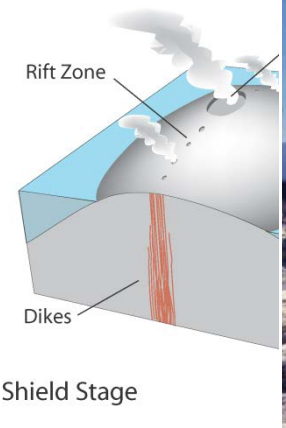
STUDY AREA – HYDROGEOLOGY

The main islands of Hawaii are formed by enormous basaltic shield volcanoes that were built from the ocean floor by mid-plate hot-spot volcanism. The islands are successively younger toward the southeast of the chain, with Miocene-age basalt on Niihau and Kauai at the northwestern end and active volcanoes on the Big Island at the southeastern end. The shield volcanoes along the island chain are also at different stages of geologic development. Three stages in the life of Hawaiian volcanoes—shield, postshield, and rejuvenation—form the land mass above sea level.

Shield Stage

Shield-stage rocks constitute 90 percent or more of the shield volcano. Highly fluid basaltic lava erupted at the summit and rift zones form lava flows that are generally only a few feet thick. The bulk of the shield volcano is thus a pile of thousands of thin lava flows.



Block diagram of the shield stage.

Mauna Loa, on the Big Island, an example of a shield volcano in the shield stage (photo by Scot Izuka).

Thin lava flows from the shield stage of the Koolau Volcano exposed in cliffs at Makapuu, Oahu (photo by Scot Izuka).

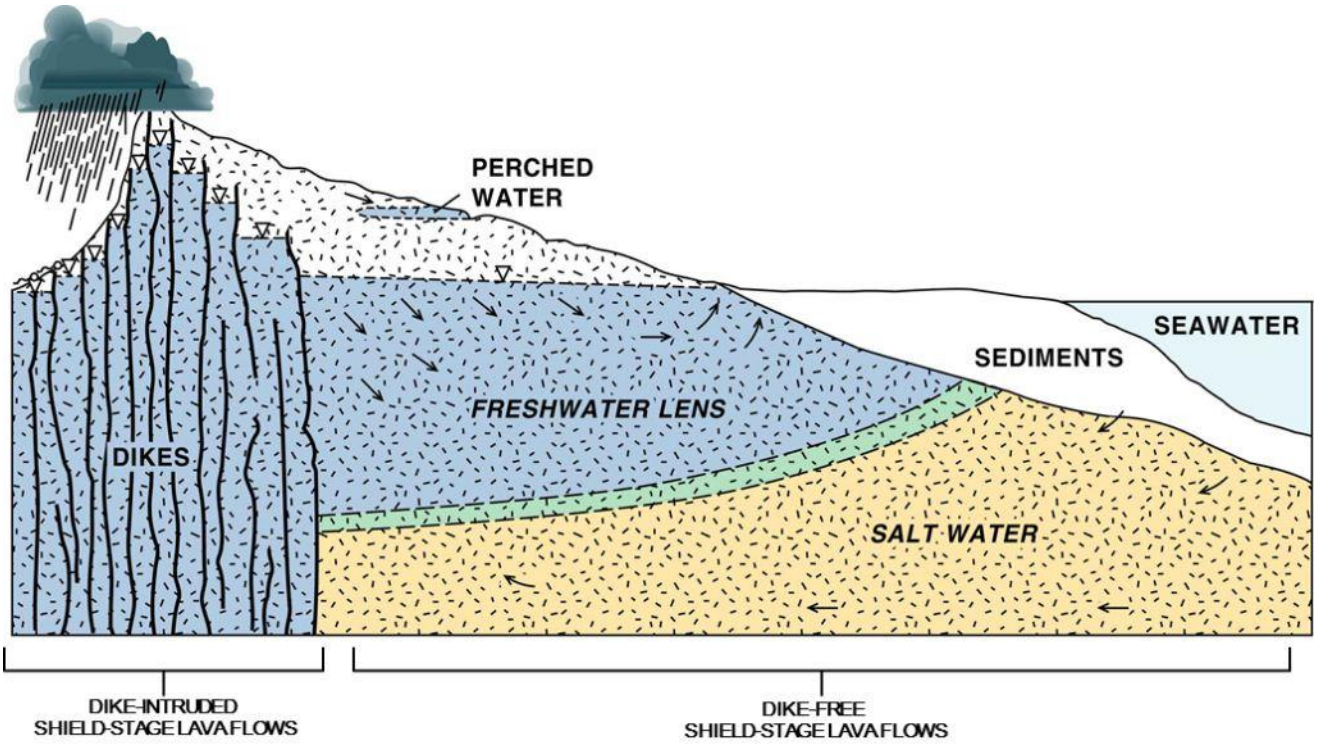
In places, especially beneath the summit and rift zones, the lava-flow pile may be cross-cut by volcanic dikes. Dikes are fractures through which

magma rises to the surface when the volcano is active; when magma cools in these fractures, it forms dense, sheet-like bodies of rock also known as dikes.

Vertical dikes cutting across nearly horizontal shield-stage lava flows exposed in the eroded Waianae Volcano, Oahu (photo by Scot Izuka).

Vertical dikes cutting across nearly horizontal shield-stage lava flows exposed in the sea cliffs of Kahoolawe (photo by Scot Izuka).

