= Axial Seamount =

Axial Seamount (also Coaxial Seamount or Axial Volcano) is a seamount and submarine volcano located on the Juan de Fuca Ridge , approximately 480 km (298 mi) west of Cannon Beach , Oregon . Standing 1 @,@ 100 m (3 @,@ 609 ft) high , Axial Seamount is the youngest volcano and current eruptive center of the Cobb @-@ Eickelberg Seamount chain . Located at the center of both a geological hotspot and a mid @-@ ocean ridge , the seamount is geologically complex , and its origins are still poorly understood . Axial Seamount is set on a long , low @-@ lying plateau , with two large rift zones trending 50 km (31 mi) to the northeast and southwest of its center . The volcano features an unusual rectangular caldera , and its flanks are pockmarked by fissures , vents , sheet flows , and pit craters up to 100 m (328 ft) deep ; its geology is further complicated by its intersection with several smaller seamounts surrounding it .

Axial Seamount was first detected in the 1970s by satellite altimetry , and mapped and explored by Pisces IV , DSV Alvin , and others through the 1980s . A large package of sensors was dropped on the seamount through 1992 , and the New Millennium Observatory was established on its flanks in 1996 . Axial Seamount received significant scientific attention following the seismic detection of a submarine eruption at the volcano in January 1998 , the first time a submarine eruption had been detected and followed in situ . Subsequent cruises and analysis showed that the volcano had generated lava flows up to 13 m (43 ft) thick , and the total eruptive volume was found to be 18 @,@ 000 ? 76 @,@ 000 km3 (4 @,@ 300 ? 18 @,@ 200 cu mi) . Axial Seamount erupted again in April 2011 , producing a mile @-@ wide lava flow and fulfilling a 16 @-@ year cycle that had been predicted in 2006 .

= = Geology = =

= = = Tectonic setting = = =

Axial Seamount is the youngest volcano and current eruptive center of the Cobb @-@ Eickelberg Seamount chain , a chain of seamounts that terminates south of Alaska . Axial lies where the chain intersects with the Juan de Fuca Ridge , approximately 480 km (298 mi) west of Oregon . It is a product of the Cobb hotspot , but now sits on an ocean spreading center between the Juan de Fuca Plate and the North American Plate , offset by the Blanco Fracture Zone to the south and a ridge @-@ built triple junction to the north .

This position is not yet entirely understood . It is believed that the chain , formed over millions of years by the now @-@ inactive Cobb hotspot , is older than the mid @-@ ocean ridge it bisects . Between 200 @,@ 000 and 700 @,@ 000 years ago , the hotspot was encroached by the tectonic spreading center , displacing it by as much as 20 km (12 mi) and building up the 500 km (311 mi) long Juan de Fuca Ridge . At least 7 spreading centers have been recognized , and plate measurements near Axial show that the ridge is separating at a rate of 6 cm (2 in) per year , producing a complex system of oceanic basins and ridges . However some scientists have questioned this theory , pointing out that the high density of the chain 's overlapping seamounts is incompatible with such an origin , as a hotspot would form a well organized , widely spaced chain . Although the exact nature of Axial Seamount remains unknown , its complex origins makes it one of the most geologically interesting features in the North Pacific .

= = = Structure = = =

Axial Seamount is the most active volcanic site in the North Pacific . Study of magnetic delineations along the seamount have modeled the ridge 's history up to 30 million years ago , and shown that growth has progressed mostly in the north , with some southward progression dating back 3 @.@ 5 million years . The base of Axial Seamount is a long , low @-@ lying plateau , and the eastern part of the seamount is defined by a series of linear scarps . Axial Seamount has two major volcanic rifts

extending approximately 50 km (31 mi) north and south of its main summit , as well as several much smaller , ill @-@ defined ones aligned in a roughly similar pattern . Basins around the volcano increase its irregularity , making it unusually complex (most seamounts of roughly the same size are circular or flattened in shape .)

