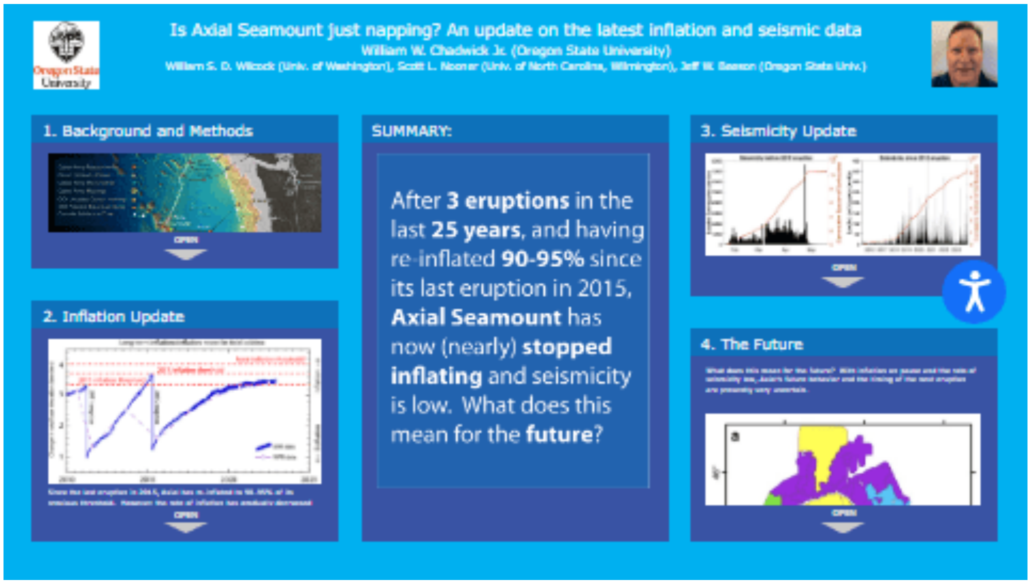
Is Axial Seamount just napping? An update on the latest inflation and seismic data



William W. Chadwick Jr. (Oregon State University)

William S. D. Wilcock (Univ. of Washington), Scott L. Nooner (Univ. of North Carolina, Wilmington), Jeff W. Beeson (Oregon State Univ.)

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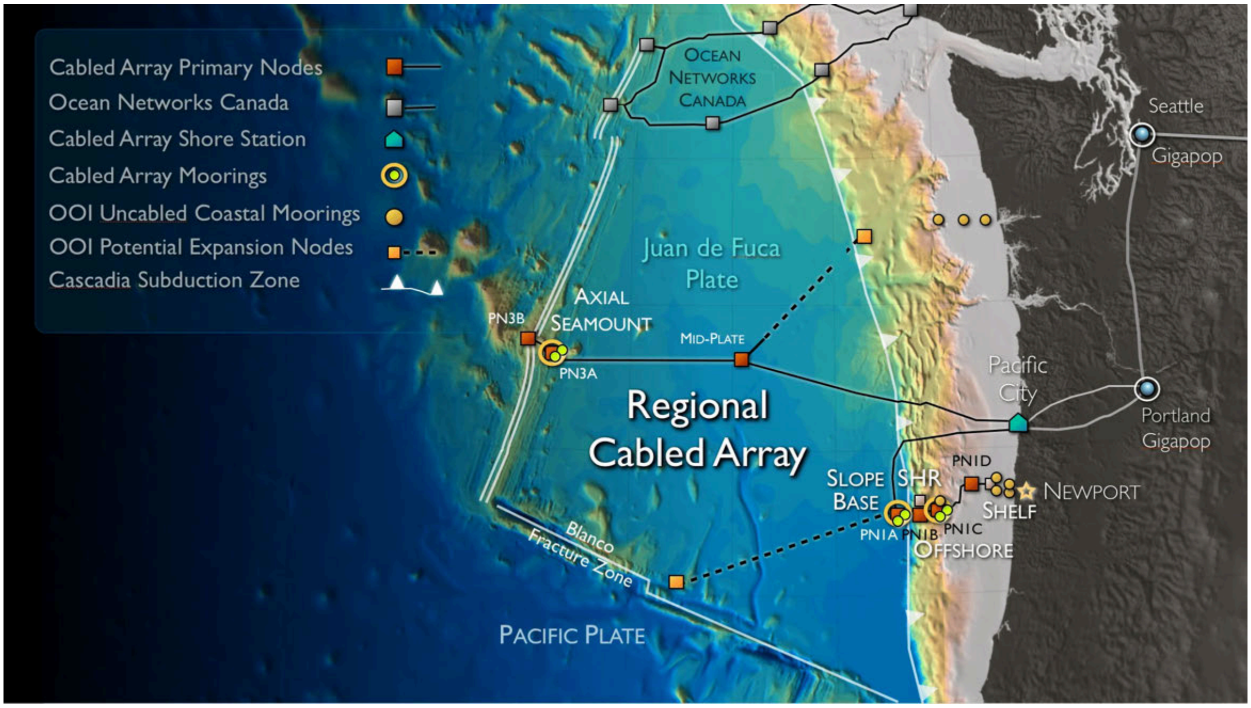
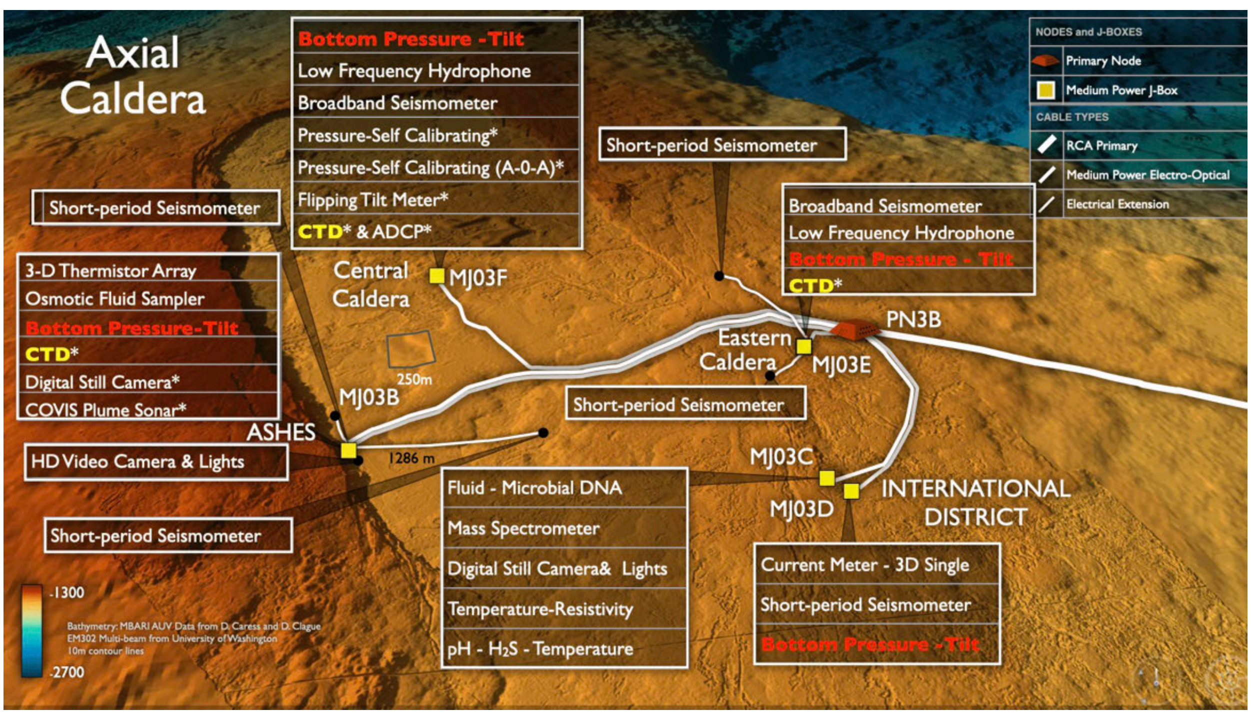
SUMMARY:

