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Finding Fault: Indigenous Seismology, Colonial Science, and the Rediscovery of Earthquakes and Tsunamis in Cascadia

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On Ash Wednesday in the new millennium's first year, the earth deep beneath Puget Sound slipped. Some thirty miles below Anderson Island, just off the Nisqually River's delta, a piece of the planet's crust fractured and slipped a meter or so, and sent out pulses of energy the equivalent of about thirty-five Hiroshima-sized atomic bombs. The resulting earthquake was felt from northern Oregon to British Columbia and had major effects throughout the region; in Seattle, the temblor damaged many of the city's cultural icons. The world headquarters of Starbucks shed its cladding, while at the Windows XP operating system's unveiling in the Westin Hotel's Grand Ballroom, Microsoft founder Bill Gates was interrupted midspeech by falling light fixtures. Perhaps most frighteningly, the Space Needle rang like a titanic bell as it swayed from side to side. Despite the low number of human casualties—just one person died, from a heart attack—the region's infrastructure was heavily impacted. Only in late 2004 did the Washington State Capitol Building, whose stone columns were shoved out of plumb, reopen to the public. Meanwhile, the future of the Alaskan Way Viaduct on Seattle's waterfront, sent listing by the quake, remains among the city's most hotly debated topics.[1]

This kind of thing had happened before. On 13 April 1949, a quake with nearly the same epicenter registered a 7.1 on the magnitude scale (in

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comparison, the 2001 event was a 6.8).[2] It was felt across 150,000 square miles of the Pacific Northwest, from northwestern Montana and the interior of British Columbia to the southern Oregon coast, and caused a total of eight deaths. On 29 April 1965, a 6.5 quake centered between Tacoma and Seattle was felt over almost the same area and resulted in seven deaths.[3] Combined with smaller seismic events throughout the Pacific Northwest's postresettlement history and the enormous Alaskan earthquake of Good Friday 1964, whose resulting tsunamis killed people as far south as California, the 1949, 1965, and 2001 earthquakes suggested that the northwest edge of North America was an unquiet place.[4]

Despite this history, most residents of the Pacific Northwest, including virtually all of the region's geologists, believed until the late twentieth century that they lived on a relatively stable chunk of planetary crust.[5] (In this respect, the region was quite different from California, where earthquakes are not only a common occurrence but also where they became a central leitmotif in what urban critic Mike Davis has called "the imagination of disaster.")[6] Beginning in the 1980s, however, this fundamental misapprehension of the region's geological realities was challenged as scientists and others found evidence of massive seismic events along the coast. More than simply the accrual of abstract environmental data, this discovery was also embedded within a complicated set of relationships between indigenous and settler societies in the region and between the kinds of knowledge those two societies had created in this place. Even at the twenty-first century's beginning, the categories of historical experience known as discovery and encounter are still very much in play.

Recent scholarship on disasters such as earthquakes—along with hurricanes, floods, and forest fires—has emphasized the fact that although the origins of such events are usually based in geological, meteorological, or other environmental processes, the resulting destruction of property and lives is shaped, and in many cases exacerbated, by human choices. Hurricanes devastate because we place trailer parks and beachfront resorts in their paths; rivers destroy because we build on their floodplains and denude their valleys' slopes; fires rage in part because forest practices and building methods allow them to. "Natural" disasters, then, are often human constructions as much as they are "acts of god."[7]

In the case of earthquakes on the Northwest Coast of North America—or Cascadia, as we refer to the region in this article—there is a manmade quality to the potential for disaster. Part of this is material: industrial areas are built on soils given to liquefaction, and neighborhoods are perched on slide-prone bluffs. Another, and less well understood, element of the manmade-ness of Cascadia's seismic peril is not so much material as cultural and, ultimately, historical. All along the Northwest Coast of North America, Native American and First Nations oral traditions include rich, explicit, and often detailed accounts of seismic events, including ones far larger than the Seattle-area quakes of 1949, 1965, and 2001. Cascadia is regularly wracked by some of the largest seismic events known to humanity; this fact and the fact that the indigenous traditions that speak to it were ignored or misunderstood until

the 1990s suggests that knowledge of the environment, including scientific inquiry, is grounded in the historical relationships between indigenous and settler societies.

Scientific understandings of the world take place within specific social, cultural, and political contexts as opposed to revealing timeless, universal, neutral truths. This has been one of the most profound, and well-documented, contributions of the last generation of scholarship in the history of science.[8] The recent "rediscovery" of Cascadia's seismicity is best understood in this way as well: as an intellectual and cultural development within the context of colonialism. In this article, we examine the Northwest Coast's rich indigenous seismological traditions; make connections between colonialism and the production and privileging of certain kinds of environmental data about the region's seismic past; and illuminate ongoing issues of proprietary cultural knowledge, environmental justice, and risk management as they relate to its seismic future. The story of modern nonindigenous Cascadians "waking up" to their home's earthquake potential illustrates the legacies, material and intellectual, of colonialism and illuminates the encounter of two very different societies with the same place and with each other (see fig. 1).[9]

The Cascadia Subduction Zone (CSZ), a deep sediment-filled trench that stretches from the north end of Vancouver Island to northern California, is the place where the Juan de Fuca crustal plate dives beneath North America; some of it emerges in molten form through the Cascade Range's volcanoes (from which Cascadia takes its name). As the location of the region's—and some of the world's—largest earthquakes, the CSZ is also the site of evidence that Cascadia is a single structural unit. Along the continental shelf's edge, particularly offshore from great rivers and inlets, ancient and massive earthquake-spawned underwater landslides known as turbidites are the CSZ's smoking guns. Turbidite layers can be counted at many offshore locations and suggest that when Cascadia goes, it often goes all at once. The result is known as a megathrust quake, which can drop the coast's large sections several meters in a matter of seconds. Planetary processes define Cascadia as a region.[10]

Not long before current theories of glaciation and human migration into the Americas began to take shape, anthropologist Franz Boas recorded a story told by the Heiltsuk, whose territories lie at the northernmost edge of Cascadia, that described how "in the beginning there was nothing but water and ice and a narrow strip of shore-line."[11] In a region where highly acidic soils destroy most vestiges of human civilization, assemblages of stone tools and other artifacts nonetheless suggest that the region's first peoples arrived soon after, and perhaps before, the great ice sheets had completely retreated.[12] During those dozen millennia, the CSZ wreaked its havoc recurrently if not regularly; turbidite evidence points to at least thirteen megathrust quakes on the CSZ in the last seven thousand years, with an average interval of about five centuries.[13] Meanwhile, smaller deep quakes, like the three that shook twentieth-century Puget Sound country in the late twentieth and early twenty-first centuries, and locally devastating surface quakes also punctuated indigenous life along the Northwest Coast.[14]