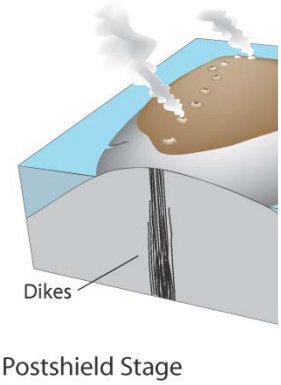
Shield-stage lavas form the most productive aquifers in Hawaii. These highly permeable aquifers have horizontal hydraulic conductivities ranging from hundreds to thousands of feet per day. Fresh groundwater in shield-stage lavas forms a freshwater lens over seawater, a system typical of ocean-island hydrology. Dikes have much lower permeability than the shield-stage lava flows they intrude, and can impede groundwater flow. In some places, dikes impound groundwater to hundreds of feet above sea level. The association between dikes and high-level groundwater, as well as the association between dike-impounded water and streamflow, is well known on windward Oahu because faulting and erosion have exposed extensive dike-intruded regions of the island. In the youngest islands, dikes are generally inferred to exist beneath the summit and rift zones. Other rocks and structures, ash layers, soil and weathered rock, unusually thick lava flows, and lava-draped faults, may alter groundwater flow. On Oahu, sedimentary rock in the thick coastal plain, locally known as caprock, retards coastal groundwater discharge and allows the freshwater lens to attain relatively great thickness; on younger islands without substantial caprock, freshwater lenses can be much thinner.



Cross-section diagram showing groundwater occurrence in shield-stage lavas and dike-intruded shield-stage lavas on Oahu.

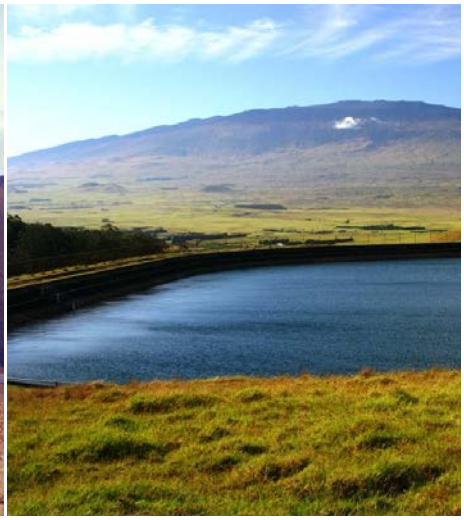
Postshield Stage

Rocks from the postshield stage cover the tops of some shield volcanoes in Hawaii. The postshield stage occurs during or after the waning of the shield stage. The postshield stage is characterized by lava with higher viscosity which results in shorter and thicker lava flows and more numerous cinder cones. Rocks from the postshield stage are important for groundwater resources in large sectors of some islands. Aquifers formed of postshield-stage rocks have been generally regarded to have lower permeability than shield-stage lava flows, but the very young postshield rocks of Hualalai volcano on the Big Island have some of the highest hydraulic conductivities (tens of thousands of feet per day) reported for volcanic rocks in the Hawaiian Islands.



Block diagram of the postshield stage.

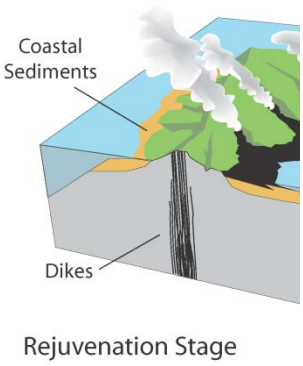
Cinder cones of the postshield stage of Mauna Kea, Big Island (photo by Scot Izuka).



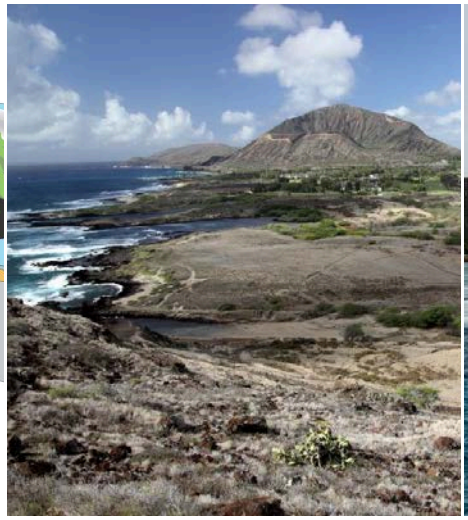
Mauna Kea, on the Big Island, shows a bumpy profile because of numerous small posthshield-stage cinder cones that form a cap on the large shield volcano (photo by Scot Izuka).

Rejuvenation Stage

On some shield volcanoes, rejuvenation-stage eruptions formed small cones and filled depressions created by erosion and faulting of the original shield-volcano surface. Rejuvenation-stage eruptions formed some of the most famous landmarks in Hawaii, including Diamond Head. On Oahu, rejuvenation-stage rocks interlayer with sediments to form the extensive coastal plain and caprock. In southeastern Kauai, rejuvenation-stage rocks have covered extensive areas and accumulated to substantial thickness. Rejuvenation-stage rocks on Kauai have been developed for groundwater resources, but high drawdowns and low-yielding wells indicate relatively low permeability.



Block diagram of the rejuvenation stage.



Koko Crater, an ash (tuff) cone of the rejuvenation stage on the Koolau Volcano, Oahu (photo by Scot Izuka).

The famous landmark known as Diamond Head is an ash (tuff) cone of the rejuvenation stage built on the coastal plain of Oahu (photo by Scot Izuka).

[*References:* *Macdonald and others (1983), Clague and Dalrymple (1987), Langenheim and Clague (1987), Hunt (1996), Oki (1997, 1998), Izuka and Gingerich (1998), Oki and others, (1999), Sherrod and others (2007), Gingerich (2008)*]