Axial Seamount 's summit is marked by an unusual rectangular caldera , 3 km × 8 km (2 mi × 5 mi) in area , ~ 3 ° in slope , and breached on the southeast side . The area is offset by the two rift zones and defined on three sides by boundary faults up to 150 m (492 ft) deep . The caldera is roughly 50 m (164 ft) deeper at the north side then it is in the south . Flows within the caldera consist mostly of sheet flows pocketed by lava ponds and pit craters . Less common are pillow lavas ; their arrangement along the caldera walls suggests that they were an important component in the volcano 's early growth . There are several dome @-@ like structures within the caldera with heights of 100 ? 300 m (328 ? 984 ft) . There are several small craters within the region , the largest of which , nicknamed the D.D. Cone , is 2 km (1 mi) in diameter and 100 m (328 ft) in relief . However , most of the features do not range over 30 to 40 m (98 to 131 ft) deep and 1 km (1 mi) across .

The northern rift zone of Axial Seamount is a 5 km (3 mi) long ridge running 10 to 20 degrees northeast of the main caldera . The rift is pocketed by multiple fissures , 100 ? 200 m (328 ? 656 ft) in length , as far as 7 km (4 mi) from Axial Volcano 's center , and reaching up to 400 m (1 @,@ 312 ft) long and 20 m (66 ft) deep . The area contains high amounts of volcanic glass ; a major eruption is still visible in the form of an elongated glassy lava flow extending off the caldera wall , east of the main rift line . Dives in 1983 found extensive low @-@ temperature venting at the northern half of the fissure . The shorter , newer southern rift zone consists of a topographically plunging rift , surrounding by subtle , discontinuous faults . Camera tows along the southern flank reveal that the area is built of delineated sheet flows , small lava ponds , and lava channels .

The youngest of the flows on Axial Seamount are aligned along the two rift zones , followed by flows inside the summit caldera ; the oldest appear to originate from directly around the caldera , where most of the basalt is completely covered in accumulated sediment . This suggests a bilateral growth pattern , a trend also found in Hawai?ian volcanics and other well @-@ known seamounts , for instance Jasper Seamount .

Axial Seamount 's growth has intersected the growth of many of the smaller seamounts around it . The largest of these is Brown Bear Seamount , to which it is connected by a narrow ridge running roughly perpendicular to its western caldera wall . However , little evidence of interactions between the two seamounts has been found . On the other hand , Axial Seamount 's southern rift zone bisects Vance Seamount by as much as 30 km (19 mi) , creating a zone of intense fissuring at the northern edge of the smaller volcano . Interactions with Cobb Seamount to the north are more complex , forming an unusual " bent spreading center . " In addition there are four smaller structures directly east , north , and south of Axial .

= = History = =

= = = Early history = = =

The first volcanoes along the Juan de Fuca ridge , including Axial Seamount , were detected in the 1970s by satellite altimetry . Axial Seamount 's proximity to the western coast and shallow depth make it one of the most easily accessible seamounts in the world , and its unique geological setting and active state also makes it one of the most interesting , rivaling Davidson Seamount to the south in scientific interest .

The first bathymetry of the seamount was compiled by the NOAAS Surveyor in 1981 , as part of SeaBeam trials in the North Pacific . The survey was specifically meant to find and link seafloor hydrothermal activity to geomorphic features . Four areas of increased temperature concentration , indicative of hydrothermal activity were found , and the then @-@ unnamed Axial Seamount was among them . Submersible dives with Pisces IV and DSV Alvin in 1983 and 1984 discovered the

first active black smoker vents in the north Pacific . Soon after Axial Seamount was named for its central position on the intersection of the Cobb @-@ Eickelberg Seamount chain and Juan de Fuca Ridge . That same year , the National Oceanic and Atmospheric Administration (NOAA) founded its VENTS program , providing impetus for studying the volcano more closely .

