LAVA CAVE MANAGEMENT IN HAWAI`I VOLCANOES NATIONAL PARK

Fred D. Stone, Ph.D.
University of Hawai`i and
B.P. Bishop Museum
Honolulu, Hawai`i

Francis G. Howarth, Ph.D.
B.P. Bishop Museum
Honolulu, Hawai`iI

Jadelyn Moniz Nakamura, Ph.D.
Hawai`i Volcanoes National Park
Volcano, Hawai`i

Abstract

Lava tubes and other caves are major features of Hawai`i Volcanoes National Park that include important geological, mineralogical, paleontological, archeological, biological, cultural, recreational, and other resources. Although caves were known and used by Hawaiians for hundreds of years, and by more recent Island residents and visitors since they began exploring Mauna Loa and Kilauea Volcanoes, systematic inventories began only within the last 30 years. National Park Service funding allowed the National Park to conduct a resource inventory of selected caves in 1990–1991 by a team including an archeologist, biologist, geographer, and National Park Cave Specialist. The first Hawai`i Volcanoes National Park Cave Management Plan was approved in 1990. Between 1994 and 1995 a monitoring program was implemented in a limited number of caves. In 1995 the National Park hired its first permanent cave specialist, and the program was managed by the Cultural Resource Manager. Additional cave inventories were conducted between 1998 and 2000 when the program protocols were revised. The cave inventory program remained active and monitoring was re-instituted in 2004. Currently Hawai`i Volcanoes National Park cave management staff continues with an active program of cave inventory, mapping, and monitoring. Current and future projects include inventory of Kahuku lands recently added to the park, continued archeological and biological surveys, and development of a monitoring program for all parks with caves within the Pacific Islands network region.

Contribution No. 2006-006 to the Hawai`i Biological Survey

Introduction

Hawai`i Volcanoes National Park is located on the island of Hawai`i, part of the most isolated island chain in the world (Figure 1). Hawai`i Volcanoes National Park is located on two active volcanoes, Kilauea and Mauna Loa, the latter being the largest single mountain on earth. The park stretches from sea level to over 13,000 feet elevation and contains 333,000 acres. It has been an International Biosphere Reserve since 1980 and a World Heritage Site since 1987. The park includes at least nine ecological zones; near shore marine, seacoast, lowland, mid-elevation woodland, rain forest, upland forest, subalpine, alpine, and aeolian. Both volcanoes have recent lava flows, on Mauna Loa the

