A 200-year look at Hawaiian volcanism—the last and the next 100 years

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Why settle for a mere 100 year gaze into the future? In 200,000 years (?) the Loihi Observatory will be monitoring activity to protect the population of the next Hawaiian Island, rejuvenated alkalic eruptions will episodically threaten Molokai, Lanai, and Maui. Kilauea will have devastated the eastern half of Hawaii for the 15th time during 5,000 years of semi-continuous explosive activity, making much of Hawaii uninhabitable. Volcanologists will be employed, well paid, and treated as local heros.
Hawaiian Volcanoes: 
*From Source to Surface*

It is tough to make predictions—especially when they’re about the future (stolen from Yogi Berra).

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There are many things we want to know about how Hawaii and other volcanoes work. Many will never be part of day-to-day monitoring efforts, but represent the fundamental understanding that will improve our understanding of those day-to-day data. It is important that monitoring is based on good science, although that will not eliminate incorrect forecasts or predictions.
Access and cost will limit our ability to address many of the questions about the long term evolution of the Hawaiian Emperor chain.

Papahānaumokuākea Marine National Monument

Remoteness of Emperor Seamounts

Glacial erratics on northern half of Emperor Seamounts
Can we develop ways to date young (and old) tholeiites, which are currently very difficult to date? Can we develop and deploy IODP coring methods to get fully oriented cores to obtain both paleolatitudes and paleolongitudes?
Does the Hawaiian-Emperor Bend represent a change in plate motion, as well as a change in motion of the source for Hawaiian magmas?

What more are we likely to know to resolve if the plate also changes direction during that time period?
How do we reconcile the current plate motion vector determined by GPS at Hawaii with the age relations and strike of the chain?
The volume of magma produced over time varies along the chain and appears to have been highest about 15 Ma and at present. What controls these long-term variations over time?
How deep is the source for Hawaiian magma? Does a plume rise from the core-mantle boundary or a shallower level in the mantle, or is the source in the uppermost mantle?
If plumes start at C-M boundary, does the core add any unique components to the plume? Is this the source of primordial He? Any short-lived isotopes from the time of Earth accretion? Siderophile elements, like Ni? Many of these have been looked for, but in general the results have been equivocal. Is it possible that with ever improving lab equipment and techniques we can revisit these with more definitive results? A clear compelling addition to the plume that HAD to come from the core would be the smoking gun that plumes originate deep.
Magma source for Hawaii: what components are present and what do they represent?

Have they changed over the >80 Ma history of the chain?
Mantle lithologies in the source remain controversial among geochemists and petrologists who see clear evidence either for the necessity to have eclogite in the source or see no evidence for its presence based on other criteria. How can some systems like Os require eclogite, whereas argue strongly against it playing a major role? Is this simply a matter of the scale of heterogeneities?
Does lava chemistry correspond to those large flux changes along the chain? Are there additional or occult enriched components when flux is smaller or larger?
Is the Hawaiian Swell a thermal phenomenon or is there a dynamic component to its formation?
Some of these questions would be resolved if we could develop thermal models for Kilauea and the islands as a whole and could constrain mechanics and rheology of key materials.
Hawaiian Eruptive Stages
We have a simple model of eruptive stages of Hawaiian volcanoes--preshield-shield-postshield-erosion-rejuvenated stages--yet all the stages and their inferred timing occur at no single volcano. What controls how the chemistry of the lavas and their timing vary? If the sequence is related to passage over a melting zone-how can the volcanoes have such different histories?
There seems to be an inverse relation between amount of postshield and amount of rejuvenated. Since they appear to come from different sources, why should this be?
Recent mapping, geochemistry, and dating, especially on Kauai, suggests that postshield and rejuvenated stages may either be continuous activity or even overlap in time. How does that change our views about the causes of rejuvenated stage activity and the magma delivery system?
Volcanic hazards associated with eruptions during the postshield and rejuvenated stages may have a different suite of precursors from the more familiar shield stage eruptions of Kilauea and Mauna Loa—what can we learn from other places like the Canary Islands, Azores, etc. about the precursors and hazards posed by infrequent alkalic eruptions?

This is important in Hawaii as the populations and infrastructure at risk are much greater on the older, more densely populated islands.
Rejuvenated activity is generally thought to be small volumes of small percent partial melts, yet chemically related strongly alkalic lavas on the seafloor north of Oahu are quite voluminous ($10^3$km$^3$). Are all these chemically related lavas formed the same way and is their formation related to lithospheric flexure that either triggers melting by decreasing pressure, or does the flexure simply provide pathways to the surface for existing melts?
Individual eruptions that form large flat-topped cones offshore Niihau or sheet flows in the North Arch suggest sustained eruptions lasting tens to hundreds of years. How are such eruptions sustained so far from the plume?
Rapid subsidence is well defined for Hawaii Island from drowned reefs and refraction cross-sections. Older islands did not subside as much based on the shallower depths of the main break-in-slope surrounding them. Does this simply mean that the large mass of Hawaii causes more rapid subsidence and that older islands subsided more slowly, or that they subsided for a shorter time period? Or both?
This period of rapid subsidence reflects isostatic adjustments to volcanic load and therefore is related to mantle rheology—which is inferred to make it very uniform through time. These adjustments are not simply mantle flow as large deep lithospheric earthquakes occur. Could downwarping occur in step increments instead of at a constant rate as indicated by progressively older ages of drowned reefs?
Numerous mega-landslides have been mapped surrounding the islands and along the entire Hawaiian chain. They can be divided into two main types—large rotational slumps and debris avalanches. Are the two types related to one another with slumps precursors to avalanches, or are they fundamentally different structures with different causes?
The south flank of Kilauea is a large rotational slump structure with considerable overthrusting and thickening—does this offshore bench stabilize or destabilize the flank?