Between 1987 and 1992 , a variety of pressure sensors , tilt sensors , temperature probes , and seismometers were dropped on the volcano in what came to be known as the Volcanic Systems Moninters (VSN) . Further bathymetries by the NOAAS Discoverer in 1991 and RV Sonne in 1996 detailed the seamount further , making it one of the best known features in the North Pacific . Also in 1996 , the New Millennium Observatory (NeMO) was established on Axial Seamount , to study volcanic perturbations and the effect they have on hydrothermal communities .

= = = 1998 eruption = = =

The 1998 eruption of Axial Seamount was preceded by several large earthquake swarms , common indicators of volcanic activity . The swarms correlated to magma movements in the volcano ; bottom pressure recorders deployed on the volcano between 1987 and 1992 recorded five instances of deflation in the summit surface (caused by lava movement) , ranging from 3 to 10 cm (1 to 4 in) . In 1991 , the National Oceanic and Atmospheric Administration (NOAA) was granted access to the United States Navy 's SOSUS system , a chain of submerged hydrophones in the North Pacific originally used by the Navy to detect Russian submarines during the Cold War . Since 1993 , the NOAA has maintained a real @-@ time monitoring system that alerts the organization whenever an event occurs . The hydrophones are able to detect even very small earthquakes (~ magnitude 1 @.@ 8) by listening for the acoustic waves generated by T @-@ waves . These waves can propagate over large distances with minimal loss in power , making them an ideal way to record otherwise unnoticeable submarine earthquakes ; over the course of the eruption , only 3 earthquakes were strong enough to register on land @-@ based systems . However , they cannot interpret earthquake depth or what caused them .

Between 1991 and 1996 Axial Seamount experienced a single earthquake swarm of over 50 events . Between May and November 1997 this activity increased markedly , with SOSUS recording 5 such swarms , culminating with a massive 11 @-@ day , 8247 @-@ quake event around the time of the eruption , in January 1998 . The seismicity began at the summit , but within 6 hours had begun to migrate south as well ; by 29 November 1997 the swarm had moved south by 50 kilometers (31 mi) . This coincided with lava release along the summit and southern flank . The seamount remained absolutely quiet thereafter , suggesting the completion of an eruptive cycle at the volcano . In all , 9055 earthquakes were detected , and 1669 were strong enough to be located . Earthquake activity was concentrated around the summit and southern rift zones , with the majority of events centered inside the summit caldera ; temperature probes and pressure recorders in the caldera recorded an average 0 @.@ 6 ° C (33 @.@ 1 ° F) increase and 3 @.@ 3 m (11 ft) height deflation , respectively , during the event . This close monitoring gives the 1998 eruption the distinction of being the only submarine eruption ever observed in situ .

The first post @-@ eruption expedition was organized and conducted by R / V Wecoma on 12 February 1998 , which conducted conductivity , temperature , depth , and optical casts to unusual results . In May , a dedicated bathymetric survey of the seamount showed topographical changes along the volcano 's southern flank , which estimated the thickest flows to 13 m (43 ft) . In July DSV Alvin made several dives on the seamount 's summit caldera , followed in August through September by an extensive observation and collection program using ROV ROPOS , confirming the bathymetric estimates . A sheet flow more than 3 km (2 mi) long and 500 to 800 m (1 @,@ 640 to 2 @,@ 625 ft) wide was produced from Axial Seamount 's upper southern flank , on the site of what was formerly an active geothermal field . The southern flows were in an area marked by a difference between older sediments and newer , glassier rock , and the maximum ridge generated by the eruption , at the crest of the southern flow , was 13 m (40 ft) high . The total eruptive volume was roughly 0 @.@ 018 ? 0 @.@ 076 km3 (0 @.@ 004 ? 0 @.@ 018 cu mi) .

The development , eruption , and close monitoring of Axial Seamount provided a fertile model on

submarine volcanic eruptions to scientists ; several scientific papers on the topic were published soon after .

