The formational history of Pu'u Ohau, Kona, Hawaii

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INTRODUCTION:

The focus of this study is a volcanic cone, Pu'u Ohau, located on the west coast of the island of Hawaii (fig. 1). Due to its relative inaccessibility, Pu'u Ohau had not been vigorously examined in the past. As a result, there was not a clear idea of how this cone formed. The goal of this project was to closely examine Pu'u Ohau and its surroundings in order to create a model that would explain the processes that formed it.

BACKGROUND:

Due to Pu'u Ohau's location, size, and appearance, there were several likely options for how Pu'u Ohau formed. The cone's location, directly on the coastline, implied formation by littoral processes, which occurs when a lava flow enters the ocean and interaction between the cool water and hot magma causes phreatomagmatic eruptions. The eruptions break the lava into very small fragments and disperses them around the eruptive center. The resulting cone is composed of hundreds of finely laminated layers of sand sized hyaloclastite (small angular fragments). (Fisher and Schmincke, 1984)

The size and appearance of Pu'u Ohau intimated that a subaerial primary vent eruption might be responsible for the formation of Pu'u Ohau. Cones formed from primary vent eruptions result from volatiles dissolved in the magma which upon eruption exsolve rapidly and create fountaining that can throw large bombs of lava into the air. Fountaining can be continuous or intermittent both of which can build a large cone of volcanic material.

METHODS:

In order to come up with a model for the formation of Pu'u Ohau, a number of methods were employed. The first of these was field reconnaissance, through which I gained information on the types of material that made up the cone, the stratigraphy, and structural information. This process included going out into the field and classifying the different materials of the cone, noting their locations and orientations, describing their relationship to each other as well as collecting representative samples

Thin sections from each rock were made for petrographic analysis. Chemical analyses for Rare Earth Elements (REE) and sulfur were done at Activation Laboratories in Toronto using Instrumental neutron activation analysis (INAA) and Leco sulfur analysis respectively. INAA measures characteristic gamma rays which are emitted from radioactive isotopes produced by irradiation with neutrons. Leco uses a process wherein powdered samples are combusted in oxygen at 1800°C and the resulting SO_2 is measured with an infrared Luft-cell detector. (Franczyk et al., 1987)

DATA:

Pu'u Ohau sits on the NW flank of Mauna Loa volcano, from which its lava is derived. The cone is elliptical and has a missing portion (10% to 15% of the complete cone) on the seaward side. Pu'u Ohau is built on a slope that dips to the west at approximately 15°.

Material. The cone is composed of 5 different types of material. The first of these, tephra, ranges in color from black and glassy to red and dull. Most clasts show airstreaming effects. The tephra is highly vessiculated, ranging from near reticulite (basaltic pumice) to mildly scoracious. In most cases, the range of vessiculation is directly related to the size of the clasts with the larger clasts being less vessiculated than the smaller clasts. The tephra is composed primarily of devitrified glass with scattered phenocrysts of olivine and plagioclase. The average size of the tephra clasts is 34 mm on the long axis and 13.25 mm thick. The deposits of tephra are clast supported indicating airfall deposition. No welding between fragments could be detected, indicating that the fragments were completely cooled by the time they were deposited. Deposits of tephra outcrop on the lower flanks of the cone and can be seen in the cliffs of the cone as thick units near the bottom of the stratigraphy and thinner deposits near the top of the stratigraphy.

Deposits of coarse, bomb sized spatter make up a large volume of the cone. The bombs range in size from 30 cm to 122 cm on the long axis and 13 cm to 50 cm thick. They show some airstreaming, and are most often of the cowpie bombs. The bombs have a chilled margin that is relative in thickness to the size of the bomb (which range in thickness from .5 to 3 cm). The chilled margins are glassy and have very little vessiculation, while the interior portions of the bombs are scoracious. The deposits of these bombs are clast supported and outcrop on the middle and upper slopes of the cone.

Another form of spatter deposit which is found primarily on the upper slopes of the cone are mounds of agglutinated spatter. These deposits are made up of spatter bombs which are welded together. On the outside of the deposits the boundaries of the fragments are visible, but within the mound the boundaries disappear. These mounds of agglutinated spatter indicate that the spatter fragments were not cool when they landed. If the fragments were even more molten when they landed, they would form the last two types of spatter deposits found on Pu'u Ohau, thin and thick agglutinated spatter flows. The thin agglutinated spatter flows range in thickness from .3 m to 1.5 m thick. The boundaries of the spatter fragments are visible on the top and bottom of the flows, but not within the core of the flow. The interior of the flow has scoracious vessiculation while the outer portions have the chilled margins of discrete spatter fragments. The thicker agglutinated spatter flows range in thickness from 2 m to 5.5 m. These flows are identical in appearance to a'a flows with a clinkery top and a cohesive, poorly vessiculated core.