We need offshore geodesy, in addition to the onshore effort, to monitor the entire system.
Are the slumps and avalanches all tied to active volcanic processes and therefore limited to the active stages of volcanic growth? How is flank movement tied to eruptive processes? How do we determine the ages of these events? How do adjacent volcanoes like Kilauea and Mauna Loa interact?
Does the volcaniclastic debris on the submarine slopes of the volcanoes become stronger or weaker as it ages and alters?
$64K question is what triggers the magaslides?
Kilauea has a long history of energetic explosive eruptions with the last one in 1924. Prior explosive eruptions include large scale phreatomagmatic explosive eruptions and some almost diatreme-like explosions. We do not yet know the full range of activity of such eruptions, but even older ones dwarfed the 1924, Keanakako’i and Uwekahuna eruptions. These deposits need to be better characterized to understand what happened, when it happened, and why it happened.
Loihi Seamount is also home to numerous explosive eruptions at a depth of about 1 km below sea level. These eruptions apparently include phreatic and phreatomagmatic eruptions. The deposits from these eruptions remain relatively unstudied because of the difficulty in sampling the unconsolidated ash deposits under water. Can we develop methods to sample such deposits so they can be better evaluated?
Kilauea explosive eruptions may postdate caldera-forming collapses. Can we develop the history of caldera formation and the history of explosive eruptions well enough to test the idea that water ingress into deep calderas might be required to trigger large phreatomagmatic eruptions during periods of low magma supply to Kilauea (and perhaps corresponding periods of high magma discharge on Mauna Loa?)
Submarine caldera-forming collapse events may also be tied to explosive eruptions at Loihi Seamount. A Halema’uma’u-sized pit crater formed in 1996-and may have erupted energetically at the same time. It was not extensively studied at the time, nor since. Submarine caldera-forming collapses or large submarine explosive eruptions pose unevaluated hazards in Hawaii.
The ongoing eruption at Kilauea has produced nearly 3 km³ of lava, but a significant portion has poured into the sea. The previous voluminous eruption paved over vast areas of Kilauea’s surface with ~5.2 km³ of the Ai la’au flows ~500 years ago. It appears to have been the last in a series of shield-building summit eruptions that continued for ~200-300 years and produced the northwest directed Volcano, the southwest directed Observatory, and south directed Ahua, Lua Manu, and Kalu’e flows, in addition to the northeast-directed Ai la’au flows. Mauna Loa has had similar long periods of summit overflows. What precedes these voluminous summit eruptions? Do Kilauea and Mauna Loa really have such eruptions out of sync?
How can we determine travel times for magma from summit to rift eruption sites? A few days, as advocated at this meeting, does not make sense to me: a dike 20 km long, 1 km tall and just 1 m thick contains 1/5 of the magma (0.02x10^9 m^3) erupted per year at Pu’u O’o and travel time is 73 days. For melt to travel from summit reservoir to Pu’u O’o in one day suggests the dike is only 70 m tall. Two days and it can be 140 m tall.
How can we determine size and shape of magma chamber(s) and get reliable estimates of residence times?

Current estimates of residence times do not make sense (to me) when one considers that it took 35 years for Kilauea Iki lava lake to solidify and a minimum of 31 years to fractionate a small volume of 1955 lava in the cool lower east rift. If residence times are longer, then chambers are larger.
Future Monitoring

It is striking that the primary monitoring measurements have not changed much for a long time, while the technologies employed to collect those same types of data have changed dramatically. Does the future of monitoring entail continuing migration to satellite-mounted sensors and remote instrumentation (such as current tilt meters, seismometers, gas samplers, and webcams)?
It is clear that in a world with ever greater populations living in harms way on and near dangerous volcanoes that monitoring of these many volcanoes will increase in importance. Perhaps more important is that we develop the communication skills to work with civil authorities and local populations before—and during—crises to reduce risks. There is room for lots of improvement here.
Observatories

My guess is that volcano observatories will be combined for efficiency with a central science group and local staff at active (and inactive) sites to maintain the instrumentation. There will be more reliance on satellite measurements. Although it makes sense to have regional international observatories, I suspect they will remain national facilities. The need for volcano monitoring will continue to grow as global populations grow.
Some personal thoughts about the future

To an alarming degree (to me), science in general has become more dogmatic and regimented, much like political parties who do not listen to or hear each other. We too live in our own “echo chambers” with experts with different specialties rarely working across disciplinary lines, much less with any group with an opposing worldview. To solve these multidisciplinary problems will require multidisciplinary cooperation.
Discourse is also impeded by the competitive scientific system of grantsmanship and publications we have created. Every proposal to be awarded and every paper published must promise to break new ground and advance “transformational” new ideas. Advancement of our science, however, comes largely from rigorous testing of existing ideas and models, with adjustments common but revolutions rare. If every study proposes a new model, we cannot narrow our sights to the real problems that remain.
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