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Japan's Natural Setting

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A COUNTRY OF MOUNTAINS

Arriving in Japan at Narita or Kansai airport, one would hardly guess that mountains are the dominant topography of Japan. Far in the distance, a thin purple undulation of skyline tells differently. Satellite photos reveal an archipelago of steep, solid-green mountains and precipitous valleys across the four main islands: Hokkaido in the north, then Honshu, leading to Kyushu, with Shikoku nestled between (see figure 1.1).

Tectonic History

This archipelago is of relatively recent formation: it detached from the edge of the Eurasian continent only about 15 million years ago upon the opening of the Japan Sea. Surprisingly, the Japanese landmass was relatively flat when it detached.

The current mountains are products of tremendous tectonic stress, as the archipelago sits at the edge of the continental Eurasian Plate, facing two offshore oceanic plates—the Pacific Plate in the north and the Philippine Plate in the southwest. The continental plate is moving eastward, while the oceanic plates head westward, causing the islands in between to buckle and uplift into folded mountains. The landmass is still rising and the mountains are becoming higher, leading to one of the greatest rates of erosion in the world. Short rivers cut down steeply from the mountainous backbones of the islands, dumping their heavy sedimentary loads into the seas.

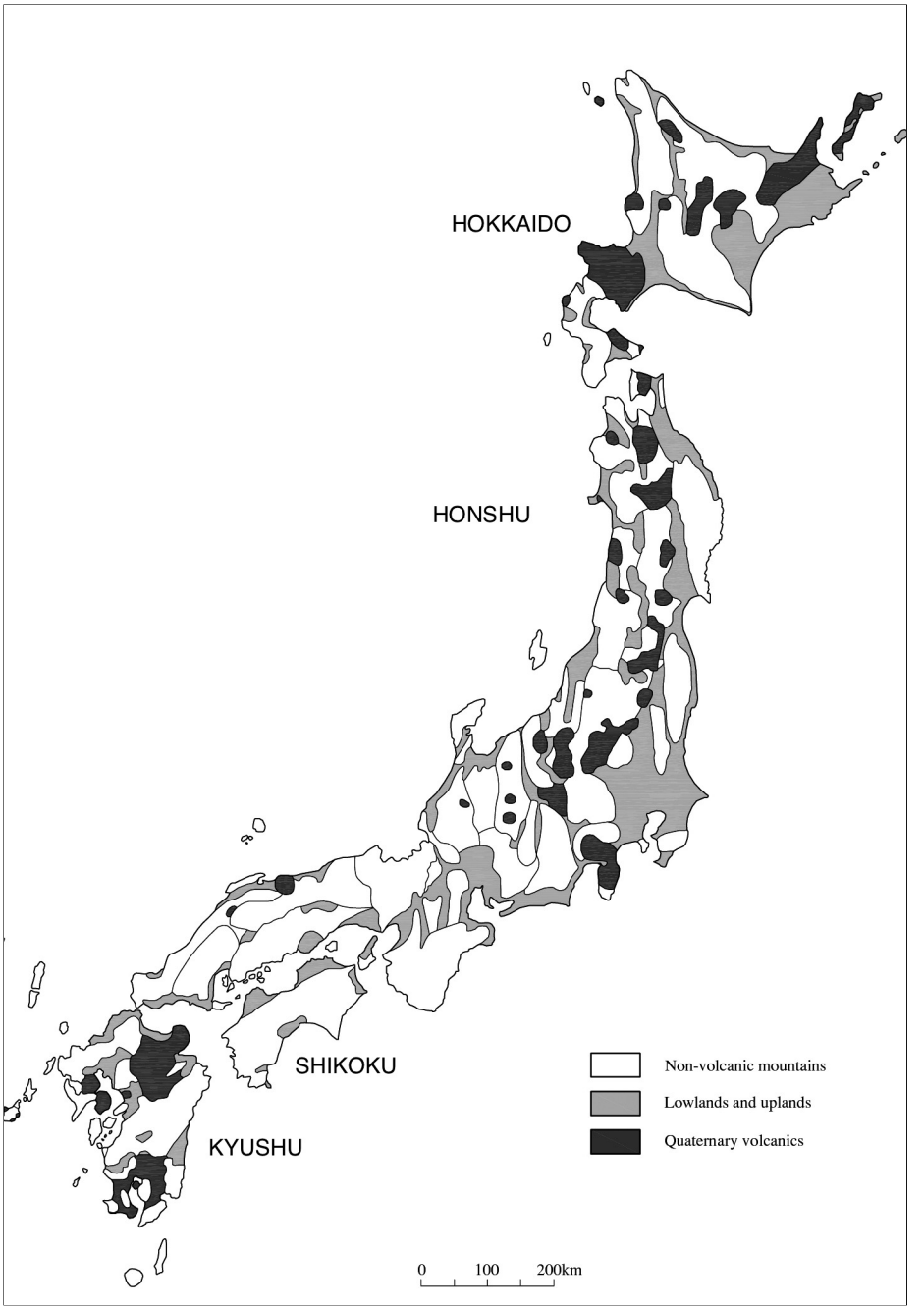

Figure 1.1. Japan and its mountains, most of which are folded along the axis of compression. The coasts and rivers are bordered by flat alluvial lands, but the uplands consist mainly of sloped or hilly volcanic deposits. (Prepared by Durham Archaeological Services after Yonekura et al., *Nihon no chikei 1,* fig. 1.3.2.)

This meeting of the plates also creates a subduction zone, where the oceanic plates are being drawn down (subducted) underneath the edge of the continental plate. Volcanoes and earthquakes are the result—constant menaces to life in the Japanese islands. The earliest volcanoes in the newly formed archipelago erupted around 14 million years ago, ranging across the Inland Sea area in western Honshu. About 2 million years ago, great volcanic explosions occurred in the Tōhoku region of northern Honshu; these left great collapsed calderas in the landscape, more than twenty kilometers in diameter, that now form some of the favorite crater lake tourist destinations, such as Lake Towada.

