SURVEY OF LAVA TUBES IN THE FORMER PUNA FOREST RESERVE AND ON ADJACENT STATE OF HAWAII LANDS

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This study was initiated after members of the Puna community brought to the attention of the Historic Preservation Office that major lava tube systems extended from the Pahoa area into at least portions of the former Puna Forest Reserve. They were concerned that planned geothermal exploration and development could damage these lava tubes which they said contained extensive evidence of past Hawaiian use including fortifications, shrines, platforms and burials. Geothermal development is currently being planned by Campbell Estate and True Geothermal Energy Company in the southern portion of the former Reserve which has been designated by the State of Hawaii as one of the three Geothermal Sub-Zones in Puna.

To demonstrate these claims, two staff members of the Historic Sites Section were shown examples in a lava tube makai of the Campbell Estate boundary. After reviewing the archaeological and historical reports commissioned for geothermal exploration, it was agreed that if these lava tubes did extend inland and continued to contain archaeological sites or burials then the potential of significant sub-surface sites had not been adequately addressed in the Historic Sites Section review process. Most reports acknowledged the possibility of lava tubes in the area and that they could contain burials, but no tube systems were ever identified or explored during any of the field surveys. These surveys primarily assessed the presence or absence of cultural properties that occur on the surface or as deposits within the soil layer (see discussion below).

With the assistance of the Division of Water Resource Management (DWRM), the Historic Sites Section agreed to conduct this survey because those community members who came forward requested that this information be handled by a neutral party. They asked that documentation occur in such a manner that it could be kept as confidential as possible while still providing enough information to protect any sites from damage.
tubes and openings in areas where construction includes bulldozing or excavation.

This report has been produced in two forms; one that remains confidential because of the numerous burials found and one that is available to the public. In the confidential report, specific locations of the lava tubes, their entrances and any burials found are documented. In the following report, only general locations are given along with enough information to characterize the nature of the lava tubes and archaeological features encountered. The Hawaii Island Burial Council helped determine the extent to which various kinds of information should be included in this report and how they should be presented.

ENVIRONMENTAL AND ARCHAEOLOGICAL BACKGROUND

The parcel acquired by Campbell Estate through a land exchange with the State in 1985 encompasses approximately 25,738 acres and lies between elevations of 1,000 and 2,280 ft above sea level (Fig. 1 - confidential). The average annual rainfall is high, between 120 and 150 inches, and the vegetation is primarily composed of wet, ohia-dominated (Metrosideros sp.) plant communities distributed in a mosaic pattern that reflects, at least in part, differing substrate types and ages (True Mid-Pacific 1986:ix and Appendix A). In structure and density, these plant communities range from dense, closed canopy forests to pioneer assemblages that are only beginning to establish on recent, nearly barren lava flows. Native or mixed native/exotic plants form dense understories in the forested areas while thick mats of uluhe fern (Dicranopteris spp.) are found in open canopy communities or where the trees are widely spaced. The latter, called an ohia-uluhe woodland by Char and Lamoureux, covers a large proportion of the study area (True Mid-Pacific 1986:Appendix A). In 1911 and 1928 these lands were designated the Puna Forest Reserve by the Territorial Government in two increments and in 1981 an area (16,847 acres) bordering the western and southern sides of the parcel became part of the State of Hawaii Natural Area Reserve System (Holmes 1985:4). This portion of the study area then became known as the Wao Kele o Puna Natural Area Reserve. Because there is no single place name for the
believed that tangible remnants of all these activities should be present but they expected them in low numbers and to be difficult to recognize, particularly when compared to those found in the more intensely used coastal areas or prime agricultural lands. The dominant activities were seen, at least in this region, as being less prone to produce stone, structural remains or substantial deposits of durable food remains, debris from tool manufacture or charcoal. The distribution of potential remains was not only predicted to be sparse but uneven. Greater concentrations were expected along trails, in areas where lava tubes could provide shelter or burial sites and in the seaward portions of the parcel where limited agriculture may have taken place. All studies emphasize the problems of dense vegetation which compound the difficulty of finding what is already hypothesized to be scant evidence. The vegetation cover severely restricts mobility and access during conventional ground surveys, greatly reduces ground visibility and obscures what are often hazardous ground conditions.

Holmes (1982) and Hommon (1982) first summarized these characterizations in their reviews of historical and archaeological information for the neighboring land of Kahaualea. Hommon reported that no historic or archaeological remains were found during his reconnaissance survey in Kahaualea which covered 8.75 miles of access road and a 5 acre proposed well site. When the proposed geothermal exploration shifted to the Puna Forest Reserve following the land exchange, Holmes (1985) expanded this document search to encompass the former Forest Reserve and essentially applied the same themes to what he saw as a similar landscape. The known historic period activities were portrayed as more diverse than Kahaualea and included timbering and cattle raising along the eastern portion of the property. Since these studies, two documents have repeated and refined some of the major points made on past land use patterns and their expected archaeological correlates. One is the Research Design (required under CDUA HA-1839) which sets guidelines for all archaeological work conducted for geothermal exploration in the former Forest Reserve (Cordy 1989) and the other assesses the archaeological potential of the three Geothermal Sub-Zones designated in Puna (Cultural Surveys of Hawaii 1989).

The six archaeological surveys conducted thus far within the Puna Forest Reserve seemed to confirm predictions that site probability is relatively low
Pacific 1985:Appendix A) and a few examples of 'awapuhi were noted during the survey of three proposed well pads and access roads (Bonk 1990:7; Lamoureux, Whistler and Imada 1990a:5; Lamoureux 1990b:9). These plants, particularly kukui, ki and banana, are considered probable indicators of past use for two reasons: they were of great value and utilitarian importance to the Hawaiian culture and are unlikely to become established in rain forest communities without the aid of man either through propagation, clearing or initial tending.

