MORPHOLOGY OF LARGE VALLEYS ON HAWAII: IMPLICATIONS FOR GROUNDWATER SAPPING AND COMPARISONS TO MARTIAN VALLEYS

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Stream channels draining the windward slopes of the islands of Hawaii, Maui, and Molokai display greatly variable degrees of dissection relative to their leeward counterparts. Leeward slopes are slightly dissected with numerous high density channel networks developed in parallel arrangement. Windward channels are dominated by deeply dissected valleys having broad U-shaped cross-sections and amphitheater headward terminations (Fig. 1). It is unlikely that the asymmetry of rainfall-runoff between opposite sides of these volcanoes can account for these differences alone, especially since dissected valleys occur on windward slopes as well. Groundwater sapping processes are suspected to play a major role in explaining the morphology observed in deep Hawaiian valleys. The contribution of groundwater to the formation of large Hawaiian valleys was discussed by early workers (1, 2). They noted the apparent coincidence of dike swarms with headward terminations of large valleys and suggested that once surface runoff incision proceeded to depth where it intersected perched dike water, the influx of groundwater caused dramatic increases in the rate of valley enlargement.

Evidence supporting the importance of sapping comes from a combination of studies of imagery and topographic maps, field observations, and laboratory experiments. Drainage basins were outlined on 7.5' topographic maps from which morphometric measurements were made. Table 1 summarizes the trends of these studies. Principal components analysis of the morphometric data showed that valleys could be distinctly separated on the basis of morphometry (i.e., Fig. 2 shows first principal component).

Field reconnaisance of several valleys verified the significance of groundwater discharge into the large valleys. Valleys appear to be retreating headwardly by plunge pool erosion at valley-head waterfalls combined with basal sapping and associated mass wasting of headwalls. Plunge pool erosion appears to have been minor. Large discharge springs occur at the base of valley heads, even in valleys without waterfalls or where falls were diverted by upstream irrigation tunnels. Piracy of groundwater flow has played a major role in the development of these sapping valleys, much as it does in the evolution of surface runoff networks.

Finally, experimental studies of groundwater sapping processes in unconsolidated sediments (3) provide useful analogs to the Hawaiian channels. The effect of a sudden increase in groundwater contribution to a channel system was mimicked with the use of stratigraphic variations in sediments of varying hydraulic condivity. Surface channels were established on a smooth slope by groundwater sapping through the sediments from a headward reservoir. A more permeable and porous medium was put in the headward area of the slope which was progressively tapped as sapping channels cut headwardly. The rate of channel widening and extension increased significantly after the headward aquifer was tapped. These experiments and others in progress lend support to the model of increased dissection in the Hawaiian valleys caused when channels incised to the level of perched dike waters near the volcano summits. Widening of the headward portions of the large valleys on Kohala (Fig. 1.) by subsurface piracy is similar to the valley head widening that occurred in experimental runs at the level of the major aquifer. The

Hawaiian and experimental valleys bear many morphologic and morphometric similarities to valleys along the slopes of Valles Matineris on Mars, also thought to have been influenced by sapping processes.

References:
(1) Stearns, H.T., 1966, Geology of the state of Hawaii: Palo Alto, California, Pacific Books, Pub., 266 p.
(2) Macdonald, G.A., Abbott, A.T., and Peterson, F.L., 1983, Volcanoes in the sea, the geology of Hawaii, 2nd edition: Honolulu, Univ. Hawaii Press, 517 p.
(3) Kochel, R.C., Howard, A.D., and McLane, C., 1985: in Woldenberg, M.J., ed., Models in Geomorphology, New York, Allen and Unwin, p. 313-341.

TABLE 1. COMPARISON OF RUNOFF-DOMINATED AND SAPPING-DOMINATED VALLEYS ON KOHALA VOLCANO

CHARACTERISTIC	RUNOFF-DOMINATED	SAPPING-DOMINATED
Basin shape (K)	extremely elongate	light-bulb shaped
Head terminations	tapered, gradual	amphitheater, abrupt
Trend of channel segments	uniform	variable
Downstream tributaries	frequent	rare
Local relief (R2)	low	high
Drainage density (TDD)	high	low-canyons high-plateaus
Drainage symmetry	symmetrical	asymmetrical low down-dip
Canyon area/basin area (BCR)	low	high
Junction angle (MJA)	lower	higher

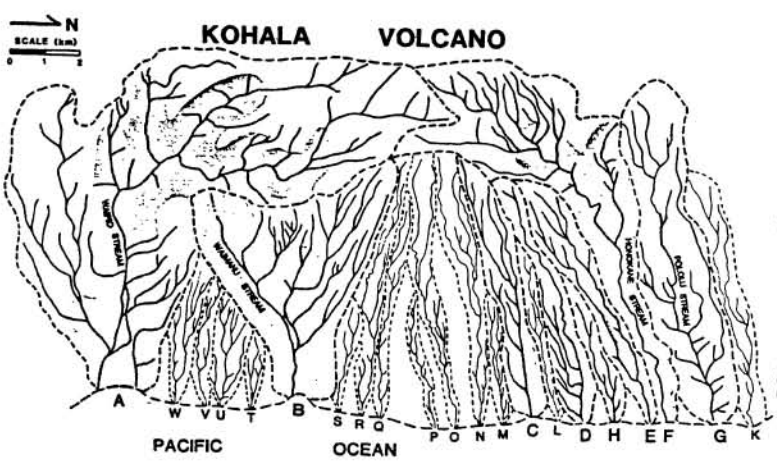

Fig. 1. Drainage networks on northeast Kohala A-G are deep valleys influenced by sapping. A,B,F,G are enlarging today. C,D,E,B may not be enlarging due to upslope piracy by A and F. H-W have negligible sapping.

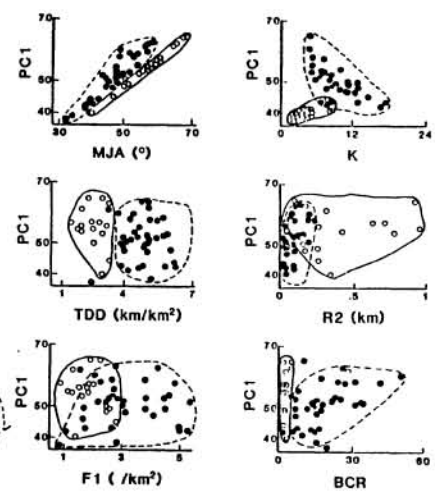

Fig. 2. Principal components analysis for 53 valleys on Molokai and Kohala. Dots are runoff valleys, open circles are sapping valleys