NASA volcanology field workshops on Hawai'i: Part 1. Description and history

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Notes
ABSTRACT

We have organized ten National Aeronautics and Space Administration (NASA)–sponsored planetary volcanology field workshops on Hawai‘i since 1992, providing an opportunity for almost 140 NASA-funded graduate students, postdocs, and junior faculty to view basaltic volcano features up close in the company of both terrestrial and planetary volcanologists. Most of the workshops have been thematic, for example, concentrating on large structural features (rift zones and calderas) or lava flows, or features best viewed in high-spatial-resolution data, but they always include a broad set of topics. The workshops purposely involve long field days—an appreciation of scale is important for planetary scientists, particularly if they are or will be working with slow-moving rovers.

Our goals are to give these young scientists a strong background in basaltic volcanology and provide the chance to view eruptive and volcano-structural features up close so that they can compare the appearance of these features in the field to their representations in state-of-the-art remote-sensing images, and relate them in turn to analogous planetary features. In addition, the workshop enables the participants to start a collection of field photographs and observations that they can use in future research and teaching. An added benefit is that the participants interact with each other, forging collaborations that we hope will persist throughout their careers.

INTRODUCTION

In the past 20 yr, the U.S. and European space agencies, National Aeronautics and Space Administration (NASA) and European Space Agency (ESA), have undertaken numerous exciting missions to Mercury (MESSENGER), Venus (Magellan), the Moon (Lunar Reconnaissance Orbiter [LRO]), Mars (Pathfinder, Mars exploration rovers [MERs], Mars Reconnaissance
Orbiter (MRO), Mars Express), and Jupiter and Saturn (Galileo and Cassini). Many of these missions have shown the importance of volcanism in creating and modifying the surfaces of planets and moons. The importance of field experience for geologists studying other worlds, who by necessity have to conduct their studies remotely, cannot be overstated. Field experience introduces a geologist to the complications and variability of natural features in a way that no textbook, satellite image, or computer model can. Usually, it strengthens those textbook, image, or model ideas, but occasionally (and more importantly), it contradicts them. An appreciation for the limits of one’s own, and the community’s, understanding of a problem is a key for conducting meaningful planetary science.

Hawaii has a long history as a planetary analog to extraterrestrial volcanic landforms (e.g., Greeley, 1974; Carr and Greeley, 1980); we have tried to continue this tradition by introducing successive generations of planetary geologists to Hawaiian volcanoes via a series of field workshops. Because Hawaii has been the focus of many remote-sensing studies, both for planetary analogs and for better understanding of terrestrial geology, we have a considerable in-house collection of analog data sets comparable to those collected for the planets, including complete IKONOS 1 m panchromatic and 4 m color coverage of the island of Hawaii. In addition to these very high-spatial-resolution visible and near-infrared (IR) images, we have high-spatial-resolution thermal infrared images, SAR (Synthetic Aperture Radar) backscatter images, and high-spatial-resolution topographic data (e.g., LiDAR [Light Detection and Ranging], TOPSAR [Topographic Synthetic Aperture Radar], and SIR-C [Shuttle Imaging Radar-C]). For our workshops, we collate the image data most suitable to studying important volcanological topics, and most days of each workshop are spent, images in hand, examining these features in the field, discussing their origins, and pointing out the aspects that can or cannot be identified in remotely sensed data. The image data are provided in hardcopy format so that participants can annotate them and use them to compare with their own observations.

Prior to each workshop, we provide an extensive reading list that covers both the terrestrial aspects of features we plan to visit and relevant studies of similar features on other planets. This reading list is quite long and more than most participants want to read. However, we feel that it is important that the resources be available for those who want it. Additionally, we provide (digitally) a set of remote-sensing data for a mapping site. The participants are strongly encouraged to produce a geologic map of the site prior to arriving in Hawaii, and we spend an evening discussing the image data, and then a full day ground-truthing their maps. This mapping exercise consistently is rated as the top experience of the workshop for many reasons. These include exposing participants to data sets they do not usually work with, providing a direct image-to-feature comparison, and providing first-hand experience with the limits imposed by spatial resolution.

The first two workshops were funded directly by NASA’s Planetary Geology and Geophysics (PG&G) program. Starting with the third workshop, funding has been granted via the successful submittal of a proposal that is reviewed along with all other PG&G proposals. The typical budget is $60,000–$70,000, which includes all travel, food, and lodging costs for the participants and staff, plus 1 mo for salary for a principal investigator (PI) and co-investigator (Co-I).

Formal presentations about the workshops were given at the 2000 Lunar and Planetary Science Conference and 2008 Geological Society of America (GSA) Cordilleran Section meetings (Rowland et al., 2000, 2008). The GSA presentation was part of a session dedicated specifically to the use of Earth analog field visits to support planetary geology. That session, and in turn this Special Paper, grew out of a collaborative effort by two alumni of our 2003 workshop. In this paper, we will present a brief summary of each workshop and its particular theme, and then discuss the specific locations on Hawaii that we visited. Some of these locations present specific logistical and access challenges, which we discuss as well (Appendix 1). Finally, we provide some advice for anyone who might be considering a similar planetary analog workshop. Appendix 2 lists the participants of each workshop. A companion paper (Mouginis-Mark et al., 2011, Chapter 26, this volume) discusses some intriguing planetary questions for which field analogs in Hawaii provide important perspectives and key constraints.

WORKSHOPS AND WORKSHOP THEMES

The workshops have evolved over the years because we learn from each experience, because we incorporate suggestions and comments of participants, and because new planetary data sets (and consequently new science opportunities and interests) have become available.

Workshop 1 (June 1992, 19 Participants)

The theme was a general introduction to basaltic volcanism in the field, and topics included lava flows, vent structures, pyroclastic deposits, and volcano morphology. We presented a mix of field excursions and indoor lectures. We had guest lectures on radar remote sensing from Dr. Bruce Campbell (Smithsonian Institution) and on thermal infrared remote sensing from Dr. Vince Realmuto (Jet Propulsion Laboratory). Jim Garvin talked about landing site geology on Venus and Mars as viewed by Venera and Viking, respectively. Considerable effort went into preparing an introduction to Hawaiian volcanism and a field guide to the locations that we visited. The Hawaiian volcanism introduction is available on the Web page of VolcanoWorld: http://volcano.oregonstate.edu/education/hawaii/intro/intro.html. The field guide has gone through many revisions and iterations, and it was split into two parts (Kilauea and Old Hawaii Island), both of which are available in pdf format at the following Web site: http://www.soest.hawaii.edu/GG/resources/ggdocuments.html. During this workshop, we realized that formal lectures were not such a great idea, not only because participants were pretty tired from field work and found staying
awake in dark rooms very challenging, but also because the
time could be spent better in the field.

Workshop 2 (August 1995, 9 Participants)

The theme again was general, but we concentrated some-
what on lava flows and vent structures, and we were thus able
to present more in-depth information on these topics. This was
the first time that we included field mapping exercises (two,
in fact), where the students were given raw image data and
allowed to examine the localities independently to make their
own observations and interpretations. They could then compare
what they were able to determine in the field with what was
available in the images. These mapping exercises turned out to
be very valuable, and thus became a feature of all subsequent
workshops.

Workshop 3 (February 1997, 10 Participants)

This time, the participants were postdocs and young
NASA-funded PIs, and the focus was on large-scale structures
of basaltic volcanoes, namely, calderas, rift zones, and unstable
flanks. We included new sites on the SW rift zone of Mauna Loa
that highlighted these structural features. We incorporated pre-
vious participants’ comments by having only one full-day field
mapping exercise. This was also the first time that we compiled
a reading list and made copies of the papers available to the
participants during the workshop.

Workshop 4 (August 1998, 13 Participants)

Similar to the first and second workshops, the fourth was
a more general introduction to basaltic volcanic features. We
spent considerable time discussing volcanic surfaces, their
weathering characteristics, and their appearance in remotely
sensed images. We overlapped our field activities on Kilauea
with a NASA Jet Propulsion Laboratory–sponsored surface
coatings workshop and were able to call upon the expertise of
some of their organizers during extended field discussions.

Workshop 5 (August 1999, 10 Participants)

Similar to the third workshop, we concentrated on large-
 scale basaltic volcano structures. We made an important modi-
fication to the mapping exercise, namely, scheduling time for
the participants to work on their maps prior to going into the
field. We also spent considerable time discussing the specific
data sets that were part of the mapping exercise because few of
the participants were familiar with all of them.

Workshop 6 (August 2001, 18 Participants)

In this workshop, the theme was lava flow morphology. Our
aim was to give participants an appreciation of the complexity of
lava flows at the field-observable scale. New activities included
a walk from Mauna Ulu, a satellitic shield on Kilauea’s east rift
zone, down a particularly prominent lava channel (Muliwai a
Pele). We also visited the ~200-m-thick Pu’u Anahulu trachyte
flow. We modified the field exercise yet again by providing the
image data to the participants prior to the workshop. Given this
extra time and the ability to work with familiar software (or color
pencils) at their home institutions, the quality of the participants’
maps was considerably better than those of previous groups.

Workshop 7 (August 2003, 18 Participants)

The emphasis for this workshop was on volcanic features
that are studied best using high-spatial-resolution images. We
spent most of the days with a collection of such images in hand,
comparing them to the appearance of features in the field. The
weather was quite uncooperative, but the participants managed
to gain a reasonable understanding of the relationship between
image views and real-life views of volcanic features. They also
got a taste of the navigational difficulties that a rover might
experience during an epic high-elevation hike in the rain and fog
on Mauna Loa’s NE rift zone. Visibility decreased to 10–20 m,
so navigation relied solely on georegistered images and handheld
global positioning system (GPS) units.

Workshop 8 (August 2005, 17 Participants)

This workshop was Mars-specific and concentrated on vol-
canic features similar to those found in recently collected Mars
Orbiter Camera (MOC) image data. This was the first year that
Dr. Sarah Fagents participated as a workshop leader (she is a
graduate of the fourth workshop), and her quantitative model-
ling skills were a very positive addition to the knowledge base.
We also invited Dr. Steve Baloga to participate as a guest vol-
canologist, and his input and experience were very valuable.
Dr. Baloga’s insights about the NASA Planetary Geology and
Geophysics Program from the dual perspectives of both an ex-
program manager and a principal investigator were significant.
These programmatic and practical training aspects of a young
scientist’s education are commonly overlooked, and it was clear
that the participants appreciated learning from Dr. Baloga’s
experience in these realms.