In regard to lava tubes, a major oversight of these studies was the omission of Yent's survey (1983) of a "Pahoa Cave" (called the Middle Tube System here). Although the report shows the location of a single entrance on State land to the east of Campbell Estate property, the distances and bearings given in the report indicate that Yent explored at least 2,000 ft into the Forest Reserve and found defensive structures, burials, midden deposits and terracing within this stretch. Despite this omission, three overviews did consider the possibility of lava tubes with archaeological remains. The Research Design calls for surveys to pay special attention to pahoehoe flows where lava tubes could be present and could contain remnants of campsites and burials. The assessment of archaeological potential for all three Geothermal Sub-Zones simply stresses that lava tubes with remains rank as one of the major site types of Puna (Cultural Surveys of Hawaii 1989). Holmes felt that it "would not be unreasonable" to "conjecture" that there were caves in the Forest Reserve (Holmes 1985:6). Their significance, however, would be "minimal" because they would be "occasional shelter or possibly but not likely burial (because of distance from regular habitation)" (Ibid.). Our survey demonstrates that, to identify lava tubes within a study area, it may be necessary to begin the search, either in the literature or on the ground, from neighboring parcels.

Native Invertebrates and Lava Tube Ecosystems

Hawaiian native invertebrates as a whole have won recognition in the world scientific community as being an integral part of Hawaii's unique "evolutionary experiment." An important dimension of studying these evolutionary processes in Hawaii has been to contrast these cave-dwelling
Fig. 2 Known Lava Tube Entrances within Campbell Estate Land and the Geothermal Sub-Zone.
slope portions of the Campbell Estate land and on neighboring State land because vegetation is less dense than that found up-slope and nearby roads make access less time consuming. Differences in vegetation between the higher and lower elevations can be traced, at least in part, to the first half of this century when cattle grazing maintained more open plant communities at lower elevations and periodic bush fires have continued to keep them more open. Once an entrance was located, all attempts were made to follow the tube up-slope as far as possible.

Most of the time was spent locating and exploring three tube systems which Holcomb (1980) shows as hypothesized tubes. The locations of these three tubes made it possible to see if the tube systems themselves or evidence of Hawaiian use varied from north to south across the property or with elevation. Also, the course of two tubes indicated that they could extend into the Geothermal Sub-Zone or near the proposed well sites. This remained a strong possibility because the up-slope extent of all three tubes and their eruptive sources have never been identified because dense vegetation obscures evidence of tube directions or flow boundaries throughout much of the property.

In the following report, these three tube systems, or segments of them, will be referred to as the Southern, Middle and Northern Tube systems. A total of 11 days was spent in the field searching for tube entrances above ground and mapping those which could be followed. In addition, a three-hour helicopter survey helped locate entrances on aerial photographs and probable access routes to them. In all, 42 tube entrances were visited, about nine miles of lava tube were traversed, and approximately 6.6 of these were mapped (Fig. 2). Another 12 to 13 miles were covered above ground by foot in attempts to find additional entrances. This effort still represents coverage of less than 1/4 of the area which could have lava tubes or tube segments on Campbell Estate land.

The lava tubes were mapped by the pace and compass survey method with corrections in alignment and distance being made where tube entrances could be identified and plotted on aerial photographs. This method was chosen primarily for its speed. Although relatively less accurate than other methods, it was the most efficient for documenting the course of tube systems
The Lower Segment stretches for approximately 3300 ft between the elevations of 700 and 780 ft and is broken by three entrances (Fig. 3). The uppermost 1300 ft of the segment is about 15 to 20 ft wide and 10 to 15 ft high while the lower 2000 ft of the tube averages 20 ft in width and 10 ft in height. Natural features within the upper section include three lava falls and two side passages which truncate after 50 and 100 ft. The central third has alternating sections of large passages and large break-down piles while only a few small collapse piles occur in the lower 1125 ft of tube.

We estimate that at least 60 to 80 individuals were buried in this tube segment. Counting the number of individuals is very difficult because most of the human remains are badly decomposed and have been disturbed or mixed by natural processes and possibly some vandalism. This problem is compounded by the number of burials that could be hidden amongst the roof fall debris and in side recesses. This problem became apparent several months after our initial survey when a section of the tube was mapped in more detail and 10 to 15 additional burials were found in a debris filled depression along the edge of a collapse pile.

Most of the burials are concentrated in three sections of the tube. The first is the 175 foot stretch (Stations U13 to U17) at the uppermost extent of the tube which is 430 ft from the nearest accessible entrance (Fig. 4a). About 13 to 17 individuals lie in this stretch, either on the floor, in crevices along the tube wall or within an elevated passage. The second section includes a 375 foot stretch (Stations U7 and U3) above and below the middle of the three entrances (Entrance 2) in which 10 to 15 burials were placed on six elevated shelves along either side of the tube (Fig. 4a & 4b). The third concentration begins at the lowest entrance (Entrance 1) and extends approximately 375 ft down-slope (Fig. 4b). It includes, in order of occurrence down-slope, an estimated 10 to 15 burials concealed among debris at the base of the entry collapse; at least three burials on shelves immediately down-slope of the entrance; four more placed in or on artificially arranged portions of a break-down pile; two individuals on a broad shelf and the burial of a single individual on another shelf. Only scattered human bones or bone fragments were found between the concentrations. Below the lowest concentration, single, isolated burials occur at 765 ft and 1095 ft from the entrance (Fig.
Fig. 3 Southern Tube System – Lower Segment

COMPASS/PACE SURVEY: 20.III.1990

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Stone, McEldowney
North = Vertical
tube course curves substantially in some segments. Instead, anything noted as being on the Hilo side lies on the right hand side of the tube as one faces up-slope and that on the left hand side is noted as being on the Ka‘u side.