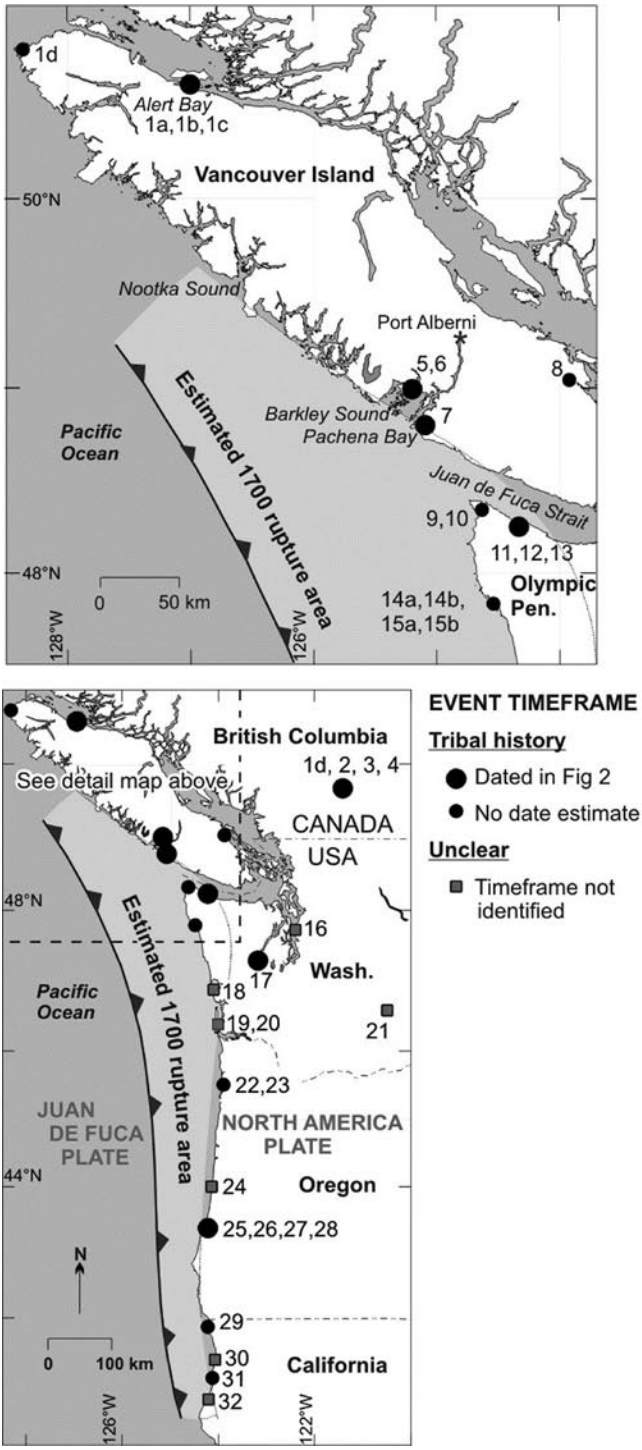

Figure 1. *Locations of Aboriginal accounts of earthquakes and tsunamis and estimated extent of the January 1700 event along the Cascadia Subduction Zone.*

Cascadia's seismicity profoundly shaped indigenous peoples' understandings of their homelands, and oral traditions collected by European, Canadian, and American newcomers paint vivid pictures of the effects of the region's earthquakes on the communities that made their homes there. An elder of the Cowichan people of the eastern coast of Vancouver Island, for example, told ethnographer Charles Hill-Tout that "in the days before the white man there was a great earthquake. It began about the middle of one night . . . threw down . . . houses and brought great masses of rock down from the mountains. One village was completely buried beneath a landslide."[15] Accounts from peoples of the outer coast, meanwhile, speak to the tsunamis generated by quakes on the CSZ. Louis Nookimus, also known as Louis Clamhouse, a Huu-ay-aht Nuu-chah-nulth elder from Vancouver Island, recalled what had happened to the people at Pachena Bay:

> They had practically no way or time to try to save themselves. I think it was at nighttime that the land shook. . . . I think a big wave smashed into the beach. The Pachena Bay people were lost. . . . But they who lived at Ma:lts'a:s [House Up Against Hill] the wave did not reach because they were on high ground. . . . Because of that they came out alive. They did not drift out to sea with the others.[16]

The Tseshaht, a neighboring Nuu-chah-nulth people, told a similar story:

> The tide began to flow, and crept slowly up to about halfway between the point of its furthest ebb and the houses. At this point, its pace was suddenly quickened, and it rushed up at fearful speed. The Sheshaht ran to their canoes [and] were all soon caught by the rising water . . . finally, the water covered the whole country.[17]

The Huu-ay-aht and Tseshaht territories are near the CSZ's northern end, but similar stories reverberate as far south as Oregon and California. The Coos of the central Oregon coast spoke of communities being "swept away clean," and the Yurok of northern California told of sinking prairies and land that would "quake and quake and quake again . . . and the water was flowing all over."[18]

As newcomers began to resettle the region in significant numbers beginning in the mid-nineteenth century, some of them collected stories of earthquakes and floods. Settler James Swan, for example, learned from his Makah neighbors that the Pacific had once risen "without any swell or waves," which inundated the Waatch River plain all the way through to the Strait of Juan de Fuca and turned Cape Flattery into an island. Swan found the story to have the ring of truth:

> There is no doubt in my mind of the truth of this tradition. The Waatch prairie shows conclusively that the waters of the ocean once flowed through it. And as this whole country shows marked evidence of volcanic influences there is every reason to believe that there was

> a gradual depressing and subsequent upheaval of the earth's crust which made the waters to rise and recede as the Indian stated.[19]

More than a century before geologists "discovered" the CSZ and the broader implications of the region's geology, settlers who had intimate contact with indigenous peoples were given the opportunity to understand this component of the place's nature.

But if colonials like Swan showed some interest in the fact that earthquakes and tsunamis happened on the Northwest Coast, they were usually unimpressed with indigenous explanations as to *why* such events happened. The indigenous peoples of Cascadia, like other peoples around the world, understood geological events to be manifestations of numinous forces in the landscape. According to many Northwest Coast traditions, earthquakes, especially big ones on the CSZ, were thought of as battles between enormous birds that embodied the spirit of Thunder and great creatures, such as whales and serpents, that dwelt in the ocean's depths. The Oregon coast Tillamook passed down a story about the struggles of a Whale, fished from the deep by a Thunderbird, which thrashed about, shook the mountains, and caused landslides. Similarly, an elder of the Olympic Peninsula Hoh people described the aftereffects of a battle between Thunderbird and Whale:

> My father . . . also told me that following the killing of this destroyer . . . there was a great storm and hail and flashes of lightning in the darkened, blackened sky and a great and crashing "thunder-noise" everywhere. He further stated that there was also a shaking, jumping up and trembling of the earth beneath, and a rolling up of the great waters.

Such indigenous explanations for seismic events did not only appear in stories: the Nuu-chah-nulth and the Kwakwaka'wakw, for example, painted Thunderbird and Whale on their cedar houses and carved them on totem poles and ceremonial screens, which created compelling images that advertised the spirit forces that transformed the land and sea and empowered the houses' owners (see fig. 2).[20] The lower Columbia River Chinook, meanwhile, told Franz Boas stories about flocks of dancing birds who sang, "Our legs are small but we make the ground shake," while other peoples in the region had their own diverse explanations. As the peoples of Cascadia struggled over millennia to come to terms with the geological realities of their homelands, they developed interpretations of seismic events that simultaneously reflected and shaped their lived experiences of place. Earthquakes and tsunamis were central components of relations between human beings and the other, nonhuman beings who inhabited the coastal regions.[21]

Although the specific explanations indigenous peoples offered for earthquakes and tsunamis differed widely up and down the coast of Cascadia and reflected those peoples' diversity, the explanations typically shared one trait: they linked environmental transformation directly to the human condition. Most notably, they commonly connected earthquakes to healing

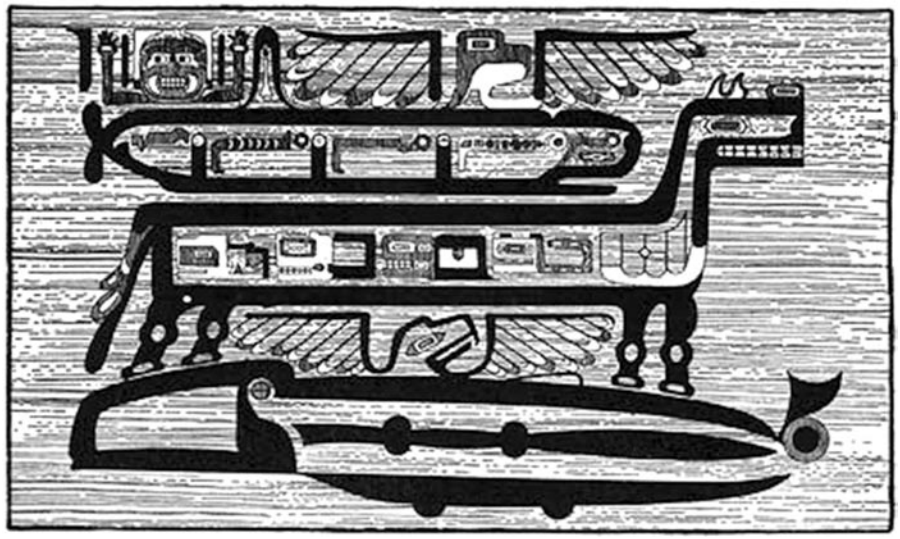

Figure 2. *One of many images of Thunderbird and Whale on the Northwest Coast, in this case from the Tseshaht Nuu-chah-nulth of Vancouver Island.*

and illness. Among the Coast Salish peoples of the Strait of Georgia and the Fraser River valley, for example, the CSZ earthquake of 1700 may be linked to the arrival of the famed *sxwayxwey* masks that are employed in winter ceremonials and doctoring practices.[22] Four such masks later arrived among the Kwakwaka'wakw to the north through marriage with the Comox-speaking Coast Salish and were used in healing rituals by professionals known as "earthquake dancers."[23]