Workshop 9 (July–August 2008, 13 Participants)

In somewhat of a combination of the seventh and eighth
workshops’ themes, we concentrated on volcanic features anal-
ogous to those on Mars that have been imaged by recent high-
spatial-resolution images. Our guest volcanologist was Dr.
Bruce Houghton (University of Hawai’i), and we were also for-
tunate that Dr. Jim Bell (Cornell University) was able to attend.
Bruce’s insights into the interpretation of pyroclastic deposits
and Jim’s years of experience with the Spirit and Opportunity
rovers were both very valuable additions to the workshop.
Workshop 10 (July 2010, 17 Participants)

We essentially repeated the high-spatial-resolution theme with the additional consideration of the types of features, as well as the views of these features, that a planetary rover might encounter. This was accomplished most explicitly by including “rover” analog photos as part of the data set that was provided to the participants for their final-day mapping project. Dr. Bruce Houghton again provided excellent insights and field activities relating to pyroclastic deposits and lava ponds.

PLANETARY ANALOG SITES

We have visited numerous sites on Hawai`i during our workshops (Fig. 1). Some of these were included in all ten workshops, and others only once. In this section, we briefly outline these sites, their key volcanological aspects, and examples of their planetary analogs. Access and logistical issues can be found in Appendix 1. Location 3 (sometimes) and locations 4–12 (all the time) are within Hawai`i Volcanoes National Park, and maps of the park are available at the park entrance and headquarters, at the Jaggar Museum, and on the park’s map Web site at http://www.nps.gov/havo/planyourvisit/maps.htm. Additional discussion of the sites can be found in the online field guides referenced previously, and a more detailed discussion of a small subset of these sites and their relevance to planetary volcanology is presented in Mouginis-Mark et al. (2011, Chapter 26, this volume).

Objectives

The objective here is to investigate the surface characteristics of lava flows that serve as an analog to the platy-ridged Amazonian-age lava flows seen on Mars (Keszthelyi et al., 2000, 2004). Discussions here include the debate about whether the platy surfaces in the Cerberus region of Mars are lava flows or ice deposits (Murray et al., 2005).

2. Ka`ūmana Cave

Ka`ūmana cave is a lava tube within the 1880–1881 tube-fed pāhoehoe lava flow of Mauna Loa (Brigham, 1909; Barnard, 1990; Rowland and Walker, 1990). This location is ~6 km upslope from the distal end of the flow in a somewhat neglected county park along Ka`ūmana Dr. (State Hwy 200). Note that the tube ceiling is unstable, and it is unwise to go more than 10 m beyond the entry skylight.

Objectives

This is a good location to discuss lava-tube formation and flow processes because intratube channels, bifurcations, remelting structures, and other features are preserved well. Lunar sinuous rilles (Hulme, 1982; Williams et al., 2000), Venusian canali, and structures on some Martian lava flows have been interpreted to be collapsed lava tubes (Fig. 3), and Ka`ūmana Cave is a good place to discuss the features one might look for in the walls of sinuous rilles to support this interpretation. It also provides an opportunity to talk about long-duration, low-volumetric-flow-rate, large-volume eruptions, thermal erosion of the substrate, and possible safe refuges for lunar astronauts seeking protection from solar flares. Finally, steep to overhanging pits have recently been discovered on Mars (Cushing et al., 2007) and on the Moon (Haruyama et al., 2009), and there are suggestions that these might be skylights that were possibly induced by meteorite impacts. The lunar features might also be pit craters (see analog site no. 10). Standing next to (or inside) a skylight is a good place to discuss these features.

3. Active Flows of the Ongoing Pu‘u ‘Ō‘ō Eruption

Eight of the ten workshops had the opportunity to observe active lava flows of the ongoing Pu‘u ‘Ō‘ō (hill of the ‘ō‘ō bird)
Figure 1. Cloud-free Landsat mosaic showing the locations of field sites discussed in this paper. The Landsat data are available on the HawaiʻiView Web site at http://hawaiiview.higp.hawaii.edu/. HVO—Hawaiian Volcano Observatory.
eruption, and this is clearly one of the benefits of holding a workshop on an active volcano (workshops 1 and 3 happened to coincide with pauses in the eruption). No PowerPoint presentation or video can convey the concept of lava flow emplacement as well as watching a flow in person. Most commonly, we have encountered slowly advancing, inflating, tube-fed pāhoehoe, but participants in the fourth workshop, in 1998, were fortunate enough to view and study some impressively fast-moving 'a'a flows (Fig. 4). During the ongoing eruption, lava has commonly been entering the ocean, so we have also had the opportunity to witness small littoral explosions (Fig. 5).

Objectives

The objective here is to observe active lava flows, investigate inflation features on a compound lava flow field, and discuss the

Figure 3. Skylights. (A) Portion of a vertical air photo showing a line of skylights (S) in the 1855–1856 Mauna Loa flow. Note that their discontinuous nature differs morphologically from the continuous negative topography produced by a lava channel (C). (B) View out one of the skylights in this flow. (C) Skylights (S) in a lava flow on the flank of Olympus Mons, Mars (Mars Orbiter Camera [MOC] image no. R2000500). In A, most of the dark lava flows are young 'a'a, and note that their margins have a crenulated outline. The large flow in the central part of C has a similar margin morphology, and is likely also 'a'a (e.g., Bruno et al., 1994). (D) Steep-sided pit in Mare Ingenii (illumination is from the upper right). This is Lunar Reconnaissance Orbiter Camera (LROC) frame: NAC M128202846LE. Credit: National Aeronautics and Space Administration (NASA)/Goddard/Arizona State University.
Sakimoto et al., 1997; Fagents and Greeley, 2001), the thermal characteristics of lava flows and lava lakes on Io (Davies et al., 2001; Lopes et al., 2001, 2004), thermal remote sensing (Flynn et al., 1994; Wright and Flynn, 2003), and the long-term evolution of lava flow fields on Mars and Venus (Roberts et al., 1992; Kesztthelyi et al., 2000; Plescia, 2003a). Rootless explosions are postulated to have been the formation mechanism for fields of small cones on Mars (Greeley and Fagents, 2001; Lanagan et al., 2001; Fagents et al., 2002; Fagents and Thordarson, 2007; Hamilton et al., 2010), and discussions of these explosions while they are occurring a couple hundred meters away is an experience that is hard to beat.

4. Mauna Ulu Satellitic Shield and Muliwai a Pele Lava Channel

The Mauna Ulu (growing mountain) eruption lasted from 1969 to 1974 (Swanson et al., 1979; Tilling et al., 1987) and at the time was considered to be a long-duration rift zone eruption. The early phase of the eruption consisted of high fountains and channelized ‘a‘ā lava flows, but these eruptive products were mostly buried by subsequent years of low-effusion-rate tube-fed pāhoehoe lavas erupted from an ever-growing satellitic shield (Mauna Ulu proper; Fig. 6). This was the first long-duration eruption to occur...
after Hawaiian Volcano Observatory became modern and well staffed, and many landmark papers about lava flow emplacement, long-duration eruptions, and long-term magma supply to Kilauea resulted from observations at this time (e.g., Swanson, 1973; Peterson and Tilling, 1980; Kilburn, 1981; Peterson et al., 1994). The Muliwai a Pele (river of Pele) channel (Fig. 7) formed during a brief return to ‘a‘ā production near the end of the Mauna Ulu eruption (Carr and Greeley, 1980; Wilson and Parfitt, 1993), and it provides excellent exposures that illustrate the complexity that can develop even during a short-lived event (Harris et al., 2009).

**Objectives**

Mauna Ulu is a classic satellitic shield, and as such, it is an excellent analog to the small shields that have been described

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**Figure 7. Lava channels.** (A) Mauna Ulu. Dashed white line indicates outlines of 1-m spatial resolution IKONOS data that workshop participants use as they walk from Mauna Ulu along the Muliwai a Pele channel. IKONOS images D, E, and F are enlarged below, and illustrate some of the complexity along even a short-lived channel (B) Synthetic Aperture Radar (SAR) image of a channel on Venus that flowed from upper right (NE, in Fortuna Tessera) to lower left (SW, in Sedna Planitia). This channel is ~2 km wide. *Magellan* image F-MIDR 45N019;1, framelet 18.
recently on Mars (Fig. 6; Mouginis-Mark, 2003; Bleacher et al., 2007, 2009; Baptista et al., 2008; Baratoux et al., 2009; Hauber et al., 2009). It is instructive to discuss the complexity of the Mauna Ulu shield, including the subsidiary shield that developed over the now-buried ‘Alae (mud hen) pit crater (Swanson et al., 1972; Tilling et al., 1987), in light of models of small-shield development. The walls of the crater clearly show how a small shield is constructed of multiple overflows, and the Mauna Ulu flow field itself shows considerable complexity, with overlapping flow units and flow types. Although much smaller than many planetary lava channels (Fig. 7), Muliwai a Pele nevertheless provides a host of discussion points regarding channel development and the assumptions and care required when modeling channelized lava flows. One concept to discuss is the fact that variations in the overall flow width and channel depth are often due to complex overflow and blockage events, respectively, and typically cannot be used as proxies for slope-rheology relationships or volumetric flow-rate calculations (Harris et al., 2009).

5. Lower Mauna Ulu Flow Field, Hilina Pali

From the Ke ala komo (the entrance path) and Holona Kahakai (sailing, traveling seacoast) overlooks along Chain of Craters Road, there are spectacular views downslope over the unstable south flank of Kilauea (Fig. 8). Because of a lack of any buttressing to the south, this unstable flank slips downward via series of large normal faults, together comprising the Hilina pali (cliff struck by wind). This downward slippage occurs during, but is not the cause of, large, south flank earthquakes. These earthquakes occur on the landward-dipping interface between the base of Kilauea and the underlying ocean crust (Swanson

Figure 8. Hilina Pali and a Martian analog. (A) Shaded relief image (illuminated from the NW and 45° above the horizon, created from a U.S. Geological Survey 10 m digital elevation model; http://hawai.gov/dbedt/gis/hill.htm) showing the numerous downdropped blocks that comprise the unbuttressed south flank of Kilauea (B and arrow indicate location and view direction of B). (B) Low-altitude oblique air photo looking to the west. Almost all of the Hilina faults are downdropped to the south, but one is down dropped to the north, forming a small horst, the summit of which is Pu‘ukapukapu (regal hill), visible in middle ground. Note the flows exposed in the 3.20-m-high cliff below Pu‘ukapukapu and the talus slopes extending to near sea level. (C) A portion of the basal escarpment of Olympus Mons, Mars, at 14.8°N, 229.6°E (Thermal Emission Imaging System [THEMIS] image V01415006; illumination is from the left). Note how lava has flowed around a high point on the scarp that is topped by a collapse pit.
et al., 1976; Lipman et al., 1985). An exhilarating way to experience these fault scarps is to climb down one of them, from the Holona Kahakai overlook to the Alanui Kahiko (old highway) pullout. There is no trail, and the slopes approach 45°, but with care (avoid the 'a‘ā) and proper field gear (boots, long pants, and gloves), it is a very rewarding experience.

