

= Lōʻihi Seamount =

Lōʻihi Seamount (also known as Loihi) is an active submarine volcano located about 35 km (22 mi) off the southeast coast of the island of Hawaiʻi . The top of the seamount is about 975 m (3 @, @ 000 ft) below sea level . This seamount lies on the flank of Mauna Loa , the largest shield volcano on Earth . Lōʻihi , meaning " long " in Hawaiian , is the newest volcano in the Hawaiian @-@ Emperor seamount chain , a string of volcanoes that stretches over 5 @, @ 800 km (3 @, @ 600 mi) northwest of Lōʻihi . Unlike most active volcanoes in the Pacific Ocean that make up the active plate margins on the Pacific Ring of Fire , Lōʻihi and the other volcanoes of the Hawaiian @-@ Emperor seamount chain are hotspot volcanoes and formed well away from the nearest plate boundary . Volcanoes in the Hawaiian Islands arise from the Hawaiʻi hotspot , and as the youngest volcano in the chain , Lōʻihi is the only Hawaiian volcano in the deep submarine preshield stage of development .

Lōʻihi began forming around 400 @, @ 000 years ago and is expected to begin emerging above sea level about 10 @, @ 000 ? 100 @, @ 000 years from now . At its summit , Lōʻihi Seamount stands more than 3 @, @ 000 m (10 @, @ 000 ft) above the seafloor , making it taller than Mount St. Helens was before its catastrophic 1980 eruption . A diverse microbial community resides around Lōʻihi 's many hydrothermal vents .

In the summer of 1996 , a swarm of 4 @, @ 070 earthquakes was recorded at Lōʻihi . This series included more earthquakes than any other swarm in Hawaiian recorded history . The swarm altered 10 to 13 square kilometres (4 to 5 sq mi) of the seamount 's summit ; one section , Pele 's Vents , collapsed entirely upon itself and formed the renamed Pele 's Pit . The volcano has remained relatively active since the 1996 swarm and is monitored by the National Oceanic and Atmospheric Administration (NOAA) and the United States Geological Survey (USGS) . The Hawaii Undersea Geological Observatory (HUGO) provided real @-@ time data on Lōʻihi between 1997 and 2002 . Lōʻihi last erupted in 1996 , before the earthquake swarm of that summer .

= = Characteristics = =

= = = Geology = = =

Lōʻihi is a seamount , or underwater volcano , on the flank of Mauna Loa , the Earth 's largest shield volcano . It is the newest volcano created by the Hawaiʻi hotspot in the extensive Hawaiian @-@ Emperor seamount chain . The distance between the summit of the older Mauna Loa and the summit of Lōʻihi is about 80 km (50 mi) , which is , coincidentally , also the approximate diameter of the Hawaiʻi hotspot . Lōʻihi consists of a summit area with three pit craters , an 11 km (7 mi) long rift zone extending north from the summit , and a 19 km (12 mi) long rift zone extending south @-@ southeast from the summit .

The summit 's pit craters are named West Pit , East Pit , and Pele 's Pit . Pele 's Pit is the youngest of this group and is located at the southern part of the summit . The walls of Pele 's Pit stand 200 m (700 ft) high and were formed in July 1996 when its predecessor , Pele 's Vent , a hydrothermal field near Lōʻihi 's summit , collapsed into a large depression . The thick crater walls of Pele 's Pit ? averaging 20 m (70 ft) in width , unusually thick for Hawaiian volcanic craters ? suggest its craters have filled with lava multiple times in the past .

Lōʻihi 's north ? south trending rift zones create a distinctive elongated shape , from which the volcano 's Hawaiian name , meaning " long " , derives . The north rift zone consists of a longer western portion and a shorter eastern rift zone . Observations show that both the north and south rift zones lack sediment cover , indicating recent activity . A bulge in the western part of the north rift zone contains three 60 ? 80 m (200 ? 260 ft) cone @-@ shaped prominences .