Even when seismic power was not explicitly associated with healing and illness, earthquakes and tsunamis were understood to be moral events reflective of relationships between and among human people and the other residents of Cascadia. The Kwakwaka'wakw believed that quakes could result from the activities of ancestral ghosts, who required burnt offerings as propitiation for being disturbed, or from the mistreatment of domesticated and wild animals.[24] And among the Tseshaht Nuu-chah-nulth, those who "made light" of retreating seas offended the whale spirits that could prevent humans from drifting too far out to sea, and thus were lost.[25] These connections between earthquakes and human morals, behavior, and health attest to the importance of propriety, order, and protocol within indigenous societies—structures that must have seemed all the more important in a place that shook itself to pieces every few generations. They also speak to the importance of the idea of reciprocity in indigenous relationships with nonhuman peoples and entities, and with the environment more generally.[26]

Through thousands of years of lived experience, then, the first peoples of Cascadia had integrated the seismic reality of their homelands into their most central cultural institutions. The Oweekeno, the Tillamook, and other local peoples understood earthquakes and tsunamis as a fundamental part

of their lives and as a product of the relationships between the people and their places. The argument made by today's environmental historians of catastrophe—that natural disasters are often in part human creations—might have made good sense to the first peoples of Cascadia. Perhaps more significantly from a historiographical perspective, indigenous histories of place, represented here by seismological traditions, are akin in many ways to the Annales approach to history with its emphasis on long-term, large-scale processes and realities rather than the eye-blink events and tumults of human life spans. Annales scholars such as Fernand Braudel profoundly influenced the field of environmental history; because the search for Cascadia's seismic past is, at its core, environmental history, it is perhaps worth seeking out similar millennia-long observations of the region's past, framed within stories like those of Thunderbird and Whale.[27]

The eminent Canadian geographer Cole Harris has argued that it is not enough merely to parse the semiotics of colonialism, the imperial fantasies, and the racist representations that have garnered so much attention from literary scholars and others. We must also, he argues, examine the material conditions that ultimately implemented those semiotics and make sense of the roles that physical power, the structures of the state, flows of capital, and technologies such as law and mapping played in turning indigenous territories into imperial properties.[28] Science was another of these forces; it combined the material and discursive elements of colonialism and reflected the linkages between European intellectual and imperial histories. That Europe's global ascendance was coeval with its own intellectual transformation is no coincidence; these two developments are the same story. As Maori postcolonial theorist Linda Tuhiwai Smith has noted,

> [t]he Enlightenment provided the spirit, the impetus, the confidence, and the political and economic structures that facilitated the search for new knowledges. The project of the Enlightenment . . . provided the stimulus for the industrial revolution, the philosophy of liberalism, the development of disciplines in the sciences and the development of public education. Imperialism underpinned and was critical to these developments.[29]

The twinned histories of Enlightenment and empire made real on a global scale the Latin adage *scientia est potentia*: knowledge is power.

Geology crystallized as a discipline in tandem with Europe's domination of large swaths of the world. It was shaped by those encounters; Alix Cooper has argued persuasively that European "discoveries" around the world led intellectuals, including mineralogists and other natural historians, to understand their own homelands in new ways, which in turn shaped how explorers, colonists, and others saw the "new" worlds.[30] Geology was central to this process in that it offered a methodology to fuel the planet's industrial and economic transformation, but it also transformed historical narratives about the earth and its peoples. In Britain, for example, geology's professional corps emerged out of technical schools and state apparatuses designed

to facilitate mining, although its amateur practitioners were rooted in the upper classes whose personal fortunes grew with the empire. But if colonial data—in the form of mining maps, ethnographic studies, and sales figures—flowed into imperial centers through the exertions of new disciplines such as geology, anthropology, and capitalist economics, only some data truly counted. Colonial scientists and administrators typically ignored or dismissed indigenous peoples' own forms of knowledge. Out of the Enlightenment's certainties, new binaries were born: Europeans and their colonial offspring had art, science, and history, while the "natives," whether in India, the Congo, or British Columbia, had corresponding (and, in the imperial mind, inferior) categories of craft, superstition, and myth. Geologists, paleontologists, and anthropologists often portrayed "races . . . whose existence had been hidden from mankind" to be "like the fossil bones of antediluvian animals," which reinforced the perceived primitiveness of colonized landscapes and colonized peoples.[31]

Enlightenment theories of race, which often corresponded neatly with older prejudices, played a key role in these formulations of knowledge, but there was a broader dynamic at work in the relationship between imperial and indigenous knowledges: the local question. The global movement of peoples and things in the Age of Empire colluded with the Enlightenment's devotion to rationality to privilege abstract forms of knowledge and to denigrate local, and thus seemingly irrational, modes of thought. From Spanish friars who referred to indigenous neophytes as *gente sin razon* ("people without reason") to Anglo-American jurists who believed Indians unfit to give legal testimony, the indigenous became synonymous with the local and the disorderly. Empires incorporated only the most obviously utilitarian aspects of the indigenous vernacular: how to grow maize, which streams carried yellow metal in their gravelly beds, or where to set up a commercial fishery. As European centers and global peripheries became linked through networks of exchange and control, only certain kinds of information carried value in the literal and figurative senses of the word. Though the agents of empire often denigrated local and indigenous forms of knowledge, however, their denigration only thinly masked the fact that to no small degree, those forms of practical knowledge made the empire possible.[32]

Just as imperialism and the Enlightenment were linked more broadly, geological investigations of the Northwest Coast of North America went hand in hand with the dispossession of the region's indigenous peoples and the denigration, dismissal, and dismantling of their systems of knowledge. From Meriwether Lewis's descriptions of Northwest geomorphology to the painstakingly detailed soil descriptions of General Land Office surveys that facilitated homesteading, the systematic cataloging of Cascadia's earthly wealth was a parallel process to—or perhaps more accurately, an integral component of—colonialism. Explorers and surveyors were the vanguards of empire and of Enlightenment.[33] Science also supported the consolidation of Cascadia into the modern continental nations of Canada and the United States. In Victorian British North America, the exploratory, organizational, and consolidating phases of geological practice exactly paralleled the political

development of what eventually became Canada, while in the American West, synthesis and transmission of geological data from beyond the frontier helped build scientific, military, and political institutions.[34] On the ground, geological discoveries—gold along the Fraser and Rogue rivers, coal in Puget Sound country and on Vancouver Island—inspired waves of immigration that accelerated, often violently, the dislocation of indigenous communities.[35] Although geology's relationship to colonialism is less well understood than that of other disciplines such as biology and anthropology, it is clear that scientific understanding of Cascadia's geological (and thus economic) nature went hand in hand with dispossession of its indigenous peoples.[36]

At the same time, scientific understanding of how that wealth came to be—and how the planet works—changed over time, often as a result of Europeans' encounters with non-European places. At the Age of Empire's beginning, European thinking about earthquakes involved theories that ranged from steam pressure to the allegedly hollow nature of Earth; some of these ideas had been in circulation since Aristotle. But as Rachel Laudan has noted, in the eighteenth century's last decades and the nineteenth century's first half—not coincidentally, the period that saw European imperial expansion approach its zenith—many conceptual foundations of modern geology had begun to take shape, often inspired by encounters with far-flung places. And by the early twentieth century, when the straightforward imperialisms of Victoria and Leopold had begun to collapse, European understanding of seismic events had been further transformed by new technologies and new understandings of human and planetary history.[37] However, the greatest transformation, the ascendancy of plate tectonic theory in the 1960s, which coincided with the discovery of the CSZ, came late. During the same years that decolonization swept many parts of the planet, geological science, which had been so transformed by the experience of imperial expansion, found its own revolutionary truth: the earth's thin skin was a dynamic thing and places like Europe and North America were, quite literally, on the move. In the words of John McPhee, people had begun to "discuss continents in terms of their velocities."[38]

