5

Hawaiian Topography

In 1840, the renowned American geologist James D. Dana (see chapter 28) correctly deduced that the main Hawaiian Islands decreased in age from northwest to southeast by observing the lessening degree of erosion of volcanic peaks from Kaua'i to Hawai'i. But, in antiquity, Hawaiians had already recognized the same age sequence and explained it in various versions of the **Pele legend.**

PELE'S WORK

The volcano goddess and her family emigrated from Kahiki (literally Tahiti, but also used for a distant mythical land) and first landed on Ni'ihau. Pele dug to establish the family home and kindle her volcanic fires, but groundwater rose in the pit and extinguished the flames. She then continued these efforts south through the islands with the same result. Finally, however, on Hawai'i, pits dug in both Mauna Loa's caldera Moku'āweoweo and the "Fire Pit" Halema'uma'u of Kīlauea's caldera remained free of water, so Pele was able to establish permanent fiery homes there.

The natural antipathy between forces of fire and water frequently appears in traditional folklore around the world. It is interesting that in Hawaiian legends this same antagonistic relationship is acknowledged not only in the extinguishing of Pele's fires but also in repeated instances of conflict between her family and *mo'o* or dragons (see chapter 19) typically closely associated with water (see, for example, the meanings of Mō'ili'ili and Mokoli'i in the Glossary).

Pele's flooded earlier residences may be seen in such forms as O'ahu's **Salt Lake** (Figure 8.5; originally Āliapa'akai, once 1.5 km or 0.9 miles in diameter but now mostly filled for a golf course) and the pond-bottomed 300-m-(990-foot-)deep crater of Kauhakō (Lua o Pele or "Pele's Pit") on Kalaupapa Peninsula of Moloka'i. Because Pele dug deep in her searches, it is not surprising that legend held that Salt Lake was bottomless, so the geologist Dana had a canoe carried up from the coast and paddled to the lake center with the longest sounding line he could find. He lowered the line only to discover that the deepest point measured 0.4 m (1.3 feet). Hawaiian legends are always interesting and are certainly worth studying because of their value in providing information on many aspects of ancient Hawaiian life not available from any other source. Obviously, however, not all can be accepted uncritically.

RIFT ZONES

Lines of cinder or spatter cones in the southeastern portion of Hawai'i Island are also said to be the mid-fourteenth-century work of Pele: some of these are masses of molten lava she hurled at a fleeing chief, Kahawali, who had displeased her. Such linear arrangements of cones usually trace the rift of a Hawaiian volcano, although most rift-zone activity is usually much more extensive. Rift zones on Hawai'i are shown in Figure 5.1, but certain of these are not especially obvious in the field because they have been obscured by lava flows of younger volcanoes. For example, the south rift of Mauna Kea is covered by Mauna Loa's flows, with the latter lavas that abut the older mountain forming the broad **Humu'ula Saddle** or "Saddle Area" between the two peaks at about 1,800 m (5,940 feet).

O'ahu shows an extreme development of rift zones; apart from the immediate volcanic summit areas (Figure 5.2), the entire Ko'olau and Wai'anae Ranges were formed by rift erup-