After **3 eruptions** in the last **25 years**, and having re-inflated **90-95%** since its last eruption in 2015, **Axial Seamount** has now (nearly) **stopped inflating** and seismicity is low. What does this mean for the **future**?

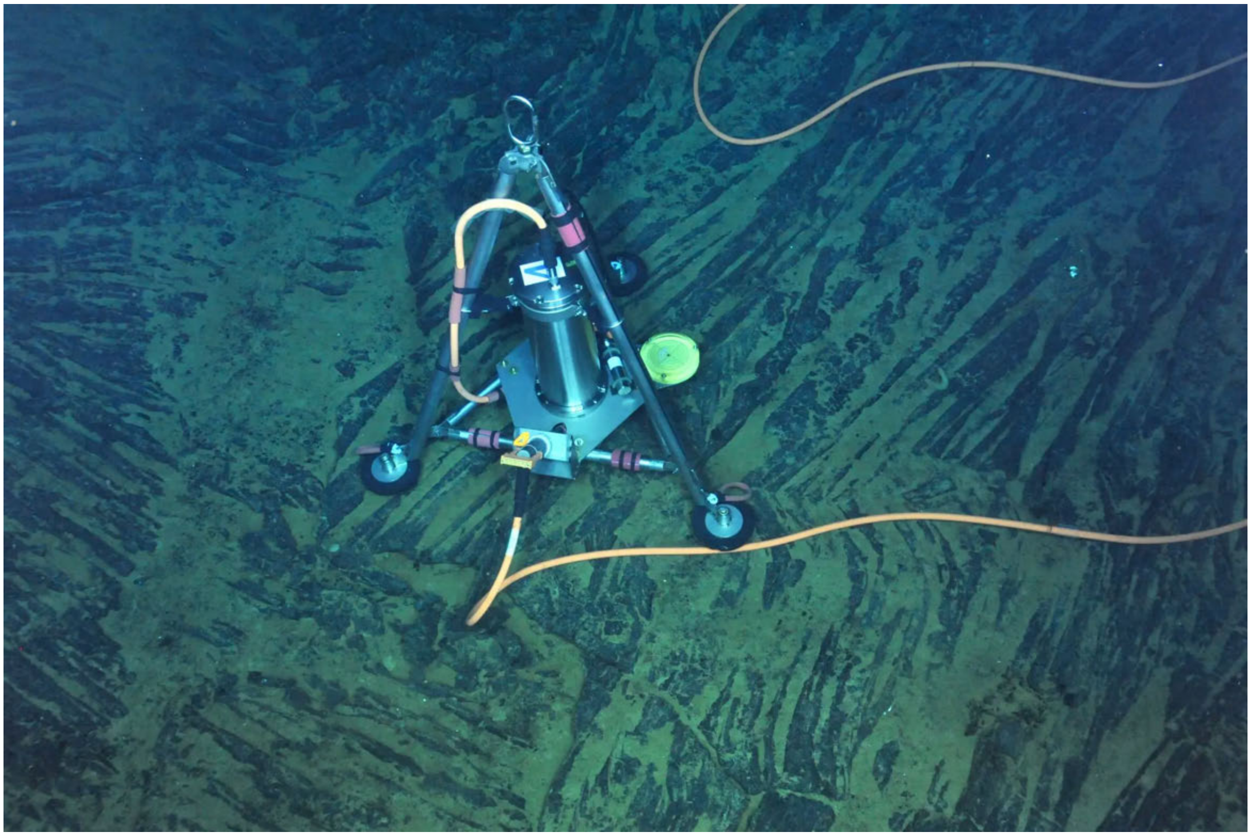
1. BACKGROUND AND METHODS



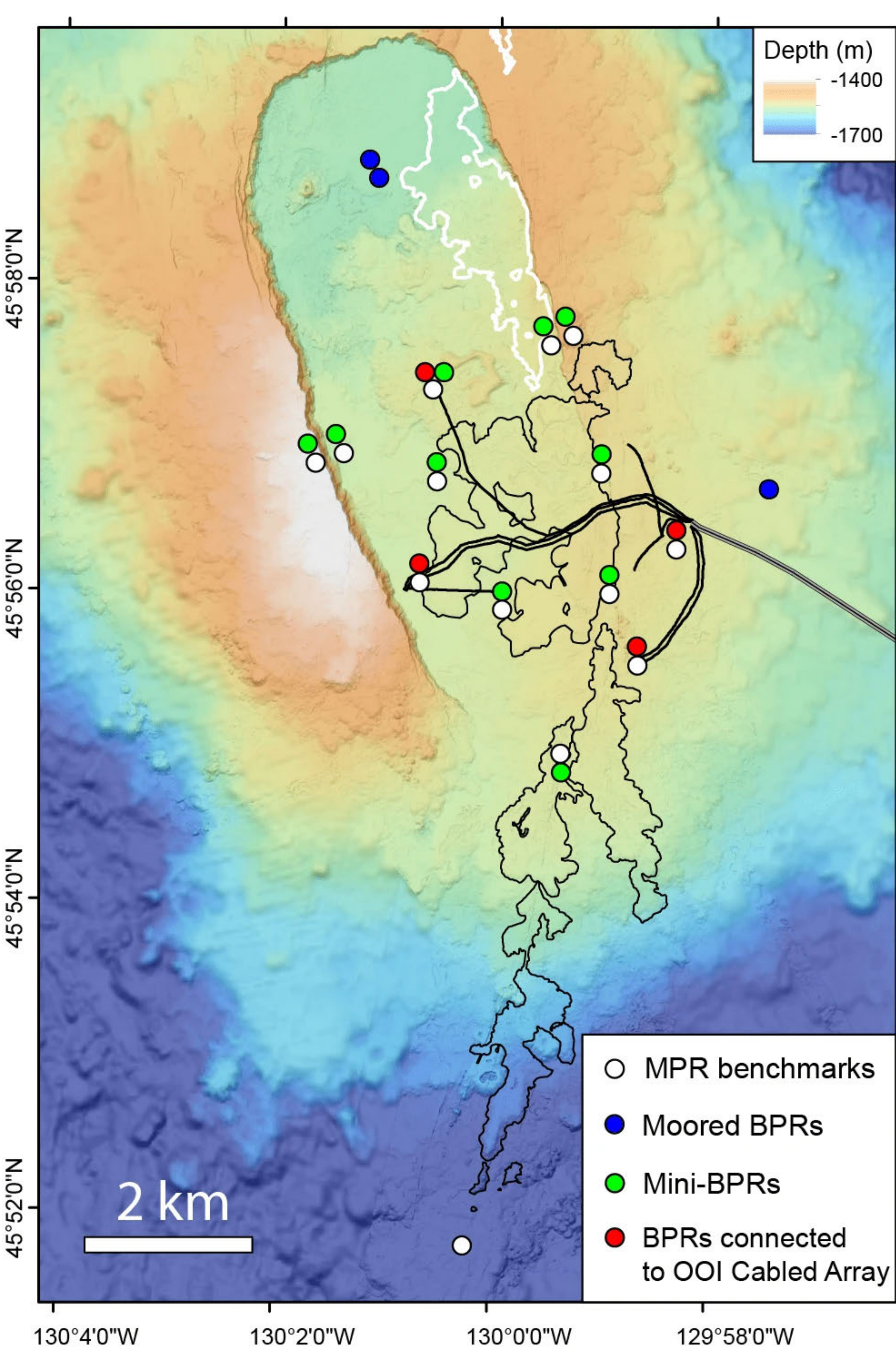