Once on the lower (and more gradual) slopes, there are excellent opportunities to observe features of 'a‘ā and pāhoehoe lava flows, often in close proximity, which are good for comparison purposes. Considerable work on the emplacement of pāhoehoe flows has been conducted on the Mauna Ulu flows in this region (Crown and Baloga, 1999; Byrnes and Crown, 2001), including the effects of the underlying slope on individual pāhoehoe flow unit shape and size. The results have been used to characterize the emplacement processes of some Venusian lava flows (Byrnes and Crown, 2002). The studies were partially inspired by these authors’ visits to this area as participants in our workshops.

Objectives

Up-close and distant views of the Hilina Pali lead into discussions of the growth and collapse of volcanoes on Mars, as well as the manner in which they may deform over time (e.g., McGovern and Solomon, 1993; McGovern and Morgan, 2009).

6. Mauna Ulu Mapping Exercise, East Rift Zone of Kilauea

We adopted this mapping site in 2008 because of unsafe SO₂ levels at Mauna Iki (little mountain; see analog site 13). Image and spectral data are provided to participants a couple months prior to the start of the workshop, and they are encouraged to produce a geologic map based on these data. We spend all of the final workshop day ground-truthing their maps. Although not as good a site as Mauna Iki due to fewer surface types and ages, there is sufficient variety for the mapping to be challenging, and it is easily accessible via Chain of Craters Road. A study of the Mauna Ulu flow field that includes a similar data set of multiple remotely sensed images along with field observations was published by three of our workshop participants (Byrnes et al., 2004).

Objectives

Objectives here are to put the previous week’s knowledge to practical use, and to use remote-sensing data to map flow textures, collapse features, tectonic features, etc. In the process of completing a reconnaissance map of lava textures and rift zone features, the participants are required to utilize

Figure 9. Kilauea Iki. (A) View west, along the ~90-m-high north wall of the crater. Note the smooth ponded lava surface and the high-lava mark (see text). The Hawaiian Volcano Observatory (HVO) is in the distance, and note that it sits atop a satellitic shield (the Observatory shield; Holcomb, 1987). (B) View south to the main 1959 vent (elev. 1067 m) and Pu‘u Pua‘i (elev. 1184 m). See Figure 11 for photo locations.

Figure 10. Coalescence of collapse pits. Photo insets show uncoalesced (A) and coalesced (B) collapse pits developed in Kilauea Iki tephra (see Fig. 12 for location). These pits overlie fissures that predate deposition of the tephra. (C) Collapse pits in lava plains NE of Asrcraeus Mons, Mars (Mars Orbiter Camera [MOC] image no. MOC2-1476).
multiple remote-sensing images that are analogs to various planetary data sets. This is an excellent opportunity to test photogeologic mapping skills that might be developed using MGS (Mars Global Surveyor), MRO (Mars Reconnaissance Orbiter), MO (Mars Observer), LRO (Lunar Reconnaissance Orbiter), Magellan, or MESSENGER data sets. Field validation of interpretations made from satellite data sets cannot be overemphasized as a learning experience!

7. Kīlauea Iki and Puʻu Puaʻi

Here, there are many hours worth of excellent volcanic features and planetary analogs all within a short walk or drive. The 1959 Kīlauea eruption partially filled a preexisting pit crater (Kīlauea Iki; little Kīlauea) with lava, and some of the highest lava fountains on record in Hawaiʻi built a substantial scoria cone (Puʻu Puaʻi; gushing hill) and downwind tephra deposit (Fig. 9; Macdonald, 1962; Richter et al., 1970). A hiking trail leads down one side of Kīlauea Iki crater, across the solidified surface of the lava lake, and up the other side. Along the way, one can stop to peer into the main vent and observe all manner of lava lake features (Stovall et al., 2009), including a so-called bathtub ring, which records the highest level that the lava lake achieved before drain-back into the vent, cooling-induced contraction, and degassing, all lowered the surface to its present level. Excellent examples of rheomorphic spatter flows can be found on the flanks of Puʻu Puaʻi, and cross sections of the scoria deposit are exposed in a series of collapse pits. These pits have developed within the tephra deposit as tephra has fallen into preexisting fractures. Thus, they provide good examples of circular depressions developed by collapse of a surface layer into a linear fissure, much like (except for their size difference) the pit chains that have been observed at many volcanic locations on Mars (Fig. 10).

Objectives

The purpose here is to walk across the frozen lava lake and observe the tephra deposits from Puʻu Puaʻi. This provides the opportunity to discuss the smooth (and therefore radar-dark) surface of the lava lake, and its meaning for the interpretation of plains materials on Venus (Fig. 11; Campbell et al., 1993; Figure 11. Synthetic aperture radar (SAR) data for Kīlauea and Sif Mons, Venus. (A) A 3-wavelength composite of P band (68 cm), L band (24 cm), and C band (5.6 cm) wavelengths in red, green, and blue, respectively. This is a mosaic of Jet Propulsion Laboratory AIRSAR images kd1 and kc4, collected in August 1990 (Glaze et al., 1992). Kīlauea caldera, Kīlauea Iki, and Halemaʻumaʻu are all radar-dark because they are mostly smooth ponded lava flows. Note that much of the area SW of the caldera is also radar-dark, and this is due to extensive coverage by Keanakākoʻi ash. Radar properties of the December 1974 flow were studied, with Venus analogs in mind, by Gaddis et al. (1989, 1990). Numbered arrows indicate locations from where Figures 9 and 13 were taken, and dashed ellipse shows area of Figure 17. (B) Numerous, complex lava flows, some of which have been constrained by preexisting fractures, on the north flank of Sif Mons, Venus (Magellan image no. PIA00471).
Rowland et al.

Campbell and Rogers, 1994; Campbell and Shepard, 1996; Carter et al., 2006). Inspection of the tephra deposits leads into a discussion of explosive volcanism on the planets, and, in particular, pyroclastic deposits such as the dark halo craters within Alphonsus crater on the Moon (Fig. 12).

8. Nā Huku (Thurston Lava Tube)

*Nā Huku* (the protuberances) is a large lava tube that leads out of the summit crater of the ‘Ai Lā‘au (forest eater) satellitic shield (Fig. 13). The ‘Ai Lā‘au eruption lasted from ca. 1410 to 1470 A.D. (Clague et al., 1999; Swanson, 2008) and produced extensive tube-fed pāhoehoe flows that extend to the coast ~40 km away. The eruption immediately preceded ~300 yr of explosive activity at Kilauea, and it may be recorded in part of the epic Hawaiian story of Pele, Hi‘iaka, and Lohi‘au (Swanson, 2008).

**Objectives**

*Nā Huku* provides another opportunity (in addition to Ka‘ūma‘na cave) to talk about long-duration basaltic eruptions, lava-tube development, thermal erosion, and sinuous rilles on the Moon.

![Figure 12. Tephra deposits. (A) Part of a panchromatic IKONOS image (no. 2000112520362450000011603357, collected 25 November 2000), showing the thickest part of the downwind tephra deposit from the 1959 Kilauea Iki eruption. The dashed ellipse shows the region of collapse pits (Fig. 10). (B) An oblique view looking west, showing dark halo deposits (DH) within the lunar Alphonsus Crater, which is ~100 km across. Apollo-16 image number AS16-M-2478.](image)

![Figure 13. Profile of the ‘Ai Lā‘au shield (the skyline; highest elev. = 1200 m), viewed to the east from the Hawaiian Volcano Observatory (5.3 km away; see Fig. 11 for view direction). The floor of Kilauea caldera is in the near and middle ground. Byron Ledge (3.2 km away; elev. ~1130 m) separates the caldera from Kilauea Iki crater.](image)
9. Kīlauea Caldera, the Hawaiian Volcano Observatory (HVO)

Kīlauea caldera probably developed shortly before the ‘Ai Lā’au eruption (Swanson, 2008; Fiske et al., 2009), but it is just one in a series of many calderas that have formed, infilled, and then reformed during the life of Kīlauea volcano (e.g., Holcomb, 1987; Decker, 1987). The structure of the caldera is visible from a number of vantage points, and it clearly illustrates the complex nature of a large caldera, including collapse blocks (Fig. 14), multiple faults, and nested collapse structures. HVO is run by the U.S. Geological Survey (USGS) and is one of the oldest and most advanced volcano observatories in the world. The Jaggar Museum, constructed out of an older part of HVO, houses many modern displays about volcanoes and volcano monitoring, and it has probably the best vantage point in the whole summit region.

Objectives

This location allows us to gain an appreciation for the scale and complexity of caldera features, and the ways in which these large-scale structures affect the morphology and distribution of lava flows, to learn more about the morphology of basaltic shields, to learn how their activity is monitored, and to understand how they evolve over time. Views of the caldera are particularly valuable for discussions of planetary calderas such as those found in the Tharsis region of Mars and on shields on Venus (Crumpler et al., 1996; Moulilis Mark and Rowland, 2001; Moulilis Mark et al., 2007). On a clear day, participants can not only gaze into Kīlauea caldera, but also turn around and look westward for a spectacular profile view of Mauna Loa, the largest shield volcano on Earth.