**Detailed Description**

St. U16 to U13 - The up-slope extent of this tube segment ends in a 10 ft high lava fall and a small, upper level passage that extends for approximately 40 ft beyond the fall. One burial is located at the base of the fall and at least six individuals were placed in crevices along the tube wall and on an elevated shelf. Although widely dispersed, the configuration of the piles suggests that they were bundle instead of extended burials. Scattered pieces of small bones cover much of the surrounding tube floor including those which appear to have washed down from the passage above. In the elevated passage, remains of 5 to 10 individuals cover the floor and are tucked in crevices along the tube walls. The remains are mixed with charcoal or decayed organics throughout and one red glass bead and some bottle glass were also present, suggesting that at least some of the burials date to the historic period. A strong breeze from a nearby entrance can be felt through cracks in the ceiling above the passage suggesting that an opening may have been artificially sealed with break-down rubble and roof fall slabs.

St. U12 to U11 - Up-slope from the St. U11, badly deteriorated human bone and charcoal are dispersed for a 20 ft stretch of the tube floor. The occasional scatter of charcoal and wood splinters continues beyond the bone scatter.

St. U10 to U9 - With the exception of horse bones and old bottles which were probably used as kerosene lamps, nothing was found between these stations and an upper level passage of the tube which truncates after 150 ft.

St. U9 (Entrance 3, Fig. 4a) to U8 - The double entrance at Station 9 is separated by a natural bridge. What appears to be an artificial or modified gap (2 m wide, 5 m long) crosses the down-slope end of the collapse pile under the lower entrance. The tube splits into an upper and lower passage below this entrance. The lower area has the appearance of having been roughly paved with a layer of flat, roof fall slabs.
Fig. 4a Detail of Southern Tube System – Lower Segment (Map 1)

COMPASS/PACE SURVEY: 20.III.1990

B = HUMAN BURIAL

H = HORSE BONES

MANY BURIALS

10' LAVA FALL

ENT 3

ENT 2

LEVELLED ROCK FILL

FT

(Thousands) FT

Stone, McEldowney

North = Vertical
Fig. 4b Detail of Southern Tube System – Lower Segment (Map 2)

COMPASS/PACE SURVEY: 20.III.1990

B = HUMAN BURIAL
H = HORSE BONES
C = CHARCOAL

SCATTERED BONES
SKULL
NUMEROUS BURIALS

-100 0 100 200 300 400 500 600
FT

-300 -100 100 300 500 700

Stone, McEldowney
North = Vertical
Fig. 4c Detail of Southern Tube System — Lower Segment (Map 3)

COMPASS/PACE SURVEY: 20.III.1990

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Stone, McEldowney

North = Vertical
Fig. 4d Detail of Southern Tube System – Lower Segment (Map 4)

COMPASS/PACE SURVEY: 20.III.1990

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- Stone, McEldowney
- North = Vertical
St. 1 (Entrance 1) to St. D2 - The collapse pile beneath this entrance shows no sign of structural modification. Bone from at least three, badly disturbed burials is scattered on shelf formations along both tube walls and on the floor beneath them. The burials were probably placed on the shelves originally and later fell to the floor as a result of natural or human disturbance. In most cases, the long bones remain the most recognizable of all the skeletal parts. A bead and chain necklace mixed with some of the bones suggest that at least some of the burials occurred during the historic period.

St. D2 to St. D3 - At least four burials are visible within a large break-down pile. These badly decayed concentrations of human bone were covered or mixed with charcoal and organic debris. One individual lay on a portion of the collapse pile that was artificially leveled with small rock debris. The other three skeletons were placed in the collapse debris with some attempt having been made to arrange rocks around or over the bones.

St. D3 - St. D4 - Only a fragment of a skull was found on the floor of the lava tube.

St. D4 to St. D5 - A triangular piece of roof fall was laid in an upright position in the middle of the tube floor, possibly to serve as a marker of some sort. Its placement had to have been artificial because there were no holes or fractures in the ceiling from which it could have fallen. Between this possible marker and a collapse pile down-slope, at least two individuals were placed on a broad triangular shaped shelf (2 m at the widest point). Within these deteriorated burials, broken skull fragments formed two distinct piles.

St. D6 - On the Ka'u side of the station, remains of a single individual lie on a broad shelf (1.5 m wide). The badly fragmented skull indicates that it is the remains of a single individual. An old bottle was also placed on the shelf but it is not clear if it was associated with the burial or if it was left by someone passing through.
intentionally leveled rubble pile or platform. As was the case in the lower segment, estimating the number of burials was difficult because the bones are badly deteriorated or disturbed and some skeletons may have been incomplete when buried. In this segment, there are more instances of individuals being intentionally covered by rock debris, which raises the possibility that some burials remain hidden and the number of burials may be underestimated. More skulls were recognizable throughout the segment suggesting that it may not have been looted or impacted as heavily as the lower segment. No historic goods or materials were seen with any of the burials indicating that use of the tube occurred predominantly during the prehistoric period.

The burials within the segment begin directly across from the small opening where at least three line the tube wall. Some were intentionally covered by slabs of roof fall and a long piece of wood, probably the remnants of a litter stick, parallels the wall. The disrupted remains of three more individuals were placed among the break-down rubble in the middle of the broad passage while another three, all extended burials, lie on the tube floor where it rises to form a low ledge.

Within the next c. 100 ft, there are at least 19 more individuals buried either along the edges of the tube or within the collapse rubble where some have been covered or surrounded by the rubble. Several structurally distinct and intentionally stacked piles (.50 x .50 and .75 x .75 km) are located 50 ft farther down-slope and could have been built to conceal burials. Another four burials were placed on a break-down pile located 50 ft down-slope from the artificial piles. One of these lies on a crude platform formed in the rubble.