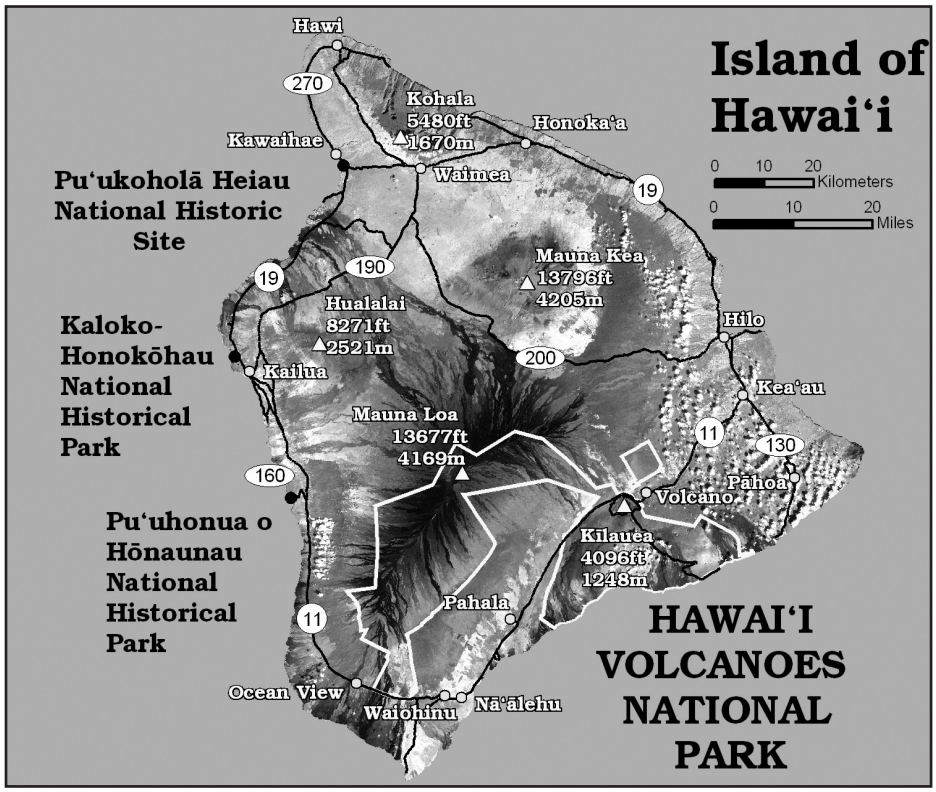

Figure 1. Map of Hawai ʻi showing Hawai ʻi Volcanoes National Park.

Lava tube formation

Lava tubes form rapidly and begin eroding almost as they form. Two types of basaltic lava occur: rough, clinkery a`a and smooth, ropy pahoehoe. Lava caves usually form in pahoehoe flows, though a`a flows are sometimes tube fed. Pahoehoe is much less viscous than a`a, and the crust generally does not stick to the molten flowing lava. Fluid pahoehoe often spreads out in thin, sheet-like flows near the flow margin. The flow advances by extruding lava toes that crust over and break to create new toes. Overflows of lava build layer on layer and fuse to older surfaces poorly, leaving numerous gaps preserved between each flow unit.

most recent being 1984, while on Kilauea a nearly continuous eruption has been active from 1983 to the present. Numerous lava caves occur throughout the park. These include lava tubes, crater vent caves, fissure and rift zone caves, pressure ridge caves, tree mold caves, and sea caves among others. Many lava tubes are quite large and some are several miles long. They include important geological, mineralogical, paleontological, archaeological, biological, cultural, recreational, and other resources. Hawaiians regularly entered and used lava tubes before European contact with the Hawaiian Islands (Figure 2).

Figure 2. Hawaiian petroglyphs in Hawai ʻi Volcanoes National Park lava tube. Photo by Fred Stone, courtesy of Hawai ʻi Volcanoes National Park.

Older toes feeding the advancing edge grow and become distributary tubes. These surface distributary tubes are usually small and rarely connect to longer lava tubes. However, fluid pressure can sometimes inflate them to small cave-size lava tubes. Also, they are often numerous within flows and provide a significant habitat for cave animals. Remnant sections occur as upper level mazes in lava tubes and as small shallow mazes on the surface.

Figure 3. Native hapu`u tree ferns in lava tube entrance. Photo by Fred Stone, courtesy of Hawai`i Volcanoes National Park.

Upslope from the advancing front, the edges solidify first, so that the flow soon becomes channeled between the vent and the flow front. Overflows cover older layers, thickening the flow and deepening the channel. Thus, lava streams advance downslope and deepen within levees built by overflows and spatter. Long lava tubes form by the crusting over of these pahoehoe rivers. Three distinct mechanisms can create a permanent roof: (1) a solid crust can grow across the stream from each edge or downstream from an already formed roof; (2) spatter and overflows can form arched roofs over streams; and (3) floating plates of crust can jam across the stream and anchor a new roof (Peterson *et al*., 1994). Once established, these roofs thicken by accretion of lava on the lower surface and by overriding flows on the upper surface. Surges or reductions in flow volume can destroy a developing roof; thus, roofs generally survive only in steady, low to moderate volume flows that last long enough for the roof to form and stabilize, usually at least several weeks. Limited observations suggest that the longer the flow the more stable the resulting cave. Molten lakes that store lava and drain into the tube are very important in moderating the flow, allowing the roof to stabilize. Skylights along the tube act as pressure valves, which allow overflows to thicken the roof downstream without destroying the established tube (Figure 3).