The final type of material present in Pu'u Ohau is shelly pahoehoe deposits. These deposits are made up of stacks of 10 to 20, 5 cm to 10 cm thick pahoehoe flows. The individual flows are somewhat convoluted indicating a relatively fast flow. These flows issued from the eruptive center of the cone and flowed seaward through the lava channel and coat part of the interior walls of the cone.

Stratigraphy. The stratigraphy of Pu'u Ohau is best exposed in the sea cliffs. Above the basal flow on which the cone lies are a series of flat-lying, alternating spatter and agglutinated spatter flow deposits. These deposits are similar in thickness (approximately 1 m to 1.5 m) and in level of oxidation. As you move up the stratigraphy, the beds bow up into a concave—down parabola shape which defines the shape of the cone. Higher up in the stratigraphy, the spatter deposits retain a relatively constant thickness throughout their extent, while the flows are thin near the apex of the parabola and get thicker as you move down the arms.

Morphology. Material from Pu'u Ohau extends from Nenue Point in the north to Keawakaheka Bay in the south. In the north, Pu'u Ohau material is overlain by a more recent flow, and in the south, it tapers out against a topographic high created by an older flow. The north rim of the cone is almost twice as tall as the south rim. A channel that trends W-SW, runs approximately 70 m from the crater of the cone to the sea. Large slump blocks line the channel which drained lava from Pu'u Ohau. Also, there an alignment of Pu'u Ohau with two smaller cones upslope and a dike downslope from the crater.

Geochemistry. LECO sulfur analysis of two samples yielded sulfur contents of 80 ppm and 230 ppm. The sample that yielded 80 ppm was from the dike that appears downslope from the crater of Pu'u Ohau. The sample that yielded 230 ppm was from a deposit of black, glassy, unoxidized tephra in the lower portion of the stratigraphy of Pu'u Ohau. The greater value is more representative of the actual sulfur value during the eruption as the dike cooled slowly and allowed more gas to exsolve.

DISCUSSION:

Data collected in the field and in the laboratory enabled me to determine the eruption conditions under which Pu'u Ohau was formed. Several pieces of evidence shed light on the type of eruption that occurred to create Pu'u Ohau. First, the sulfur values of material from Pu'u Ohau are higher than what would come from the distal end of a flow (80 ppm to 140 ppm for a littoral cone). Second, the sulfur values are low enough that it is likely that a primary vent eruption (400 ppm to 600 ppm) would have experienced high fountaining causing a lot of volatiles to be lost. (Swanson and Fabbi, 1973)

The stratigraphy and morphology of the cone are also good indicators of what kind of eruption built Pu'u Ohau. Pu'u Ohau's high rims relative to the width of its crater, its lack of truncated beds, and the fact that it is composed entirely of juvenile lava make it unlike any littoral cones, maars, and tuff rings. The stratigraphy and morphology of Pu'u Ohau are most like that of a scoria cone except for the fact that it has not weathered as much as would be expected with a scoria cone. This can be attributed to the agglutinated spatter flows which stabilize the whole structure. (Cas and Wright, 1987)

Finally, the orientation of Pu'u Ohau's crater, two smaller upslope cones, and the downslope dike create a trace of the fissure from which the lava that built Pu'u Ohau was erupted.

CONCLUSION:

The formation of Pu'u Ohau began when magma from the central magma chamber found its way through a conduit system to the area where Pu'u Ohau now lies (fig. 2a). A fissure opened up approximately 2.2 km upslope from the crater of Pu'u Ohau, and lava began to pour out. Activity concentrated at the lowest point of the fissure which led to fountaining and the creation of a small cone. The fissure continued to open rapidly as evidenced by the small size of this cone. The opening paused again as a second small cone was built about 50 m further downslope from the first cone (fig. 2b). After the second cone was built, the fissure continued to open at a steady rate until its lowest point was at the crater of Pu'u Ohau.

The initial building stages of Pu'u Ohau were characterized by high fountaining from an elongate vent. Evidence of this elongate vent can be seen in the elliptical shape of the cone (fig. 2c). The high fountaining laid down deposits of tephra and agglutinated spatter flows. The tephra represents extremely violent fountaining, while the agglutinated spatter flows represent longer and less violent periods of fountaining. The alternating pattern between agglutinated spatter flow and tephra deposit indicate that the fountaining, which was driven by volatile exsolution, was spending itself during violent fountaining then rebuilding its volatile supply during the less violent fountaining.