Axial Seamount is a submarine basaltic hotspot volcano superimposed on the Juan de Fuca Ridge in the NE Pacific Ocean, located ~500 km offshore the US west coast.



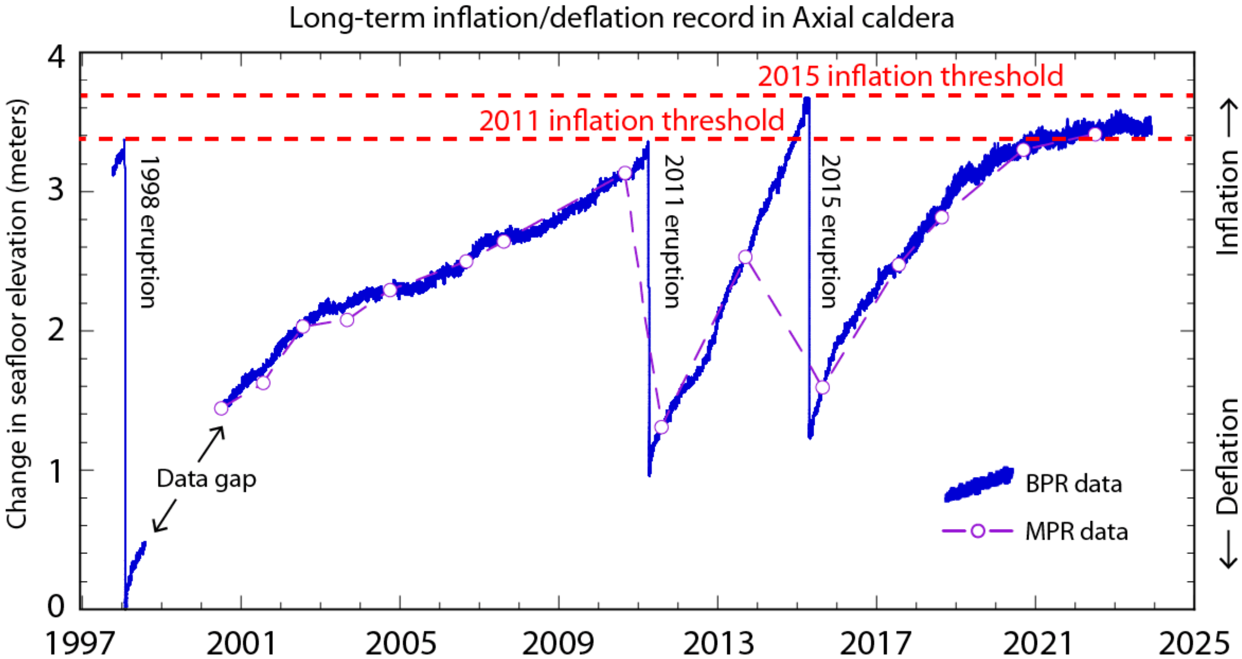
It is monitored by a network of sensors on the Ocean Observatories Initiative's (OOI) Regional Cabled Array (RCA), operated by University of Washington and funded by the US National Science Foundation (Kelley et al., 2014).