The tube segment ends in a small chamber where five individuals rest in discrete piles, indicating that they were probably bundle burials. The remains of one individual lies just outside this last chamber.

MIDDLE LAVA TUBE

What we are calling the Middle Lava Tube (Site 50-10-45-14,900) can now be shown to run continuously for approximately 10 miles between the elevations of 470 and 1620 ft (Fig. 5). Diverse evidence of Hawaiian use occurs at least
Fig. 5 Middle Lava Tube System and Known Tube Entrances to the Northern Tube System

○ = lava tube entrances

X U.H. WELL

X TRUE WELL

(Thousands) FEET

(Thousands) FEET

FEET (Thousands)
An additional lava tube was entered near entrance U20 of the Middle Tube. Only a few hundred ft was explored and no evidence of human use was found. This tube should be fully explored in the future, particularly if there are any planned development activities to the north of the Middle Tube.

Despite occasional sections where the tube narrows to crawl ways or is constricted by break-down piles, the average width and height of the tube chamber remained relatively similar throughout the length mapped. Between entrances U20 and U27 (3.5 miles), the width of the tube averages 15 to 16 ft and, above U27 (1.6 miles), it averages 20 ft. The average heights vary from 11 to 13 ft throughout the 5.1 mile stretch. Some of the larger chambers mapped reach maximum widths of 35 to 40 ft and have heights of 20 to 25 ft.

Not only is this tube notable for its size, but two long sections run continuously without any openings or entrances to the surface, one being 1.4 miles long (U20 to U21) and the other 1.5 miles long (U26 to U27) (Fig. 5). A one mile segment between U20 and U21 is particularly striking because the chamber remains intact with no major roof or wall collapses. Within the lower 3.5 mile stretch (U20 to U27), the six openings that do occur are clustered in two groups where the distance between the openings is less than 1000 ft (290 to 721 ft) (Fig. 5). This contrasts with the upper 1.6 miles where four of the five openings have a scattered distribution (1200, 1360, 2365, 3120 ft apart) and break-down piles increase substantially in frequency and size with elevation (Fig. 7c-7a). This upper section of the tube crosses an area shown on the geologic map as having a large number of faults and cracks which may explain the greater frequency of break-downs. Overall, only about half of the openings, seven of 13, provide ready access to the tube without the aid of ladders or ropes.

Archaeological evidence in the Middle Tube is dominated by structural features which are almost all constructed of break-down rubble at entrances or within the tube. In seven cases, artificially stacked rocks block or constrict passage through the tube. Of these, five are interpreted as having been constructed for fortification during civil conflicts or wars while the function of the other two remains less certain. In three cases, two at entrance U20 and one at U27, the shared attributes which suggest fortification
down either the up-slope or down-slope sides of the collapse pile. Their position just within the drip-line affords protection from the rain or sun while still providing access to the light or the surrounding terrain. Similar features elsewhere in Hawaii are generally interpreted as having been modified to create a comfortable sleeping, resting or working surface for those who come to cultivate, hunt, gather, fish or pass through an area.

The remaining structural features noted vary from distinctly formed walls and platforms to less formalized modifications in which alignments or leveled surfaces were created by simply rearranging the rubble. Most occur in a 600 ft stretch above entrance U20 and were fashioned out of collapse debris. Several of the alignments appear, for lack of any other explanation, to delineate and possibly differentiate use areas on the tube floor.

Deposits of shell and bone midden, organic debris, and charcoal or ash occur in varying densities near four of the eight entrances that have other signs of human use, and two additional deposits lie near the burial and blockade located in the long stretch between U26 and U27. Of the food refuse, 'opīhi shell (Cellana sp.) is by far the dominant remain with some bone (dog, pig, bird and fish) and other unidentified shells being only sporadically represented. In the more heavily used areas, midden is scattered continuously across the tube floor, but in some sections the shells and some bone form a pattern of dispersed or evenly spaced clusters that may represent refuse from a single sitting. Most of the organic debris, excluding the occasional kukui nut, was decomposed beyond recognition although the form of the decayed matter indicated that some had been sticks or poles. Charcoal and ash are generally mixed with these deposits but they sometimes occur in concentrations which probably represent individual fireplaces. Some of the thicker deposits, including decayed organics, charcoal and smaller bone and shell fragments, have been badly disturbed and redistributed by water runoff from the tube walls and floor but even the most dense deposits are little more than thick scatters with no true or consistent depth. This probably reflects the relative youth of the tube as well as the degree to which it was used. Away from these distinct deposits, the occasional piece or pieces of charcoal are the only indication that those sections had been visited or explored in the past.
of entrance U20 and U23, most are located in areas that are spatially discrete or removed from areas where other major activities took place. In two cases, both reported by Yent, roof fall debris was used either to cover the burial or surround it. No grave goods were found with any of the burials which again may indicate that the lava tube may have been looted. The lack of any historically manufactured items, particularly small glass beads, suggest that the burials are more likely to be prehistoric than historic period burials. Most burials appeared to be those of adults although we caution that neither author has the background to make definite age determinations.

Detailed Archaeological Descriptions of the Middle Tube between Entrances U20 and U32

U20 (900 ft el., Fig. 6a, 7a) - Of all the tube sections described below, that which extends from this entrance contains the greatest amount and diversity of evidence for past Hawaiian use. The following description essentially summarizes that given by Yent (1983) with some of our own observations and interpretations added.

In the down-slope direction, the width of the collapse pile has been modified to form a series of five terraces just beyond the drip-line. Three of these form a tiered alignment along the Hilo side of the tube, a single one lies along the Ka'u wall and a fifth crosses the center of the pile, forming a base which links the terraces to either side. All were constructed with a retaining wall, some faced with upright slabs, and rubble fill. The leveled areas range in size from 1 to 2 m wide by 2 to 4.5 m long and have retaining walls from 1 to 1.2 m in height. Five burials were found including three which were on a ledge; one covered by stacked stone and one placed on the floor of a small side passage.