10. Devil’s Throat Pit Crater

Not quite 100 m NE of Chain of Craters Road is Devil’s Throat pit crater. It was described by Jaggar (1912 [1988]) as being ~75 m deep with an overhanging rim. Since then, perhaps as recently as the 1960s (Blevins, 1981), the last vestiges of overhangs fell in to produce essentially vertical walls (Fig. 15). The idea of the surface layers being the last to fall in led Blevins (1981) and Walker (1988) to propose stoping as the mechanism for pit crater formation. Modeling by Blevins (1981) suggested that the cavity into which material is falling is at a depth of 50–100 m below the surface, and may therefore be immediately beneath the present crater floor. Okubo and Martel (1998) proposed an alternative based on the propagation of fractures upward from the top edge of a dike. The angle between these two fractures is constant.

Figure 14. Failure of caldera walls as coherent blocks. (A) Oblique air photo northward across Kīlauea caldera. The length of the contact between the lowest fault blocks and the caldera floor is ~1100 m. (B) Mosaic of Thermal Emission Imaging System (THEMIS) images of the NE portion of Ascraeus Mons caldera, Mars. Illumination is from the left. Mosaic of images V01464013 and V01826008.
meaning that as the top of the dike nears the surface, the fractures approach one another. When they reach a critical distance, the strength of the rock between them can no longer remain coherent, and it collapses into the top of the dike.

Objectives

The objective here is to observe a structure formed in relatively horizontal lava flows purely by collapse and discuss the relationship between fractures and open pits. The newly discovered pits on the Moon and Mars (Fig. 3D; analog site no. 2) resemble Devil’s Throat in both morphology and size, and a discussion of whether they might be skylights or pit craters, as well as the differences between skylights and pit craters, is appropriate here.

11. Kilauea SW Rift Zone Fractures

At a pullout along Crater Rim Drive, much of the stratigraphy of the explosive Keanakākoʻi (the adze cave) ash deposit is exposed in a series of fissures that opened during the huge 1868 earthquake (Fig. 16). These fissures are the proximal end of Kilauea’s SW rift zone. The pyroclastic material exposed in the fissures ranges from fine-grained ash fall to lithic-rich pyroclastic density current deposits. All of these deposits were first interpreted as having been emplaced over hundreds of years (e.g., Powers, 1948), but they were later reinterpreted to have been emplaced in perhaps as little as a month (Decker and Christiansen, 1984; McPhie et al., 1990). Based on $^{14}$C dating, the interpretation has come full circle, and the Keanakākoʻi ash is now known to have been deposited over an ~300-yr-long period, specifically between ca. 1500 and 1790 A.D. (Swanson, 2008; Fiske et al., 2009). These are some of the best exposures of basaltic pyroclastic features on Kilauea. Unfortunately, as of this writing (June 2011), this part of Hawai‘i Volcanoes National Park, as well as the features described in locality 12, are closed due to high SO$_2$ levels associated with the vapor plume emanating from Halemaʻumaʻu (house of the amaʻu fern) crater. Visitors should inquire at Park Headquarters regarding these locations and never attempt to enter closed areas.

Objectives

The goal is to provide close-up views of explosive deposits of many kinds and stimulate a discussion of the causes of explosive eruptions on basaltic volcanoes (Dvorak, 1992; Mastin, 1997).


The region SW of Kilauea caldera is blanketed by the Keanakākoʻi ash (Malin et al., 1983; Fiske et al., 2009), which is currently being gullied whenever heavy rains occur (Fig. 17). This region therefore provides good examples of both the surface (e.g., dunes) and subsurface (e.g., cross-beds) characteristics of a basaltic pyroclastic deposit. South of the sandwash area are the vents of the December 1974 lava flow (Lockwood et al., 1999). This flow has been the focus of numerous radar roughness and topography-interaction studies.
The transition from smooth pāhoehoe to rough 'ā'ā is particularly well displayed, as are interesting controls by the north-facing Koa'e (tropic bird) fault zone (Fig. 11). Mouginis-Mark et al. (2011, Chapter 26, this volume) discuss these radar studies in more detail (see references therein and their Figs. 9–12).

**Objectives**

The purpose here is to discuss explosive basaltic activity, windblown deposits, gully formation, lava surface transitions, and fault scarps. Many of the pyroclastic surfaces have developed a duricrust by precipitation of silicic material between grains (Malin et al., 1983). The deposits are mostly very smooth in SAR data (Fig. 11) and provide a good impetus to start a discussion of what constitutes “smooth” and “rough” on planetary surfaces (e.g., Campbell et al., 1993; Campbell and Rogers, 1994; Campbell and Shepard, 1996; Carter et al., 2006). This, of course, is also an excellent place to discuss gully formation and whether or not the obvious surface-water cutting of these gullies can be scaled upward to explain the huge gullies observed on Mars, or if some other mechanism is required (e.g., Kochel and Piper, 1986; Kochel and Baker, 1990; Malin and Edgett, 2000; Gulick, 2001; Lamb et al., 2007). The 1974 vents are fine examples of en echelon spatter ramparts, and the exposures of lava flows in cross section and of the interaction between windblown basaltic sands and preexisting topography.

**13. Mauna Iki**

Mauna Iki (Fig. 18) is a satellitic shield and associated flow field, erupted during the first 9 mo of 1920. The eruption occurred near the end of at least 100 yr of constant lava lake activity at Halemaʻumaʻu, and Rowland and Munro (1993) found evidence that during parts of the Mauna Iki eruption, there was direct drainage of lava from the summit down the SW rift to this eruption site.

**Objectives**

Except in 2008, when it was closed to the public due to high concentrations of SO₂ and H₂SO₄, this has been our full-day mapping site. Participants are provided with image data in the weeks leading up to the workshop, and from these, they are expected to produce a geologic map. Mauna Iki is probably the best location on Kīlauea for this exercise because it presents a wide variety of geological surfaces, structures, and ages, and because it is essentially unvegetated and easily accessed from a trailhead on Hwy 11.

Figure 16. Keanakākoʻi ash exposed in fractures. (A) View NE of the uppermost part of Kīlauea’s SW rift zone, marked here by a series of fractures. The arrow indicates the location from which photo B was taken. The road is 2 lanes wide, and Halemaʻumaʻu (middle distance) is 990 m wide, rim to rim. (B) Participants in our first workshop examining a large block that produced a sag structure in the underlying air-fall ash layers. (C) An image taken by the panoramic camera on the Spirit Mars exploration rover (MER) at the “Home Plate” site, which shows a ~4-cm-wide sag structure in layers (National Aeronautics and Space Administration [NASA] MER press release image 20070503a).
14. Ninole Hills

The Ninole (bending) Hills (Fig. 19) are enigmatic, high-standing hills with sloping upper surfaces that are mostly, but not entirely, coplanar. These hills have been interpreted in a number of ways, including that they represent a very early stage of Mauna Loa or perhaps a separate, pre-Mauna Loa volcano (Stearns and Clark, 1930; Macdonald et al., 1983). A pre-Mauna Loa volcano in this location would be inconsistent with the increase in ages of Hawaiian volcanoes to the NW; however, the rocks that comprise the hills are indeed old. Ages of 100,000–200,000 yr have been determined...
(Lipman et al., 1990), although there is considerable uncertainty due to the weathered nature of the rocks and their low K content. The interpretation of Lipman et al. (1990) is that the Ninole Hills are in-place remnants of Mauna Loa’s east flank, which was isolated from resurfacing lavas because of the presence of a west-facing collapse scar, which lowered the axis of the SW rift zone such that lavas only flowed west. Only after the rift zone had rebuilt itself above the head of the scar were lavas able to begin resurfacing the east flanks, in the process partially burying valleys and ridges (i.e., the Ninole Hills). A recent interpretation (Morgan et al., 2010) is that the Ninole Hills are remnants of an old and abandoned Mauna Loa rift zone.

Examination of digital topography (Fig. 19) shows that the hills are downslope of a somewhat subdued, concave-downslope scarp, that probably is the headwall of a collapse that produced the Punalu’u (spring that is dived for, i.e., submarine spring) avalanche deposit offshore (e.g., Mark and Moore, 1987; Moore et al., 1989; Moore and Mark, 1992). Another interpretation, therefore, is that the Ninole Hills are toreva blocks that only moved a short distance from a large-scale collapse scar. It is probably safest to say that the Ninole Hills are not fully understood.

Objectives

With views of the Ninole Hills in the distance, the various formation mechanisms that would produce these peculiar structures can be discussed and compared to ideas about volcano collapse in general. Several analogous Martian volcano collapses have been proposed, including formation of the basal escarpment of Olympus Mons, and arcuate collapses on both the east and west flanks of Tharsis Tholus (Fig. 20; Plescia, 2003b).

15. Thermally Eroded Lava Tube at Honu’apo

In a low ocean cliff at Honu’apo (caught turtle), there is an example of a partially drained lava tube that eroded into its substrate (Coombs and Rowland, 1994). The idea of thermal (or thermomechanical) erosion by flowing lava was proposed and studied mostly by planetary geologists for many years as a possible mechanism for forming sinuous rilles on the Moon (Hulme, 1973, 1982; Carr, 1974; Williams et al., 2000). Although observations consistent with thermal erosion were made during the Mauna Ulu eruption (Peterson and Swanson, 1974; Peterson et al., 1994), only somewhat recently have most terrestrial volcanologists taken much interest in the topic. This changed more recently with the publication of a catalog of thermal erosion examples (Greeley et al., 1998), evidence of erosion observed in active tubes during the current Kilauea eruption (Kauahikaua et al., 1998, 2003), and serious consideration of the physical processes involved (Fagents and Greeley, 2001; Kerr, 2001). The example at Honu’apo is associated with a pāhoehoe flow that underlies ~26,000-yr-old Pāhala ash, and it has cut through an ‘a’ā flow, a layer of scoria, another ‘a’ā flow, and partially into a pāhoehoe flow (Fig. 21).

Objectives

The main planetary topic is a discussion of the thermomechanical erosion of substrates, including the heat-transfer concepts and ways in which erosion is accomplished. The
Figure 20. Tharsis Tholus, Mars, located at 13.2°N, –90.725°E. (A) Viking Orbiter image mosaic, showing the entire volcano, with higher-resolution subscenes B and C outlined. (B–C) High-Resolution Science Experiment (HiRISE) images ESP_012612_1940 and PSP_002169_1940, respectively, showing details of the caldera walls. In C, the height of the caldera wall is ~4 km.