The current series of volcanic eruptions began around 700,000 years ago in three distinct areas: from Hokkaido through Tōhoku to central Honshu, from Tokyo south through the Izu Islands including Mt. Fuji, and north-south through Kyushu. Today, Japan claims about 10 percent (one hundred or so) of the world's active volcanoes, including Sakura-jima at the southern end of Kyushu. Nevertheless, volcanoes actually form a small proportion of all the mountains in Japan (see figure 1.1)—most of which are tectonically folded mountains.

New Coastal Plains

The contrast between mountains and plains is abrupt: the change in slope is often steep (35–40 degrees), wooded mountainsides meeting gently sloping (1–2 degrees) flatlands. Statistics vary: some say Japan is 86 percent mountains and 14 percent plains, while others measure 65 percent mountains and 35 percent plains. The difference lies in what is considered a plain (*heiya*). The coastal fringing plains are relatively flat, but the great Kantō Plain around Tokyo is actually a rolling dissected volcanic terrace landscape, while Hokkaido, northern Kantō, and southern Kyushu are characterized by broad volcanic slopes and plateaus. Add these volcanic uplands to the alluvial plains, and the percentage of "flat" land goes up. Thus, as a rule of thumb, everything but steep mountains fits in the category of 35 percent plains, and we can distinguish uplands, terraces, levees, and alluvial flats within that category.

The coastal plains that fringe the islands are relatively recent, emerging only when the high sea levels of the postglacial Climatic Optimum (6,000–4,000 years ago) receded. Groups of hunter-gatherers, the Jōmon, exploited the mountains (for hunting and gathering and some horticulture) and seashores (for shellfish collecting and coastal and deep-sea fishing). Soon thereafter, however, in the early first millennium BCE, rice agriculture was adopted from the continent. From that point onward, the plains became the focus of settlement, agricultural exploitation, and urban development.

