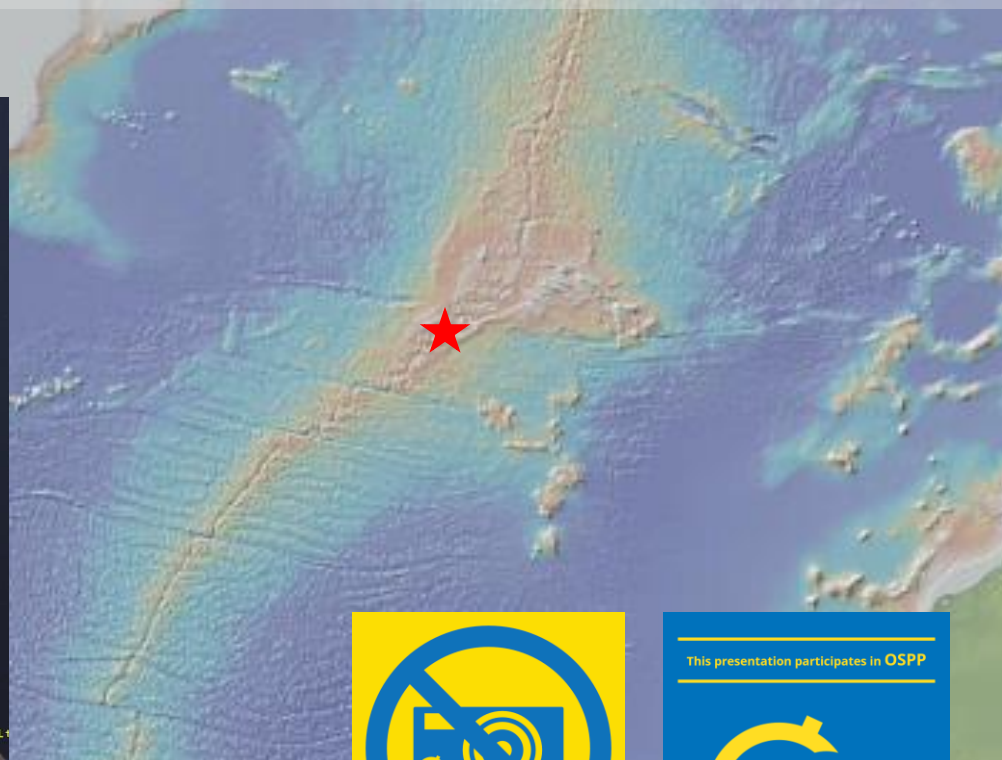


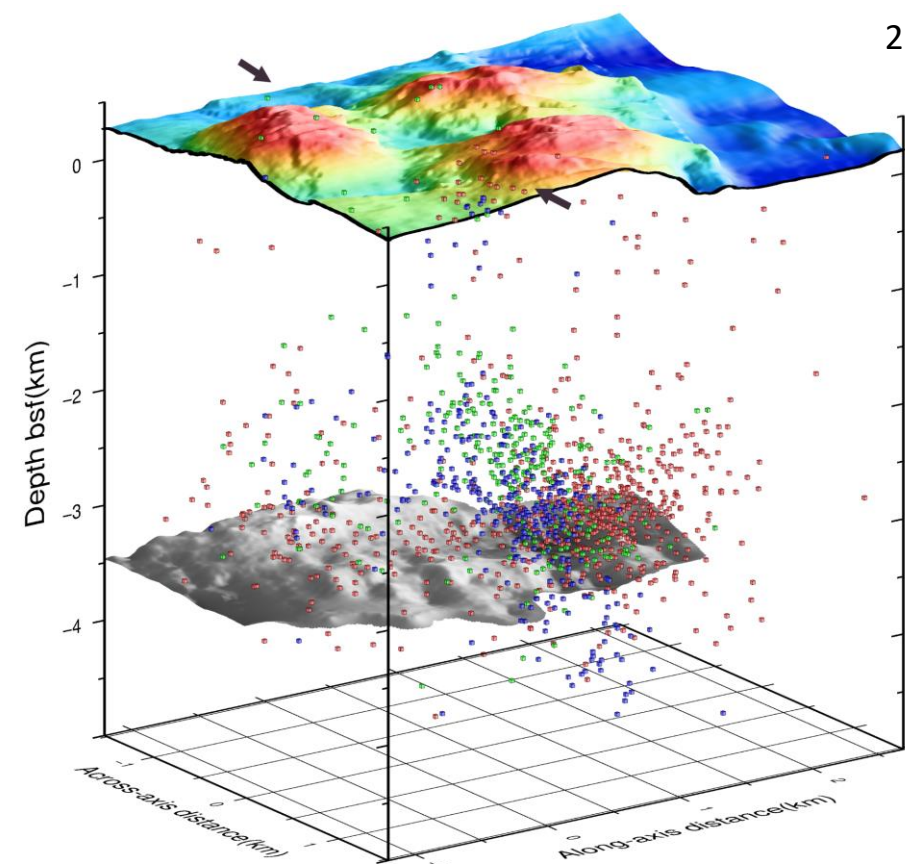
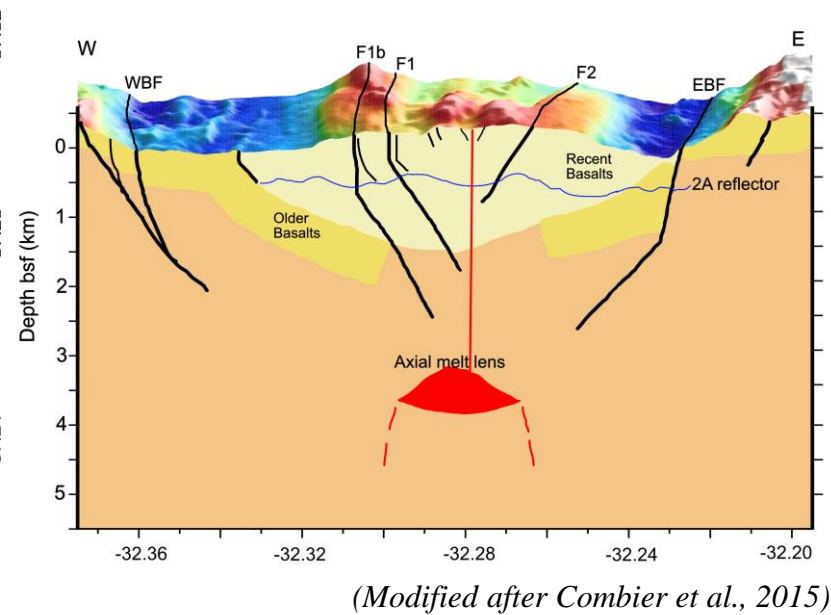
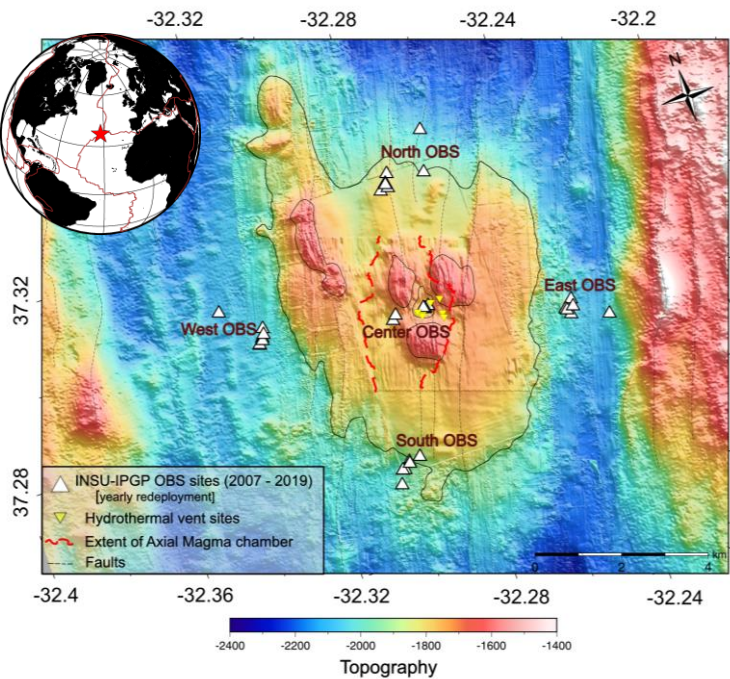
Seismic Constraints on Hydrothermal Circulation and Magmato-Tectonic Interactions beneath Lucky-Strike Volcano, Mid-Atlantic Ridge

Soumya Bohidar (soumya@ipgp.fr), Wayne Crawford, and Mathilde Cannat

Equipe de Géosciences Marines, Institut de Physique du Globe de Paris, Université de Paris Cité, Paris, France



Sources of Seismicity:



Time periods with at least 4 working OBSs:
(part of European Multidisciplinary Seafloor and water-column Observatory(EMSO)-Azores)

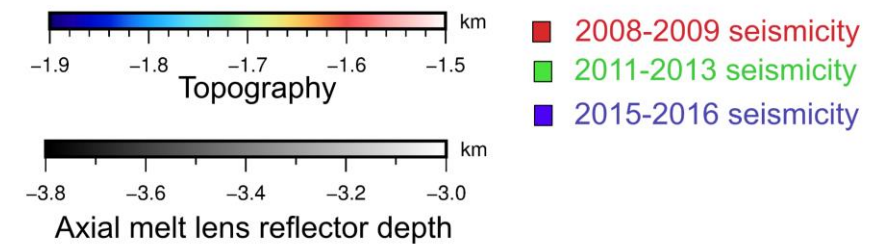


- Hydrothermal field on the top of the volcano
- Axial magma chamber (AMC): 3-3.8km beneath the sea floor

1. Seismic events present in a narrow bin in N-NW of the hydrothermal field just above the AMC
2. Very small magnitude seismic events (ML: -1 to 0)
3. Mixed (Normal and thrust) focal mechanisms