Until 1970 , Lōʻihi was thought to be an inactive volcano that had been transported to its current location by sea @-@ floor spreading . The seafloor under Hawaiʻi is 80 ? 100 million years old and was created at the East Pacific Rise , an oceanic spreading center where new sea floor forms from

magma that erupts from the mantle . New oceanic crust moves away from the spreading center . Over a period of 80 ? 100 million years , the sea floor under Hawai'i moved from the East Pacific Rise to its present location 6 @, @ 000 km (4 @, @ 000 mi) west , carrying ancient seamounts with it . When scientists investigated a series of earthquakes off Hawai'i in 1970 , they discovered that L??ihi was an active member of the Hawaiian @-@ Emperor seamount chain .

L??ihi is built on the seafloor with a slope of about five degrees . Its northern base on the flank of Mauna Loa is 1 @, @ 900 m (6 @, @ 200 ft) below sea level , but its southern base is a more substantial 4 @, @ 755 m (15 @, @ 600 ft) below the surface . Thus , the summit is 931 m (3 @, @ 054 ft) above the seafloor as measured from the base of its north flank , but 3 @, @ 786 m (12 @, @ 421 ft) high when measured from the base of its southern flank .

L??ihi is following the pattern of development that is characteristic of all Hawai'ian volcanoes . Geochemical evidence from L??ihi lavas indicates that L??ihi is in transition between the preshield and shield volcano stage , providing valuable clues to the early development of Hawaiian volcanoes . In the preshield stage , Hawaiian volcanoes have steeper sides and a lower level of activity , producing an alkali basalt lava . Continued volcanism is expected to eventually create an island at L??ihi . L??ihi experiences frequent landslides ; the growth of the volcano has destabilized its slopes , and extensive areas of debris inhabit the steep southeastern face . Similar deposits from other Hawaiian volcanoes indicate that landslide debris is an important product of the early development of Hawaiian volcanoes . L??ihi is predicted to rise above the surface in 10 @, @ 000 to 100 @, @ 000 years .

= = = Age and growth = = =

Radiometric dating was used to determine the age of rock samples from L??ihi . The Hawaii Center for Volcanology tested samples recovered by various expeditions , notably the 1978 expedition , which provided 17 dredge samples . Most of the samples were found to be of recent origin ; the oldest dated rock is around 300 @, @ 000 years old . Following the 1996 event , some young breccia was also collected . Based on the samples , scientists estimate L??ihi is about 400 @, @ 000 years old . The rock accumulates at an average rate of 3 @. @ 5 mm (0 @. @ 14 in) per year near the base , and 7 @. @ 8 mm (0 @. @ 31 in) near the summit . If the data model from other volcanoes such as K?lauea holds true for L??ihi , 40 % of the volcano 's mass formed within the last 100 @, @ 000 years . Assuming a linear growth rate , L??ihi is 250 @, @ 000 years old . However , as with all hotspot volcanoes , L??ihi 's level of activity has increased with time ; therefore , it would take at least 400 @, @ 000 years for such a volcano to reach L??ihi 's mass . As Hawaiian volcanoes drift northwest at a rate of about 10 cm (4 in) a year , L??ihi was 40 km (25 mi) southeast of its current position at the time of its initial eruption .

= = Activity = =

L??ihi is a young and fairly active volcano , although less active than nearby K?lauea . In the past few decades , several earthquake swarms have been attributed to L??ihi , the largest of which are summarized in the table below . The volcano 's activity is now known to predate scientific record keeping of its activity , which commenced in 1959 . Most earthquake swarms at L??ihi have lasted less than two days ; the two exceptions are the 1991 ? 92 earthquake , lasting several months , and the 1996 event , which was shorter but much more pronounced . Both of the earthquakes followed a pattern of activity that began on the flank and migrated to the summit . The 1996 event was directly observed by an autonomous ocean bottom observatory (OBO) , allowing scientists to calculate the depth of the earthquakes as 6 km (4 mi) to 8 km (5 mi) below the summit , approximating to the position of L??ihi 's extremely shallow magma chamber . This is evidence that L??ihi 's seismicity is volcanic in origin .