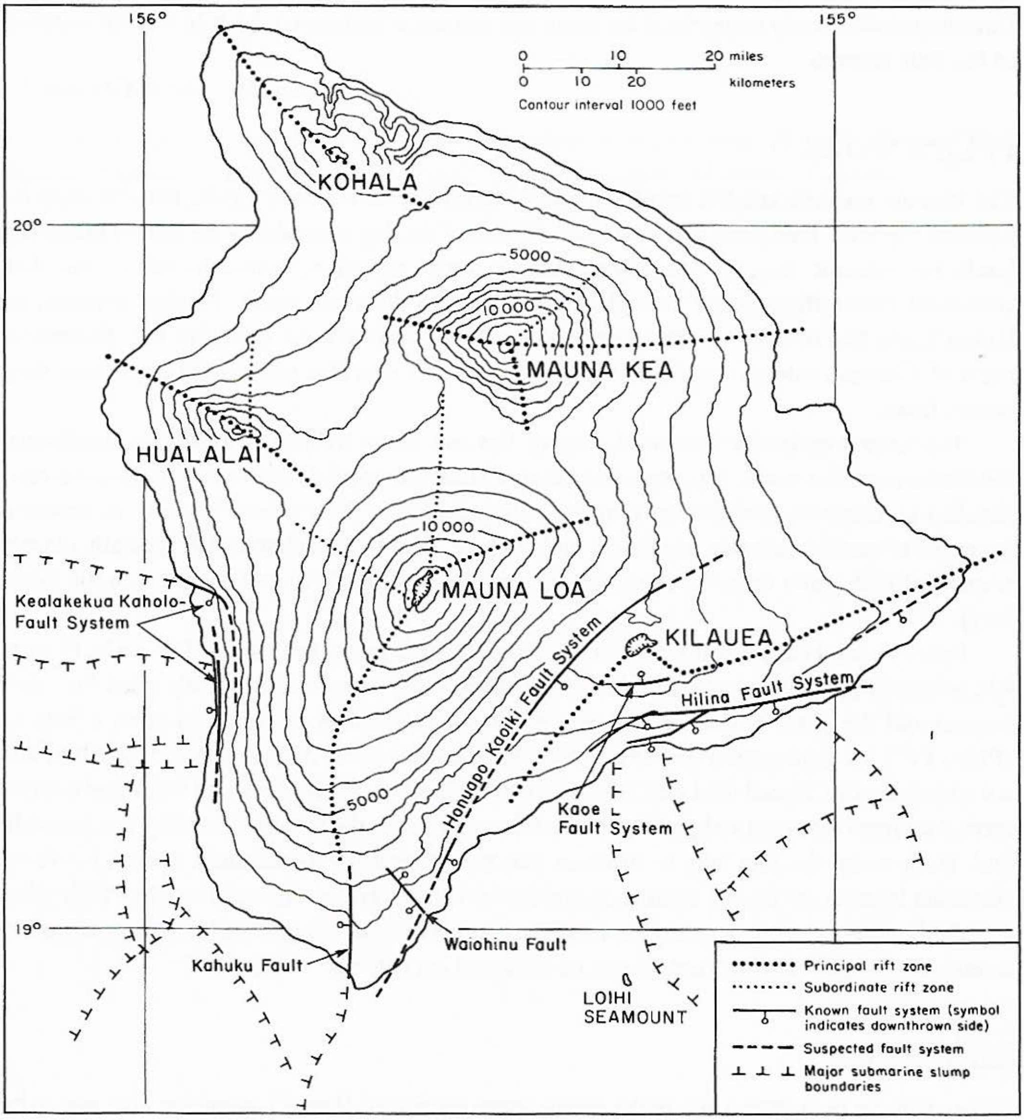

Figure 5.1. Contour map of Hawai'i Island. Volcanic rift zones and tangential faults on land, as well as submarine slumps and the location of the submarine volcano Lō'ihi are also shown. (Fig. 19.6 of Macdonald et al. [1983], used with permission of Frank L. Peterson.)

tions. Lava flowing west from the Ko'olau summit and rift zone partially covered the eastern slopes of the older Wai'anae Range (Figure 3.5), producing the elevated Schofield Plateau. The summit areas of these two volcanoes, on each of which two or more calderas formed at different times, are no longer present, but quite likely reached between 3,050 and 4,575 m (10,000 and 15,000 feet) above sea level at maximum volcano growth. The upper subaerial two-thirds or more of each volcano, however, was subsequently lost to giant land slumps (see next section), erosion, and island subsidence (see chapter 3).