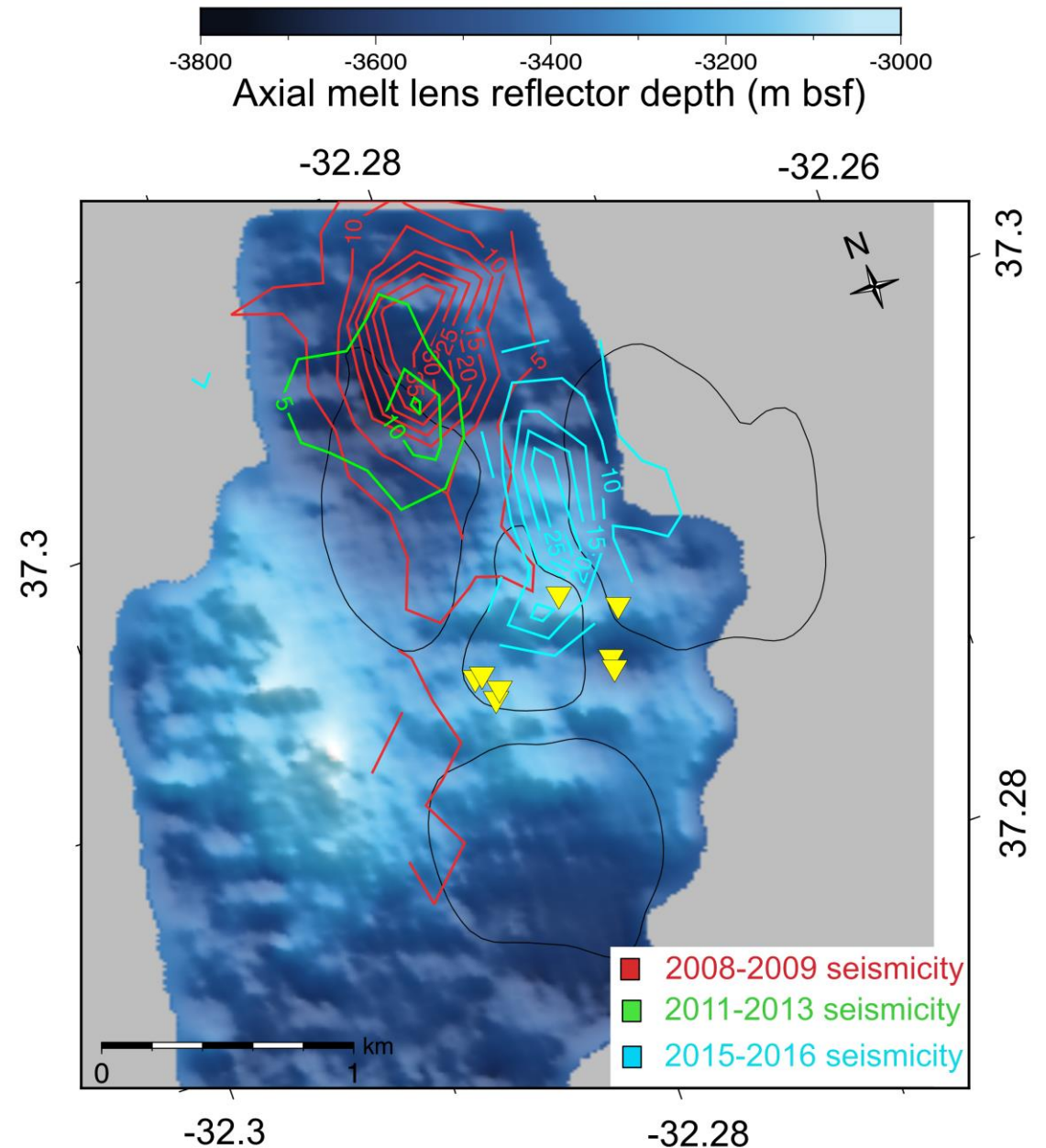
Thermal contraction of rocks at the base of downflow/heat extraction zone of an along axis hydrothermal circulation



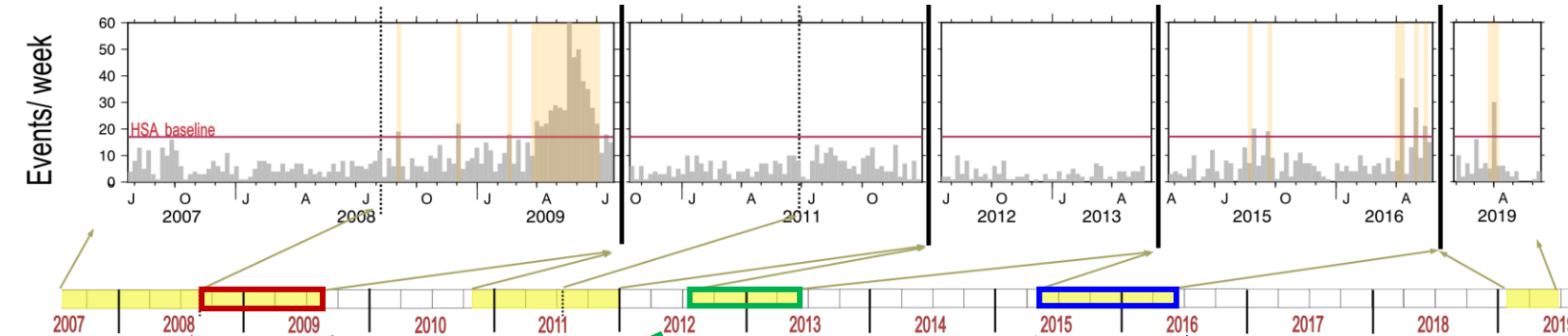
Shifts of the main domain of heat extraction with time:

