# VALLEY DEVELOPMENT ON HAWAIIAN VOLCANOES

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Work in progress on Hawaiian drainage evolution (Baker, 1986; Baker and Kochel, 1984; Kochel and Baker, in press; Gulick and Baker, 1986) indicates an important potential for understanding drainage development on Mars. Similar to Mars (Baker and Partridge, 1986), the Hawaiian valleys were initiated by surface runoff, subsequently enlarged by groundwater sapping, and eventually stabilized as aquifers were depleted.

We have used quantitative geomorphic measurements to evaluate the following factors in Hawaiian drainage evolution: (1) climate, (2) stream processes (surface runoff versus groundwater sapping), and (3) time. In comparing regions of similar climate, drainage density shows a general increase with the age of the volcanic island (Table 1). With age and climate held constant, sapping dominated valleys, in contrast to runoff-dominated valleys, display the following: (1) lower drainage densities, (2) higher ratios of valley floor width to valley height ($V_f$ ratios), and (3) more positive profile concavities (Table 2). Some anomalies in drainage density development with time were idenitifed: (1) unusually high values on the windward side of Mauna Kea and Kohala, where low permeability ash deposits mantle relatively young, high permeability basalt flows; (2) low values on Oahu because of the dominance of sapping processes; (3) low values on Kahoolawe, Lanai, and Nihau, probably because of rain-shadow effects.

Studies of stream junction angles (Table 3) indicate increasing junction angles with time on the drier leeward sides of the major islands. However, relatively low values occur on the dry side of Oahu. On the windward sides of the major islands, sapping processes and associated slope changes result in variable junction angles.

The quantitative geomorphic studies and earlier field work (Baker, 1980, 1982) yielded important insights for Martian geomorphology. The importance of ash mantling in controlling infiltration on Hawaii also seems to apply to Mars. Some valleys, such as Kaupo and Keanae on Maui, evolve from lava surfaces, enlarge by groundwater sapping, and later become conduits for lava flows and lahars (Baker, 1982). Some valleys on Martian volcanoes seem to have similar experiences of multiple flow processes.

The Hawaiian valleys also have implications for the valley networks of the Martian heavily cratered terrains. Baker and Partridge (1986) found evidence for two types of valleys in this area: (a) slightly older, more dense networks on higher, probably relict land surfaces, and (b) younger, less dense networks of deeply incised valleys that seem to have grown headward at the expense of type (a) valleys. It is hypothesized that these relationships indicate an evolutionary sequence similar to that observed in the Hawaiian volcanoes. High-density surface-water ravines formed initially because of low-permeability rock types, appropriate climate, adequate relief, or some combination of these factors. With time, some valleys deepened sufficiently to tap ground-water flow in deeper, more permeable rock types. These valleys then enlarged by headward growth at the expense of the older networks. The latter were isolated as relict, degraded components of the landscape. The entire system ceased functioning and was "frozen" in its approximate present configuration at the termination of the heavy bombardment on Mars.

Table 1. Drainage densities ($km/km^2$) for Hawaiian Study Sites

| | Hawaii | Maui | Molokai | Oahu | Kahoolawe | Lanai | Nihau |
|---|---|---|---|---|---|---|---|
| humid areas | 0.3-7.0 | 1.2-3.5 | 2.4-5.5 | 1.7-5.1 | --- | --- | --- |
| dry areas | 0.2-1.1 | 1.2-2.4 | 1.2-4.0 | 1.0-4.0 | 1.4-3.9 | 0.9-3.5 | 1.8-2.9 |

Table 2. Properties of Drainage Networks

| | Drainage Density ($km/km^2$) | $V_f$ Ratio | Profile Concavity |
|---|---|---|---|
| Sapping-Dominated | 0.7-2.0 | 0.8-3.2 | positive |
| Runoff-Dominated | 2.1-3.2 | 0.1-0.8 | negative |

Table 3. Junction Angles of Hawaiian Valleys and Channels

| | Humid Study Sites | | | Dry Study Sites | | |
|---|---|---|---|---|---|---|
| Volcano/Island | $\theta_1$ | $\theta_2$ | $\theta_1+\theta_2$ | $\theta_1$ | $\theta_2$ | $\theta_1+\theta_2$ |
| Mauna Loa | 34 | 11 | 45 | -- | -- | -- |
| Mauna Kea | 34 | 5 | 40 | -- | -- | -- |
| Kohala | 38 | 11 | 49 | 33 | 14 | 47 |
| Maui | 41 | 19 | 60 | 44 | 15 | 58 |
| Molokai | 38 | 10 | 52 | 49 | 17 | 64 |
| Oahu | 41 | 16 | 57 | 37 | 21 | 57 |

$\theta_1$, $\theta_2$, and $(\theta_1+\theta_2)$ are mean values.

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