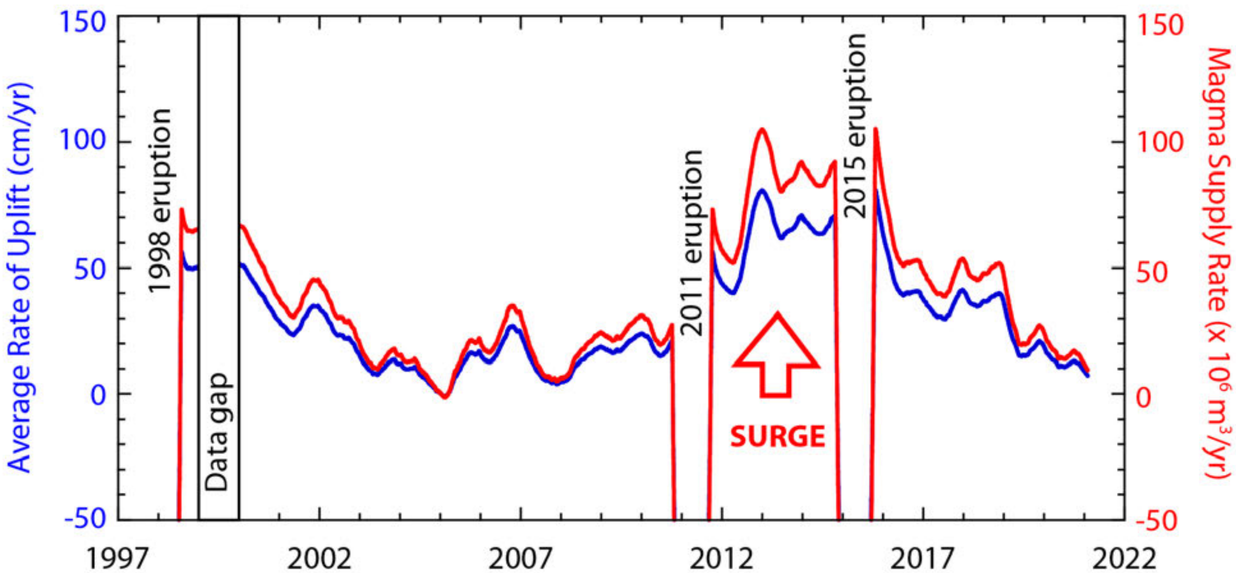
A repeatable inflation-deflation cycle has been documented at Axial Seamount over the last 30 years, using Bottom Pressure Recorders (BPRs) connected to the OOI-RCA, additional autonomous uncabled BPRs, and by Mobile Pressure Recorder (MPR) on repeated ROV-based campaign-style surveys at an array of seafloor benchmarks.



This map shows the current array of MPR benchmarks, autonomous BPRs, and cabled BPRs at Axial Seamount.

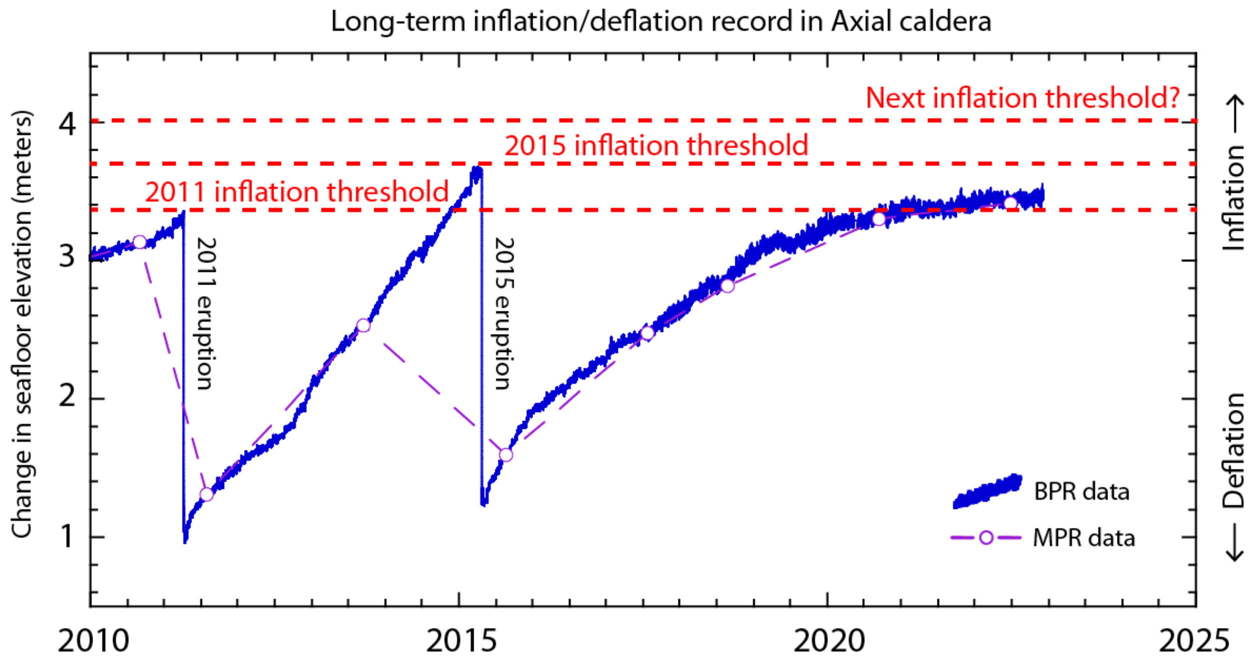


The long-term record of inflation/deflation shows that Axial has had a continuous but variable magma supply and that the volcano erupts at a similar level of inflation each time, which was used to successfully forecast the 2015 eruption (Nooner and Chadwick, 2016; Chadwick et al., 2022).