There is good evidence that well established active lava streams can erode the substrate. In some caves in Hawai`i Volcanoes National Park and a few other caves on Hawai`i Island, there are fossil plant remains and charred soil layers embedded in the cave wall, indicating that the flowing lava cut its way down through the pre-existing ground surface as it flowed (Howarth, Stone, and Pearthree, unpublished data).

Active lava tubes are remarkably efficient insulators; at Mauna Ulu, they carried lava over 12 kilometers from the vent to the ocean with only a 10°C loss of temperature (Peterson and Swanson 1974). Thus, pahoehoe lava flows build and repair their own conduits or lava tubes, which then transport the lava great distances from the vent. This mechanism is now recognized as the major factor in building shield volcanoes (Peterson and Swanson, 1974; Peterson *et al*., 1994). It also means that pahoehoe flows can cover large areas and create abundant underground habitats for cave animals.

Precontact use by Hawaiians

Lava caves were an important resource for Hawaiians who lived in the area that now forms the

park. Many caves were used as living sites, particularly those along the coastal zone where fishing and agriculture were practiced. In other zones, caves were used for temporary shelter by forest gatherers, bird catchers, or travelers. These contain leveled sleeping areas just inside the entrances. Lava tubes were the major source of water for much of the area in the park. Even in areas with high rainfall, the water rapidly infiltrates into the porous lava. In arid zones the lava tubes were one of the few reliable sources of water for human consumption and for agriculture. The water catchments in the lava tubes are still intact in many cases, with prop stones for calabash gourds (and even gourd fragments in some places) and ash and charcoal from the torches used to light the interior. Some tubes have pecked water holes and opihi (*Cellana* sp.) shell dippers still in place and thick ash deposits surrounding them (Figure 4). William Ellis, an early missionary to Hawai`i, in 1823 was traveling in the vicinity of "Kearakomo" (on the trail from Kilauea crater to the coast) and was ". . . so favored as to procure a calabash-full of water from the caves in the mountains, where it had filtered through the strata of lava, and was received into vessels placed there for that purpose." (Ellis, 1842). Small caves and openings in lava were used by petrels as nesting sites, and the petrel chicks were a major food source. Where the pahoehoe was suitable, Hawaiians sometimes broke open the shallow surface layer to create additional nesting sites for the petrels (Moniz Nakamura *et al*., 1998; Moniz Nakamura, 1999; Hu *et al*., 2001).

Lava tubes were used as hiding places and refuges in time of warfare. These tubes often have fortified entrances and living spaces on either side of a central walkway. A term in Hawaiian *pe'epao* refers to these secret caves. Refuge caves are known to occur elsewhere in Oceania including Easter Island, Mangareva, Tonga, the Reef Islands, and Samoa (Kennedy and Brady, 1997). Several park lava tubes have petroglyphs pecked into the smooth surface lining near certain entrances. In some cases, these petroglyph caves may have served as boundary markers. Caves were also used for religious ceremonies, and as burial places.

Threats to Hawai`i Volcanoes National Park Caves

Lava flows create new lava tubes, but also cover and destroy old lava tubes. This natural process is recognized in Hawaiian legends of Pele the creator and destroyer. Lava flows can also cause fire in dry areas of the park. Many of the native plants are resistant to natural fires, but with introduction of fire climax grasses, fires occur more often and may burn hotter than natural fires, causing a loss of the native *'ohi'a* forests and their root systems on which the cave species depend. Invasive species including pigs, sheep, goats, and the fire tree (*Myrica faya*) can destroy or out-compete surface vegetation (Figure 5). Archaeological remains in park caves are subject to looting by vandals. In one case, a section of petroglyph appears to have been broken loose from a wall lining and removed, only to be dropped, broken,

Figure 4. Hawaiian pecked water hole with 'opihi (limpet) shell scoops and ash from torches (photo monitoring site). Photo by Fred Stone, courtesy of Hawai'i Volcanoes National Park.