3

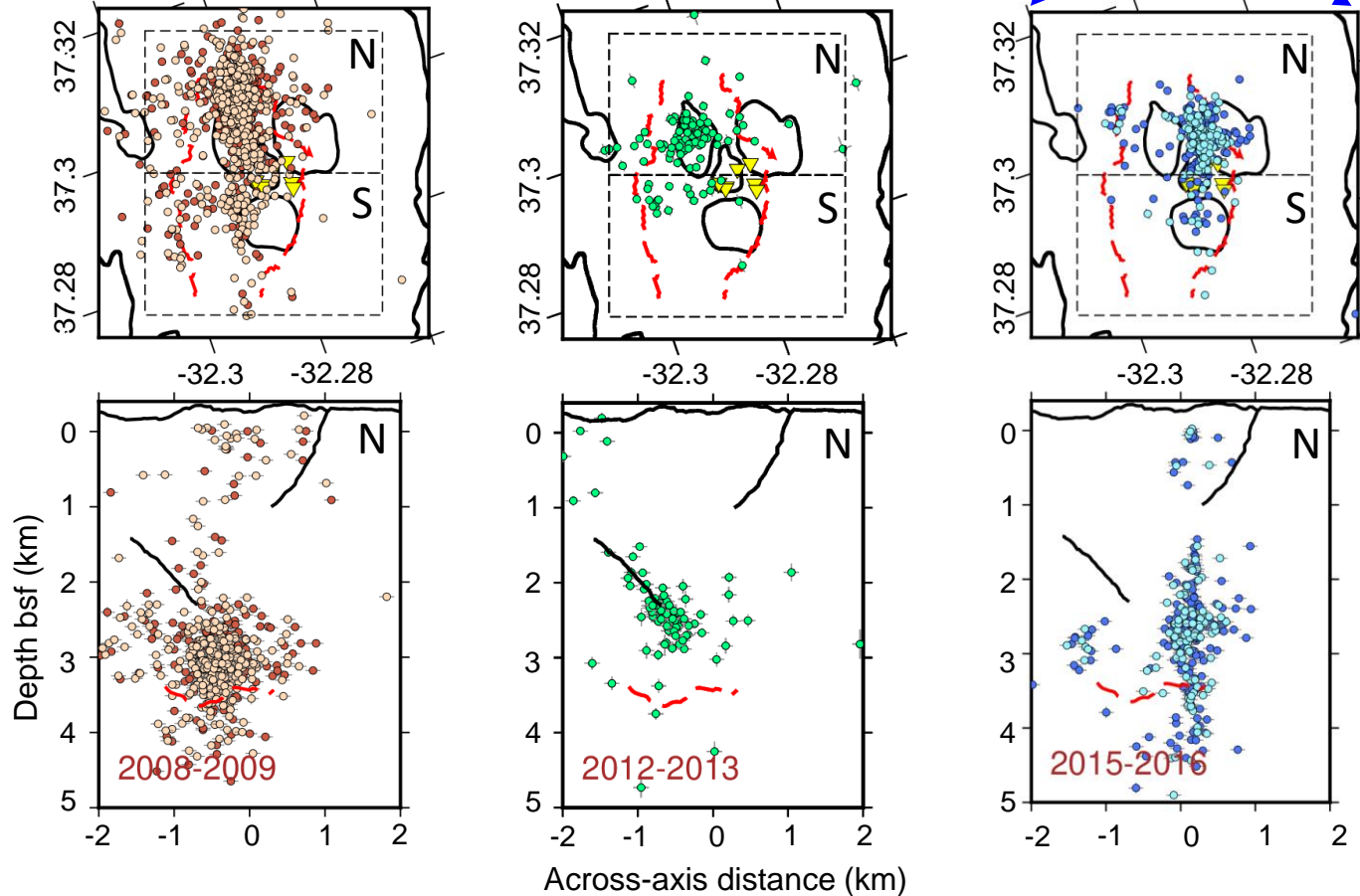
- 2 shifts:
 - In between 2007-2009 to 2010-2013: Moved ~550m South
 - In between 2013 to 2015-present: Moved ~600m East
- Possible mechanisms:
 - Relocation of heat extraction zone to a shallower part of the AMC.
 - Relocation of heat extraction zone to recent magmatic injections.
 - Tectonically driven change in the hydrothermal fluid pathways.