In late-twentieth-century Cascadia, continental velocities were outpaced by the speed with which the region's new geological understandings developed. Although the CSZ had been identified soon after the rise of plate tectonic theory, most geologists imagined that it slipped slowly, evenly, and imperceptibly—essentially, they imagined that Cascadia was relatively safe. Then, in the 1980s, a series of events took place that challenged these basic assumptions. First, the Mount St. Helens eruption on 18 May 1980 leveled more than 600 square kilometers of forest, killed fifty-seven people, and blocked commercial shipping on the Columbia River for several weeks. The eruption also drove home the point that the CSZ's volcanic offspring were active, far more active than most people previously thought.[39] Meanwhile, investigations into the seismic safety of a proposed nuclear energy facility in southwest Washington yielded additional evidence of the region's seismic potential. First made public in the late 1980s, a picture had begun to develop of Cascadia's potential for what one journalist called a "big jolt." A subduction

quake on the Pacific coast of Mexico that heavily damaged Mexico City and killed more than seven thousand people drew intense public interest; this was most Cascadians' first glimpse of the true nature of their region.[40]

The story of how geologists and others proceeded to determine the precise nature and timing of the most recent big jolt—a megathrust quake on the CSZ—illustrates the best in interdisciplinary environmental research. Throughout the 1980s and 1990s, scholars from several disciplines in at least three countries reopened a window into Cascadia's precolonial environmental history. Sediment cores from the region's coastal zones showed sharp horizons between soil and overlaying sand, which suggested an abrupt and catastrophic drop followed by a rushing-in of seawater and sand. Similar horizons were found as far as eight miles up some coastal rivers. Stands of dead trees along the Washington coast were inundated and salt-killed during the same event. Using dates from radiocarbon and from comparisons between tree rings in these "ghost forests" and those of neighboring old-growth trees, scientists began to look to the eighteenth century's dawn as the date of this most recent great quake. The winter of 1699–1700 coincided neatly with Japanese records of a mysterious "orphan" tsunami that had struck the island nation in late January 1700. Based on the waves' amplitude, direction, and timing as they struck a series of Japanese harbors, the earthquake that caused the tsunami was determined to be at least magnitude 9 and most likely to have occurred on the coast of Cascadia. (It *was* the coast of Cascadia—the whole thing moved as a single entity.) Tsunamis also travel at a known velocity, and so the most recent megathrust quake on the CSZ could be dated to about 9:00 p.m. on the night of 26 January 1700. Cataclysm had come on a Tuesday.[41]

Although some scientists looked to tree rings, soil horizons, and Japanese documents, other scholars, including this article's authors, began to look for evidence of that midwinter night's terrible events in the histories of the indigenous peoples of Cascadia. In conjunction with published sources and living Native communities, they brought the stories of Thunder and Whale into conversation with more obviously empirical data. What they found was that these stories strengthened the case for regionwide megathrust quakes.[42] Archaeologists, meanwhile, contributed evidence that not only corroborated the reality of those quakes but also suggested that indigenous stories of great, people-dispersing floods may be memories of actual events.[43] Together, oral tradition and archaeological evidence brought indigenous experiences of place and history back into Cascadia's geological story. Thus, interdisciplinary inquiry resuscitated, and ultimately vindicated, indigenous and local forms of knowledge while science, which in its literalism had hitherto been deficient in its ability to grasp the metaphorical meanings of Whale and Thunderbird, began to "catch up" with indigenous environmental knowledge.[44]

But beyond providing localized descriptions of seismic events and simply corroborating what science has already proven, can indigenous seismological traditions also be considered scientific data in their own right? More to the point, might they be able to point us toward new scientific discoveries? This has certainly been the case in fields such as medicine and agriculture; whether it will be so with seismology remains to be seen—it is only in the late

twentieth century that geologists have begun to understand their inquiry into the region's environmental past as a historical question, rather than simply a scientific one. Robert S. Yeats, a former Oregon State University professor and advocate for seismic hazard education, wrote recently that "maybe the time during which records have been kept, less than two hundred years, is too short for us to conclude that the Pacific Northwest is not earthquake country." Noting that the Northwest was "the last region of the Pacific Rim to receive settlers willing to record their history," Yeats suggests that the recent arrival of textuality to Cascadia has limited our ability to apprehend the region's past.[45] On one level, this is true: writing came last to this part of North America. At the same time, the recentness of written records does not explain colonial science's tardiness in confronting indigenous data. Almost as soon as colonialism arrived in the Northwest, its agents—Franz Boas, James Swan, and numerous others—began to collect stories of earthquakes and tsunamis. These sources effectively push Cascadia's written history back several generations before the arrival of explorers like Cook and Vancouver. The recentness of regional textuality, then, cannot explain by itself why stories of Thunder and Whale are only now being brought into the discussion of the region's dangers.

Instead, the problem seems to be with the data. Seismic hazards researcher Ian Hutchinson and archaeologist Alan McMillan have noted that indigenous stories can be extremely difficult to work with because of compression, fragmentation, and lack of contextual detail. "Perhaps because of the difficulty of working with such materials," they suggest, "few academic researchers have given the evidence of past seismic events contained in the oral traditions much credibility."[46] Most notable among the perceived shortcomings of indigenous environmental knowledge is its alleged resistance to dating: only rarely can stories be placed in linear, calendrical time. But a number of stories that describe the CSZ's megathrust quakes and tsunamis include references to time (examples include "perhaps not more than three or four generations ago" in a story collected in the 1860s and "about seven generations ago" in another collected seventy years later).[47] Examined in aggregate, these stories line up with the tree rings, turbidites, and other kinds of data associated with the January 1700 megathrust event. In other words, they might have helped point the way to that fateful Tuesday, had researchers been more prepared or inclined to look (see fig. 3).[48]

What this suggests, then, is that colonial science's struggle with indigenous seismology in Cascadia comes not just from the region's short textual history or from the perceived "timelessness" of indigenous oral traditions. Rather, that struggle also has its origins within colonial science: from its own youth in this region and from its technological and disciplinary limitations but more importantly from its preferences for certain kinds of data and for data produced by certain kinds of people. The rediscovery of Cascadia's seismic potential—for the use of the word *discovery* certainly seems hubristic in this context—is thus embedded in, and reflective of, the relationships between the two different kinds of societies, indigenous and settler, that have inhabited the Northwest Coast of North America.

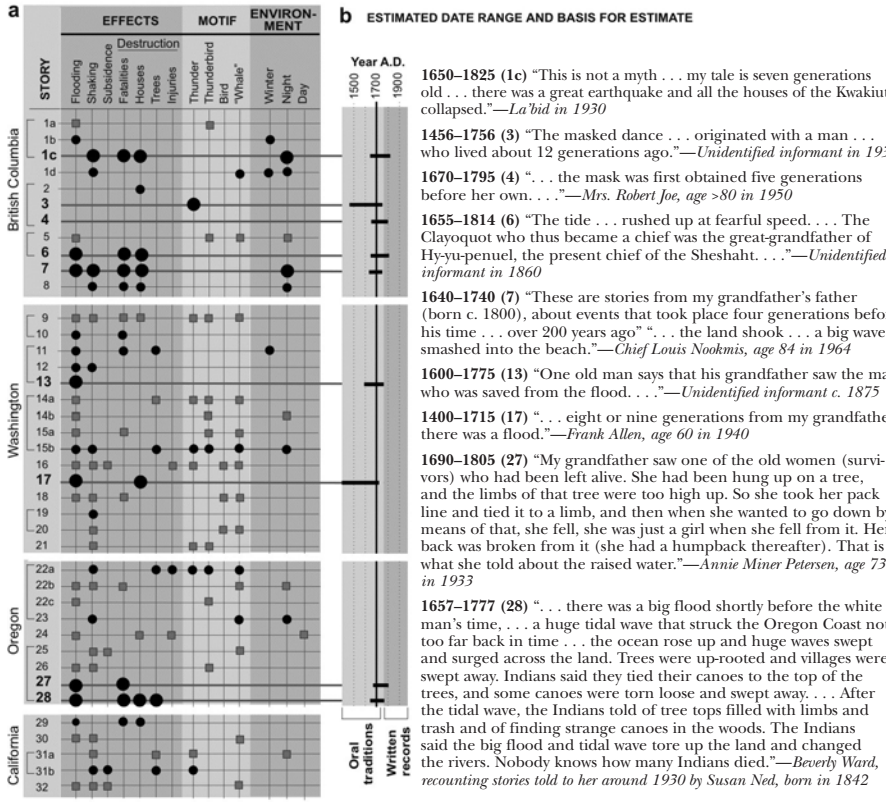

Figure 3. *Earthquake and tsunami story elements from accounts in figure 1 and the accounts' estimated date ranges.*