Figure 5. Roots of invasive Myrica faya (white) and native ʻohiʻa (brown). Photo by Fred Stone, courtesy of Hawai`i Volcanoes National Park.

and abandoned in the cave entrance (Stone, 2005 unpub). Accidental destruction of roots, cultural deposits, and formations by carelessness or ignorance by those entering the caves often occurs. This is particularly dangerous when tourists without knowledge of unique features enter caves without permission from the park. A section of fragile sand castle deposits was found to be trampled after entry by a group of 30 people from Germany who signed the register in the cave, and wrote that they learned of the cave from a German publication. Ash piles and gourd fragments near water catchment areas can be trampled, as can bone deposits from extinct birds. Graffiti and garbage are left in caves that are open to the public or in areas easily accessible to the public. Trash that is clearly of modern origin should be removed; however, some trash can be historic in nature and should be documented as part of the historical use of the cave. Graffiti has been found in cave slime deposits, and the dark portion of Thurston Lava Tube needs regular cleaning due to its high visitation.

A problem that has occurred in other areas, but has not been documented in Hawai`i Volcanoes National Park, is the change in air flow that occurs when entrances and passages are opened by explorers or managers to allow for human access. This changes the pattern of air flow through the cave, causing areas with high humidity to dry out, and reducing the area of deep cave available for cave adapted species.

Park Cave Exploration, Inventory and Management

Thurston Lava Tube was found by Charles H. Birdseye of the U.S. Geological Survey in 1912. Birdseye discovered the middle skylight while surveying the boundaries for the proposed national park. In 1913, L.A. Thurston and a large group explored the cave (Apple, 1986). It soon became a regular stop on the tourist route.

The first systematic cave inventories occurred in 1959 and 1965 by teams of archeologists from the Bishop Museum (Emory *et al*., 1959; Emory *et al*,. 1965; Smart, 1965). Such National Park Service driven archeological surveys have led to the inventory of over 50 cultural cave sites in the park with many more still undocumented.

Speleological inventories with a particular focus on mapping and cave morphology began in the 1970s with the work of Bill Halliday and Stefan Kempe. Chris Wood led a British expedition that mapped Ainahou Cave in the early 1980s (Wood, 1981), and Swiss caver George Favre mapped the Ka`u Desert Pit Craters and Mauna Ulu Crater Cave.

Hawai`i Volcanoes National Park cave biological studies began in 1971 with the discovery of cave adapted species by Frank Howarth in Bird Park Cave. He has continued his studies of Hawai`i Volcanoes National Park cave biology up to the present, and has led an international team of scientists in the study of the systematics, behavior, physiology, communication systems, and DNA of park invertebrates.

In 1976 Storrs Olson and Helen James with

Alexander Wetmore began long-term studies on the paleontology of extinct birds in Hawaiian caves and sand dunes. Bird bones of unkown taxa were more recently found in National Park caves and bat bones were recorded in 1992. (Howarth *et al*., 1994; Stone, 2005 unpub). Collection and further identification of the materials by such specialists is needed.

Following these early inventories the park began to systematically plan the management of the caves in the early 1980s. R. Seibert wrote the first Draft Lava Tube Management Plan for Hawai`i Volcanoes National Park in 1982. Management of caves within National Park Service lands was later strengthened with the Federal Cave Resources Protection Act of 1988 that required federal land managers to develop plans to protect cave resources.

In 1990 Susan Heftel-Liquido and A. Kikuta wrote a second draft management plan for Hawai`i Volcanoes National Park Caves, and in the same year the Park completed a Draft Environmental Assessment for the plan. Soon after the first cave management plan was adopted for Hawai`i Volcanoes National Park in 1991 the park followed with the development of a detailed proposal for Hawai`i Volcanoes National Park cave inventory. The subsequent inventory project that followed the 1991 proposal lasted through 1993. The final report (Howarth *et al*., 1994) submitted in 1994 addressed four principal objectives:

(1) Refine protocols and a standard inventory form for assessing cave resources and recording information on caves.