Change in seismicity pattern:



Average seismic rate: 8.6 events/week



2008-2009

- Clustered in a patch just above the AMC reflector

2012 - 2013

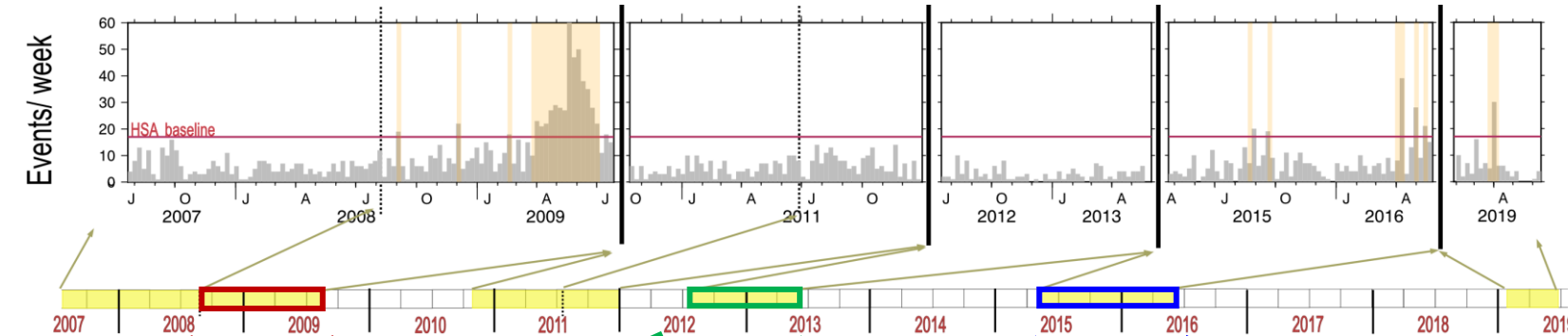
- Strong alignment with the trace of the normal fault

2015 - 2016

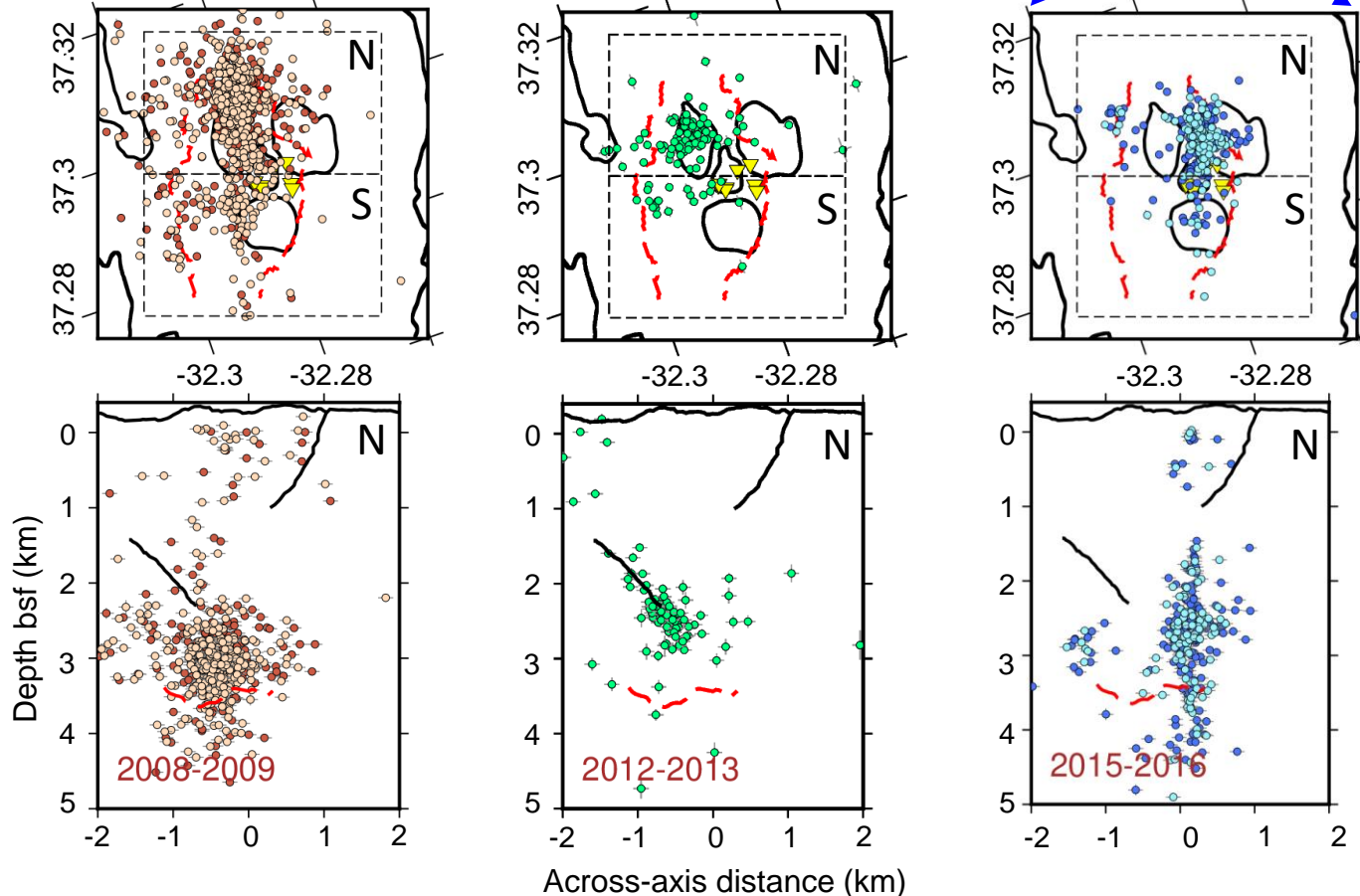
- Formed a pipe-like distribution between the AMC and seafloor