Figures for today's Japan make it the fifth most densely populated country in the world, at an average of 343 persons per square kilometer. Nevertheless,

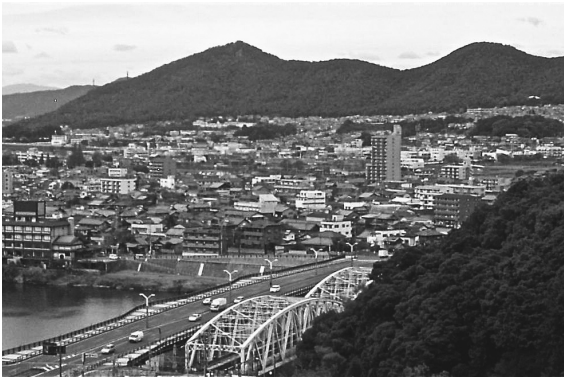

Figure 1.2. The city of Nagoya spreads over coastal plains and lower slopes, but the virtually uninhabited mountains behind rise abruptly. Remnants of the previous border between plains and mountain slopes can be seen in a series of isolated woods along the terrace paralleling the greenbelt line. (Author's photo, November 2008.)

this average is taken across virtually uninhabited deep mountains and solidly residential plains (figure 1.2). The density for Tokyo is 5,751 persons per square kilometer, seventeen times the "average" but indicative of the imbalance between mountains and plains. With so much population concentrated in the lowlands, mountain areas have been relegated to places of leisure: skiing, soaking in hot springs, viewing cherry blossoms. For the majority of the Japanese population, living in their national heartland is an unknown experience (figure 1.3).

A COUNTRY OF PADDIES AND DRY FIELDS

Historically, agriculture in Japan has been divided into upland crops and lowland rice paddies. Both uplands and lowlands are ecological areas subsumed under the term "plains," but their constituents are radically different. Uplands do not include steep mountain slopes, but in general the term refers to the rolling, eroded surface of volcanic terraces, riverine levees and terraces, and basin flanks. "Lowlands" generally refers to alluvial bottomlands and coastal flatlands. Over time, paddy fields have encroached on the uplands, but this is a trend now in reversal.

Rice Paddy Landscapes

Once wet rice agriculture was initiated in Japan, paddy field construction greatly modified the natural topography of lowland Japan. The nature of the soil was less important than the control of water: Rice paddies need to be leveled in order to maintain an even water depth for nourishing the rice during the three growing months. Thus, coastal plains of gley soils having small slope gradients were the first to be exploited from the beginning of the Yayoi period, in the early first millennium BCE. Rice paddies were initially carved out of river bottomlands, near sources of irrigation water, but these were often subject to

Figure 1.3. An isolated residence in the Yoshino River valley, Nara Prefecture, located on a steep slope hosting a Japanese cedar (*sugi*) plantation. (Author's photo, August 2008.)

floods. With the advent of iron digging tools in the early first millennium CE, coarse sediments of lower basin flanks could be cultivated and irrigation canals built to supply them with water.

The first large-scale transformation of the lowland landscape, however, occurred in the seventh to eighth centuries, when the Yamato court adopted Chinese-style ruling technologies from Tang China. One of the innovations was the surveying and laying out of both agricultural land and cities on a grid framework, the *jōri* system. The gridded paddy fields, about one hectare in size, could then be subdivided into smaller units and allocated to individuals for rice tax purposes. The *jōri* layout can still be seen in the ever disappearing fields of the Nara Basin and in other areas of the Kinai, a regional designation for the "home provinces" of old Yamato now subsumed in Osaka, Kyoto, and Nara Prefectures.

Terracing of lower slopes and river valleys (of 5 to 6 percent slope) began in the seventh century. Only in the medieval period, however, as irrigation technology advanced, did terracing begin in steeper river valleys, with a gradual extension onto hillslopes (up to 16 percent gradient). This, in effect, pushed the forests farther up the mountains and increased the amount of arable land near the lowlands. In the Edo period, rice-growing was also extended onto volcanic soils in the Kantō region around Tokyo, a development facilitated by the digging of irrigation canals to supply both water and nutrients. In the nineteenth century, marginal lands including tidal flats, estuaries, lagoons, and some inland

lakes were reclaimed for rice cultivation. For instance, Kyoto basin used to have a large lake near the juncture of the Yodo and Uji Rivers that was eventually reclaimed for use as paddies.