= = = 2011 eruption = = =

Seismic activity at Axial Seamount virtually disappeared after the 1998 eruption , and monitoring of the volcano was done principally with bottom pressure recorders deployed on the volcano 's flanks , supplemented since 2000 by annual measurements using pressure sensors mounted on Remotely Operated Vehicles (ROVs) and applied to local benchmarks . The sensors have shown that Axial Seamount is slowly reflating ; just after the eruption the seamount was swelling at 20 cm (8 in) per month , a number that decreased to 15 cm (6 in) by 2006 . In eight years Axial Seamount recovered approximately 50 % of its 3 @.@ 2 m (10 @.@ 5 ft) of pre @-@ eruption swelling , and in 2006 , William Chadwick of the Oregon State University and his associates calculated an eruption recurrence interval of ~ 16 years , predicting the next eruption would occur in approximately 2014 :

Axial Seamount behaves in a more predictable way than many other volcanoes ; likely due to its robust magma supply coupled with its thin crust , and its location on a mid @-@ ocean ridge spreading center . It is now the only volcano on the seafloor whose surface deformation has been continuously monitored throughout an entire eruption cycle .

This prediction was fulfilled when , in July 2011 , a dive using ROV Jason discovered new lava flows on the volcanoes that had not been present a year ago . The expeditionary crew recovered two bottom @-@ pressure recorders and two hydrophones (a third was found buried in lava) off the volcano , which together showed that the eruption had occurred during April , starting on 6 April 2011 . Although the instruments recorded hundreds of seismic events , only a handful had been noticed by SOSUS and land @-@ based seismometers , as many components of the system had been offline at the time . The volcano subsided by more than 2 m (7 ft) and produced a 2 km (1 mi) wide lava flow during the event , which was as much as three times larger than the 1998 eruption .

= = Ecology = =

In 1983 , a Canadian @-@ American collaborative expedition , named the Canadian American Seamount Expedition (CASM) , visited the northwestern edge of Axial Seamount 's summit caldera to investigate a persistent temperature anomaly in the region . In a series of eight dives conducted by Pisces IV , the scientists discovered a vibrant hydrothermal vent community on the leading edge of a 300 m (984 ft) fissure within the caldera . Vent temperatures were measured around 35 ° C (95 ° F) , approximately 30 ° C (86 ° F) hotter than the surrounding environment . Camera tows and submersible dives through the 1980s and 1990s revealed Axial Seamount 's active state , including the only known black smoker in the northwest Pacific . Three venting centers have been recognized : the original site , named CHASM ; a southwestern caldera field discovered in the late 1980s , named ASHES ; and a site located on its southeastern rift zone , named CASTLE . All are primarily sulfur / sulfide emitting .

The temperature and composition of Axial Seamount 's hydrothermal vents changes over time , but always maintains a roughly common identity , as do the vents ' individual microbial communities . Vents generally have a lower pH than the surrounding fluid , and are acidic and alkaline as a result . The temperature of the magma feeding the system is uncertain , and may vary between 300 and 550 ° C (572 and 1 @,@ 022 ° F) . Curiously , vent fluid are heavily enriched in helium , containing five times the amount of the element as similar vents in the Galapagos , and 580 times that of regular seawater .

Tube worms of the Pogonophora family thicket the largest vents on Axial Seamounts , forming colonies up to 6 m2 (65 sq ft) thick in places ; smaller , less nutritious vents feed bacterial mats , smaller tube worms , and limpets . The three most common microbial groups are bacterial epsilonproteobacteria , archaeon thermophilics of the Methanococcus family , and archaeons of the Euryarchaeota family . The most common flora at Axial Seamount 's hydrothermal vents is the worm Ridgeia piscesae , which is found at hydrothermal sites of all descriptions on the Juan de Fuca ridge

, and is the base of Axial Seamount 's hydrothermal ecosystem . Other species on the seamount include the tube worm P. palmiformis , the sea snail Lepetodrilus fucensis , the bristle worm Amphisamytha galapagensis , and the sea spider Sericosura verenae .