
**Introduction:** The Ka’u Desert is located on the western flank of Kilauea volcano on the Big Island of Hawaii. Although the area receives little annual rainfall (~150 mm/yr) the desert is also subjected to constant outgassing from Kilauea, which creates a harsh, acidic environment prohibiting plant growth. Near the summit of Kilauea the Ka’u Desert is characterized by the Keanakako’i tephra deposit, which averages several meters deep thinning out to a discontinuous deposit ~1.5 km (1 mile) towards the center of the desert. The deposit itself has been incised by a number of gullies that are flat-floored and terminate in a series of amphitheater-shaped plunge pools (Fig. 1). Most of the interior desert contains undulating weathered lava flows, more recent, unweathered flows, extensive deposits of sand, and a variety of volcanic edifices. The southern portion of the desert is bounded by the Hilina Pali fault scarp, which is ~500 m (~15,000 ft) above the nearby Pacific Ocean and contains a complex series of alluvial fans.

**Figure 1.** The flat-floored nature of the Keanakako’i gullies can be seen in this Landsat image. What is also evident is that surface flow becomes unconfined beyond the continuous tephra deposit forming a series of floodouts. Periodic flooding provides fresh sediment for the sand dunes located in the Ka’u Desert.

**Relevance to Mars.** Similar to martian valley networks [e.g. 1], the development of channels and gullies in the Ka’u Desert has been interrupted by resurfacing events, associated fluvial deposits have been heavily modified by eolian processes, and the ratio of fan gradient to drainage area is high by terrestrial standards but similar to those found on Mars [2], suggesting that the characteristics of the deposits may also be similar. Our studies have focused on understanding the history of gully incision in the Keanakako’i tephra, channel development in the Ka’u Desert (most of which is a bedrock surface), the deposition and reworking of materials associated with fluvial erosion of the tephra, and alluvial fan formation.

**Tephra Emplacement:** At least 9 layers of volcanic ash are exposed along cliffs in the Hilina Pali fault system, 6-8 miles (10-13 km) south of Kilauea’s summit [3]. The layers are a few feet to several tens of feet thick. The oldest deposits represent at least 2 eruptions that occurred between 2,000 and 2,700 years ago. These Uwekahuna Ash deposits are more voluminous and widespread than the younger Keanakako’i Ash deposits. The Keanakako’i eruptions occurred during a period of approximately 300 years starting around 1490 and deposited more than 100 million cubic yards (75,000,000 m$^3$) of ash and devastated an area on the Big Island at least 75 square miles (190 km$^2$). In places near the summit of Kilauea the Keanakako’i is 35 ft (10 m) thick.

Although early investigators recognized the fact that the Keanakako’i ash deposits were emplaced over a long period of time [e.g., 3], contemporary workers have mistakenly interpreted them to have all occurred in the famous 1790 eruption that decimated a large group of Keoua warriors [e.g., 4]. Our field investigations show that there were generally long hiatuses between eruption events that allowed reworking of the deposits by fluvial processes as well as extensive gully incision (Fig. 2).

**Gulley Formation:** The morphology of gullies that incise the Keanakako’i tephra is consistent with channels controlled by groundwater sapping. All gullies are flat-floored and terminate with amphitheater heads (Fig. 3). However, the water
The table is currently about 500 m below the rim of Halema’uma’u, making their formation by groundwater flow unlikely. Alternatively their morphology seems to be controlled by the many erosion resistant, indurated layers interbedded in the Keanakakoi tephra. These layers have been cemented by opaline silicate that we believe resulted when former surfaces were exposed to volcanic outgassing during periods of quiescence. This characteristic of the tephra results in a series of plunge pools within the gullies that generally increase in size as the drainage area increases downslope.

**Figure 2.** The contact between the upper, lithic tephra and the lower, vitric tephra marking a change in eruption styles. Person is pointing to a gully cut into the lower unit.

**Alluvial Fan Formation:** The gullies incising the Keanakakoi ash deposit are only part of the complicated channel system in the Ka’u Desert. Beyond the continuous ash deposit surface water flow becomes unconfined. Material eroded from the Keanakakoi is then deposited as a series of floodouts, providing a fresh source of sand for dunes that extend out into the desert. Water continues to flow over a series of prehistoric and modern lava flows eventually making its way down the Ka’u lava ramp and towards the 1,500 ft high (450 m) Hilina Pali fault scarp. During severe storms runoff from the Ka’u Desert cascades over the Pali in a series of waterfalls that cut back into the scarp. In our cursory study of the depositional features that form along the base of the Pali we found evidence for both Type I and Type II fans [5] indicating that the catchment hydrology of the Ka’u Desert is very complex.

**Figure 3.** An amphitheater head associated with one of the larger gullies that incise the Keanakakoi tephra. Indurated or erosionally resistant layers occur throughout the Keanakakoi deposit. Layers that are not indurated are more friable and are easily eroded. This results in a series of plunge pools of increasing size downslope.