The maximum extent of paddy land in Japan was reached in the early 1930s. Thereafter, the area devoted to rice production decreased with changing food preferences, including imported rice. In the inland mountain valleys, abandoned paddy fields are being recolonized by forest, while former paddies on valuable coastal plains have been consumed by urban expansion. Some of the large conurbations that now characterize many coastal areas have entirely obliterated the natural plains (Osaka, Kobe), and mountain basins are filling in fast with urban sprawl (Kyoto, Nara). Some municipalities have enforced greenbelt areas along the foot of the mountains, protecting the forests on the slopes, while others have encroached on lower foothills, blurring the distinction between plains and mountains. So the traditional landscape once demarcated between forest and paddy is now recast between forest, paddy, and conurbation.

Between Paddy and Forest

In contrast to lowland paddy fields, lands beyond the plains were highly diverse in the premodern period. Forests were traditionally distinguished by proximity to settlements: *Okuyama* (inner mountains) were places for hunting and collecting—rich in animal and plant (often nut) resources—while *satoyama* (village mountains) were forested areas near settlements and heavily exploited for wood for fires and tools; these trees were often chopped down and burned to provide more field space for dry crops. This latter pattern, referred to as slash-and-burn or swidden agriculture, lasted into the 1970s but is rarely seen today.

The deep mountain forests are discussed in a later section. Here let's look at the various forms of uplands within the plains that sustain dry-field crops, orchards, and vegetables. These plantings are often found around settlements, which were traditionally sited on high ground to avoid flooding. Even on alluvial flats, villages sat on natural river levees, and these natural levees also supported vegetable gardens. The difference in height between a paddy field and a vegetable garden could be as little as half a meter—reflecting the difficulty of lifting irrigation water up onto the levee.

A specific sector of Japanese plains is the volcanic terrace as seen in the Kantō Plain. The entire Kantō region, where Tokyo is sited, is such a terrace, comprising thick layers (some three hundred meters deep) of volcanic ash deposited in the Pleistocene period more than 10,000 years ago. Large rivers such as the Tone, Arakawa, and Sumida have washed out great portions of these layers. At the Nippori station on the Yamanote train line in Tokyo, one may see bluffs carved out by the Arakawa River towering above the tracks. Situated on these bluffs are Edo-period temples and their cemeteries, Tokyo University, and the

Ueno Park complex, including several national museums. When the Tokugawa established Edo as its capital, the bluffs were virtually unoccupied, with most activity carried out by fishing villages along the shore of Tokyo Bay. Thus developed the social distinction between the aristocratic occupation of the upper terraces now served by the Yamanote (hill-fingers) circle line and the commoner habitation of the coastal lowlands of *shitamachi* (lower town). But why were the bluffs previously unoccupied?

Volcanic soils in areas of high precipitation like Japan are notoriously poor in nutrients. The rain leaches out the calcium, magnesium, and potassium, and an unusual colloidal fixing of phosphate in volcanic soils also makes this element unavailable for plant growth. The absence of these vital nutrients from the Kantō Plain, plus their being too high above the streambeds for irrigation, made them poor for agriculture. Many volcanic soils around Japan, particularly on the flanks of volcanoes, are virtually unused for crops. They are often colonized by bracken, sasa bamboo, and pampas grass, as seen on the northern flanks of Mt. Fuji—used for filming galloping-samurai movies. Only with irrigation and fertilization have they been brought into production. Vegetables, particularly root crops such as radishes, carrots, and sweet potatoes, grow well in the fine-grained volcanic soils; orchards are another good investment, as in the thick deposits of white pumice of southern Kyushu.

Despite the image of Japan as a country of rice agriculture, in the nineteenth century before urbanization and industrialization, rice paddy accounted for 58.5 percent of the arable land, while dry fields amounted to a full 41.5 percent. To ignore the prominent role of dry crops in Japan's agricultural history is to misunderstand the life of the peasants, who were often barred from eating the rice they grew and were forced to subsist on dry crops such as barley and millet, and vegetables from their gardens.

A COUNTRY OF CLIMATIC EXTREMES

The Japanese archipelago, including the Ryūkyū Islands in the south, forms an arc that stretches from 45°30" to 20°24" north latitude. In North American terms, this is from Augusta, Maine, to Nassau in the Bahamas; in European terms, from Bordeaux, France, to the Aswan Dam on the Nile; and in Australian terms, from Brisbane in the north to Tasmania in the south. The archipelago thus stretches between cold temperate and subtropical regimes, so it is no surprise that Hokkaido is cool in summer and snowed over in winter, while Okinawa basks in mild temperatures year-round.