The low @-@ level seismic activity documented on L??ihi since 1959 has shown that between two and ten earthquakes per month are traceable to the summit . Earthquake swarm data have been used to analyze how well L??ihi 's rocks propagate seismic waves and to investigate the relationship

between earthquakes and eruptions . This low level activity is periodically punctuated by large swarms of earthquakes , each swarm comprising up to hundreds of earthquakes . The majority of the earthquakes are not distributed close to the summit , though they follow a north ? south trend . Rather , most of the earthquakes occur in the southwest portion of L??ihi . The largest recorded swarms took place on L??ihi in 1971 , 1972 , 1975 , 1991 ? 92 and 1996 . The nearest seismic station is around 30 km (20 mi) from L??ihi , on the south coast of Hawai'i . Seismic events that have a magnitude under 2 are recorded often , but their location cannot be determined precisely as it can for larger events . In fact , HUGO (Hawai'i Undersea Geological Observatory) , positioned on L??ihi 's flank , detected ten times as many earthquakes as were recorded by the Hawaiian Volcano Observatory (HVO) seismic network .

= = = 1996 earthquake swarm = = =

The largest amount of activity recorded for the L??ihi seamount was a swarm of 4 @, @ 070 earthquakes between July 16 and August 9 , 1996 . This series of earthquakes was the largest recorded for any Hawaiian volcano to date in both amount and intensity . Most of the earthquakes had moment magnitudes of less than 3 @. @ 0 . " Several hundred " had a magnitude greater than 3 @. @ 0 , including more than 40 greater than 4 @. @ 0 and a 5 @. @ 0 tremor .

The final two weeks of the earthquake swarm were observed by a quick response cruise launched in August 1996 . The National Science Foundation funded an expedition by University of Hawai'i scientists , led by Frederick Duennebie , that began investigating the swarm and its origin in August 1996 . The scientists ' assessment laid the groundwork for many of the expeditions that followed . Follow @-@ up expeditions to L??ihi took place , including a series of manned @-@ submersible dives in August and September . These were supplemented by a great deal of shore @-@ based research . Fresh rock collected during the expedition revealed that an eruption occurred before the earthquake swarm .

Submersible dives in August were followed by NOAA @-@ funded research in September and October 1996 . These more detailed studies showed the southern portion of L??ihi 's summit had collapsed , a result of a swarm of earthquakes and the rapid withdrawal of magma from the volcano . A crater 1 km (0 @. @ 6 mi) across and 300 m (1 @, @ 000 ft) deep formed out of the rubble . The event involved the movement of 100 million cubic meters of volcanic material . A region of 10 to 13 km² (4 to 5 sq mi) of the summit was altered and populated by bus @-@ sized pillow lava blocks , precariously perched along the outer rim of the newly formed crater . " Pele 's Vents , " an area on the southern side , previously considered stable , collapsed completely into a giant pit , renamed " Pele 's Pit " . Strong currents make submersible diving hazardous in the region .

The researchers were continually met by clouds of sulfide and sulfate . The sudden collapse of Pele 's Vents caused a large discharge of hydrothermal material . The presence of certain indicator minerals in the mixture suggested temperatures exceeded 250 ° C , a record for an underwater volcano . The composition of the materials was similar to that of black smokers , the hydrothermal vent plumes located along mid @-@ ocean ridges . Samples from mounds built by discharges from the hydrothermal plumes resembled white smokers .

The studies demonstrated that the most volcanically and hydrothermally active area was along the southern rift . Dives on the less active northern rim indicated that the terrain was more stable there , and high lava columns were still standing upright . A new hydrothermal vent field (Naha Vents) was located in the upper @-@ south rift zone , at a depth of 1 @, @ 325 m (4 @, @ 350 ft) .

= = = Recent activity = = =

L??ihi has remained largely quiet since the 1996 event ; no activity was recorded from 2002 to 2004 . The seamount showed signs of life again in 2005 by generating an earthquake bigger than any previously recorded there . USGS @-@ ANSS (Advanced National Seismic System) reported two earthquakes , magnitudes 5 @. @ 1 and 5 @. @ 4 , on May 13 and July 17 . Both originated from a depth of 44 km (27 mi) . On April 23 , a magnitude 4 @. @ 3 earthquake was recorded at a

depth of approximately 33 km (21 mi) . Between December 7 , 2005 , and January 18 , 2006 , a swarm of around 100 earthquakes occurred , the largest measuring 4 on the Moment magnitude scale and 12 km (7 mi) to 28 km (17 mi) deep . Another earthquake measuring 4 @. @ 7 was later recorded approximately midway between L??ihi and P?hala (on the south coast of the island of Hawai?i) .