The main focus of activity was, however, along the up-slope section of the tube where some form of cultural remains, including scatter midden and features constructed out of roof-fall debris, occurs for approximately 1,240 ft. The first feature encountered lies at the base of the collapse pile and covers the entire width of the tube floor. In basic construction and form, it resembles an incomplete large platform that is 2 to 2.5 m wide and has a 1 m
Fig. 6a Middle Lava Tube with Numbered Entrances – Up-slope End of State Land


- U14: Fortification Walls, Platforms, Charcoal
- U15: Fortification Walls, Platforms, Charcoal
- U18: Fortification Walls, Platforms, Charcoal
- U19: Fortification Walls, Platforms, Charcoal
- U20: Fortification Walls, Platforms, Midden Deposits, Burials

Gap will be closed in final report.
Fig. 6b  Middle Lava Tube with Numbered Entrances – Campbell Estate Land

Pace/compass survey: 1990

U21: Fortification Wall Blocks Passage Near Skylight Entrance
U22: Fortification Wall Blocks Passage, Burial
U23: Platforms, Entrance in Closed Forest
U24: Platforms
U25: Platforms, Burials
U26: Concealed Lower Passage, Charcoal

Gap will be closed in final map.

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Fig. 6c Middle Lava Tube with Numbered Entrances - Campbell Estate Land and Geothermal Sub-Zone

Compass/tope survey: 1990

U29: Burials, Entrance in Rich Native Forest
U30: Skylight
U31: Large Pit Entrance
U32: Upper End in Old Ohia/Uluhe Forest

F. Stone, T. Stone — H. McEldowney
burials or as resting surfaces. Another, smaller platform (1 by 2 m, 40 cm high) lies just beyond this continuous stretch of modified rubble and, directly beyond it, two 5 m long parallel alignments lie in the center of the tube floor. In some respects, they resemble alignments that delineate trails.

Evidence for human use occurs continuously for the next 425 ft (600 ft from the entrance) but with less over all density. Included in this stretch are more leveled and rearranged break-down piles and several instances where single rock alignments appear to delineate portions of the tube floor. The stones in some of these alignments had to have been brought into that specific locale because the ceiling and walls of the surrounding tube remained unbroken. Distinct scatters of bone (pig and bird), shell (mostly 'opihii), organic debris and charcoal concentrations occur along the tube floor in four sections. In many cases, the midden form small clusters adjacent to the tube walls, leaving the center of the floor free of refuse. Yent collected a basalt pestle and two adze from these midden areas. From 600 to 1264 ft from entrance U20, the only indications of past use were very scattered pieces of shell, bone, charcoal, organic material and roof-fall that had obviously been shifted from its original location.

U21 (1090 ft el., Fig. 6b & 7b) - About 25 ft up-slope from the skylight the tube divides into a shallow, dead-ended upper passage and a lower passage through which the main tube continues. Below this divide, a false or greatly enhanced collapse pile blocks the main tube, allowing only a narrow passage along the Ka'U side of the pile and a small gap at the roofline which could be used for observation. Looking from the down-slope side, the blockade appears natural with the exception of a small (1.5 x 1.5 m), slightly leveled area on the Hilo side of the rubble slope. The break-down pile below the skylight is uncharacteristically flat and uneven, suggesting that it was robbed of stone to build the blockade. The artificiality of the pile is obvious on the up-slope side and along the narrow passage where the rocks clearly form a stacked face. Charcoal and decayed sticks, with some opihi, are prevalent along the up-slope side of the tube floor for approximately 25 ft.

U22 (100 ft el.) - At 133 ft from U22, another break-down pile has been modified to block passage through the main tube, probably for defensive
m) sitting immediately above the leveled area (4.5 x 2 m) which is distinctly edged with stacked rocks. These modifications themselves seem to suggest shelter more than fortification although the difficult entrance may have provided some defense.

U25 (1180 ft el.) - The lava tube here divides into an upper and lower passage, with the skylight being accessible only through the upper passage. Two leveled terraces were built on the down-slope and Hilo side of the collapse pile 2.5 m from the drip-line. Passage through the main tube was blocked, naturally, by a large collapse pile which can be skirted by crawling through a narrow space at the edge of the pile. About 50 ft past the collapse, the tube narrows into a crawl way, and at the juncture of the collapse and the narrowed tube two bundle burials were placed in a small alcove.

U26 (1185 ft el., Fig. 6b, 6c) - Again, the outside entrance leads to an upper level of the tube while that to the main tube is a narrow segment blocked by break-down-debris. To a great degree, this break-down appears to have been rearranged to conceal the passage. Access is only through an artificially created hole (50-60 cm wide) that is faced with flat roof fall slabs and leads to a drop of about 2 m. A conveniently placed stone underneath the hole provides a foothold so that access is through lifting oneself in and out of the hole.

U26 (1185 ft el) to 27 (1435 ft el.) - A number of features are present in the long stretch between entrances 26 and 27. Heading up-slope 1,972 ft, the first is an area of scattered charcoal concentrations and midden composed mostly of shell (ʻōpihi) and some bone (including dog). Shortly beyond this area (205 ft), but clearly distinct from it, is a burial with three individuals. One is fully extended, lying on the floor perpendicular to the tube walls, while the bones of the other two are mixed with the lower half of the extended burial. A long, decaying stick lies along the length of the extended burial.