After the Indian Ocean tsunami of 2004, it is all too clear what a subduction zone megathrust quake and its resulting tsunamis look like. The event that claimed nearly a quarter-million lives near the Indian Ocean's shores on 26 December 2004 captured the world's attention and compassion with apocalyptic scenes of destruction and suffering. Tsunamis along the coast of Aceh, near the quake's epicenter, piled as high as twenty-five meters, moved at a clip of fifteen meters per second, and wiped away entire cities. From Thailand to Sri Lanka and eastern Africa, human choices gave shape to the disaster's specifics: dense communities built on in-filled shorelines, the lack of a regional tsunami warning system, and the killing curiosity that brought many down to the beach to watch the sea recede. The largest and costliest disaster in recent human history, the Indian Ocean earthquake and its tsunamis have illustrated the unthinking agency of nature at its most horrific and humanity's role in the specific shapes that disasters take.[49]

In Cascadia, geologists and other observers have closely examined the events of Boxing Day 2004 for one very good reason: the Sumatran

Subduction Zone and the CSZ are virtually the same size and thus bear similar destructive capabilities.[50] Combined with the 305th anniversary of the last CSZ megathrust event, the Aceh quake inspired a wide range of public discussion about the region's tectonic dangers, from media coverage of "inevitable disaster" and "haughty assumptions" to public hearings on improved warning systems and coastal shelters. Such discussions have not been limited to the threats of the CSZ; Seattle's *Post-Intelligencer* also reported in detail what would happen if another quake struck the fault zone that runs through that city. At last, Cascadia might be taking such warnings seriously. Since the Indian Ocean quake and tsunamis, emergency management agencies have held town hall meetings in coastal communities, while one member of Washington's congressional delegation, using the political rhetoric of the day, called "nature . . . the real weapon of mass destruction." State and provincial disaster-management officials have also begun meeting with tribal communities who live on the coast. As Cascadians debate what to do about the seismic threats they now understand they face, indigenous accounts of earlier earthquakes and tsunamis are routinely included in the discussion, not just as colorful stories but also as incontrovertible proof.[51]

Recognizing indigenous seismological data, putting it to use, and understanding the politicized landscape in which such deployments of knowledge take place are three separate things. Just as the development of geology took place within the context of colonialism and just as colonial science has struggled with indigenous knowledge, policies intended to mitigate the next big jolt's effects in Cascadia are still entwined with the colonial structures that continue to shape life in the region. Just as the "discovery" of Cascadia's past great earthquakes highlighted differential power relations between indigenous and settler populations, so too will efforts to prepare for future earthquakes.

As the old forms of colonialism have collapsed throughout the world, indigenous peoples have placed new and increasingly successful demands on the nation-states, colonial or postcolonial, in which they have found themselves. These demands—individual and collective ownership, access to subsistence resources, and the sacred nature of traditional territories—often center on the question of land. In some places, indigenous communities have taken on the role of co-managers of those territories; this is especially true in large swaths of Cascadia. In British Columbia and western Washington, the past three decades' treaty-rights cases have provided a legal and political platform from which indigenous communities exert control over the use and management of their homelands. Treaty law in Cascadia has provided critical precedent for indigenous land rights throughout the world.

Along with this new political ascendancy of indigenous land rights, indigenous forms of knowledge have also arrived at center stage as a way to understand and manage ecosystems and natural resources. During the same years that Cascadian scientists were "discovering" their region's seismic potential, interest in traditional ecological knowledge (TEK) also began to develop momentum. The 1987 publication of *Our Common Future*, more commonly known as the Brundtland Report, by the World Commission on Environment and Development gave voice to a growing sentiment among

scholars, practitioners, and indigenous people that traditional forms of knowledge could and should have a place at the table.[52] Since the 1980s, the collection and use of TEK has not only contributed to the growing role of indigenous communities as co-managers of their territories but also has brought a renewed interest in local forms of knowledge more generally, which challenges earlier preferences toward abstract, delocalized knowledge and further reinforces indigenous claims to territory and resources.[53]

But for all its potential, TEK also presents new challenges. The first, as anthropologist Michael F. Brown has noted, is that "categories basic to science, such as the distinction between the animate and inanimate, may have no standing in indigenous knowledge systems." Second, the differential power relationships between indigenous communities and governmental and scientific bodies has caused scholars such as Paul Nadasdy, as well as many indigenous leaders, to question whether shoehorning TEK into bureaucratic environmental management regimes only replicates older inequalities. Third, the tension between bureaucratic and indigenous understandings of expertise is compounded by the belief among many indigenous people that using TEK out of context renders it meaningless or even dangerous. The earthquake and tsunami traditions included in this article, for example, were part of specific ceremonial and social settings, and, in many cases, the details of these contexts are lost to the historical record, which calls into question exactly how much use present-day researchers—geological, anthropological, or historical—can really make of them.[54]

Perhaps the greatest concern in regard to TEK, however, is that it will not be used to benefit the people among whom it originated, which will result in what scientist and global justice advocate Vandana Shiva has named *biopiracy*: "the creation of property through the piracy of other's [*sic*] wealth."[55] Biopiracy has a long history; as Londa Schiebinger and others have documented, colonial botanizing—the search for new foods and medicines—was often at the imperial project's heart and routinely depended on indigenous and other forms of local knowledge.[56] In more recent eras, indigenous knowledge, resources, and practices obtained through corporate prospecting have been patented or trademarked, with the original bearers of that knowledge then being labeled as having infringed on a corporation's rights. Similar concerns exist in regard to academic research; as Linda Tuhiwai Smith has noted, "indigenous peoples are deeply cynical about the capacity, motives, or methodologies of Western research. . . . [I]t told us things already known, suggested things that would not work, and made careers for people who already had jobs."[57]

In Cascadia, where indigenous notions of intellectual and cultural property are particularly strong, the relationship between researchers and the researched have been complex and fractious, particularly regarding TEK and resource management. Recent studies of traditional indigenous uses of devil's club (*Oplopanax horridum*) in the treatment of adult-onset diabetes, for example, have spurred rapacious overharvesting of the plant and a renewed commitment among ethical researchers and their indigenous collaborators to protect certain kinds of knowledge and resources.[58] South

of the border, the Tulalip tribes of Washington State are currently drafting laws—according to some observers, the first of their kind anywhere—that will trademark not only indigenous knowledge but also cultural resources on and off the reservation, including plants used for medicines and other purposes.[59] These kinds of on-the-ground encounters radically transform the terms by which research, management, and exploitation—whether of resources or of peoples—take place.

Similar tensions are now beginning to appear in Cascadia in regard to seismology. Although in some indigenous communities in the region, seismological traditions fell dormant or even disappeared in the chaos of resettlement, in other communities these traditions persisted into the late twentieth century. For example, even before the Indian Ocean devastation, Chief Robert Dennis of the Huu-ay-aht people on the west coast of Vancouver Island had announced that his people were considering relocating their village on Pachena Bay—the destruction of which is described above—to higher ground and were asking for Canadian federal funding to do it. Since the events of Boxing Day 2004, the Huu-ay-aht have also been meeting with other Nuu-chah-nulth communities, most of whom also have shoreline settlements that a tsunami would wipe out, to decide on a broader plan in regard to relocation, evacuation planning, and community education. To make their case, Dennis and other Nuu-chah-nulth leaders note that knowledge from their communities has helped science understand seismological phenomena in Cascadia. That they should benefit from the use of that knowledge is, to them, obvious.[60] And on Washington State's Olympic Peninsula, the Quileute tribe has closed public access to a popular scenic beach in order to encourage the National Park Service either to cede or purchase for the tribe about eight hundred acres of high ground, citing the tsunami threats to their low-lying coastal reservation. Their close relatives the Hoh, meanwhile, conduct evacuation drills and seek congressional approval to change their reservation's boundary to include higher ground.[61] Such savvy mobilizations of the settler society's new awareness of seismic danger, informed by indigenous traditions and the findings of Western science, have the potential to force governments and scientific bodies to come to terms with the political and economic ramifications of the use of indigenous knowledge. Anything else, particularly in Cascadia where indigenous communities make up a significant portion of coastal populations, would be the geological equivalent of biopiracy.