Figure 21. Photograph of the thermally eroded lava tube at Honu’apo. The top and bottom of the pāhoehoe flow that hosts the lava tube are outlined with solid lines; other flow boundaries are dashed.

particular planetary examples to reference are lunar sinuous rilles and the canali on Venus. Also noteworthy is the proximity of this site to the undersea volcano Lōʻihi, and a fiber-optic data and power cable from the short-lived Hawaiʻi Undersea Geo-Observatory (HUGO) on Lōʻihi’s summit that came ashore here.

16. Large Lava Channels and Tubes in the Pōhue Bay Flow, SW Flank of Mauna Loa

One of the most spectacular lava tube and channel systems in Hawaiʻi is located just downslope of the SE corner of the Hawaiian Ranchos subdivision, within the ~2500-yr-old Pōhue (gourd) Bay lava flow (Fig. 22; Jurado-Chichay and Rowland, 1995). The tube diameter is ~8 m, which is not particularly large. However, in places, the roof of the channel is ~20 m thick (Fig. 23). Along much of its exposed course, the tube has collapsed completely, to produce a structure that topographically resembles a channel. At the coast, the Pōhue Bay flow hosts a collection of littoral cones, some of which are circular in planform (Jurado-Chichay et al., 1996a), and resemble recently described features on Mars (Lanagan et al., 2001; Fagents et al., 2002; Hamilton et al., 2010).

Objectives

If access is granted, this series of skylights and collapses provides hours of topics to examine and discuss. Examples include the complex interplay between effusion rate and lava surface texture, the limitations of simple numerical models if not applied carefully, and the complexity of flow behavior (e.g., a younger flow apparently invaded and utilized the tube-channel complex; Jurado-Chichay et al., 1996b). Additionally, the more circular skylights resemble the newly discovered pits on the Moon (Fig. 3D), and whether the lunar pits are skylights or pit craters (e.g., analog site no. 10) is a good discussion topic here.

17. Upper Part of the Hawaiian Ocean View Estates (HOVE) Subdivision

Upslope from Hwy 11 are the Hawaiian Ocean View Estates (HOVE), a civil defense nightmare. Some 45 streets
extend diagonally upslope from the highway, almost to Mauna Loa’s SW rift zone (Fig. 24). The 1887 lava flow and both arms of the 1907 lava flow (Zimbelman et al., 2008) cut through the area, where the average slope is ~10°. If a SW rift zone eruption were to break out upslope from HOVE, people in the upper reaches of the subdivision would have only minutes to evacuate. Nevertheless, the views from this location are stunning, and the lots are cheap, so it is difficult for...
Rowland et al.

18. Nā Puʻu a Pele Littoral Cones

These cones are hosted in 750–1500-yr-old Mauna Loa lava flows (Wolfe and Morris, 1996). At least five cones and cone remnants are visible in high-spatial-resolution imagery (Fig. 25). Cross sections of the cones are well exposed in a low coastal cliff.

Objectives

Because of the many cones, cone morphologies, and outcrops in this area, it is well worth spending a full day. Topics to discuss include the nature of fuel-coolant (lava-water) interactions, the methods used to differentiate between secondary and primary pyroclastic features and deposits in images and outcrops, and issues relating to water availability on Mars, where fields of small circular cones have been mapped and interpreted as having a rootless origin (e.g., Fagents et al., 2002; Hamilton et al., 2010).

19. Guided Mapping Exercise on Mauna Loa’s NE Flank

Along a stretch of the access road to the Mauna Loa Solar Observatory, there is a series of completely unvegetated lava flows that provide a variety of surface types, structures, and ages. Importantly, some high-spatial-resolution (~8 m per pixel) thermal infrared images are available for this site, which can be processed into a principal component (PC) image (Fig. 26). This is a classic area for studying the character of basaltic lava flows in thermal infrared data (Kahle et al., 1988; Abrams et al., 1991). We have found that it is extremely instructive for workshop participants to walk along the road and “navigate” by means of the PC image as well as 1 m spatial-resolution IKONOS images.

Objectives

The objective here is to gain an understanding of the subtle yet detectable differences on basaltic surfaces that arise from different flow textures and exposures to weathering. The very different characteristics of the flows that are apparent in thermal infrared wavelengths are important concepts for participants who will be using THEMIS (Thermal Emission Imaging System) infrared data in Martian volcanic regions.

20. Saddle between Mauna Loa and Mauna Kea, Mauna Kea Scoria Cones

The summit of Puʻu Huluhulu (bristly hill) offers, on a clear day, excellent views of both Mauna Kea and Mauna Loa. The profiles of the two volcanoes can be compared, and their differences discussed (Fig. 27). Mauna Loa, being in its active tholeiite shield stage, erupts with fountains a few tens to hundreds of meters high, resulting in small scoria/
spatter cones and voluminous, long lava flows. From a distance, the cones along the rift zone profile are barely discernible. Mauna Kea, however, in its postshield alkalic stage, erupts cooler, gas-rich lava, resulting in large scoria cones and shorter, more stubby lava flows. The result is a volcano profile that is considerably more bumpy and steep than that of Mauna Loa (Figs. 27A–27C). Mauna Kea was glaciated at least three times, and this has complicated its topographic profile (Porter, 1987; Wolfe et al., 1997; Moore and Mark, 1992; Rowland and Garbeil, 2000). Pu’u Huluhulu itself is a Mauna Kea scoria cone that has been surrounded by Mauna Loa lavas, most recently by inflated tube-fed pāhoehoe of the
1935–1936 eruption. There are excellent examples of inflation features in this 1935–1936 flow, including lava rise pits that expose the underlying surface (Fig. 27D; Walker, 1991, 2009), and an old cattle wall, the top of which is now lower than the inflated lava surface (Fig. 27E). Walking around the west side of the cone into the partially quarried crater, there are views of complex scoria-lava contacts within the cone.

**Objectives**

This is a good location to observe and discuss inflation of lava flows and the complex interior structure of a scoria cone, and to discuss the time-variable nature of high-fountaining eruptions as they may relate to volcanic cones on Mars, and possibly the formation of the dark halo deposits on the Moon.

21. Mauna Kea Scoria Cones

From the summit of Pu’ukalepeamoa (comb of the chicken hill), a small, spindle-bomb–rich scoria and spatter cone near the Ellison Onizuka Center for International Astronomy, there are fine views downslope to lower-elevation Mauna Kea cones (Fig. 28). These cones exhibit a variety of morphologies depending on their erosional modification (e.g., Wood, 1980a, 1980b), relative amounts of spatter versus scoria, and degree of interaction with associated lava flows.
Figure 27. The Mauna Kea–Mauna Loa saddle. (A) Shaded relief image of the saddle, showing Mauna Kea (MK) and Mauna Loa (ML; illuminated from the NW and 45° above the horizon, created from a U.S. Geological Survey 10 m digital elevation model; http://hawaii.gov/dbedt/gis/hill.htm). (B) Mauna Kea viewed from the north flank of Mauna Loa. Examples of deeply gullied moraines (m) and large scoria cones (s) are indicated. (C) Mauna Loa viewed from near the summit of Mauna Kea. Spatter/scoria cones (s) and Moku‘aweoweo (‘aweoweo [a red fish] section) caldera (c) are indicated. In A–C, note the very different morphologies of these two shield volcanoes, with Mauna Kea possessing numerous very large scoria cones and steeper gullied slopes. In contrast, the scoria cones along Mauna Loa’s NE rift zone are barely visible. (D) Photo showing a participant in our 2010 workshop studying a lava-rise pit within the 1935–1936 Mauna Loa pāhoehoe flow, just NE of Pu‘u Hulululu. The older surface in this instance is rough, spalled pāhoehoe, outlined by a dotted line for clarity, around which the 1935–1936 lava has inflated by ~1 m. (E) Photo from the top of Pu‘u Hulululu of the top of an old cattle wall (dashed line) near the west base of the cone. The 1935–1936 lava approached the wall from the west (i.e., toward the viewer) and inflated by as much as 2 m in places before overtopping it.

Figure 28. Views downslope (A) and upslope (B) from Pu‘ukalepeamoa. In A, note the various stages of erosional rounding of the scoria cone crater rims and flanks. The rim of the crater of the nearest cone is ~400 m across. In B, the prominent unit with downslope-parallel dark and light streaks is a lava flow that postdates the most recent glacial deposits (Wolfe et al., 1997). The dark streaks are outcrops of blocky ‘a‘ā lava, and the light streaks are talus. The buildings in the lower right corner are the Hale Pōhaku astronomy facility.
Objectives

View a variety of pyroclastic constructs in varying states of erosion, and discuss volcano-ice interactions.

22. Trachyte Pumice Cone and Lava Flow on North Flank of Hualalai

The ~105,000-yr-old trachyte pumice cone (Pu´u Wa´awa´a—furrowed hill) and lava flow (Pu´u Anahulu—ten-day hill; Fig. 29) comprise the largest single erupted volume on any Hawaiian volcano (e.g., Moore et al., 1987). Pu´u Wa´awa´a is purely pyroclastic, with radial gullies cut into its flanks. The Pu´u Anahulu lava flow is ~9 km long, and, in places, it is 200 m thick. From the air, prominent convex-downslope pressure ridges are visible on its upper surface. These have an amplitude of a few tens of meters and wavelengths of 100–200 m. All of Pu´u Wa´awa´a and most of Pu´u Anahulu are contained in the Pu´u Wa´awa´a ahupua´a (land division), which recently reverted to state of Hawai´i management after many decades of cattle grazing. The ahupua´a is home to many rare and endangered plants and birds, and, unfortunately, a huge number of invasive species as well; efforts are being made to restore the ecosystem (Giffen, 2009). An old pumice quarry near the NE base of Pu´u Wa´awa´a offers the opportunity to see both pumice and obsidian.

Objectives

This is a good location to talk about evolved magmas on basaltic shield volcanoes, and the viscosity of their lava flows,
to initiate a discussion of pancake domes on Venus and the Grutithuisen dome and the Marius Hills on the Moon, and to explore the idea that evolved magmas may have erupted on these bodies too. We point out that although the planimetric shape of Pu‘u Wa‘awā‘a is similar to that of a lava dome (such as those that have been interpreted to be lava domes on Alpha Regio, Venus), it is actually Pu‘u Anahulu that is lava.