PALI, FAULTS, AND MASSIVE SLUMPS

Especially noticeable on the south and southeast slopes of Kīlauea and Mauna Loa are several long lines of cliffs or *pali.* These are termed **tangential faults** because their geometric relationship to the general volcanic contours is that of a tangent to a circle (Figure 5.1). They were formed when subaerial and upper submarine slopes of a growing mountain slumped down the unbuttressed ocean side of the island, either suddenly or incrementally over an extended period of time. In these landslides, substantial portions of a volcano were sometimes lost. One gigantic slump on the north side of East Moloka'i, which carried away perhaps half of the original

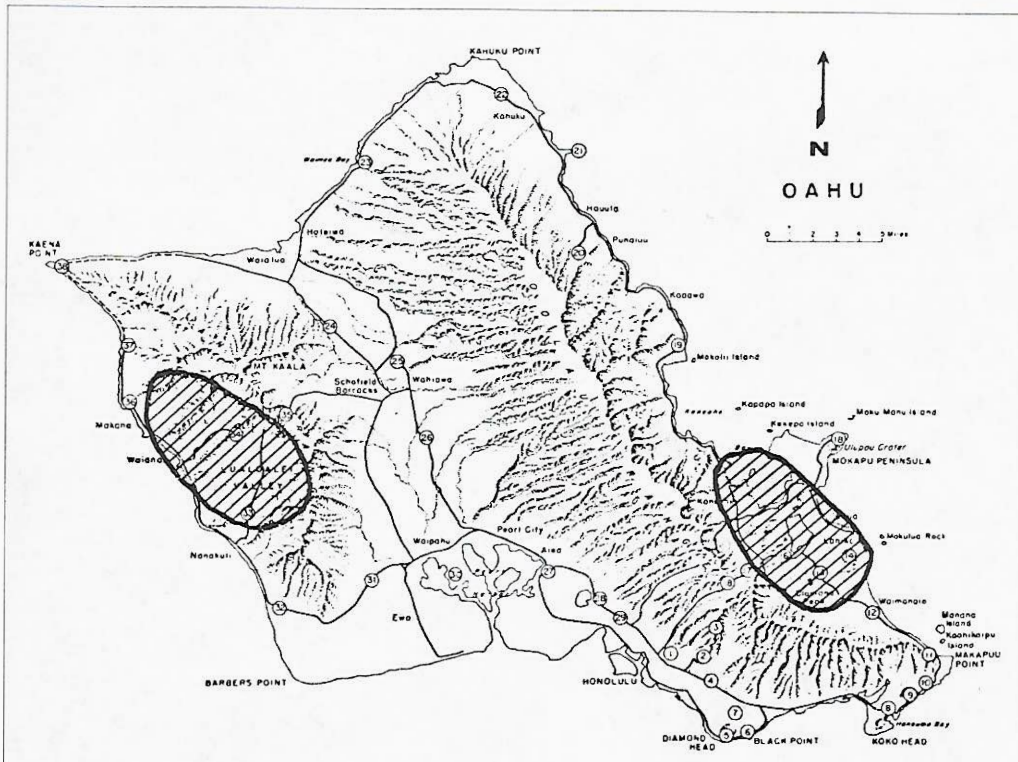

Figure 5.2. Relief map of O'ahu. The Wai'anae *(left)* and Ko'olau *(right)* Ranges built up along rift zones of two ancient volcanoes, whose original caldera-bearing summits (cross-hatched areas) and upper slopes have long since collapsed or eroded away. (Base map from Fig. 5.1 of Stearns [1985], used with permission of Pacific Books, Publishers.)

volcano there and scattered debris out over the ocean floor for well over 160 km (100 miles), is said to be among the largest landslides on earth. These slumps may also involve parts of the volcano's rift zones and are very likely responsible for the initial formation of high elongate escarpments such as, for example, the Ko'olau Pali of Windward O'ahu (Figure 5.3). Wave action during subsequent heightened sea stands and, on the windward side of islands, prolonged freshwater erosion have accentuated such impressive clifflike alignments.

When such great landslides occur suddenly, they invariably produce earthquakes, of which the largest one recorded in Hawai'i during the last hundred years, 7.2 on the Richter scale, occurred in November 1975. It apparently resulted from seaward land slumping along the Hilina fault system (Figure 5.1) of Kīlauea's east rift zone. This early morning earthquake caused shoreside Halapē Campground of Hawai'i Volcanoes National Park to drop 4 m (13 feet) into the ocean, with the inrushing water from a series of immediately following tsunami waves (see chapter 6) killing two of the thirty-two campers sleeping there, as well as four horses.