Japan, however, also has clear east-west differences in climate. It is a monsoonal country with seasonal influences of oceanic and continental regimes. In the summer, onshore winds from the Pacific Ocean bring heavy rain in June

and typhoons from July through September; in winter, offshore winds from the continent bring cold air down from Siberia. These wintertime winds, however, are moderated by both the sea and high mountains. The dry cold winds pick up moisture crossing the Japan Sea; then, as they are forced upward over the backbone of the mountain ranges, they drop their precipitation as snow. Thus, the northwestern flanks of Honshu and the high mountains suffer under heavy snowfall, while the eastern seaboard enjoys a maritime winter with relatively mild temperatures. The now dry winds, however, signal a deprivation of moisture, making winter in the eastern mountain flanks a time of forest fires.

The western snowbound regions are known traditionally as Snow Country, also the title of a novel by Kawabata Yasunari. The protagonist views a winter escape to the Snow Country as an antidote to city living. Not only did time slow down relative to other regions, because deep snow made getting about extremely difficult, but people living in these regions developed distinct customs to accommodate the snow. The children's snow "igloos" of Akita Prefecture are famous, and the Niigata Prefectural Museum gives an adult view of living with ten feet of snowpack in winter.

Average annual precipitation in Japan ranges from 944 to 4,060 millimeters, but usually exceeds 1,020 millimeters. This rate puts Japan on a par with South China, the Congo, and Brazil but is not as high as Indonesia's. One result of all this precipitation is a high rate of erosion of the land surface, as mentioned above; another is the acidification of volcanic soils as alkali and alkaline elements are leached away. A third is high humidity. In the dry winters, humidity can drop as low as 50 percent in Tokyo, but in summer, the humidity throughout the lower islands is often 98 percent even when it is not raining—all the more reason to escape to Karuizawa in summer, a famous mountain resort in central Honshu, or to Hokkaido for a cooler, drier summer.

A COUNTRY OF FORESTS

High precipitation also contributes to a lush growing season. The *okuyama* forests of Japan are dense, but their composition has changed over the centuries. Because of the north-south range of the islands, the climax forests in the northeast are cool temperate deciduous forests harboring familiar nut tree varieties such as chestnut, walnut, and deciduous oak. In the southwest, the climax forest was, until the arrival of agriculture, a laurelignosa forest similar to that in South China. This forest, largely unfamiliar to Westerners, consisted of evergreen oak, *hinoki* cypress (*Chamaecyparis* sp., used to build Ise Shrine and sushi bar counters), *kusunoki* (*Cinnamomum camphor*), and *sakaki* (*Cleyera japonica*, the sacred tree of Shintō), among others. This forest was decimated by the mid-first millennium CE because of agriculture, the iron and pottery industries, and urban-

ism. The majestic broad-leaved evergreens now survive only on shrine and temple lands, where they have been protected for the past fifteen hundred years; they can be seen in Meiji Shrine in Tokyo, around Miwa Shrine in Nara, and at Dazaifu in Kyushu, for example.

The changing state of Japanese forests throughout history has been perceptively and incisively documented by Conrad Totman. He identifies three periods of excessive forest degradation: in the Nara-Heian periods of court culture, affecting mainly the Kinai region; between 1570 and 1670, extending through the three main islands; and in the early twentieth century—the last period of destruction clearly apparent in photographs taken by visiting Westerners.