The next time that the CSZ, the Seattle Fault, or one of the other seams that run through Cascadia shudders and gives way, the resulting earthquakes and tsunamis will likely overshadow all the seismic events of the past century and a half—*combined*.[62] The most recent event on the CSZ, for example, was one thousand times stronger than the deep quake that struck Puget Sound in 2001. The more we learn about this place, the grimmer the prognosis, which is only compounded by the development that has taken place since the arrival of empire in Cascadia. In a region where perhaps two hundred thousand indigenous people once lived, now millions make their home, and where great longhouses and elaborate fish traps were once the most complex built structures, now highways, gas pipelines, and water and sewer mains cross the

Seattle Fault, and oil refineries, sewage treatment plants, and populous and vulnerable cities now cover the landscape. One study, focused only on Oregon and using conservative estimates, predicts that a magnitude 9 CSZ quake and its concomitant tsunamis would claim five thousand lives and do some $12 billion worth of damage—if it came in the winter, when the coastal population is at its lowest. Add Washington, British Columbia, and northern California into the equation, as well as other places throughout the Pacific Basin that would surely be affected by tsunamis, and have the quake take place during a sunny summer weekend, and the death tolls would likely be on a scale more like that of December 2004.[63]

Despite the regional soul-searching inspired by recent events in the Indian Ocean, widespread denial regarding Cascadia's seismic fate remains a serious possibility now that the easily distracted public eye has wandered from the tragedy of Indonesia, Sri Lanka, and their neighbors. Robert Yeats has described the responses he received after warning other Cascadians about the risks they face:

> Telling my Northwest neighbors that we have an earthquake problem has been like telling them about carpenter ants in their basement or about high blood pressure and high cholesterol as a result of high living. The reaction was, "Yes, I know, but I don't want to think about it, let alone do anything about it." . . . I began to feel like the watchman on the castle walls warning about barbarians at the gate, begging people to take me seriously.[64]

Perhaps unsurprisingly, there are significant forces arrayed against disaster prevention in Cascadia. Some business leaders on the Oregon coast worry about the effects of tsunami paranoia on the local economy, and thus are resisting lengthy public discussion of the issue. Meanwhile, despite calls to add dozens of new warning buoys to the Pacific's tsunami warning system, half of those already in existence are inoperative thanks to budget shortfalls, while relevant federal agencies such as the National Oceanographic and Atmospheric Administration and the US Geological Survey are notoriously underfunded, even as offshore oil drilling is back on the table in Canada and the United States. For the moment, the region's geological realities have yet to be integrated into the administrative, economic, and cultural structures of settler society.[65]

Beyond controlling the line between survival and death, Cascadia's seismological destiny will also reshape the region in ways we cannot predict. As Jelle Zeilinga de Boer and Donald Theodore Sanders have shown, giant earthquakes typically have a "vibrating string" of social aftereffects. On a scale of weeks and months, such events can spawn epidemics, economic decline, religious revivals, social unrest, and even diaspora. Infrastructure reconstruction and economic revival, if they happen, can take years or decades, while over the course of centuries—as in the case of Cascadia's indigenous traditions—earthquakes can become indelible parts of a region's culture.[66] Such events can also shape societies' encounters with each other, as in the case of the Great

Nobi Earthquake of 1891, which killed thousands in Japan and transformed Meiji-era attitudes toward Japanese nationhood and culture, modern science, and the West.[67] In Cascadia, the land is a contingent historical force that acts within specific contexts of power, morality, and social relationships, which suggests that it may be time to return to the notion of reciprocity between humans and nonhuman forces that was once so dominant in the region and perhaps add to that a greater reciprocity between the diverse human societies that now exist there.

In his exploration of earthquakes, science, and culture in California, David L. Ulin has asked, "How do we talk about earthquakes? How do we even approach them, let alone integrate them into our lives?"[68] This is perhaps one of the greatest questions that faces not only Californians, who already have strong—if also superficial—cultural understandings of "the big one," but also anyone who lives in a place where the earth shakes and the sea suddenly rushes inland. In the case of Cascadia's seismic past, present, and future, such questions are closely related to each other, and, at their core, they are not just scientific inquiries. A few months after the 1906 earthquake that destroyed San Francisco, for example, a Yurok elder told an ethnographer that "now Earthquake is angry the Americans have bought up Indian treasures and formulas and taken them away to San Francisco to keep. He knew that, so he tore the ground up there."[69] Settler society's scientists may not be ready to see earthquakes as moral events, as indigenous people (and others) did and sometimes still do, but social relations of power and knowledge have inherently moral dimensions, from which scientific inquiry cannot easily or ethically be divorced. The rediscovery of indigenous seismology in Cascadia attests to the power of interdisciplinary inquiry and of the relationship between different forms of knowledge and their social contexts. That we may all benefit, indigenous and newcomer alike, should be the goal.

NOTES

1. For in-depth coverage of the Nisqually Quake, see seattlepi.nwsource.com/quake/yearlater.asp (accessed 25 August 2007). The event is also discussed in Robert S. Yeats, *Living with Earthquakes in the Pacific Northwest: A Survivor's Guide*, 2nd ed. (Corvallis: Oregon State University Press, 2004), 47, 49–50.

2. Magnitude determination is based on measurement and varies somewhat according to which quantity is measured. For details, see http://earthquake.usgs.gov/learning/faq.php (accessed 25 August 2007).

3. *The Puget Sound Lowland Earthquakes of 1949 and 1965: Reproductions of Selected Articles Describing Damage*, comp. Gerald W. Thorsen, Washington Division of Geology and Earth Resources, Information Circular 81 (Olympia: Washington State Department of Natural Resources, 1986).

4. The term *resettlement* (as opposed to *settlement*, which implies that the land colonized by Europeans and others was empty) is taken from R. Cole Harris, *The Resettlement of British Columbia: Essays on Colonialism and Geographical Change* (Vancouver: University of British Columbia Press, 1997).

See table of historical Pacific Northwest earthquakes in Yeats, *Living with Earthquakes in the Pacific Northwest*, 365–68.

5. See, e.g., early editions of Bruce A. Bolt, *Earthquakes: A Primer* (San Francisco: W. H. Freeman, 1978).

6. Mike Davis, *Ecology of Fear: Los Angeles and the Imagination of Disaster* (New York: Vintage Books, 1998), esp. 32–33, 326–27.

7. See Theodore J. Steinberg, *Acts of God: The Unnatural History of Natural Disaster in America* (Oxford: Oxford University Press, 2000); Stephen J. Pyne's multi-volume Cycle of Fire series.

8. One of the most articulate explications of this idea remains Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump* (Princeton, NJ: Princeton University Press, 1989).

9. Story-source location map from R. S. Ludwin, R. Dennis, D. Carver, A. D. McMillan, R. Losey, J. Clague, C. Jonientz-Trisler, J. Bowechop, J. Wray, and K. James, "Dating the 1700 Cascadia Earthquake: Great Coastal Earthquakes in Native Stories," *Seismological Research Letters* 76, no. 2 (2005): 140–48. Estimated 1700 rupture from K. Wang, R. E. Wells, S. Mazzotti, H. Dragert, R. D. Hyndman, and T. Sagiya, "A Revised 3-D Dislocation Model of Interseismic Deformation for the Cascadia Subduction Zone," *Journal of Geophysical Research* 108, no. B1 (2003): 2026.

10. There is some debate about the exact extent of the CSZ; some of the peoples mentioned here have traditional territories outside its most commonly cited boundaries. Their stories, however, may well reflect experiences with events on the CSZ. Cascadia more broadly conceived is also marked by seismic activity on additional faults such as the Queen Charlotte-Fairweather Slip Zone, a northern fault similar in many respects to the famed San Andreas Fault in California. For information on turbidite evidence, see Alan R. Nelson, Harvey M. Kelsey, and Robert C. Witter, "Great Earthquakes of Variable Magnitude at the Cascadia Subduction Zone," *Quaternary Research* 65, no. 3 (2006): 354–65.