(2) Inventory and assess selected accessible park caves, their resources, threats, and management needs.

(3) Develop a computer database that can be later converted to a GIS system and begin to input data from inventories.

(4) Document methods for monitoring cave resources within the park.

The assessments completed as part of this project resulted in values that were assigned to caves based on presence of resources (see sample below). As a result of the inventory, an additional cave, Pua'po'o or Cockscomb Cave, was opened to the public for guided tours. Kipuka Puaulu Cave #1 was made available for recreational caving but only with an approved permit. The dark end of Thurston Lava Tube was also opened for self-guided exploration without the need for a permit. In 1994 Hawai`i Volcanoes National Park updated its Cave Management Plan and included many of the recommendations that were a result of the inventory program.

A main recommendation of the Howarth *et al*. (1994) inventory report was that regular cave monitoring, photo points, and registers be established. Staff from the Resources Management Division of Hawai`i Volcanoes National Park, began this program in 1993 and continued it through 1995. Photo points were established and entrance monitoring occurred in 22 caves and registers were placed

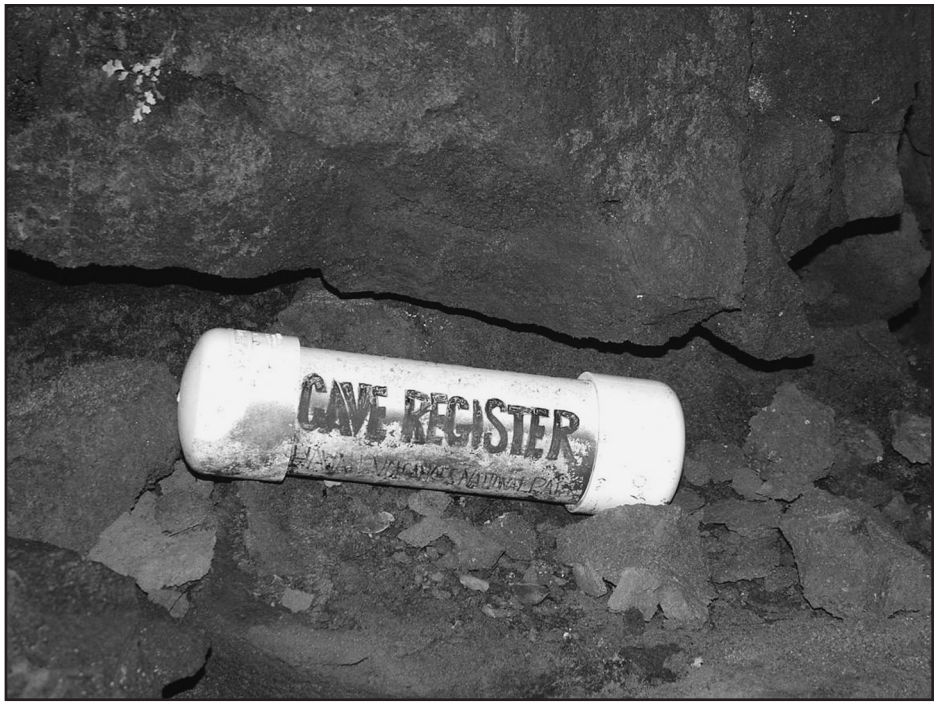

Figure 6. Cave register placed in park cave in 1993.
Photo by Fred Stone, courtesy of Hawai`i Volcanoes National Park.

in 20 caves. After 1995 the monitoring program waned although many of the registers remained in place. This program was revised in 2003 and currently 21 of the original caves are being monitored again (Figure 6). Caves selected for monitoring are near roads and trails where park visitors are most likely to encounter them.