23. Waipi‘o Valley Overlook, Kohala

Waipi‘o (curved water) Valley is a prominent amphitheater-headed valley that has cut far into the flanks of Kohala volcano (Fig. 30). The valley cuts southwestward from a high cliffed coastline and, ~6 km inland, makes an almost 90° turn to the northwest. This bend is the result of erosion having preferentially exploited faults (Stearns and Macdonald, 1946). The head of the valley is not visible from the overlook (and is almost always shrouded in clouds anyway), but it is a classic example of a Hawaiian amphitheater-headed valley.

Objectives

This is a good location to discuss the cutting of large valleys into basalt volcanoes and the possibility that they may (e.g., Gulick, 2001; Gulick and Baker, 1990) or may not (Lamb et al., 2007) have developed via sapping.

RECOMMENDATIONS FOR PLANNING FIELD WORKSHOPS

After running ten successful workshops, we have developed some valuable insights into what does or does not work for these projects. The following suggestions are our best advice for other investigators who are considering similar workshops:

1. Start all logistical planning early. Even before the funding is in hand, make tentative reservations for lodging and arrangements for food. You should also submit any permits and/or permission letters that may be required to access otherwise closed areas (e.g., the active flow field) or private lands. Prepare your workshop announcement flyer so that it can be distributed the moment you know that you will be funded.

2. Once notified that your workshop will be funded, do your best to get the money from the funding source early, or at least on time. We once had to postpone a workshop for a year because by the time we received both notification of funding and the actual funds, there was insufficient time for adequate planning.

Figure 30. Large valleys on Kohala and Mars. (A) Shuttle Imaging Radar-C (SIR-C; data taken 122.20, 16 April 1994, 22:42:18 GMT) image overlain on a shaded relief image (illuminated from the NW and 45° above the horizon, created from a U.S. Geological Survey 10 m digital elevation model; http://hawaii.gov/dbedt/gis/hill.htm). Waipi‘o, Waimanu (bird water), Honokāne (Kāne’s bay), and Pōlolū (long spear) are indicated, as are a few of many normal faults, downdropped to the SW, which are controlling the orientations of Waipi‘o and Honokāne. The dotted box indicates the location of B. (B) Shaded relief image of Waipi‘o and Waimanu valleys. (C) Mars Global Surveyor image no. MGS-MOC-NA/WA-2-DS-DP-L0-V1.0 (red visible light), showing Dao and Niger Valles on the south flank of Hadriaca Patera, Mars. The dotted box indicates the location of D. (D) Portion of Thermal Emission Imaging System (THEMIS) visible image V25970005, showing the headwall of Dao Vallis, Mars.
3. Advertise early, and give applicants detailed instructions about required elements in their applications. Make sure they are aware of the physical demands involved in field work. This is particularly the case if the weather turns bad or the active lava flows are a long hike away from the transportation; warning potential participants multiple times that this is not a driving field trip is key! Most of our participants have been perfectly happy out in the field, but on a few occasions, there have been participants who were not physically or mentally prepared for the effort that is required.

4. Once applicants are selected, send information early about what to bring, what to read, what to expect, etc., and again warn about physical effort. Encourage them to break in new boots, and discourage them from expecting to sustain electronic contact with the rest of the world during the workshop; field trips work on their own schedule and do not wait for checking e-mail, running telecoms, or taking breaks for Mauna Kea observations.

5. Make reading materials available online. It is great if the participants read everything, but they will be busy people, so list papers in order of priority.

6. Include a mapping project. The supporting image data must be sent out early (at least 4 wk before the start of the workshop), with explanations of the data sets and the methods used to process them (for those participants who may be unfamiliar with certain remote-sensing technologies).

7. Do not plan too much activity. This includes not packing every day with dawn to dusk driving stops and hikes. The best learning during a workshop takes place during discussions at outcrops and overviews, and it is counterproductive to feel that these need to be hurried in order to stay on a tight schedule.

8. Have contingency sites and activities in case of bad weather, bad roads, active lava flows, lack of active lava flows, or other access problems.

9. Do not script your field presentations. The beauty of field workshops is, after brief introductions to a site, to let discussions wander where they may. This is much more productive than giving long preplanned speeches.

10. Provide some down time. Do not plan formal talks in the evening when everybody is exhausted from the day’s efforts.

11. Give some thought to your overall schedule so that participants do not face long hikes or long drives on successive days.

12. Learning is plenty—do not feel the need for a “product” such as a group paper.

13. Have the participants actively participate, and not merely listen or discuss. The mapping project is one example, as are outcrop interpretations, isopach derivations, etc.

14. Provide a detailed schedule that lists where each day’s activities will be, what they will entail (driving, hiking, etc.), which images in their handout, pages in the field guide, and references are pertinent, etc. The better the participants know what to expect, the better prepared they will be for the activities of the day, and the better they will deal with changes in the plan that may be necessary.

15. Pick your leader team with regard to scientific background and compatibility. These team leaders may also be expected to drive long distances, so they should have a “tour leader mentality” (i.e., willing to discuss geology, plants, culture, science, lousy radio stations, etc.) to make these journeys tolerable.

16. Keep all participants involved and pay attention to folks who appear to be consistently left out of discussions.

17. Utilize participant evaluations, particularly when planning your next workshop. These evaluations are valuable metrics for assessing the success of the workshop, and they provide supplemental information for future workshop proposals and for tenure or promotion applications.

18. Learn something new yourself and have fun! Include at least one site that you have visited only rarely or a topic that is new to you—somebody will know something about it. A happy organizer makes the whole workshop experience that much more enjoyable for the participants.
APPENDIX 1. LOGISTICS FOR EACH FIELD SITE

<table>
<thead>
<tr>
<th>Location</th>
<th>Getting there</th>
<th>Spatial and temporal scale</th>
<th>Comments and considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Kapoho</td>
<td>From Hilo, head SW (toward Volcano) on Hwy 11. Turn left at the Kea'au bypass. Go through or around Pāhoah (dagger), and turn left at Hwy 132. The intersection of State Hwy 132 and 137 is within the 1980 Kapoho flow field and prior to January 1980 was the center of town. A dirt road extends east from this intersection to the Kapoho lighthouse, which was surrounded on two sides by excellent examples of toothpaste lava.</td>
<td>Depending on the time available, minutes to hours can be spent at Kapoho. The best toothpaste lava examples are near the lighthouse, but some can be found near the highway intersection.</td>
<td>The dirt road to the lighthouse is passable in a regular car. Toothpaste lava is very sharp and abrasive, and proper footwear is essential. The eruptive vents are NW of the highway intersection, but are being quarried away for decorative scoria. The vents are on private land and should not be trespassed.</td>
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<td>2. Kaūmana cave</td>
<td>Kaūmana cave is along the Saddle Rd. (Hwy 200), which starts along the Hilo bayfront as Waiānuenue (rainbow in water) Ave. and then changes its name to Kaūmana Dr. Kaūmana Caves County park is ~19 km from the bayfront. Alternatively, one can take the new Saddle Rd. bypass, turn right (downhill) where it intersects Kaūmana Dr., and drive ~2.5 km to the park.</td>
<td>This is an area of high rainfall, and it is interesting (although not very planetary) to notice how difficult it is to actually see the 1981 lava except where plants have been cleared. The entrance is a sometimes slippery stairway into a large skylight, which is just off the highway. It takes 10–15 min to explore the skylight area.</td>
<td>We advise that you not go very far uphill nor downhill in this lava tube because the ceiling is unstable. There are ample lava tube features that can be seen in the area near the entrance skylight anyway, so there is no reason to go beyond the reach of natural light.</td>
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<tr>
<td>3. Active lava flows</td>
<td>Access to the active flows depends on eruption conditions. The flows block Chain of Craters Rd. and Hwy 137, and our workshops have accessed them via both of these, depending on which happens to result in a shorter hike. For the latest information on access from Chain of Craters Rd., inquire at Hawai'i Volcanoes National Park Headquarters (808-985-6000) or their eruption update Web site: <a href="http://www.nps.gov/havo/planyourvisit/lava2.htm">http://www.nps.gov/havo/planyourvisit/lava2.htm</a>, or the Hawaiian Volcano Observatory (HVO) eruption update Web site: <a href="http://volcano.wr.usgs.gov/kilaueastatus.php">http://volcano.wr.usgs.gov/kilaueastatus.php</a>. Hawai'i County Civil Defense maintains a visitor viewing area on the east side of the flow field via Kalapana (&quot;announce noted place&quot;) and Hwy 137, and it is open from the late afternoon to early evening. Access on to the active flows themselves requires an approved lava guide. For information, contact Darcy Bevens (808) 974-7631.</td>
<td>Depending on the exact location of the activity, viewing the flows can require as little as an hour to all day. The tourist viewing areas generally require 10–20 min of walking, usually on an uneven pāhohoe surface.</td>
<td>Hiking to active lava may require a hike of 1–2 h (or more) each way. For any hiking on young lava, sturdy boots, long pants, and gloves are absolutely necessary, as are plenty of water and sun protection. You will undoubtedly encounter others who are not well prepared, but they are not geologists, and they probably are not planning to come back again. Be extremely careful around active skylights. Never approach an active ocean entry site or hike onto a lava bench at the coastline.</td>
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<tr>
<td>4. Mauna Ulu and Mulawai a Pele</td>
<td>Mauna Ulu's summit is accessed by cutting south off the Mauna Ulu–Nāpau (the endings) Crater trail near Pu'u Huluhulu (bristy hill), first climbing the margins of, and crossing, a perched lava pond (Wilson and Parfitt, 1993), and then walking up the margin of a prominent channel. The east edge of the crater can be traversed (staying at least 10 m from the edge) to the south flank, where a prominent set of overflowed channels and skylights can be followed downslope.</td>
<td>The hike to Pu'u Huluhulu, up and around Mauna Ulu, and back to the Mauna Ulu parking lot takes 2–3 h. Continuing down on the Mulawai a Pele channel to a pullout along Chain of Craters Rd. adds another 2–3 h, depending on how many times you stop to look at channel features. Car shuttling makes it practical to start at the Mauna Ulu parking lot and finish at the Mulawai a Pele pullout.</td>
<td>Extreme care must be taken at the summit of Mauna Ulu! There is an 85 m drop into the crater, and the edges are unstable and in many places undercut. Care must be taken here as well because the edges of many of these skylights are overhung. Navigating from the base of the Mauna Ulu shield to the upper end of the Mulawai a Pele channel is difficult, but once on the channel levees, it can be followed with ease.</td>
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<td>5. Lower Mauna Ulu, Hilina Pali</td>
<td>The Ke'ala Komo and Holona Kahakai overlooks are ~16 and ~17 km along Chain of Craters Rd., from where it starts at its intersection with Crater Rim Dr. Alanui Kahiko is at ~23 km from this start.</td>
<td>If you do not hike from Holona Kahakai to Alanui Kahiko, each of these overlooks will take 20–30 min for discussions of unstable volcano flanks. If you do the hike, it will require 1–2 h, depending on the abilities of the hikers.</td>
<td>Anyone hiking from Holona Kahakai to Alanui Kahiko should wear long pants, boots, and gloves. As long as you stay on pāhohoe, the footing is reasonably good, but there is still a chance of stumbling, so foot, leg, and hand protection is important. Hikers should be given the chance of turning back after a short distance in case they become uncomfortable with the slope.</td>
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<tr>
<td>6. Mauna Ulu mapping exercise</td>
<td>The Mulawai a Pele turnout is ~12 km along Chain of Craters Rd. from its intersection with Crater Rim Dr., and this is central to the Mauna Ulu mapping area.</td>
<td>Depending on how much time the participants have been given to make their maps, at least half a day should be dedicated to this exercise.</td>
<td>Participants navigating by themselves should be equipped with global positioning system (GPS) receivers and two-way radios, and should know how to use them. There is 'a'ā in the mapping area, so long pants, boots, and gloves are necessary.</td>
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### APPENDIX 1. LOGISTICS FOR EACH FIELD SITE (Continued)