11. Franz Boas, *Tsimshian Mythology* (Washington, DC: Bureau of American Ethnology, 1916), 883.

12. For the most recent synthesis, see Kenneth M. Ames and Herbert D. G. Maschner, *Peoples of the Northwest Coast: Their Archaeology and Prehistory* (London: Thames and Hudson, 2000). It should be noted that many indigenous communities in the region believe that they were created *in situ*.

13. See www.activetectonics.coas.oregonstate.edu/main_pages/turbidites/turbidites.html (accessed 25 August 2007).

14. Yeats, *Living with Earthquakes in the Pacific Northwest*, 82.

15. Charles Hill-Tout, *The Salish People: The Sechelt and the South-Eastern Tribes of Vancouver Island*, ed. Ralph Maud (Vancouver, BC: Talonbooks, 1987).

16. E. Y. Arima, D. St. Claire, L. Clamhouse, J. Edgar, C. Jones, and C. Thomas, "Between Ports Alberni and Renfew: Notes on West Coast Peoples," Canadian Ethnology Service, Mercury Series Paper 121 (Ottawa, ON: Canadian Museum of Civilization, 1991), 231.

17. G. M. Sproat, *Scenes and Studies of Savage Life* (London: Smith, Elder, 1868), 124–25. Tseshaht and Sheshaht are two Anglicizations of the same Nuu-chah-nulth name.

18. A. L. Kroeber, *Yurok Myths* (Berkeley: University of California Press, 1976),

463; Melville Jacobs, "Coos Narrative and Ethnologic Texts," *University of Washington Publications in Anthropology* 8, no. 1 (1939): 53; Cora A. Dubois, "Tolowa Notes," *American Anthropologist* 34 (1932): 261.

19. James G. Swan, Diary, January 1864, Manuscripts, Special Collections, and University Archives, University of Washington. Interestingly, to date, no paleoseismic evidence of subsidence or tsunamis has been discovered at Waatch Prairie.

20. Franz Boas, "Traditions of the Tillamook Indians," *Journal of American Folklore* 11 (1898): 23–38 and A. B. Reagan, "Myths of the Hoh and Quileute Indians," *Utah Academy of Sciences* 11 (1934): 17–37.

"Pictographic painting, the coat of arms of Shewish, Seshaht Chief. . . . The figure at the base . . . represents the mammoth whale upon whose back the whole creation rests. Above the whale are seen the head and wings of the giant . . . Thunder Bird." Illustration by J. Semeyn, from A. Carmichael, *Indian Legends of Vancouver Island* (Toronto: The Musson Book Company, 1922), 32.

21. For references to many of these stories, see Alan D. McMillan and Ian Hutchinson, "When the Mountain Dwarfs Danced: Aboriginal Traditions of Paleoseismic Events along the Cascadia Subduction Zone of Western North America," *Ethnohistory* 49, no. 1 (Winter 2002), 41–68; Ruth S. Ludwin et al., "Dating the 1700 Cascadia Earthquake"; R. S. Ludwin, C. P. Thrush, K. James, D. Buerge, C. Jonientz-Trisler, J. Rasmussen, K. Troost, and A. de los Angeles, "Serpent Spirit-power Stories along the Seattle Fault," *Seismological Research Letters* 76, no. 4 (July/August 2005), 426–31.

22. Keith Thor Carlson, ed., *Coast Salish-Stó:lō Historical Atlas* (Vancouver: University of British Columbia Press, 2001), 10–11; Edward S. Curtis, *The North American Indian*, vol. 9 (1913; repr. New York: Johnson Reprint, 1970), 37–38; Claude Lévi-Strauss, *The Way of the Masks* (Vancouver, BC: Douglas and McIntyre, 1982), 159.

23. Franz Boas, *Kwakiutl Tales* (New York: Columbia University Press, 1910), 27–32; Franz Boas, *Ethnology of the Kwakiutl* (Washington, DC: Bureau of American Ethnology, 1921), 951–56.

24. Franz Boas, "The Nootka," *Second Annual Report on the Indians of British Columbia* (London: British Association for the Advancement of Science, 1891), 613; Boas, *Kwakiutl Tales*, 123.

25. G. M. Sproat, *The Nootka: Scenes and Studies of Savage Life*, ed. C. Lillard (Victoria, BC: Sono Nis Press, 1987), 124–25; Edward Sapir, "A Flood Legend of the Nootka Indians of Vancouver Island," *Journal of American Folklore* 32 (1919): 351–55.

26. For discussion of reciprocity between Aboriginal societies and their environments in British Columbia, see Nancy M. Turner, *The Earth's Blanket: Traditional Teachings for Sustainable Living* (Vancouver, BC: Douglas and McIntyre, 2005).

27. For an overview of Annales approaches to history and their impact, see Peter Burke, *The French Historical Revolution: The Annales School, 1929–1989* (Palo Alto, CA: Stanford University Press, 1990). For one of the most well-known examples, see the 1992 University of California Press reprint of Fernand Braudel's *Civilization and Capitalism, 15th–18th Centuries*. For two examples of North American environmental history that draw on the Annales tradition—one from the first years of the field's modern development and one that has been published recently—see William Cronon, *Changes in the Land: Indians, Colonists, and the Ecology of New England* (New York: Hill and Wang, 1983) and Brian Donahue, *The Great Meadow: Farmers and the Land in Colonial Concord* (New Haven, CT: Yale University Press, 2007).

28. Cole Harris, "How Did Colonialism Dispossess? Comments from an Edge of Empire," *Annals of the Association of American Geographers* 94, no. 1 (2004): 165–82.

29. Linda Tuhiwai Smith, *Decolonizing Methodologies: Research and Indigenous Peoples* (London: Zen Books, 1999), 58.

30. Alix Cooper, *Inventing the Indigenous: Local Knowledge and Natural History in Early Modern Europe* (Cambridge: Cambridge University Press, 2007).

31. See Michael A. Bryson, *Visions of the Land: Science, Literature, and the American Environment from the Era of Exploration to the Age of Ecology* (Charlottesville: University Press of Virginia, 2002), 3–31.

Colin Scott, "Science for the West, Myth for the Rest?: The Case of James Bay Cree Knowledge Construction," in *Naked Science: Anthropological Inquiry into Boundaries, Power, and Knowledge*, ed. Laura Nader (New York: Routledge, 1996).

32. See James C. Scott, *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed* (New Haven, CT: Yale University Press, 1998); David Wade Chambers and Richard Gillespie, "Locality in the History of Science: Colonial Science, Technoscience, and Indigenous Knowledge," *Osiris* 15 (2000): 221–40.

33. Gerald Holton, "On the Jeffersonian Research Program," *Archives Internationales d'Histoire des Sciences* 36, no. 117 (1986): 325–36; Kathleen Tobin-Schlesinger, "Jefferson to Lewis: The Study of Nature in the West," *Journal of the West* 29, no. 1 (1990): 54–61; cadastral survey field notes and plats for Oregon and Washington (Denver, CO: US Department of the Interior, Bureau of Land Management, 1982). For the application of Enlightenment ideals to indigenous territories in the region, see Daniel W. Clayton, *Islands of Truth: The Imperial Fashioning of Vancouver Island* (Vancouver: University of British Columbia Press, 2000).

34. Suzanne Zeller, "The Colonial World as a Geological Metaphor: Strata(gems) of Empire in Victorian Canada," *Osiris* 15 (2000): 85–107; John R. Hensley, "Transacting Science on the Border of Civilization: The Academy of Science of St. Louis, 1856–1881," *Gateway Heritage* 7, no. 3 (1986–87): 18–25.

35. See Robert E. Ficken, *Unsettled Boundaries: Fraser Gold and the British-American Northwest* (Pullman: Washington State University Press, 2003); E. A. Schwartz, *The Rogue River War and Its Aftermath, 1850–1890* (Norman: University of Oklahoma Press, 1997); David Burley, *Senewélets: Culture History of the Nanaimo Coast Salish and the False Narrows Midden* (Victoria: Royal British Columbia Museum, 1989); *Morda C. Slauson, From Coal to Jets* (Renton, WA: Renton Historical Society, 1976).

36. See *Cultures of Natural History*, eds. N. Jardine, J. A. Secord, and E. C. Spary (Cambridge: Cambridge University Press, 1996).