Tectonic and Magmatic processes along with the hydrothermal circulation affect the spatio-temporal variations in seismicity.

Higher Seismic Activity(HSA) periods:



- Average seismic rate: 8.6 events/week
- Higher Seismic Activity (HSA) period: $2 * \text{Avg. seismic rate}$
- 3 Major HSA periods



2008-2009 HSA period:

- Lasted ~13 weeks

2015 – 2016 HSA periods:

- Short-lived and consisted of smaller seismic swarms

In all HSA periods, seismicity pattern remained same as the background events.

Enhanced seismicity is probably caused by downward propagation of the hydrothermal circulation and/or dike injections.

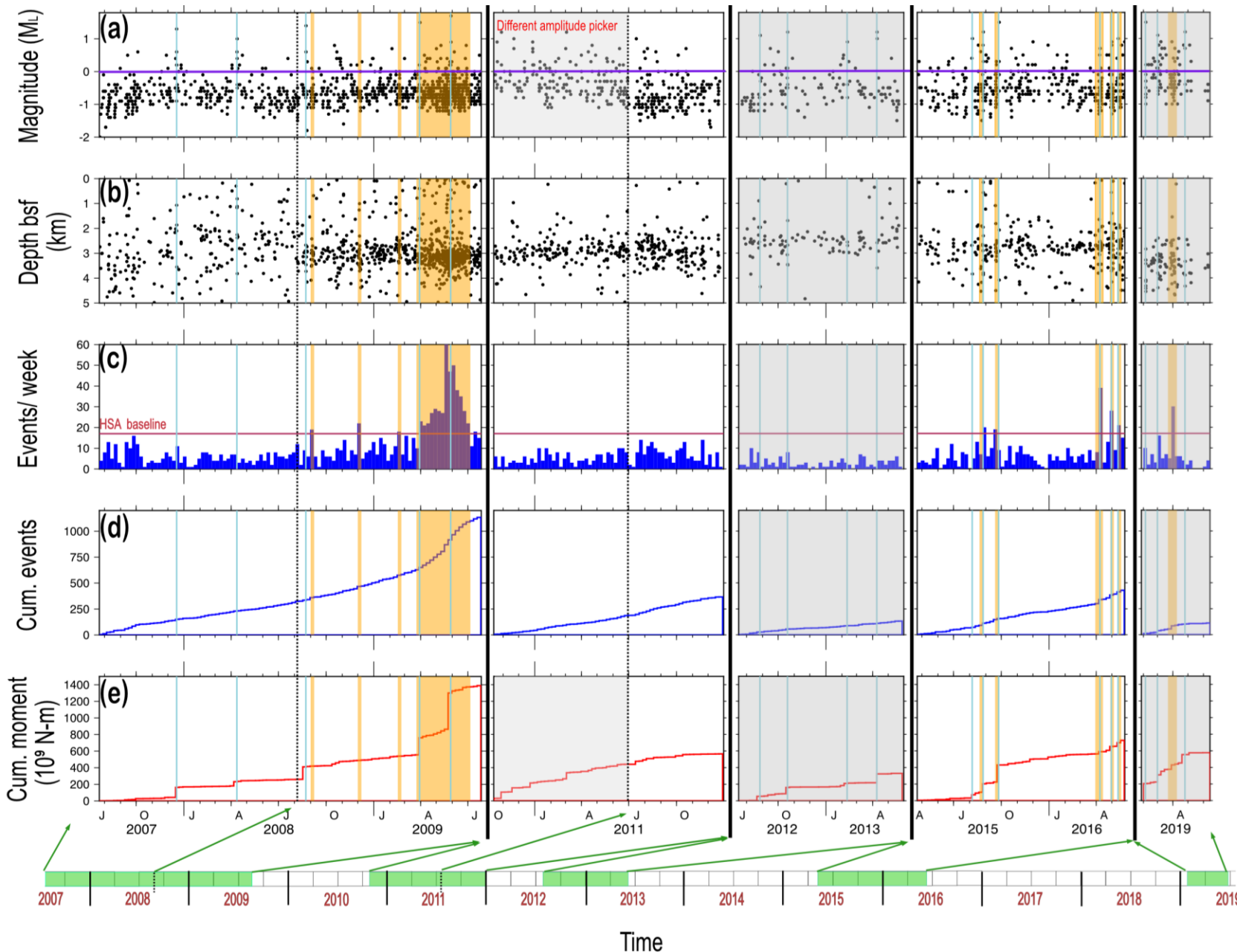
The major source of seismicity observed beneath Lucky Strike volcano is proposed to be **thermal contraction at the base of hydrothermal circulation. Seismicity distribution** supports a mostly single cell **along-axis** hydrothermal flow geometry **with the downflow zone to the N-NW of the hydrothermal field (upflow zone).**