Later on, during the building of Pu'u Ohau, the vent concentrated to a circular conduit. As the cone was built up, increased slope allowed agglutinated spatter flows to flow faster and farther. Some of these flows came around the back of the cone toward the front as a way to drain the excess lava being produced (fig. 2d). Another drainage was forming as the lava channel that runs from the crater to the sea was being formed. It is likely that the channel was a zone of non-deposition as everything that landed in there was drained. However, at times, especially during periods of high fountaining, it is possible that the channel may have crusted over and deposition would have occurred in that area for short periods of time. The channel did develop a tube system downslope from the crater, which may account for the fact that the volume of Pu'u Ohau is not as great as one would expect from a primary vent eruption.

The fissure responsible for Pu'u Ohau opened a little more during the later stages of formation. Evidence of this is seen in the dike downslope from the crater. There was very little subaerial eruption associated with this dike; however, there is some evidence of a spatter rampart. The dike represents the end of the fissure as there is no evidence of eruption any further downslope (fig. 2e).

Towards the end of the formation, the fountaining ceased due to a decrease in pressure from the magma source and a decrease in volatile content, and passive flowage began. Pahoehoe flows issued forth and capped the deposits downslope from the crater. These flows lapped up onto the inner flanks of the cone as well as undermined small portions of the cone (fig. 2f).

After the formation was complete, the cone underwent some structural deformation. Large slumps on both sides of the lava channel, and mass wastage of the inner flanks filled the channel and crater with debris (fig. 2g). The tube system that drained Pu'u Ohau collapsed as it was devoid of any material. At this point the formation of Pu'u Ohau was complete.

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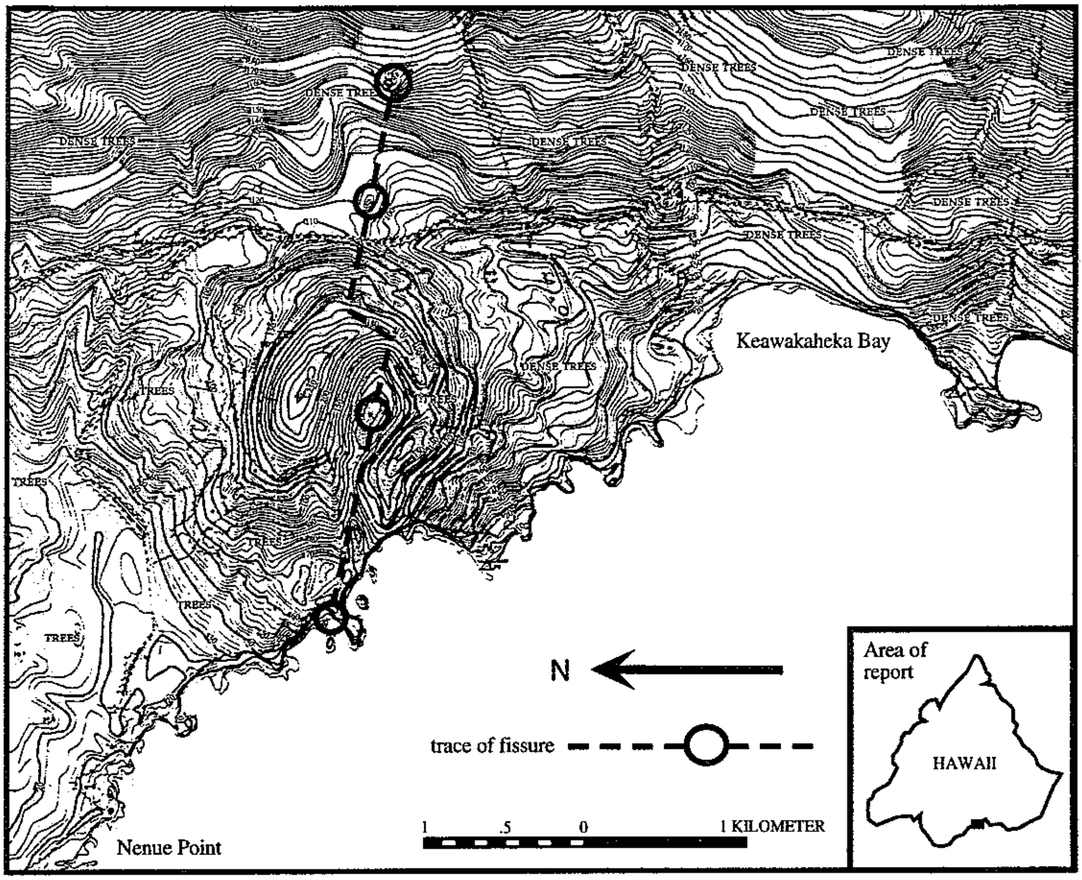

Figure 1: Topographic map of field area compiled by Ocenside 1250. Trace of fissure denoted by dotted line.