The larger of ancient slump-related earthquakes, much more powerful than any subsequently witnessed in Hawai'i, would have generated enormous waves that devastated nearby

Figure 5.3. The great Ko'olau Pali of Windward O'ahu. The southern half of this escarpment between Waimānalo (center foreground) and Kāne'ohe (right background) is shown. The forked peak in the large cloud shadow is Olomana. (Photograph by Agatin T. Abbott; Fig. 21.12 of Macdonald et al. [1983], used with permission of Frank L. Peterson.)

main islands. For example, numerous coral reef fragments enigmatically situated at about 325 m (1,073 feet) on southeastern Lāna'i and at 70 m (231 feet) on Moloka'i are thought by some investigators to have been washed there on such tsunamis produced by major slides occurring along the western coast of Hawai'i between about 100,000 and 200,000 years ago.

CALDERA-FILL REMNANTS

The basalt that filled calderas of senescent Hawaiian volcanoes is so dense that portions of it may occasionally remain as isolated jutting structures long after the rest of the summit region has eroded away. The striking forked peak of Olomana on Windward O'ahu (Figure 5.3) and 'Īao Needle of West Maui are considered to be such remnants. Although water easily penetrates most lava formations, caldera-fill basalt is relatively impervious. On Kaua'i, a large, flat portion of the fill of Wai'ale'ale Volcano's caldera (originally the largest in the Islands, about 15 to 20 km or 9.3 to 12.4 miles across) remains on the island's summit (Figure 5.4). Here, the area's abundant rainwater collecting on this thick basalt maintains the anomalous high-elevation Alaka'i Swamp.

REJUVENATION-STAGE ERUPTION FEATURES

O'ahu

Most of the more-obvious O'ahu Rejuvenation-Stage features (see chapter 3) are located in the southeastern part of the Ko'olau Volcano complex and were commonly formed by large hydromagmatic and phreatic explosions (see chapter 4). Such eruptions, probably sometimes extending over several days, formed a number of prominent cratered cones, made up primarily of the cemented fine-ash rock known as tuff. Punchbowl (originally Pūowaina), Diamond Head (Lē'ahi), Koko Head, Koko Crater (Kohelepelepe), Rabbit (Mānana) Islet, as well as Ulupa'u Head and Mokumanu Islet of the Windward Mōkapu Peninsula, are examples of such structures. Even Hanauma Bay appears to be the remnant of a tuff cone, with its original seaward rim eroded away and its crater now flooded (Figure 5.5). When formed on land, cones of this and other types are almost invariably called ***pu'u,*** the general Hawaiian term for an isolated protuberance of essentially any type or size. Incidentally, the fact that the southwestern rim of at least some of these tuff cones (Diamond Head, for example) is higher than that on the north-

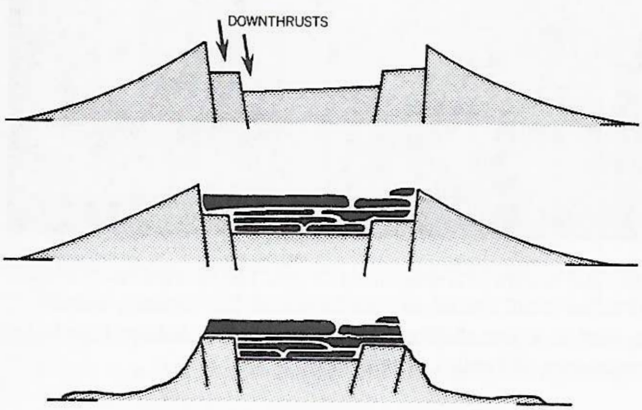

Figure 5.4. Development of Kaua'i Island's flat summit. *Top,* formation of original Wai'ale'ale Volcano caldera; *middle,* filling of caldera by dense basalt; *bottom,* erosion of surrounding summit basalt. The low permeability of the dense caldera fill material to rainwater contributed significantly to development of the high-elevation Alaka'i Swamp. (Unnumbered figure on p. 54 of Carlquist [1980], used with permission of the National Tropical Botanical Garden.)

eastern side indicates that the primary trade wind direction while they were formed was probably the same as at present.

