and *Charles Wallace*, deputy director, Grays Harbor County Department of Emergency Management.

Most of this mile-wide strip between the Pacific Ocean and Grays Harbor, Washington, has been mapped as tsunami-prone. The circular building on the school grounds was being replaced, in 2015, by a gymnasium specially designed to withstand a giant Cascadia earthquake and to accommodate as many as a thousand persons on its roof during the tsunami that soon follows.

VULNERABILITY TO CASCADIA TSUNAMIS in Washington, Oregon, and northern California was recently examined by Wood, N.J., Jones, J., Spielman, S., and Schmidtlein, M.C., 2015, Community clusters of tsunami vulnerability in the US Pacific Northwest: Proceedings of the National Academy of Sciences, v. 112, p. 5354-5359, doi:10.1073/pnas.1420309112.

THE AIRPHOTO was taken for the Washington Department of Ecology in 1977 (https://fortress.wa.gov/ecy/coastalatlas/tools/ShorePhotos.aspx).

A SECOND-GENERATION TSUNAMI EVACUATION MAP, published in 2014, identifies the rooftop refuge (http://wa-dnr.s3.amazonaws.com/Publications/ger_tsunami_evac_westport.pdf).

HOURS BEFORE THE MARCH 2011 TSUNAMI began, Grays Harbor County was hosting its first workshop under Project Safe Haven, an initiative for planning vertical evacuation structures where high ground is scarce or distant (Wood, N., Jones, J., Schelling, J., and Schmidtlein, M., 2014, Tsunami vertical-evacuation planning in the U.S. Pacific Northwest as a geospatial, multi-criteria decision problem: International Journal of Disaster Risk Reduction, v. 9, p. 68-83, doi:http://dx.doi.org/10.1016/j.ijdrr.2014.04.009).

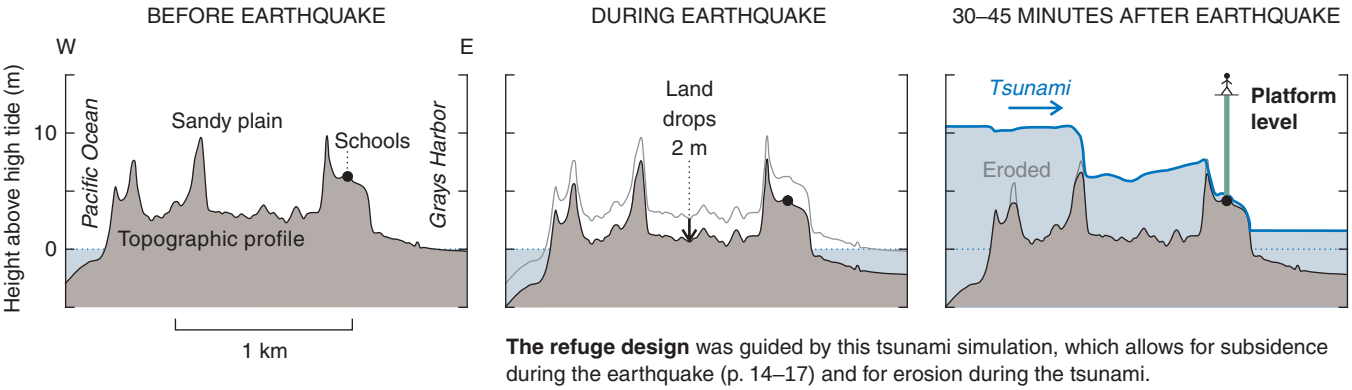
THE BOND MEASURE of April 23, 2013, won approval in 70 percent of the 1,518 ballots cast (http://ballotpedia.org/Ocosta_School_District_172_Renovation_Bonds_Measure_%28April_2013%29).

THE SIMULATED TSUNAMI begins with a scenario earthquake selected to resemble or exceed the 1700 event. Fault rupture occurs in a mainly offshore area about 1,000 km long between southern British Columbia and northern California. A hypothetical splay off the master fault raises the ocean floor by as much as ten meters on the continental slope west of Grays Harbor (González, F., LeVeque, R., and Adams, L., 2013, Tsunami hazard assessment of the Ocosta School site in Westport, WA: https://digital.lib.washington.edu/researchworks/handle/1773/24054).

THE ROOFTOP CAPACITY compares with a campus population of 700 and a Westport total of close to 2,000 persons counted in the 2010 census.

CONSTRUCTION PHOTO by Sonya Miller, Ocosta School District, July 27, 2015.

ARTIST'S CONCEPTION from TCF Architecture, used by permission.



The refuge design was guided by this tsunami simulation, which allows for subsidence during the earthquake (p. 14–17) and for erosion during the tsunami.

The four corner towers rose first (photo, July 2015). The completed tsunami refuge will span the flat roof of a gymnasium, with doors at ground level providing access through the corner towers (artist's conception).