<table>
<thead>
<tr>
<th>Location</th>
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</tr>
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<tr>
<td>7. Kilauea Iki, Pu'u Pua'i</td>
<td>Access to Pu'u Pua'i and the Kilauea Iki overlook is via a short road that cuts off from Crater Rim Dr., ~4 km clockwise from the national park entrance. A 10 min hike from the Pu'u Pua'i parking lot along the Devastation Trail takes you through the proximal part of the 1959 scoria deposit. You can shuttle your cars to the Devastation Trail parking lot to meet the hikers. From the Devastation Trail parking lot, a 5 min walk NW toward the caldera will bring you to the collapse pits, just before a low rise. The hike across Kilauea Iki crater starts at the Nā Huku parking lot, switchbacks into Kilauea Iki, then across the crater floor, and up out the other side.</td>
<td>The Kilauea Iki crater hike should be given 3–4 h in order to see all the features along the way. If only the overlooks are visited, then the combination of them plus the Devastation Trail hike can take as little as half an hour.</td>
<td>Make sure participants carry sufficient water. Although the hike may start out in a drizzle, chances are it will become sunny later, and the hike out of Kilauea Iki is strenuous.</td>
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<td>8. Nā Huku</td>
<td>Nā Huku is located ~3 km clockwise along Crater Rim Dr. from the park entrance. The parking lot is usually quite full between the hours of 10 a.m. and 2 p.m., so you should try to avoid those times.</td>
<td>The lighted portion of the lava tube takes as little as 15 min to hike through. Continuing on requires an additional 30 min.</td>
<td>The first ~100 m of Nā Huku is lighted and heavily traveled, so many small-scale tube features have been worn away. However, an additional, more interesting ~200 m is available for exploration with a flashlight, but sturdy shoes and gloves are recommended here.</td>
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<td>9. Kilauea caldera and Hawaiian Volcano Observatory</td>
<td>The Hawaiian Volcano Observatory (HVO) and the Jaggar Museum are located ~5 km counterclockwise around Crater Rim Dr. from the park entrance. A thorough view and discussion of the caldera from the Jaggar Museum requires 10–20 min, but you should give participants plenty of time to admire the view. The museum itself requires an additional 20–30 min.</td>
<td>The museum has a bookstore with a good selection of popular and scientific titles, plus a variety of posters, patches, T-shirts, and other national park paraphernalia.</td>
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<td>10. Devil's Throat pit crater</td>
<td>Devil's Throat is ~80 m NE of the intersection of Chain of Craters Rd. and Hilina Pali Rd. From the intersection of the two roads, it is a 5 min walk to Devil's Throat, but be extremely careful when approaching the edge, and do not linger. It is instructive to examine the fractures that lead from the south wall of Devil's Throat SW to Chain of Craters Rd. and beyond. The National Park Service discourages visits to the crater because it is very hazardous, and extreme care should be taken near the edges. There are numerous crater-parallel fractures, indicating that large blocks are poorly supported and liable to fall in. Additionally, invasive ground-nesting wasps live in the area. They are aggressive and their stings are quite painful for a long time.</td>
<td>The National Park Service discourages visits to the crater because it is very hazardous, and extreme care should be taken near the edges. There are numerous crater-parallel fractures, indicating that large blocks are poorly supported and liable to fall in. Additionally, invasive ground-nesting wasps live in the area. They are aggressive and their stings are quite painful for a long time.</td>
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<td>11. Kilauea SW rift zone fractures</td>
<td>The SW rift zone fractures are ~3 km beyond HVO along Crater Rim Dr. They extend perpendicular to the road in both directions. Examination of the fractures, from their floor takes 10–40 min.</td>
<td>The floors of the fractures are somewhat uneven, so good footwear is recommended. Note that this part of the park has been closed since March 2008 due to high levels of SO2.</td>
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<td>12. Keanae-kao'i ash, sandwash, upper SW rift zone</td>
<td>The easiest access to this region is by walking SW from Crater Rim Dr. across the September 1982 lava flow, which ponded in the southernmost part of the caldera. The easiest access to the Keanae fault zone and the middle part of the 1974 flow is via the Mauna Iki trail, off Hilina Pali Rd. Examination of the caldera-proximal parts of the Keanae-kao'i deposit requires at least an hour. The hike to the 1974 vents and back adds another 2 h. Some of the Keanae-kao'i ash areas are somewhat featureless, and can become disorienting. There is shelly pahoehoe near the 1974 vents, so boots, long pants, and gloves should be worn. Carry sufficient water if you plan to hike that far or farther. Note that this part of the park has been closed since March 2008 due to high levels of SO2.</td>
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<td>13. Mauna Iki</td>
<td>Mauna Iki is accessible via the Ka'ū Desert trailhead, which is along Hwy 11, ~17 km SW of the national park entrance (entry to the park is not necessary). A full day is required to see all of the surficial and structural features of Mauna Iki, especially if participants have produced their own maps that they want to ground-truth. Participants navigating by themselves should be equipped with GPS receivers and two-way radios, and should know how to use them. There is 'a'a and shelly pahoehoe in the mapping area, so long pants, boots, and gloves are necessary. This trail and the Mauna Iki area were closed by the National Park Service from 2008 to 2009 due to high levels of SO2. Inquire at park headquarters to be sure the trail is open.</td>
<td>Participants navigating by themselves should be equipped with GPS receivers and two-way radios, and should know how to use them. There is 'a'a and shelly pahoehoe in the mapping area, so long pants, boots, and gloves are necessary. This trail and the Mauna Iki area were closed by the National Park Service from 2008 to 2009 due to high levels of SO2. Inquire at park headquarters to be sure the trail is open.</td>
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<td>14. Ni'ūle Hills</td>
<td>Access to the Ni'ūle Hills themselves is difficult, and involves permission from private landowners. It is much more useful to view them from the intersection of Hwy 11 and the road to Punalu'u, ~6 km southwest of Pāhala (cultivation by burning mulch). The discussion of volcano instability, recovery, and resurfacing can take 10–30 min, depending on the interests and backgrounds of the participants.</td>
<td>Be careful of fast highway traffic.</td>
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APPENDIX 1. LOGISTICS FOR EACH FIELD SITE (Continued)