Anthropogenic destruction of upland woodlands is apparent from the very beginning of rice agriculture, in which Yayoi and Kofun farmers cut southwestern evergreens (both broad- and needle-leaved) for housing and fuel. With the beginning of stoneware production and iron forging in the Kofun period, vast areas were cleared to supply kilns and forges with fuel. This trend was accelerated with the intensification of shipbuilding and the introduction of monumental wooden architecture from China via Korea—the latter requiring kiln-fired roof tiles and large pillars to support the roofs. Construction of the Todaiji temple in Nara in 742 required eighty-four columns, each four feet in diameter and a hundred feet high, "900 hectares (2,200 acres) of first-quality forest" for post-and-beam buildings, and 163,200 cubic feet of charcoal for casting the large Buddha housed therein. By the end of this "Ancient Predation," as Totman terms it—between 2,000 and 1,500 years ago (0–500 CE)—the indigenous broad-leaved evergreen forest of southwestern Japan had mostly been replaced by secondary red pine growth.[1]

By 1550 CE, Totman notes, the forests of west-central Honshu were heavily exploited for green fertilizer and selected logging for elite construction until demand for monumental architecture and urban construction rose even higher after 1570. Competition for woodland products among elites, merchants, and commoners led to such devastation of the forest cover that upland erosion caused flooding and heavy sedimentation on the plains, disrupting the rice-growing tax base. Totman outlines two successive responses: an initial negative regulatory regime that closed forests to promote regeneration or prohibited the logging of certain tree sizes or species, and in the late Edo period, a positive afforestation movement that encouraged active intervention both governmentally and locally. The latter response was initially a grassroots phenomenon led by "itinerant scholars, village headmen, practicing farmers, minor officials," and others who wrote "agricultural treatises" or "farm manuals."[2] Their campaign sought to influence daimyo policies as well as villager activities.

Totman offers several reasons why afforestation was broadly successful: The natural succession patterns of forest suited human needs; cultural prohibitions

against wheeled vehicles and crosscut saws prevented complete destruction of forests; an ideology of conserving resources and planning for the future made people sensitive to changes in their environment; the maintenance of peaceful relations discouraged outright competition; and the semiclosure of the country to outsiders precluded international sourcing of materials. It was eventually in the daimyos' interests to keep their forests well stocked not only to protect their tax base but to fulfill their feudal obligations, so afforestation efforts were permitted and encouraged on intimate local levels.

Totman cautions that the lush greenery seen today (as in the satellite photos referred to above) is a product of both eighteenth-century and postwar reforestation programs that have saved Japan from the fate of nations that have lost their forest cover. Unfortunately, much postwar forestry effort has been devoted to timber plantations, with the result that 41 percent of Japan's forests is now occupied by these monocultures with little biodiversity of plant and animal life.

A COUNTRY OF NATURAL DISASTERS

Because of its tectonic setting, Japan is subject to four major natural disruptions: earthquakes, volcanic eruptions, landslides, and tsunamis. A fifth disruption is caused by the islands' geographic positioning at the western edge of the Pacific, where typhoons (hurricanes) develop along the equator in the south and travel northwest toward land. Famine and disease can also be named as causes of considerable social disruption, having taken as much as a quarter of the population several times in the medieval period.

Perhaps living in a land of unpredictability has contributed to the Japanese reputation for stoic forbearance and a grain of fatalism. Nevertheless, the government has been working hard since the 1995 Kobe earthquake disaster to educate the public and provide resources for avoiding the worst of geohazard damages. The Japan Meteorological Agency (JMA) website provides key information on earthquakes, volcanic eruptions, and tsunami, in addition to weather reports including coverage of typhoon progressions.[3] These efforts are limited, however, as shown by the swiftness and severity of the tsunami accompanying the March 2011 Tōhoku-Oki earthquake. Buildings meeting earthquake standards survived the quake, but many were washed away in the tsunami. Moreover, the short time between the earthquake and tsunami, plus residential complacency, contributed to a great many deaths. One solution is not to build on coastal plains vulnerable to tsunami, as attested by stone markers showing historical tsunami heights. But human nature is territorially tenacious, and short-term economics override long-term safety.

The seismological network that monitors earthquakes throughout and around Japan is one of the world's most extensive and sophisticated. Informed

by 4,400 monitoring sites, the JMA can, within three minutes of an earthquake, post on its website the location of the hypocenter (deep in the earth), magnitude, and seismic intensity. If the intensity of an earthquake is 3 or higher (on a log scale of 1 to 10), local "disaster prevention authorities" are notified within one and a half minutes, and reports are sent to the media. Since 2007, an Earthquake Early Warning service detects initial tremors and is able to issue warnings of an impending earthquake. The JMA issues a Tsunami Warning/Advisory within three and a half minutes of an earthquake in Japan, and it is linked into the Pacific Tsunami Warning Center in Hawai'i.