= = Exploration = =

= = = Early work = = =

L??ihi Seamount 's first depiction on a map was on Survey Chart 4115 , a bathymetric rendering of part of Hawai?i compiled by the US Coast and Geodetic Survey in 1940 . At the time , the seamount was non @-@ notable , being one of many in the region . A large earthquake swarm first brought attention to it in 1952 . That same year , geologist Gordon A. MacDonald hypothesized that the seamount was actually an active submarine shield volcano , similar to the two active Hawaiian volcanoes , Mauna Loa and K?lauea . Macdonald 's hypothesis placed the seamount as the newest volcano in the Hawaiian @-@ Emperor seamount chain , created by the Hawai?i hotspot . However , because the earthquakes were oriented east ? west (the direction of the volcanic fault) and there was no volcanic tremor in seismometers distant from the seamount , Macdonald attributed the earthquake to faulting rather than a volcanic eruption .

Geologists suspected the seamount could be an active undersea volcano , but without evidence the idea remained speculative . The volcano was largely ignored after the 1952 event , and was often mislabeled as an " older volcanic feature " in subsequent charts . Geologist Kenneth O. Emery is credited with naming the seamount in 1955 , describing the long and narrow shape of the volcano as Loihi . The Hawaiian word l??ihi means " long " . In 1978 , an expedition studied intense , repeated seismic activity known as earthquake swarms in and around the L??ihi area . Rather than finding an old , extinct seamount , data collected revealed L??ihi to be a young , possibly active volcano . Observations showed the volcano to be encrusted with young and old lava flows . Fluids erupting from active hydrothermal vents were also found .

In 1978 , a US Geological Survey research ship collected dredge samples and photographed L??ihi 's summit with the goal of studying whether L??ihi is active . Analysis of the photos and testing of pillow lava rock samples appeared to show that the material was " fresh " , yielding more evidence that L??ihi is still active . An expedition from October 1980 to January 1981 collected further dredge samples and photographs , providing additional confirmation . Studies indicated that the eruptions came from the southern part of the rift crater . This area is closest to the Hawai?i hotspot , which supplies L??ihi with magma . Following a 1986 seismic event , a network of five ocean bottom observatories (OBOs) were deployed on L??ihi for a month . L??ihi 's frequent seismicity makes it an ideal candidate for seismic study through OBOs . In 1987 , the submersible DSV Alvin was used to survey L??ihi . Another autonomous observatory was positioned on L??ihi in 1991 to track earthquake swarms .

= = = 1996 to present = = =

The bulk of information about L??ihi comes from dives made in response to the 1996 eruption . In a dive conducted almost immediately after seismic activity was reported , visibility was greatly reduced by high concentrations of displaced minerals and large floating mats of bacteria in the water . The bacteria that feed on the dissolved nutrients had already begun colonizing the new hydrothermal vents at Pele 's Pit (formed from the collapse of the old ones) , and may be indicators of the kinds of material ejected from the newly formed vents . They were carefully sampled for further analysis in a laboratory . An OBO briefly sat on the summit before a more permanent probe could be installed .

Repeated multibeam bathymetric mapping was used to measure the changes in the summit following the 1996 collapse . Hydrothermal plume surveys confirmed changes in the energy , and

dissolved minerals emanating from Lʻōʻihi . Hawaiʻi Undersea Research Laboratory , HURL 's 2 @, @ 000 m (6 @, @ 562 ft) submersible Pisces V allowed scientists to sample the vent waters , microorganisms and hydrothermal mineral deposits .

In 1997 , scientists from the University of Hawaiʻi installed an ocean bottom observatory (OBO) on the summit of Lʻōʻihi Seamount . The submarine observatory was nicknamed HUGO , (Hawaiʻi Undersea Geological Observatory) . HUGO was connected to the shore , 34 km (21 mi) away , by a fiber optic cable . It gave scientists real @-@ time seismic , chemical and visual data about the state of Lʻōʻihi , which had by then become an international laboratory for the study of undersea volcanism . The cable that provided HUGO with power and communications broke in October 1998 , effectively shutting it down . On January 19 of the following year , HUGO was visited by Pisces V . The observatory functioned for four years before it went dead again in 2002 .