Approximately 3,890 ft above these burials is another artificial barrier which blocks the main passage at a point where the lava tube divides into an upper
Fig. 7a  Middle Lava Tube with Numbered Entrances – Distribution of Natural Features, Collapse Piles, Archaeological Features, Cave Invertebrate Species and Tree Root Formations

Compass/pace survey: Mar. 1990

- walls, platforms
- platform
- opihis
- human bones
- opihu, charcoal
- collapse, roots, cave species
- collapse, roots, cave species
- roots, cave species
Fig. 7b Middle Lava Tube with Numbered Entrances – Distribution of Natural Features, Collapse Piles, Archaeological Features, Cave Invertebrate Species and Tree Root Formations

Compass/pace survey: Mar. 1990

- collapse, roots
- roots, cave species
- charcoal, opiihi
- wall collapse
- 10' lava fall
- rock wall, fortified
- platforms, opiihi, charcoal
- platforms, small pieces of bones
- concealed passage, burials: 2–3 individuals
- scattered charcoal
- roots, cave species
- roof collapse, roots, cave species
- roots, cave species
- collapse
- platforms
- U24
- U25
- U26
- U21
Fig. 7c  Middle Lava Tube with Numbered Entrances - Distribution of Natural Features, Collapse Piles, Archaeological Features, Cave Invertebrate Species and Tree Root Formations

Compass/pace survey: Mar. 1990

- charcoal
- collapse, charcoal
- roots, cave species
- collapse, leveled, charcoal
- charcoal
double walls

U27 El. 1460': Macaoering bog

- large collapse, roots, cave species

U28

- large collapse

- collapse

U29: El. 1500': Rich native forest

- human skull, skeleton
- collapse

- roots, cave species

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FEET (Thousands)

FEET (Thousands)
Fig. 7d Middle Lava Tube with Numbered Entrances – Distribution of Natural Features, Collapse Piles, Archaeological Features, Cave Invertebrate Species and Tree Root Formations

Compass/pace survey: Mar. 1990

- Roots
- Collapse, roots
- Collapse, roots, cave species
- Charcoal, opihis, dog bones
- Charcoal, roots
- 3 human skeletons
- Rock cairn, roots
- Abundant roots, cave species
- 9’ lava fall
- Abundant roots, cave species
- Roots
- Roots, cave species
- Collaps
- Large collapse
- Rock wall with mud mortar

F. Stone, T. Stone
H. McEldowney
Fig. 7e  Middle Lava Tube with Numbered Entrances – Distribution of Natural Features, Collapse Piles, Archaeological Features, Cave Invertebrate Species and Tree Root Formations

Compass/pace survey: Mar. 1990

10’ lava fall

large collapse

collapse, roots, cave species

collapse

large collapse

collapse, roots, cave species

collapse

U30

large collapse

collapse

U31

collapse

U32: El. 1620’: Ohia regrowth, native spp. understory

F. Stone, T. Stone

H. McEldowney
part, by the large number of break-down piles in this stretch of the lava tube, which made access through the tube substantially more difficult than it had been in the lower segments.

U29 (1495 ft el.) - At this entrance, access through the main chamber is entirely blocked by break-down. On the up-slope side of the opening, an upper level passage lies above the main chamber. The height of the passage is low and, for much of its distance (25 to 40 ft), access is only by crawling. At least three individuals were buried in this passage. The remains of two are mixed with the break-down pile directly behind the entrance and the other, located at the narrow end of the truncated passage, was clearly a flexed burial. With no evidence of human use in the main tube between entrances 27 and 32, it seems probable that these burials were carried to this entrance over land instead of underground through the tube.

U29 to U32 (1620 ft el) - This portion of the lava tube is again characterized by increasing numbers of large break-down piles which make passage difficult. The lack of human evidence within the tube continues to entrance U32.

**NORTHERN TUBE SYSTEM**

What we designated the Northern Tube is a series of sizable tube openings that run diagonally across the northern half of Campbell Estate land for at least 3 miles (Fig. 2). Beginning near the border of Hawaiian Acres subdivision, it heads towards the Geothermal Sub-Zone and reaches a minimum elevation of 1660 ft. The two tube entrances we were able to enter did not lead to segments of any great length suggesting that the system, like that of the Southern Tube, is fragmented. The large size of the tube openings indicate that it had been the main channel of a very-high volume flow but the flow probably did not run consistently or long enough to create a stable or continuous tube.

A total of 3 days was spent locating access routes to this tube system and finding the two segments which we mapped. Approximately eight to nine miles were covered in these efforts which included a brief reconnaissance of a forested kipuka to the southeast of the tube system. It was clear from the air that kukui trees (*Aleurites moluccana*) and *ki* plants (*Cordyline*
Fig. 8 Northern Lava Tube System – Lower Segment

9.IV.1990: Pace–compass survey

Printed text:

Northern Lava Tube System – Lower Segment

9.IV.1990: Pace–compass survey

Above Ent. A: Cave species present
No human use

Ent A: Three Burials, Pit Entrance 20' Deep
Ent B: Platform, Paving, Skylight
Ent C: Small Opening, Not Passable

Stone,McEldowney
Howarth
NORTH = VERT.
Fig. 9 Northern Lava Tube System – Upper and Lower Segments

8.IV./13.IV.1990: Pace-compass

No Human Use
reach the skylight. The tube floor leading to the platform on the up-slope side was paved with flat, roof fall slabs forming a pathway about 5 m long. The location of these features beneath a small skylight suggests restricted access and the possibility that they were used for refuge or defensive purposes. No midden was seen in association with these features.

Beyond the second skylight, we followed the tube for another 350 ft to an opening too small to enter and a very small crawl way which we did not pursue. The average size of the tube remained similar to the up-slope extent with average widths of 8 ft and heights of 20 ft.

NATIVE INVERTEBRATES

Preliminary observations made during the current study indicate that native invertebrates are abundant both in the native forests and in the cave ecosystems. This is true for the Campbell Estate property as well as the designated Geothermal Sub-Zone. Although not listed here, native cricket species were observed around tube entrances, and moths, flies and other insects swarmed the lamps at night.