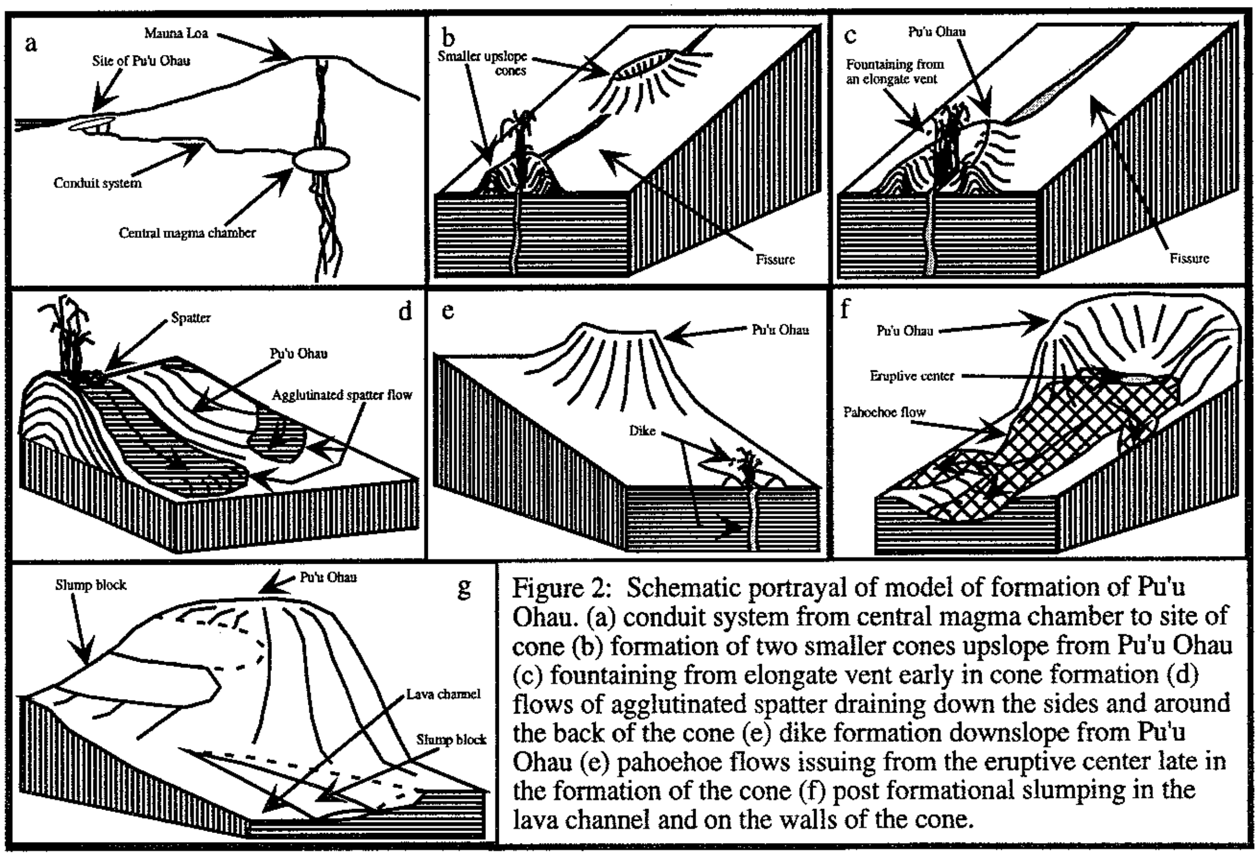

Figure 2: Schematic portrayal of model of formation of Pu'u Ohau. (a) conduit system from central magma chamber to site of cone (b) formation of two smaller cones upslope from Pu'u Ohau (c) fountaining from elongate vent early in cone formation (d) flows of agglutinated spatter draining down the sides and around the back of the cone (e) dike formation downslope from Pu'u Ohau (e) pahoehoe flows issuing from the eruptive center late in the formation of the cone (f) post formational slumping in the lava channel and on the walls of the cone.