In 1995 the park hired a Biological Technician whose primary task was to function as the first permanent Cave Specialist for Hawai`i Volcanoes National Park. One of his primary focuses was on traditional Hawaiian cultural use of caves. In addition, during this period the park began to work with the Hawai`i Speleological Survey on specific cave projects, such as the long-term surveys by Bill Halliday and Survey cavers of caves in Kilauea Caldera and initiated a survey for cave entrances on the slopes and summit of Mauna Loa and in the southwest corner of the park near *Kamo'oali'i*. A total of 22 cave systems were documented (Stock and Bumgardner, 1999). While strides were made in identifying new caves during this period, systematic cave monitoring lapsed. The Biological Technician held this position until 1999 when it was vacated.

In 2001 Hawai`i Volcanoes National Park utilized the vacancy to develop a professional series position and hired an Integrated Resources Manager. This individual was tasked to develop a program that would manage both the archeology program and cave resources. In developing this position, managers recognized the unique cultural aspects of the Hawai`i Volcanoes National Park cave program. In addition, the Federal Cave Resources Protection Act and the National Historic Preservation Act could provide both resources with the legal protections needed for preservation and management.

Since 2001 the cave inventories have expanded and intensive location and documentation of known caves has begun. A cave database has been developed and all known caves are being re-inventoried and condition assessments are being updated. By combining the cave and archeology programs, managers are able to better utilize the limited funding resources. Program funds from the archeological inventory program, for example, have been extended to the inventory of cultural caves. In addition, funding that has come from other sources specifically for cave management has been targeted for inventory and monitoring of all cave resources. A systematic program for relocating, inventorying and mapping all known park caves is well under way and is expected to be a multi-year phased project conducted primarily in-house and contracted specialists. In addition to the inventories, regular monitoring of selected caves has been re-instituted.

In 2005 as part of the overall inventory program, the Bishop Museum was contracted by the National Park Service to re-inventory the original caves surveyed between 1991 and 1993 to determine what changes have occurred (Figure 7). Several additional caves are included in the detailed inventories, totaling about 30 caves. This project has been a joint field effort by both the National Park

Figure 7. Frank Howarth conducting timed biological inventory in Bird Park Cave. Photo by Fred Stone, courtesy of Hawai`i Volcanoes National Park.

Service crew and the Museum. In addition to these in-house and contracted efforts, the National Speleological Society cavers have assisted in a survey of caves in the newly acquired Kahuku Park lands.

Future plans include development of Pacific Islands Network-wide inventory and monitoring program for all National Parks. Limited funding has been received and a contract between the Park Service and the Bishop Museum to begin the inventories in June 2006 has been agreed to. Hawai`i Volcanoes National Park is also strongly committed to continuing its integrated cave inventory and monitoring program.

References

Apple, R. 1986. Mo`olelo no Apu. Hawai`i Tribune Herald, Hilo, HI. Sept. 28, 1986. p. 23.

Bonk, W.J. 1969. Lua Nunu O Kamakalepo: A cave of refuge in Ka`u, Hawai`i. Pp 75- 92. In: Archaeology on the island of Hawai`i. R. Pearson, editor. Asian and Pacific Archaeology Series No. 3. University of Hawai`i, Honolulu

Ellis, William. 1842. Polynesian Researches: Hawai`i. Peter Jackson, London. Reprinted 1969, Charles E. Tuttle Co., Rutland, VT. P. 280.

Emory, K., J. Cox, W. Bonk, Y. Sinoto, and D. Barrere. 1959. Natural and Cultural History Report on the Kalapana Extension of the Hawai`i National Park. Volume I Cultural History Report. (Report on file at Hawai`i Volcanoes National Park).

Emory, K., L. Soehren, E. Ladd. 1965. The Archaeological Resources of Hawai`i Volcanoes National Park, Hawai`i. Part II, Additional Sites, Test Excavations and Petroglyphs. (Report on file at Hawai`i Volcanoes National Park)

Emory, K.P., W.J. Bonk, and Y.H. Sinoto. 1969. Waiahukini shelter site (H8), Ka`u, Hawai`i. Pacific Anthropological.