The cave-adapted species now known to be present within the Geothermal Sub-Zone include:

- Oliarus sp. (Cixiidae): cave plant-hopper
- Caconemobius varius, C. sp. A (Gryllidae): cave crickets
- Lycosa howarthi (Lycosidae): cave hunting spider
- Schrankia sp. (Noctuidae): cave moth
- Dimerogonus sp. (Cambalidae): cave millipede
- Forcipomyia sp. (Ceratopogonidae): fly
- Isopoda sp.: cave isopod

Additional species can be expected to occur in lava tubes within the Campbell Estate land based on their documented presence in the lower part of the Middle Tube and in near-by Kazamura Cave (Howarth 1981: 323 and Stone data files). These taxa include:
It was suggested in the Supplemental EIS (1986:134) that disturbed wildlife may have to relocate to another area. If disturbance proves to be substantial and extensive it is unfounded to assume that native invertebrate fauna would migrate or that they could become established in neighboring areas where the forests may already be supporting a maximum number of native species. Given the great diversity of native species, neighboring forests or other lava tubes even a few miles away will have different species or varieties which may not be compatible with intruding migrators. More important, however, is the fact that the amount of forest to which species could migrate is diminishing. Substantial portions of neighboring forest land to south, west and north have been removed or depleted by the current eruption, expansion of papaya plantations, woodchipping and development within private subdivisions. Apart from the Kahaulea area, very little of the adjacent land currently has preservation zoning.

If the native invertebrates and the lava tube ecosystems in the Middle Tube are to be provided positive protection, the native forest above the course of the tube must be protected by an adequate buffer zone. These tube ecosystems are primarily dependent on tree roots, mostly those of Metrosideros sp. ('ohia), through which essential organic nutrients are continually renewed.

**GEOLOGY AND GEOLOGIC FEATURES**

Despite its considerable archaeological and biological value, the Middle Tube merits attention in its own right as a significant geologic or natural feature. It has now been mapped for about 10 miles, making it one of the longest known lava tubes in the world.

Identifying the location of these lava tubes, particularly that of the Middle Tube, could provide valuable information for improving the accuracy of the current geologic maps. Holcomb discusses the difficulty of dating lava flows, especially in Kilauea's densely vegetated Middle East Rift Zone where the study area is located (Holcomb 1987:267). As previously noted, Holcomb groups roughly half of the study area as being part of the Ai-Laau series based on magnetic and vegetation similarities with flows dated by C-14 dating methods at 350 to 500 BP. He estimates the remaining half to be older than 1500 BP.
identified during the survey: the justification and means for preserving the Middle Lava Tube System; procedures for predicting lava tubes and significant archaeological remains within the study area; identifying and protecting unknown lava tube segments which could contain historic remains (including burials); approaches that could minimize disturbance of undetected tubes during construction activities and drilling.

Most recommendations apply specifically to geothermal exploration and development within this Geothermal Sub-Zone and accommodate the guidelines stipulated in the CDUA Decision and Order (No. Ha-12/20/85) for these projects. In some cases, the suggested approaches could serve as guidelines for geothermal or other development projects in areas where lava tubes with historic remains are likely.

SIGNIFICANCE EVALUATIONS:

These initial significance assessments are based on criteria set out in the Draft Rules and Regulations of the State Historic Preservation Division which, with the exception of Criterion "e", conform with those used to determine eligibility for inclusion in the National Register of Historic Places. (36 CFR Part 60). All sites possess a high degree of integrity in location, setting, feeling and association.

1. Southern Tube Segment (Sites 14,901 - 3). These three tube segments were all used for burial and are therefore significant for their importance or value to the Hawaiian culture (Criterion "a"). They are also significant for the information they could yield (Criterion "d").

2. Middle Lava Tube (Site 14,900). This extensive lava tube and the combined historic properties found over at least 9 miles of its length, is significant under several criteria. Despite probable looting of artifacts, most of the lava tube above the Pahoa Highway is essentially undisturbed. It contains burials and is therefore significant to the Hawaiian culture (Criterion "e"). The numerous structural features and midden deposits found are significant for information they could yield on the prehistory of the region, particularly concerning past resource use and conflict
accidental impacts from activities occurring on adjacent lands and protect a belt of ohia forest whose roots are essential for the viability of the cave-adapted invertebrate populations. It should also be sufficient to accommodate any minor or cumulative errors that may occur in the mapping and plotting of the lava tube.

The buffer zone will also help to minimize potential dispersal of air pollutants. The existence of a 20 to 40 foot diameter lava tube passing from the Middle Rift Zone to Pahoa could have a bearing on the potential dispersal of pollutants which was not addressed in the Supplemental EIS. Under normal trade wind patterns, air flows up the mountain during daytime and down the mountain at night. Air flow through the lava tubes is linked to the surface pattern, with flow generally up-tube during the day and down-tube at night. Surface air flow might be expected to disperse pollutants, but lava tubes could allow a heavier-than-air substance such as hydrogen sulfide to be channeled for a long distance.

3. Definition of Buffer Zone Boundary. The boundary of the buffer zone should lie 1,500 ft to either side of a line which averages, in increments, the many bends and meanders in the tube's course. This places Alternative Well Site # 2 about 3,200 ft from the boundary and Alternative Well Site # 3 about 3,500 ft from it. At the closest point, the Alternative Well Sites are 4,800 ft and 4,500 ft from the lava tube itself. If development plans followed that depicted in the Supplemental EIS (Fig. 5), development areas A and C would lie on the boundary of the buffer zone. An adequate buffer reduces the possibility of damage due to construction activities, accidental waste spillage or destruction of the forest above the tube. Final definition of this buffer zone should follow a more accurate survey of the portion of Middle Tube where it passes beneath Campbell Estate land.