The tsunami that often accompany earthquakes may be propagated by fault movement on the ocean floor or by landslides. These waves move out from the earthquake epicenter (location on the surface above a hypocenter) or the landslide entry point like the concentric waves caused by a pebble thrown in the water. In deep water, the waves are typically only one meter high and a kilometer apart, but they can move at seven hundred kilometers per hour. As they approach shallow water, the waves heighten and compact and can flow far inland at altitude. Waves twenty-five to thirty-five meters high are known in Japan to have flowed eleven kilometers inland, wiping out coastal fishing villages. The 2011 tsunami, however, was the first to destroy infrastructure to such an extent that it affected the global economy. As population densities increase in hazardous areas such as low-lying coasts or volcanic flanks, the world can expect to see more such disasters.

Volcano activity is also monitored by the JMA. Of 108 currently active volcanoes, 30 have seismic monitoring equipment in place, while the rest are under periodic observation. When magma moves in a volcanic chamber or neck, it causes earth tremors or small earthquakes. These are monitored seismologically just like those caused by subduction or active faults. Also in 2007, the JMA began its Volcanic Warning and Volcanic Forecast service. Volcanic ash warnings are also in place—as of this writing, for Sakura-jima and Suwanose-jima, both in southern Kagoshima Prefecture.

Volcanoes pose other hazards that can affect nearby communities. Pyroclastic flows and lahars are extremely dangerous. The former consist of hot ash, hot air, and rocks that can race down a mountainside at more than one hundred kilometers per hour. About a quarter of volcano-related deaths result from pyroclastic flows, as was the case for the volcanologists killed by the dome collapse on Mount Unzen in 1991. Once the ash settles from a pyroclastic flow or airfall, it can turn into a lahar (mud flow) if sodden with rain. Thus volcanic slopes can become highly unstable in a regime of high precipitation or further volcanic tremors or both. Given the steep-sided mountains with villages tucked at their feet, Japanese communities fear landslides more than they do other hazards because they are more frequent and can happen any time without warning.

Although "science" is not usually a part of Japanese studies, understanding the composition and natural environment of the Japanese islands is important to understanding life and events throughout Japan's history. The historical record is littered with natural disasters that modern society is struggling to prevent, mitigate, or avoid altogether in future. The linking of scientific monitoring with local government is crucial for eliminating human-caused disasters such as the one bred of inaction after the Kobe earthquake. Living in Japan, one should be aware of the programs for protection and evacuation that this partnership offers.

A COUNTRY OF GREAT NATURAL BEAUTY AND COMPRESSED HUMANITY

In sum, Japan well deserves its tourist poster image, once one gets beyond the large cities, at least. Most human activity, however, occurs on the coastal plains. In particular, the urban corridor from north Kyushu through the Inland Sea to Tokyo is the focus of modern life. Iain Stewart, the BBC's geologist guide in the *Journeys into the Ring of Fire* series, made the outsider's observation that much of Japan's economic success is due to the compression of human resources on these coastal plains, allowing the development of efficient rail transport for commuting and for moving goods to and from deepwater ports. No other country in the world has population densities that can support such technologically advanced communication and transportation systems.

If one ventures into the countryside, on the other hand, it can be a long time getting there. One of the most interesting hot springs in Tōhoku (Geto, in Iwate Prefecture) is accessible only by a two-and-a-half-hour public bus ride over narrow mountain roads from the nearest train station. Getting from Matsumoto City in Nagano Prefecture across the border to the Kusatsu hot springs in Gunma takes more than three hours by bus. And traveling by train from Nagoya City to Lake Kawaguchi to see Mt. Fuji can take an entire twelve-hour day. All these places are worth the wait once gotten to.

Japan is a vast country with a rich history, a volatile but beautiful nature, and a welcoming population. Studying Japan within its natural setting is greatly enjoyable and ever intriguing.

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Notes

1. Totman, *The Green Archipelago*, 17–18, 22.
2. Ibid., 116.
3. Japan Meteorological Agency (JMA), http://www.jma.go.jp/jma/indexe.html (accessed 24 August 2010).