The inflation record can be used to show how the rate of inflation and calculated magma supply has varied over the same time period (Chadwick et al., 2022).

2. INFLATION UPDATE



Since the last eruption in 2015, Axial has re-inflated to 90-95% of its previous threshold. However, the rate of inflation has gradually decreased from >100 cm/yr to <10 cm/yr, and over the last year inflation has nearly stopped.

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Realtime data from the OOI instruments at Axial Seamount

The maps below show the locations of four Bottom Pressure/Tilt (BOTPT) instruments at Axial Seamount, part of the National Science Foundation's (NSF) Ocean Observatories Initiative (OOI) Regional Cabled Array (RCA) seafloor observatory, operated by the University of Washington. Click on the "DATA" links (below right) to see plots of near-real-time data (updated every 20 minutes) from the 4 BOTPT instruments and 3 seafloor CTD instruments. The BOTPT instruments were built by NOAA's Pacific Marine Environmental Lab and Oregon State University. Follow our attempts to use the BOTPT data to forecast the next eruption -> **HERE** and using the "INFLATION FORECAST" links below. Information on our previous expeditions to Axial Seamount is available -> **HERE**.

INFLATION FORECAST COMPARISONS

INFLATION FORECASTS - Method #4

INFLATION FORECASTS - Method #3

INFLATION FORECASTS - Method #2

INFLATION FORECASTS - Method #1

DATA FROM BOTPT INSTRUMENTS

BOTPT-A301-MJ03F - Central Caldera

BOTPT-A302-MJ03E - Eastern Caldera

BOTPT-A303-MJ03D - International District

BOTPT-A304-MJ03B - ASHES Vent Field

INFLATION & TILT RATES OVER TIME

Differential Uplift Rate from MJ03E-F

Long-Term Rates of Uplift (BPR data)

Long-Term Rates of Tilt (LILY data)

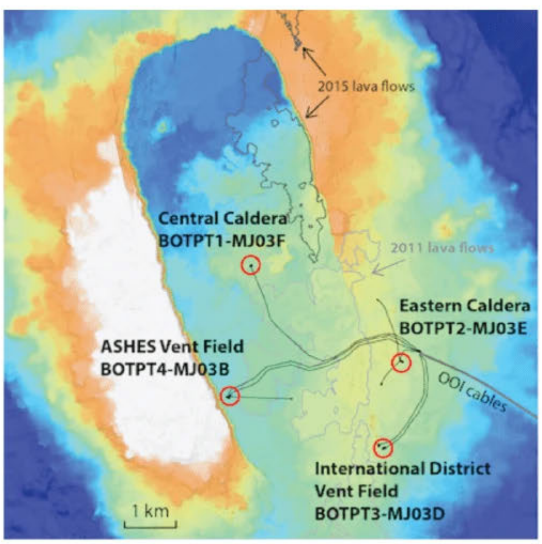
Event Alarms

DATA FROM CTD INSTRUMENTS

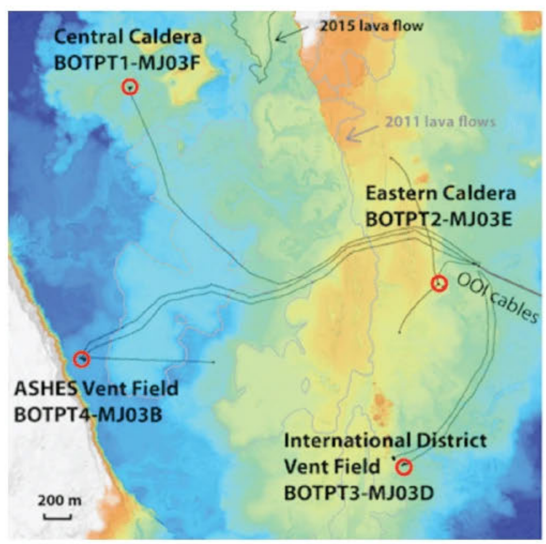
ASHES Seafloor CTD (MJ03B-CTDPFB304)

Eastern Seafloor CTD (MJ03E-CTDPFB306)

Central Seafloor CTD (MJ03F-CTDPFB305)



Map of Axial caldera with OOI cables (black lines), recent lava flows (grey outlines), and locations of BOTPT instruments (red circles).

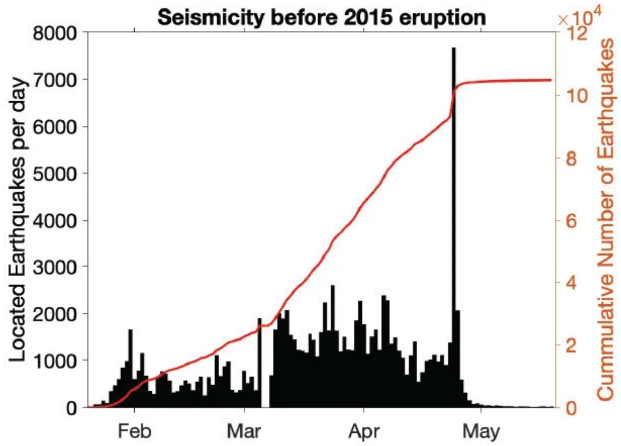


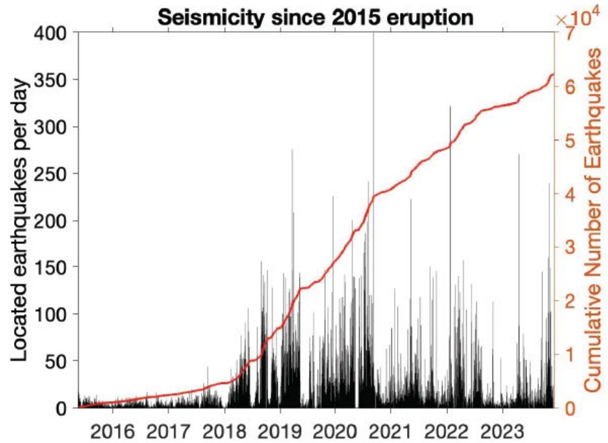
Map of Axial caldera with OOI cables (black lines), recent lava flows (grey outlines), and locations of BOTPT instruments (red circles).