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<tr>
<td>15. Lava tube at Henu‘apo</td>
<td>The tube and channel system is best exposed downslope of the Hawaiian Ranchos subdivision, ~15 km west of Nā‘ālehu (the volcanic ashes). The area is privately owned, and access is complicated by conflicts between adjoining landowners. The tube and channel system itself is on land managed by Yamanaka Enterprises (808) 935-9766. Access via the Hawaiian Ranchos subdivision can be arranged via the Hawaiian Ranchos Road Maintenance Corp. (808) 989-4140.</td>
<td>The discussion of thermal erosion and lo‘ihi can take 20–40 min, depending on the interests and backgrounds of the participants.</td>
<td>Do not leave valuables in your vehicle.</td>
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<tr>
<td>16. Pōhūe Bay flow</td>
<td>The tube and channel system is best exposed downslope of the Hawaiian Ranchos subdivision, ~15 km west of Nā‘ālehu (the volcanic ashes). The area is privately owned, and access is complicated by conflicts between adjoining landowners. The tube and channel system itself is on land managed by Yamanaka Enterprises (808) 935-9766. Access via the Hawaiian Ranchos subdivision can be arranged via the Hawaiian Ranchos Road Maintenance Corp. (808) 989-4140.</td>
<td>From the SE corner of the Hawaiian Ranchos subdivision, the lava tube and channel system is 10 min walk over rough lava and gravel roads. Following the system another km or so is instructive, and will require 2–3 h round-trip.</td>
<td>Although there are roads and trails in this area, it is advisable to be prepared to walk over ‘a‘a lava flows, so boots, gloves, and long pants are necessities.</td>
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<td>17. Hawaiian Ocean View Estates</td>
<td>Hawaiian Ocean View Estates is upslope of Hwy 11 from ~15 to ~20 km west of Nā‘ālehu. The roads are in a diagonal pattern, so getting to the top of the subdivision requires zigzagging up the slope. The quarried scoria cone is in the NE (upper-right as you head uphill) portion of the subdivision bounded by Lurlene Ln., Mahimahi Dr., Liliana Ln., and Kailua Blvd.</td>
<td>Driving from the highway to the scoria cone takes 15–20 min, and another 30 min can be used discussing the pyroclastic outcrops and the proximity of houses to the SW rift zone.</td>
<td>The quarry is private property, so you must not leave the shoulder of the road. Additionally, at times there are very steep drop-offs near the road edge.</td>
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<td>18. Nā Pu‘u a Pele</td>
<td>Nā Pu‘u a Pele is accessible via a poor-quality four-wheel-drive road (the “Road to the Sea”), which intersects Hwy 11 ~20 km west of Nā‘ālehu. The cones are within Manukā (blundering) Natural Area Reserve. A special use permit must be obtained for groups of 20 or more: <a href="http://hawaii.gov/dlnr/dofaw/nars/permit-guidelines">http://hawaii.gov/dlnr/dofaw/nars/permit-guidelines</a>.</td>
<td>The drive to the cones from the highway is slow because of the road’s poor quality, and it will require at least an hour each way. An entire day can easily be spent wandering among the cones.</td>
<td>The road really is bad, so unless you have a high-clearance four-wheel-drive vehicle, do not attempt to drive beyond the first ~4 km., and even this upper portion is barely passable by a regular vehicle.</td>
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<td>19. Mauna Loa NE rift zone mapping exercise</td>
<td>The road to the Solar Observatory heads south off Saddle Rd. (Hwy 200) ~46 km west of Hilo. The turnout is ~200 m east of Pu‘u Huluhulu, a prominent scoria cone.</td>
<td>The walk from a prominent bend in the road ~15 km from the Saddle Rd. intersection downhill to a cinder quarry access road takes a couple hours if you stop and discuss most of the flows and flow margins that are encountered along the way.</td>
<td>The Solar Observatory road is narrow and barely paved, and most rental car contracts prohibit driving on unimproved roads. This area is often clouded-in by 11 a.m., and the weather can change from warm and sunny to very cold and rainy in only a few minutes. Be prepared for both intense sun and cold rain.</td>
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<td>20. Mauna Loa, Mauna Kea saddle</td>
<td>Pu‘u Huluhulu is just south of Saddle Rd. (Hwy 200), ~46 km west of Hilo, ~200 m west of the road to the Mauna Loa Solar Observatory, and immediately across from the road to the Mauna Kea summit. From the parking lot, the inflation features are immediately to the west. A short trail leads through a gate and around the west flank of the cone to the old quarry, and then continues up counterclockwise to the cone’s summit.</td>
<td>A walk around the cone to view inflation features and the scoria outcrops in the old quarry will take 30–40 min.</td>
<td>Please be sure to close the gate near the parking area so that feral goats don’t get into the Pu‘u Huluhulu reserve.</td>
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<td>21. Mauna Kea scoria cones</td>
<td>The road up Mauna Kea is an obvious right (north) turn off the Saddle Rd. (Hwy 200), immediately across from Pu‘u Huluhulu. The Onizuka Center is ~10 km up from this intersection. The dirt road to the upslope base of Pu‘ukalepeamo‘a is ~200 m downslope from the Onizuka Center parking lot, on the west side of the road.</td>
<td>The drive from Hwy 200 to the Onizuka Center takes ~20 min, and it is worth spending some time in the center itself. The hike up the flank of Pu‘ukalepeamo‘a takes ~10 min.</td>
<td>The road up Mauna Kea is paved as far as the Onizuka Center, but it is quite steep. Cars will be slow, even in low gear. Low gear is especially important on the way down because of the steepness—do not rely only on your brakes! The road upslope from the Onizuka Center is unimproved, and a high-clearance vehicle is required. There are plenty of already broken spindle bombs along the trail to the summit of Pu‘ukalepeamo‘a, and many of them are cored with mafic and ultramafic xenoliths. There is no need to break open any more, so please don’t.</td>
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<td>22. Trachyte on Hualālai</td>
<td>Both the pumice cone and lava flow can be viewed easily from a small pullout along Māmalahoa (splintered paddle or splintered friendship) Hwy (Hwy 190), ~100 m west of a prominent bend in the road. There is a locked gate (that leads to the pumice quarry) and sufficient space for 3–4 vehicles to pull over safely.</td>
<td>Discussion of Hualalai at the highway pullout can take 10–30 min, depending on the participants. The drive to the pumice cone and back plus time to look at the exposures requires about an hour.</td>
<td>Access to the pumice quarry must be obtained in advance from the State of Hawai‘i Department of Land and Natural Resources: (808) 937-2501.</td>
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<td>23. Waipi‘o Valley lookout</td>
<td>The Waipi‘o Valley overlook is at the end of Hwy 240, which branches off of Hwy 19 at the town of Honoka‘a (rolling [stones] bay).</td>
<td>From Honoka‘a, the drive to Waipi‘o and back takes about an hour and a half.</td>
<td>Do not leave any valuables in your vehicle at the Waipi‘o Valley overlook.</td>
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APPENDIX 2. PARTICIPANTS IN THE WORKSHOPS

The following lists the 142 participants in our 10 workshops. Many of the names are familiar as prominent, productive, young (or not-so-young) planetary scientists. It is always a pleasure to see one or more of these names on author lists, instrument teams, and NASA press releases, and feel that maybe some tiny bit of their field experience in Hawai‘i helped get them to where they are today. We have included a few comments about their field-trip experiences.


“I had been studying planetary volcanology for 2 or 3 years, and had yet to see a real basalt flow! The workshop allowed me to finally put the planetary images in a mental context.” —Tracy Gregg, associate professor, State University of New York at Buffalo

“As a participant of the first of these workshops, I can attest to their importance to my own work in planetary science. I have also seen their value for my colleagues and students.” —David Crown, senior scientist, Planetary Science Institute

**1995.** Ben Bussey, Jeffrey Gillis, Diane Hanley, Matt Peitersen, Louise Prockter, Susan Sakimoto, Selima Siddiqui, Cathy Weitz, Kevin Williams.

“Also I’ve met lifelong colleagues at your workshop. Louise Prockter—who I’m now on the MESSENGER mission with, Kevin Williams—who I wrote a successful Lunar Reconnaissance Orbiter proposal with, Cathy Weitz, who was also studying the Moon at that time but I didn’t know and I still chat with her at conferences, and Susan Sakimoto who I talk to at conferences and might do work with eventually. I might get one of Susan’s undergraduates to come here to grad school.” —Jeffrey Gillis-Davis, assistant researcher, University of Hawai‘i

**1997.** Steve Anderson, Mary Chapman, Vicki Hansen, Catherine Johnson, Pat McGovern, Jeff Plaut, Sue Smrekar, Ellen Stofan, Ken Tanaka, Maria Zuber.


“...this workshop was the first field work I ever did. How sad is that?...For someone who wrote an entire thesis chapter on lunar lava ponds, finally seeing an actual potential Earth analog was intensely revealing....” —Aileen Yingst, professor, University of Wisconsin–Green Bay

**1999.** Brian Banks, Jeffrey Byrnes, David Finnegan, John Grant, Elissa Koenig, Laurent Montesi, Matthew Staid, Elizabeth Turtle, Duncan Young, Cathy Weitz.

“I often think of the things I learned in the workshop, which I found to be among the best field experiences I’ve ever had... Additionally, I made several new contacts at the workshop and often run into these same people at conferences and meetings.” —Nathaniel Putzig, Southwest Research Institute


“For those who’ve stayed on course for Mars and other planets, I guess the main thing is to remember a little humility... remote sensing can’t teach you everything.” —Bethany Bradley, Princeton University

**2003.** Jacob Bleacher, Joseph Boyce, Joshua Cahill, Tabatha Cavendish, Andrew Dombard, Melissa Farley, William Garry, Cheryl Goudy, Brian Hynek, Amy Knudson, Will Koeppe, Nicholas Lang, Aisha Morris, Cara Mulcahy, Jim Rice, Deanne Rogers, Valerie Slater, Livio Tornabene.

“I would say that the workshop has contributed most to my skills in the field (identifying geologic features on a map, etc.). It has also contributed a lot to my ability to teach intro labs—students are very interested in seeing pictures of their TA braving things like lava flows/tubes/etc., and they seem to be more interested in the samples of basalt that I collected in the field.” —Cara Thompson, University of Tennessee, Knoxville.

“I work mostly on Mars, but even when working with terrestrial data sets, I have a much clearer idea of what might be happening on the surface. Hands-on (and feet-on) experience hiking over the different lava flow textures (even the much despised rainy death march on Mauna Loa from our year) really made a difference in my ability to interpret images.” —Amy Trueba Knudson, Bellevue College

“This workshop was one of the best experiences I had in my training as a planetary scientist. There is not a lot of planetary field work, especially so for a planetary geodynamicist like myself (who mainly sits in front of a computer), so getting out to see these things has been incredibly useful.” —Andrew Dombard, Carnegie Institution

**2005.** Alice Baldrige, Sarah Black, Devon Burr, Shelby Cave, Matt Chojnacki, Frank Chuang, Colin Dundas, Tasha Dunn, Jeffrey Hanna, Jennifer Lougen, Joe Michalski, Melissa Nelson, Nathaniel Putzig, Mike Rampsey, Mindi Searls, Sharon Wilson, Danielle Wyrick. Guest: Steve Baloga.

“The necessity of correlating remote sensing data to what is actually occurring on the ground is often overlooked in this field. This workshop goes a long way toward reminding us planetary geologists to look under our feet before we start waving our arms about in space.” —Danielle Wyrick, Southwest Research Institute

“I think the biggest thing I gained was just understanding how basaltic volcanism works and seeing the geologic structures/materials in the field. I found the last day (I think), where we went out in the field and mapped out units using satellite images, is a good exercise to how we would map using images of Mars.” —Frank Chuang, Planetary Science Institute
ACKNOWLEDGMENTS

Our first workshop (and thus all of them) benefited from the foresight of Planetary Geology and Geophysics (PG&G) program managers Steve Baloga and, subsequently, Trish Rogers. We thank them both for this vision. Most regrettably, Trish is no longer with us, so we would like to dedicate our efforts to her memory. Our thanks also go to Harold Garbeil, who processed almost every planetary and terrestrial image we've used, and to Ronnie Torres and Mary Mackay, who helped run workshops two through seven. Gordon, Joann, and Ki’i Morse from “My Island” Bed and Breakfast in Volcano Village played an important role as hosts for the first eight workshops; their hospitality and great cooking helped foster a strong feeling of camaraderie among all the workshop participants. Pineapple Park hostel and especially Marshall, Virgie, and Maggie Freitas filled the Morses’ big shoes very well for the ninth and tenth workshops. Guest volcanologists Bruce Campbell, Vince Realmuto, Jim Garvin, Steve Baloga, and Bruce Houghton, and guest Martian Jim Bell III provided valuable insight and knowledge. Finally, we would like to thank all the participants (see Appendix 2), who have made every workshop a memorable, enjoyable experience! Mahalo to D. Crown and J. Bleacher for helpful reviews of this paper.

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Rowland et al.


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