- The main domain of heat extraction gradually **moved ~550m South and then ~600m East over 12years of survey, driven by recent magmatic injections and/or change in fluid pathways.**
- The seismicity pattern also changed **from a patch above the AMC to a pipe like structure** over time.
- Several periods of higher seismicity are interpreted as **episodes of enhanced thermal cracking.**

These changes may be related to melt injection, or to axial tectonics opening for new fluid pathways.

Thank you

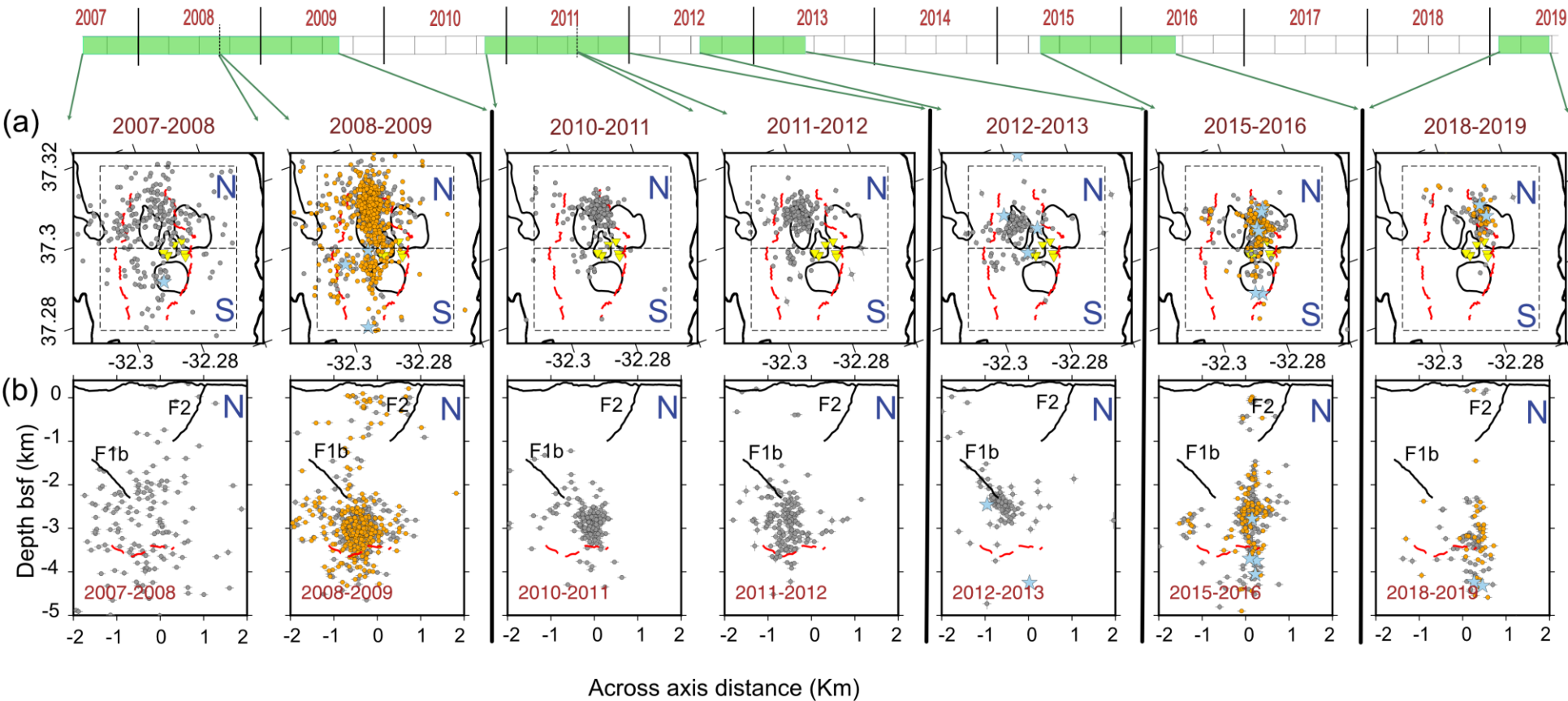
Results: Temporal variation in seismicity



- Magnitude Range (ML) : -1 to 0
- Depth: 2.5 to 3.5 km bsf
- Average seismic rate: 8.6 events/week
- Higher Seismic Activity (HSA) period: $2 * \text{Avg. seismic rate}$
- 3 Major HSA periods:
 1. End of March – July 2009
 2. August – September 2015
 3. March – May 2016

NB: Time scale is not continuous!