37. For an exhaustive catalog of European ideas about earthquakes and their causes, see Erhard Orser's Historical Earthquake Theories (HEAT) at www.univie.ac.at/Wissenschaftstheorie/heat/heat-1/heat000f.htm (accessed 25 August 2007). Transition example: Peter Gould, "Lisbon 1755: Enlightenment, Catastrophe, and Communication," in *Geography and Enlightenment*, eds. David N. Livingstone and Charles W. J. Withers (Chicago: University of Chicago Press, 1999), 399–413; Theodore E. D. Braun, *The Lisbon Earthquake of 1755: Representations and Reactions* (Oxford: Voltaire Press, 2005). For a comprehensive account of the origins of modern geology, see *Rachel Laudan, From Mineralogy to Geology: The Foundations of a Science, 1650–1830* (Chicago: University of Chicago Press, 1987).

38. John McPhee, *Annals of the Former World* (New York: Farrar, Strauss, and

Giroux, 1998), 34. For discussion of the history of plate tectonics theory, see H. W. Menard, *The Ocean of Truth: A Personal History of Global Tectonics* (Princeton, NJ: Princeton University Press, 1986); Naomi Oreskes, ed., *Plate Tectonics: An Insider's History of the Modern Theory of the Earth* (Cambridge, MA: Westview Press, 2003).

39. For an account of this process of rediscovery, see Yeats, *Living with Earthquakes*, esp. 3–4. See also Linda Roach Monroe, "Scientists Fear Big Jolt Can Happen in Oregon," *The Oregonian*, 26 February 1987, E1.

40. T. H. Heaton and H. Kanamori, "Seismic Potential Associated with Subduction in the Northwestern United States," *Bulletin of the Seismological Society of America* 74, no. 3 (1984): 933–41; Brian F. Atwater and Wendy C. Grant, "Holocene Subduction Earthquakes in Coastal Washington," *Eos, Transactions, American Geophysical Union* 67, no. 44 (1986): 906; Yeats, *Living with Earthquakes in the Pacific Northwest*, 54–57.

41. A. R. Nelson et al., "Radiocarbon Evidence for Extensive Plate-Boundary Rupture 300 Years Ago at the Cascadia Subduction Zone, *Nature* 378 (1995): 371–74; K. Satake, K. Wang, and B. F. Atwater, "Fault Slip and Seismic Moment of the 1700 Cascadia Earthquake Inferred from Japanese Tsunami Descriptions," *Journal of Geophysical Research* 108 (2003): 2325; D. K. Yamaguchi, B. F. Atwater, D. E. Bunker, B. E. Benson, and M. S. Reid, "Tree-Ring Dating the 1700 Cascadia Earthquake," *Nature* 389 (1997): 922–23; C. D. Peterson and G. R. Priest, "Preliminary Reconnaissance Survey of Cascadia Paleotsunami Deposits in Yaquina Bay, Oregon," *Oregon Geology* 57, no. 2 (1995): 33–40; Brian F. Atwater, *The Orphan Tsunami of 1700: Japanese Clues to a Parent Earthquake in North America* (Seattle: University of Washington Press, 2005).

42. T. H. Heaton and P. D. Snavely, "Possible Tsunami along the Northwestern Coast of the United States Inferred from Indian Traditions," *Bulletin of the Seismological Society of America* 75, no. 5 (1985): 1455–60; John J. Clague, "Early Historical and Ethnological Accounts of Large Earthquakes and Tsunamis on Western Vancouver Island, British Columbia," *Current Research* 1995-A (1995): 47–50.

43. Ian Hutchinson and Alan D. McMillan, "Archaeological Evidence for Village Abandonment Associated with Late Holocene Earthquakes at the Northern Cascadia Subduction Zone," *Quaternary Research* 48 (1997): 79–87; Diamond Jenness, *The Faith of a Coast Salish Indian* (Victoria: British Columbia Provincial Museum, 1955), 33; Oliver N. Wells, *Myths and Legends of the Staw-loh Indians of South Western British Columbia* (Sardis, BC: privately printed, 1970), 19; Oliver N. Wells, *The Chilliwacks and Their Neighbours* (Vancouver, BC: Talonbooks, 1987), 88–92; Charles Hill-Tout, "Report on the Ethnology of the Southeastern Tribes of Vancouver Island, British Columbia," in Maud, *The Salish People*, 157; Dorothy Kennedy and Randy Bouchard, *Sliammon Life, Sliammon Lands* (Vancouver, BC: Talonbooks, 1983), 154; T. F. McIlwraith, *The Bella Coola Indians* (Toronto: University of Toronto Press, 1948), 2: 504; Susanne Storie, ed., *Oweekano Stories* (Victoria: British Columbia Indian Advisory Committee, 1973), 59; E. Y. Arima et al., "Between Ports Alberni and Renfrew: Notes on West Coast Peoples," 164; Ella Clark, *Indian Legends of the Pacific Northwest* (Berkeley: University of California Press, 1953), 323; Elizabeth Colson, *The Makah Indians: A Study of an Indian Tribe in Modern American Society* (Minneapolis: University of Minnesota Press, 1953), 47.

44. Dorothy Vitaliano, *Legends of the Earth* (Bloomington: Indiana University Press, 1973); Luigi Piccardi, "Active Faulting at Delphi: Seismotectonic Remarks and a Hypothesis for the Geological Environment of a Myth," *Geology* 28 (2000): 651–54;

Robert L. Kovach, *Early Earthquakes in the Americas* (Cambridge: Cambridge University Press, 2004).

45. Yeats, *Living with Earthquakes in the Pacific Northwest*, 2, 8.

46. Ian Hutchinson and Alan D. McMillan, "Archaeological Evidence for Village Abandonment Associated with Late Holocene Earthquakes at the Northern Cascadia Subduction Zone," *Quarternary Research* 48 (1997): 79–87.

47. Swan, Diary, 57; Myron Eells, "Traditions of the 'Deluge' among the Tribes of the North West," *American Antiquarian* 1, no. 2 (1878): 70; Boas, *Kwakiutl Tales*, 122.

48. Brackets by story numbers group stories from a common geographic locale; symbols are as in figure 1. The "Whale" motif is enclosed in quotation marks to cover a variety of sea monsters that appear in the stories. Date range estimates used the following assumptions: a "generation" is no fewer than fifteen and no more than forty years; events before age five are not remembered; the maximum life span is one hundred years; flood survivors were "old" when interviewed; and an "old" person is at least forty. From R. S. Ludwin et al., "Dating the 1700 Cascadia Earthquake."

49. Multiple news outlets reported on the mysterious "primitive sixth sense" that told Andamanese and other tribespeople living on islands in the Indian Ocean to move away from the coasts before the tsunami's arrival. E.g., see "Knowledge of Natural World Saved Primitive Tribes of Andaman and Nicobar Islands from Tsunami," *The Hindu* (New Delhi), 5 January 2005.

50. Information on the US Geological Survey's press conference comparing geological structures in Indonesia and Cascadia can be found at soundwaves.usgs.gov/2005/03/outreach.html (accessed 25 August 2007).

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52. Nancy J. Turner, "Traditional Ecological Knowledge," in *The Rain Forests of Home*, eds. Peter K. Schoonmaker, Bettina von Hagen, and Edward C. Wolf (Washington, DC: Island Press, 1997), 275–98.

53. See Sarah A. Laird, ed., *Biodiversity and Traditional Knowledge: Equitable Partnerships in Practice* (London: Earthscan, 2002); Doreen Stabinsky and Stephen B. Brush, eds., *Valuing Local Knowledge: Indigenous People and Intellectual Property Rights* (Washington, DC: Island Press, 1996); Darrel A. Posey and Graham Dutfield, eds., *Beyond Intellectual Property: Toward Traditional Resource Rights for Indigenous Peoples and Local Communities* (Ottawa, ON: International Development Research Centre, 1996); Paul Sillitoe, *Participating in Development: Approaches to Indigenous Knowledge* (London: Routledge, 2002).

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58. See Trevor C. Lantz, Kristina Swerhun, and Nancy J. Turner, "Devil's Club (*Oplopanax horridum*): An Ethnobotanical Review," *Herbalgram* 62 (2004): 33–48.

59. Krista J. Kapralos, "Copyrighting Culture: Tulalips Assert Rights to Stories," *Everett Herald*, 15 April 2007, http://www.heraldnet.com/article/20070415/NEWS01/704150722/-1/extras01 (accessed 25 August 2007).

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69. Kroeber, *Yurok Myths*.