Heftel-Liquido, S. and A.H. Kikuta. Feb 28, 1990. Draft Cave Management Plan, Hawai`i Volcanoes National Park.

Howarth, F.G. 1972. Cavernicoles in lava tubes on the island of Hawai`i. Science 175:325-326.

Howarth, F.G. 1981. Lava tube ecosystem as a study site. Pp. 222-230. In: Island Ecosystems: Biological Organization in Selected Hawaiian Communities. D. Mueller-Dombois, K.W. Bridges, and H.L. Carson, eds. US/IBP Synthesis Volume 15: Hutchinson Ross. 583 pp.

Howarth, F.G. 1982. The ecology of Hawaiian lava tubes. IN: R.C. Wilson and J.J. Lewis, eds. Proc. National Cave Management Symposium, Mammoth Cave National Park, KY, 1980. Pygmy Dwarf Press, Oregon City, Oregon.

Howarth, F.G. 1983. The conservation of cave invertebrates. In: Proc. First International Cave Management Symposium, Murray, KY., 1981. J.E. Mylroie, ed.

Howarth, F.G. & F.D. Stone. 1982. The Conservation of Hawai`i's Cave Resources. In: C.W. Smith (ed.) Proc. 4th Conf. Natural Sciences, Hawai`i Volcanoes National Park.

Howarth, F.G., F.S. Stone, E. Pearthree & J. Lippert. 1994. Development of Protocols for Cave Inventories and Assessment Survey of Selected Caves in Hawai`i Volcanoes National Park. (Report on file at Hawai`i Volcanoes National Park).

Hu, D., C. Glidden, J. Lippert, L. Schnell, J. MacIvor and J. Meisler. 2001. Habitat Use and Limiting Factors in a Population of Hawaiian Dark-Rumped Petrels on Mauna Loa, Hawai'i. In Studies in Avian Biology: Vol. 22, No. 1, pp.234-242.

Kempe, S. & C. Ketz-Kempe. 1978. Three Lava Tubes on Hawai`i, a caving report.

Geological-Paleontological Institute, University of Hamburg, Fed. Rep. Germany.

Kempe, S. & C. Ketz-Kempe. 1991. Lava Tube Systems of the Hilina Pali Area, Ka`u

District, Hawai`i. Institute for Biogeochemistry and Marine Chemistry, University of Hamburg, Fed. Rep. Germany.

Moniz Nakamura, J. 1999. The Archaeology of Human Foraging and Bird Resources on the Island of Hawai'i: The Evolutionary Ecology of Avian Predation, Resource Intensification, Extirpation and Extinction. Doctoral Dissertation. University of Hawai`i at Manoa.

Moniz Nakamura, J., K. Sherry and L. Tamimi. 1998. Foraging For Food? Prehistoric Pit Features at Pohakuloa, Hawai'i Island. In Rapa Nui Journal, Vol. 12, No. 4, pp. 110-117.

Peterson, D.W., R.T. Holcomb, R.T. Tilling, and R.L. Christiansen. 1994. Development of lava tubes in the light of observations at Mauna Ulu, Kilauea Volcano, Hawai`i. *Bull. Volcanol*. 56:343-360.

Peterson, D.W., D.A. Swanson. 1974. Observed formation of lava tubes during 1970-71 at Kilauea Volcano, Hawai`i. Studies in Speleology 2(6):209-223.

Seibert, R. 1982. Draft Lava Tube Management Plan, Hawai`i Volcanoes National Park

Smart, C. 1965. The Archaeological Resources of Hawai`i Volcanoes National Park, Hawai`i. Part I, An Archaeological Survey of Parts of Hawai`i Volcanoes National Park (Report on file at Hawai'i Volcanoes National Park).