Since 2006 , the Fe @-@ Oxidizing Microbial Observatory (FeMO) , funded by the National Science Foundation and Microbial Observatory Program , has led cruises to Lʻōʻihi investigate its microbiology every October . The first cruise , on the ship R / V Melville and exploiting the submersible JASON2 , lasted from September 22 to October 9 . These cruises study the large number of Fe @-@ oxidizing bacteria that have colonized Lʻōʻihi . Lʻōʻihi 's extensive vent system is characterized by a high concentration of CO₂ and Iron , while being low in sulfide . These characteristics make a perfect environment for iron @-@ oxidizing bacteria , called FeOB , to thrive in .

= = Ecology = =

= = = Hydrothermal vent geochemistry = = =

Lʻōʻihi 's mid @-@ Pacific location and its well @-@ sustained hydrothermal system contribute to a rich oasis for a microbial ecosystem . Areas of extensive hydrothermal venting are found on Lʻōʻihi 's crater floor and north slope , and along the summit of Lʻōʻihi itself . Active hydrothermal vents were first discovered at Lʻōʻihi in the late 1980s . These vents are remarkably similar to those found at the mid @-@ ocean ridges , with similar composition and thermal differences . The two most prominent vent fields are at the summit : Pele 's Pit (formally Pele 's Vents) and Kapo 's Vents . They are named after the Hawaiian deity Pele and her sister Kapo . These vents were considered " low temperature vents " because their waters were only about 30 ° C . The volcanic eruption of 1996 and the creation of Pele 's Pit changed this , and initiated high temperature venting ; exit temperatures were measured at 77 ° C in 1996 .

= = = Microorganisms = = =

The vents lie 1 @, @ 100 m (3 @, @ 600 ft) to 1 @, @ 325 m (4 @, @ 347 ft) below the surface , and range in temperature from 10 to over 200 ° C . The vent fluids are characterized by a high concentration of CO

2 (up to 17 mM) and Fe (Iron) , but low in sulfide . Low oxygen and pH levels are important factors in supporting the high amounts of Fe (iron) , one of the hallmark features of Lʻōʻihi . These characteristics make a perfect environment for iron @-@ oxidizing bacteria , called FeOB , to thrive in . An example of these species is Mariprofundus ferrooxydans , sole member of the class Zetaproteobacteria . The composition of the materials was similar to that of black smokers , that are a habitat of archaea extremophiles . Dissolution and oxidation of the mineral observed over the next two years suggests the sulfate is not easily preserved .

A diverse community of microbial mats surround the vents and virtually cover Pele 's Pit . The Hawaiʻi Undersea Research Laboratory (HURL) , NOAA 's Research Center for Hawaiʻi and the Western Pacific , monitors and researches the hydrothermal systems and studies the local community . The National Science Foundation (NSF) funded an extremophile sampling expedition to Lʻōʻihi in 1999 . Microbial mats surrounded the 160 ° C vents , and included a novel jelly @-@ like

organism . Samples were collected for study at NSF 's Marine Bioproducts Engineering Center (MarBEC) . In 2001 , Pisces V collected samples of the organisms and brought them to the surface for study .

NOAA 's National Undersea Research Center and NSF 's Marine Bioproducts Engineering Center are cooperating to sample and research the local bacteria and archaea extremophiles . The fourth FeMO (Fe @-@ Oxidizing Microbial Observatory) cruise occurred during October 2009 .

= = = Macroorganisms = = =

Marine life inhabiting the waters around L??ihi is not as diverse as life at other , less active seamounts . Fish found living near L??ihi include the Celebes monkfish (*Sladenia remiger*) , and members of the Cutthroat eel family , Synaphobranchidae . Invertebrates identified in the area include two species endemic to the hydrothermal vents , a bresiliid shrimp (*Opaepele loihi*) of the family Alvinocarididae (described in 1995) , and a tube or pogonophoran worm . Dives conducted after the 1996 earthquake swarms were unable to find either the shrimp or the worm , and it is not known if there are lasting effects on these species .

From 1982 to 1992 , researchers in Hawai'i Undersea Research Laboratory submersibles photographed the fish of L??ihi Seamount , Johnston Atoll , and Cross Seamount at depths between 40 m (130 ft) and 2 @,@ 000 m (6 @,@ 600 ft) . A small number of species identified at L??ihi were newly recorded sightings in Hawai'i , including the Tassled coffinfish (*Chaunax fimbriatus*) , and the Celebes monkfish .