Near-real-time inflation data from the OOI-RCA BPR sensors can be viewed at this web site:

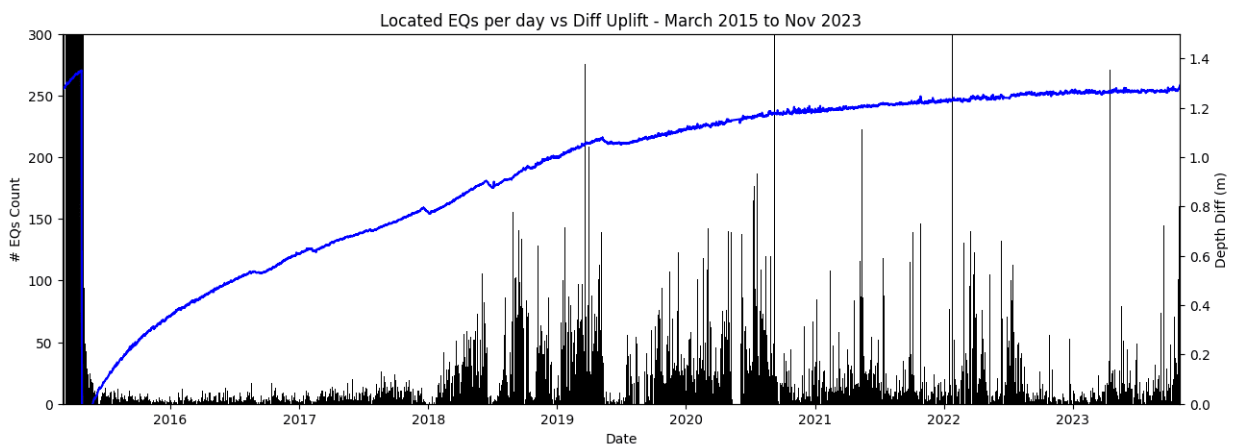
https://www.pmel.noaa.gov/eoi/rsn/ (https://www.pmel.noaa.gov/eoi/rsn/index.html)

3. SEISMICITY UPDATE





Similarly, the rate of seismicity (also monitored by the OOI-RCA) is currently at relatively low levels (right plot above), with averages of ~5 earthquakes/day in Jan-Mar 2023, 15-35/day in Apr-May, 10-20/day in Jun-Aug, and 20-40/day since then with peaks up to a few 100/day. This is low compared with a rates of 1000-2000/day in the months leading up to the 2015 eruption (left plot above, Wilcock et al., 2016).



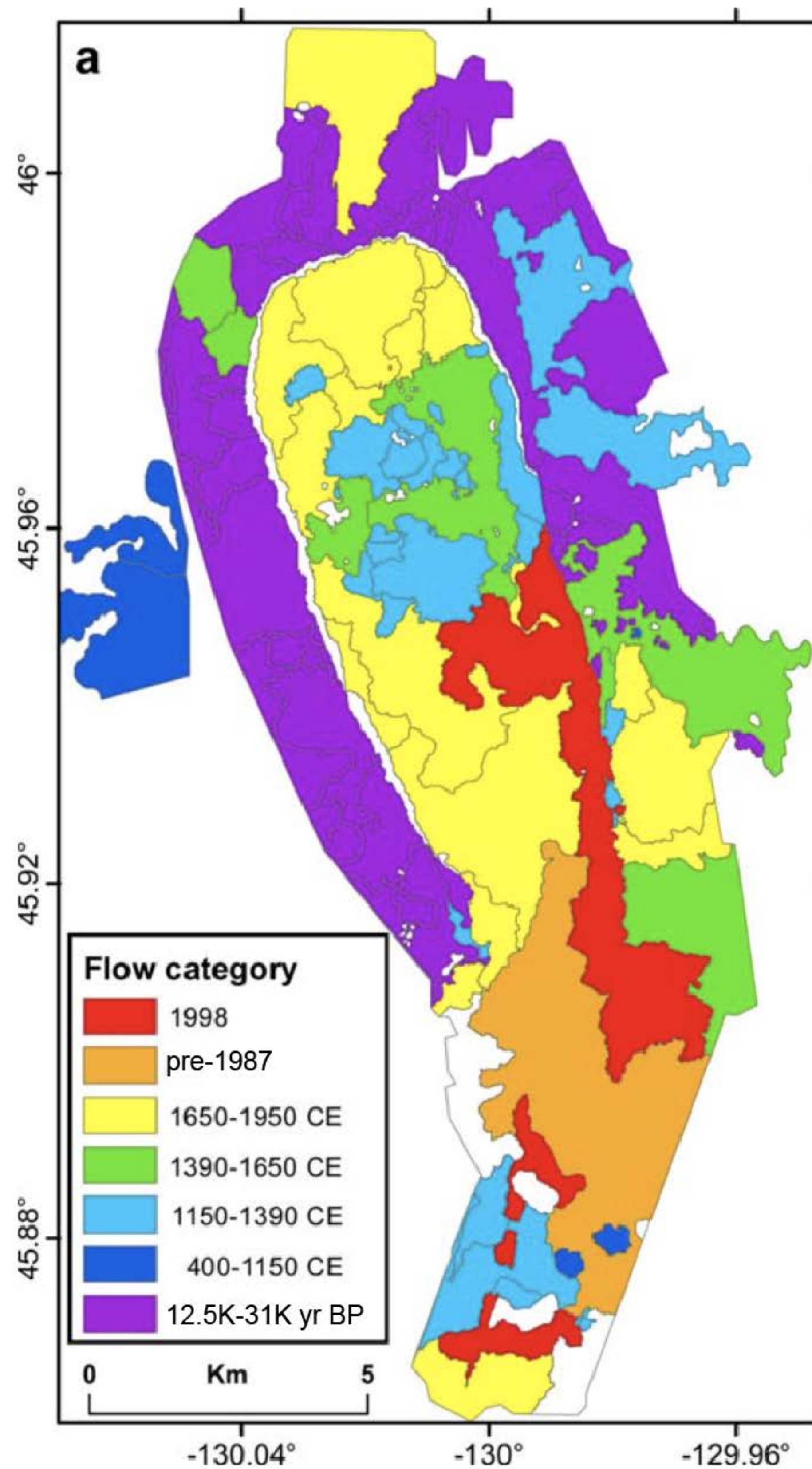
The plot above shows how inflation (blue curve) and seismicity (black histogram) have varied together. Right after the 2015 eruption, the rate of earthquakes was very low (~5/day) for several years until early 2018 when it started to gradually increase. The average rate of seismicity was ~35/day in 2018-2020, with peak days of up to several hundred per day. However, since mid-2020 while the rate of inflation has been decreasing, the rate of seismicity has been more variable, alternating between low and moderate rates rather than steadily increasing with time.