4. Complete Mapping of the Middle Tube System. The Middle Lava Tube was only mapped to an elevation of 1,620 ft and, based on its size at this point, we assume that it continues. We expect that continuous and diverse evidence of human use is unlikely in the upper, unmapped portions of the Middle Tube although burials could be present at entrances as is the case at entrance U29. If any exploration or development is planned for that portion of the
contain lava tubes than those grouped with the massive, tube-fed Ai-Laau lava flow series.

3. Re-evaluation of Prehistoric Land Use Intensity in the Study Area. Most of the historical and archaeological reports, including the Research Design, depict the area as forested and remote. Land use is seen as leaving few tangible remains because of the kinds of land use associated with these areas and their periodic use. Our survey suggests that the intensity with which the study area was used should be broken into two sections; those areas below 1,500 ft in elevation and those above. While there are similarities in the kinds of land use that occurred in both areas, the diversity and intensity of this use appears to have been greater below 1,500 ft. This is demonstrated by the distribution of three factors: evidence of human use is continuous in the Middle Lava Tube up to an elevation of 1,420 ft; cultigens or plants considered to reflect past Hawaiian use are documented up to an elevation of 1,600 on the north and south flanks of the Middle East Rift Zone; several, presumably agricultural lands were surveyed as lying within the Forest Reserve between the elevations of 1,400 and 1,550 ft during the mid 1800's (Baldwin 1902). Over all, this probability would still be less than that of the coastal or prime agricultural lands. The Research Design should be amended to reflect this difference.

Some perceptions of the study area being remote probably arose when many of the basic themes and approaches used for the Kahaualea study were applied to the former Puna Forest Reserve. In the case of Kahaualea, the land division was a single ahupua’a and more conventional land use patterns could be applied when predicting the probability of historic remains. Major settlement areas were depicted as being located near the coast while the agricultural or planting areas stretched up-slope until reaching the vast forested area which grew increasingly remote with elevation. This general orientation becomes more complex in the case of the Puna Forest Reserve. At least six ahupua’a converged in the study area from the south and the east (Holmes 1985) and generalized assessments of land use would have to be viewed as converging from these directions. A combination of factors, however, tended to focus attention on the southern approach to the
period may not have been readily available in these younger and developing vegetation communities. Use that did occur would probably be distributed unevenly in that it would be concentrated or intensified in those areas with older flow surfaces or where advanced vegetation communities developed more quickly. This pattern would probably be reinforced by open pahoehoe with no or little vegetation which is relatively easy to traverse and would allow increased access to any resources available. If substantial portions of the landscape were open at various times, this could significantly lessen the over all degree to which the project area was remote and inaccessible. This uneven and concentrated distribution of potential sites should be given greater emphasis in the Research Design where it discusses predicting and identifying archaeological remains. In preparing for an inventory survey and reporting its results, even greater attention should be paid to identifying areas with older flow surfaces or those in which vegetation communities may have advanced more quickly.

4. Probability of Burials within the Study Area. Based on survey results from below and within Campbell Estate land, at least half the tube segments found were used for burial. Thus, if tube segments are found, we can roughly estimate that the probability of burials is approximately 50%, particularly below 1,500 ft in elevation.

5. Relocation of the "Wilkes Trail" within the Forest Reserve. While reviewing historic documents for references to lava tubes, we noted a possible error in the proposed location of the "Wilkes Trail" (Holmes 1985:Fig. 22a). In his literature review, Holmes reconstructs what he believes to be the route taken by the U.S. Exploring Expedition under the command of Charles Wilkes in 1840-41 when they crossed through inland Puna. Based primarily on the map presented in the Narrative of the Expedition, Holmes plots the route as passing almost directly through the East Rift Zone before heading slightly south to pass north of Heiheiahulu and south of Ilewa. Wilkes also shows a series of other trails passing east and west of the hill "Kalalua" which, to Holmes, indicates that other trails passed through the southern and eastern portions of the Forest Reserve. In the Research Design required by the CDUA (HA-1830), the identification of trail routes is singled out as an important step in predicting areas of
would have to reflect the dominant flow direction of that particular area. Although two segments of the Middle Tube System run for 1.4 and 1.5 miles without openings, we feel a 2,000 ft long survey corridor would have located many entrances from different points along the tube's course. The 1,000 ft width of the corridor accommodates the degree to which the tube meanders between most entrances.

2. Coverage within the Survey Corridor. To locate entrances within the survey corridor we feel that visual coverage should be as close to 100% as possible unless a sampling design can be devised which targets particular flow types or formations that prove, over time, to be associated with a high incidence of lava tubes. The analysis of clear, low level aerial photographs and maps of the vegetation, geology and surface topography could help identify indicators of tube openings or trends. A sampling design would help lessen problems of reduced mobility and low ground visibility due to dense vegetation and hazardous ground conditions.

3. Treatment of Tube Segments Found. The treatment of archaeological remains found should be in keeping with the policies of the State Historic Preservation Division and the stipulations of the CDUA Decision and Order. If burials are discovered, the Hawaii Island Burial Council should be consulted. Mitigation measures, like those for all historic properties, will depend on their significance evaluation and, to some degree, the feasibility of shifting the well or road location. A possible problem with long tube segments, is that indirect damage could be caused down-slope, particularly by fluids or fumes. To minimize this possibility, any tube segment found should be followed for a considerable distance down-slope or until it is no longer passable.

4. Identifying Suspected Lava Tubes Not Discovered During Surface Surveys. In areas with a high probability of lava tubes with archaeological remains or burials, we recommend the steps outlined below. We stress that it is difficult to prescribe specific mitigative measures to deal with every possibility because there are no well defined and tested archaeological precedents upon which to base these decisions. We expect our recommended procedures to be refined by experience. For the time being, many decisions
BIBLIOGRAPHY