A few other O'ahu Rejuvenation-Stage eruptions included lava flows along with ash production, such as those forming Mount Tantalus (originally Pu'u 'Ōhi'a) and Sugarloaf (Pu'u Kākea), as well as possibly also Round Top (Pu'u 'Ualaka'a), above Mānoa Valley. Lava from Sugarloaf streamed down Mānoa Valley to form both the flat floor of the lower valley and the deposit of basalt that was extracted from the "Quarry Area" of the University of Hawai'i campus. The small Kaimukī shield volcano, in the eastern Honolulu section of that name, formed from lava flows of the Rejuvenation Stage.

Other Islands

On Maui, the most recent volcanic activity occurred low on the southwest rift zone of Haleakalā and resulted in the formation of two spatter cones and at least two partially coalesced lava flows that entered the ocean at La Pérouse Bay to form the present Cape Kīna'u. No written record documents the actual event, but information obtained from local informants about

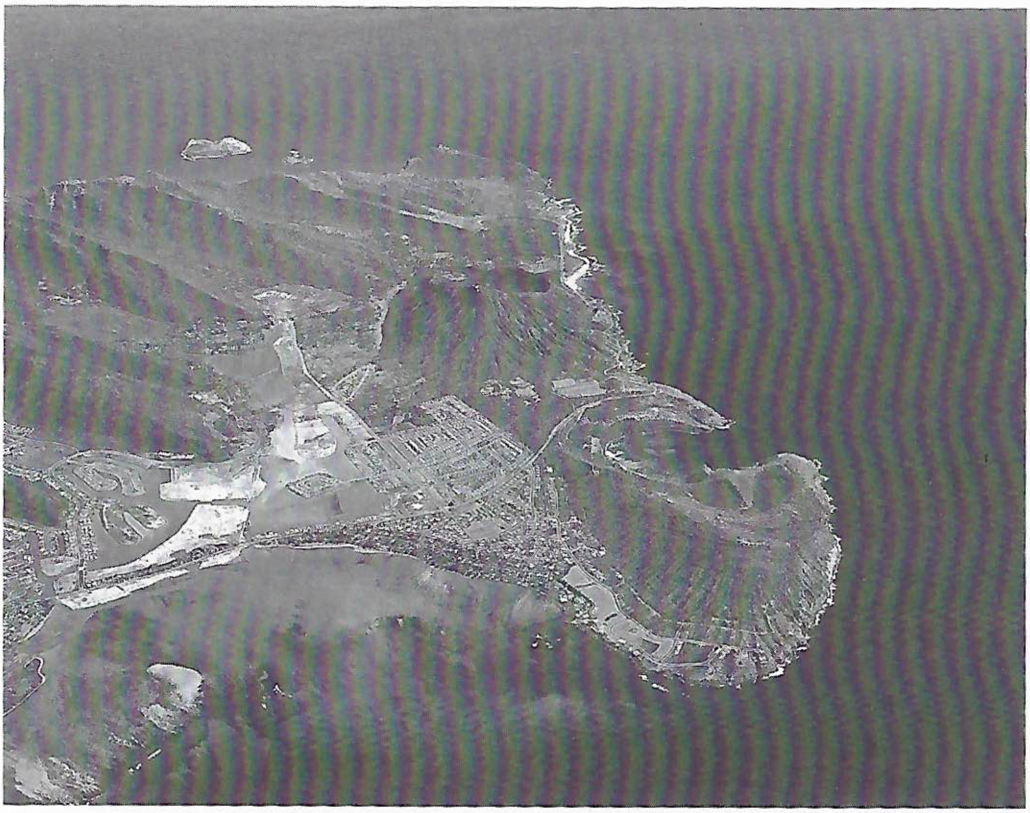

Figure 5.5. Rejuvenation-Stage tuff cones and craters of southeastern O'ahu. The flooded crater in the right center is Hanauma Bay; below it is Koko Head, and above it Koko Crater. The similarly created Rabbit (Mānana) Islet is visible in the far left background. (Photograph by Agatin T. Abbott; Fig. 21.18 of Macdonald et al. [1983], used with permission of Frank L. Peterson.)