Near-real-time seismic data from the OOI-RCA sensors can be viewed at this web site (the Axial Seamount Earthquake Catalog produced by William Wilcock and Maochuan Zhang):

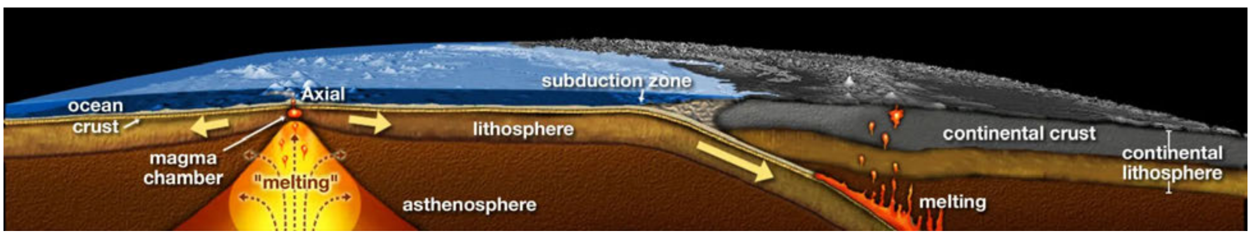
http://axial.ocean.washington.edu/ (http://axial.ocean.washington.edu/)

4. THE FUTURE

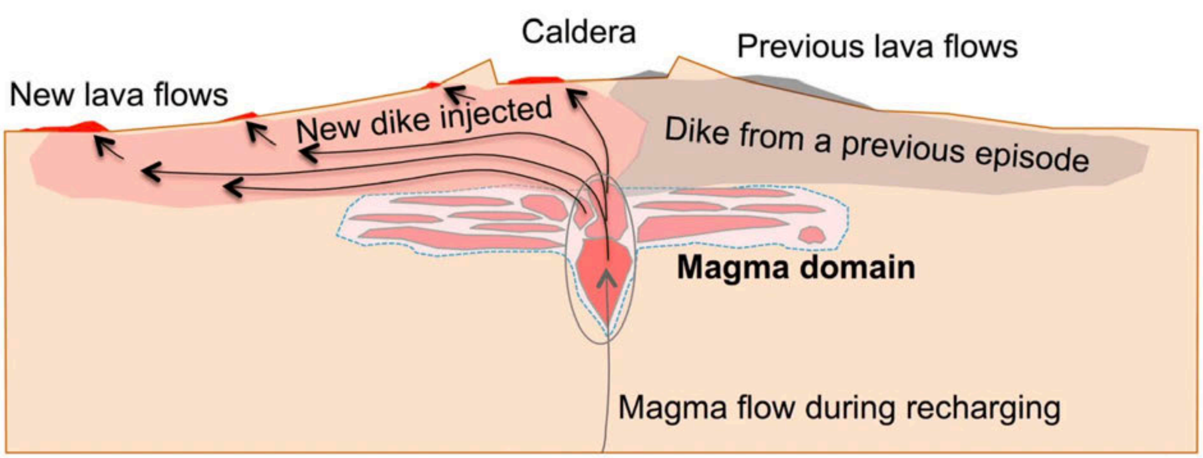
What does this mean for the future? With inflation on pause and the rate of seismicity low, Axial's future behavior and the timing of the next eruption are presently very uncertain.



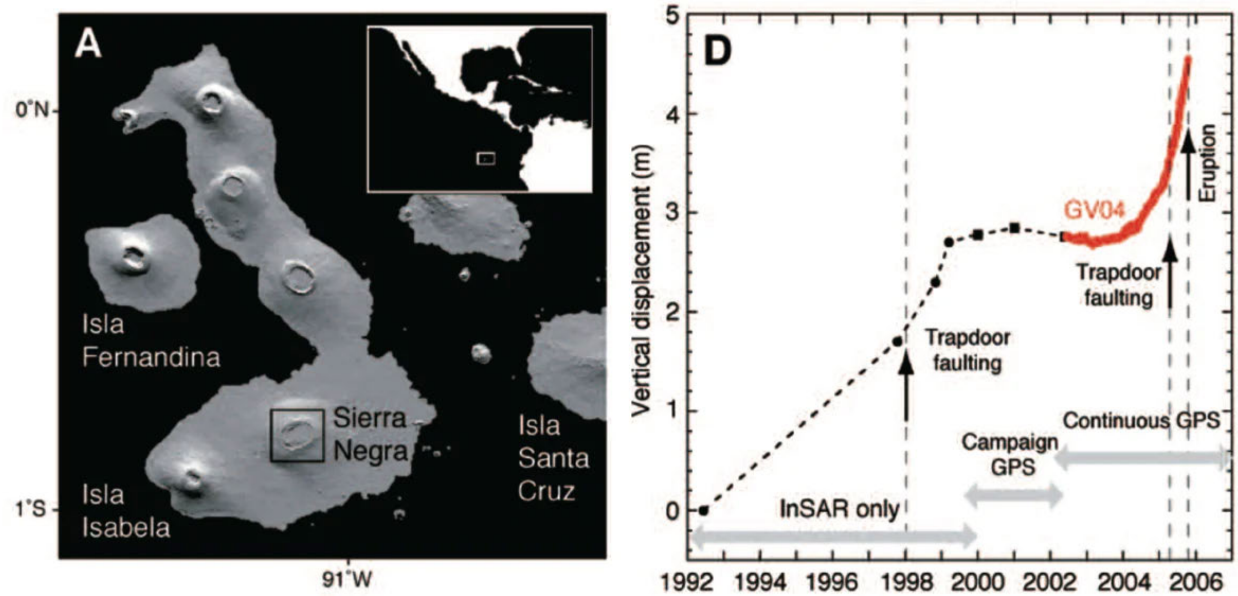
However, the longer-term eruptive history documented by mapping and dating lava flows at the summit shows that Axial has produced at least 50 eruptions in the last 800 years, an average of one every 15-18 years (figure above is slightly modified from Clague et al., 2013). This suggests that the current lull at Axial might not be long.



Axial's location on a seafloor spreading center also means that its tectonic environment should promote intrusions/eruptions at about the same frequency. The spreading rate on the Juan de Fuca Ridge is ~6 cm/yr, which can accommodate a 1-m wide dike every 17 years, on average.



Since Axial has two rift zones (north & south), and dikes only intrude into one or the other, the recurrence interval could be half that if the magma supply were sufficient (see figure above of an cross-section along Axial's rift zones from Sigmundsson, 2016).



The recent behavior Sierra Negra in the Galapagos (another basaltic hotspot volcano) shows that long-term inflation can be interrupted by short pauses. Before its 2005 eruption, Sierra Negra stopped inflating for several years, and even deflated slightly, before inflation resumed and quickly accelerated into the eruption (Chadwick et al. 2006).

ARTICLES
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Eruption at basaltic calderas forecast by magma flow rate

Federico Galetto[1,3] ✉, Valerio Acocella[1], Andrew Hooper[2] and Marco Bagnardi[2,4]

Forecasting eruption is the ultimate challenge for volcanology. While there has been some success in forecasting eruptions hours to days beforehand, reliable forecasting on a longer timescale remains elusive. Here we show that magma inflow rate, derived from surface deformation, is an indicator of the probability of magma transfer towards the surface, and thus eruption, for basaltic calderas. Inflow rates ≥0.1 $km^3 yr^{-1}$ promote magma propagation and eruption within 1 year in all assessed case studies, whereas rates <0.01 $km^3 yr^{-1}$ do not lead to magma propagation in 89% of cases. We explain these behaviours with a viscoelastic model where the relaxation timescale controls whether the critical overpressure for dyke propagation is reached or not. Therefore, while surface deformation alone is a weak precursor of eruption, estimating magma inflow rates at basaltic calderas provides improved forecasting, substantially enhancing our capacity of forecasting weeks to months ahead of a possible eruption.

Modeling by Galetto et al. (2022) suggests that eruptions at basaltic calderas can be delayed when the rate of shallow magma supply is too low. Therefore, an increase in the rates of inflation and seismicity (and magma supply) may be necessary before Axial Seamount is ready to erupt again.

AUTHOR INFO

First author Bill Chadwick can be reached at william.w.chadwick@gmail.com or bill.chadwick@oregonstate.edu

ABSTRACT

Axial Seamount is a submarine basaltic hotspot volcano superimposed on the Juan de Fuca Ridge. It has had a continuous but variable magma supply since systematic inflation monitoring began with bottom pressure recorders in 1997. Three observed eruptions since then suggest the volcano erupts at a similar level of inflation each time. Since the last eruption in 2015, Axial has re-inflated to ~94% of its previous threshold. However, the rate of inflation has gradually decreased from >100 cm/yr to <10 cm/yr, and as of August 2023, inflation has essentially stopped. Inflation is monitored in real-time by a network of tilt and pressure sensors on the NSF-funded Ocean Observatories Initiative Regional Cabled Array (OOI-RCA).

Similarly, the rate of seismicity (also monitored by the OOI-RCA) is currently at relatively low levels of ~10/day, compared with a rates of ~1000/day in the months leading up to the 2015 eruption. Right after the 2015 eruption, the rate of earthquakes was very low (~5/day) for several years until early 2018 when it started to gradually increase. The average rate of seismicity was ~35/day in 2018-2020, with peak days of up to several hundred per day. However, since mid-2020 while the rate of inflation has been decreasing, the rate of seismicity has been more variable alternating between low and moderate rates, rather than steadily increasing with time.

With inflation on pause and the rate of seismicity low, Axial's future behavior and the timing of the next eruption is very uncertain. The longer-term eruptive history documented by Clague et al. (2013) by mapping and dating lava flows at the summit showed that Axial had produced at least 49 eruptions in the last 800 years, an average of one every 15-18 years. This might suggest that the current lull at Axial will be temporary, consistent with the recent behavior of some other basaltic calderas like Sierra Negra in the Galapagos. Axial's location on a seafloor spreading center also implies that its tectonic environment should also promote intrusions/eruptions at about the same frequency. But modeling by Galetto et al. (2022) suggests that eruptions at basaltic calderas can be delayed when the rate of shallow magma supply is too low. Therefore, an increase in the rates of inflation and seismicity (and magma supply) may be necessary before Axial Seamount is ready to erupt again.

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