Results: Spatial variation in seismicity



2007-2009

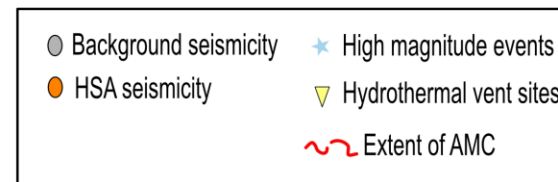
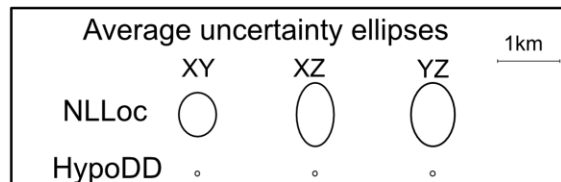
- Events clustered N-NW of hydrothermal field.
- Depth: 0-1km above the AMC

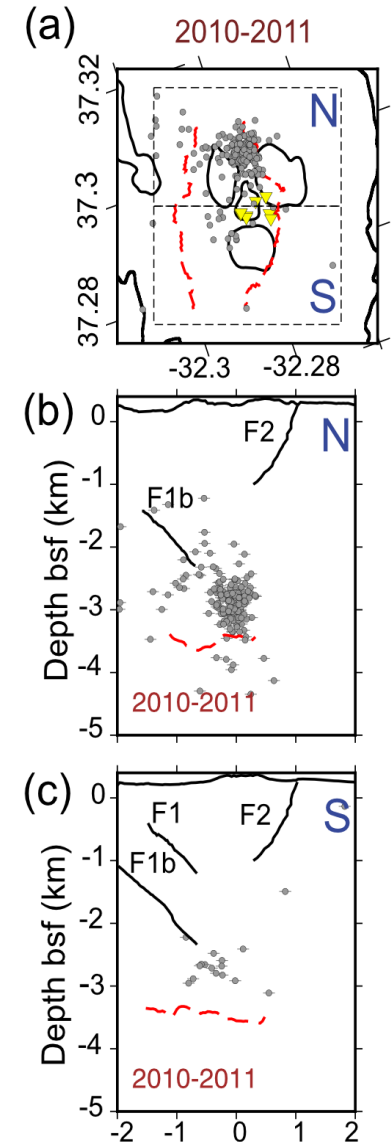
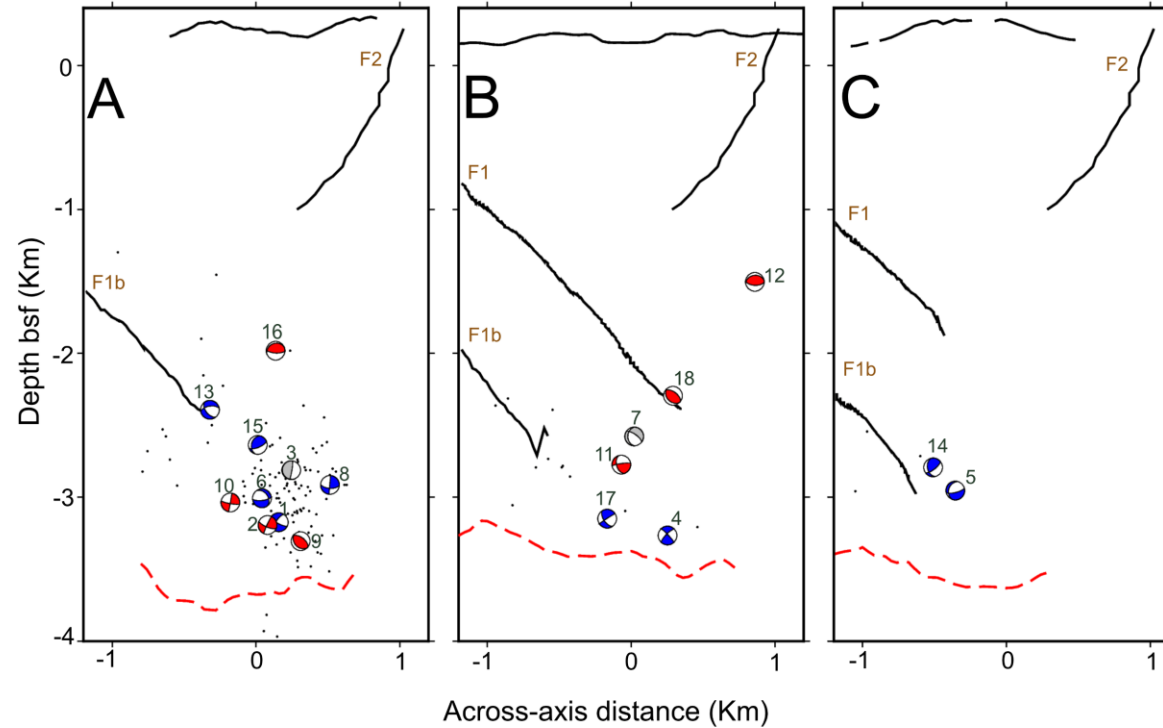
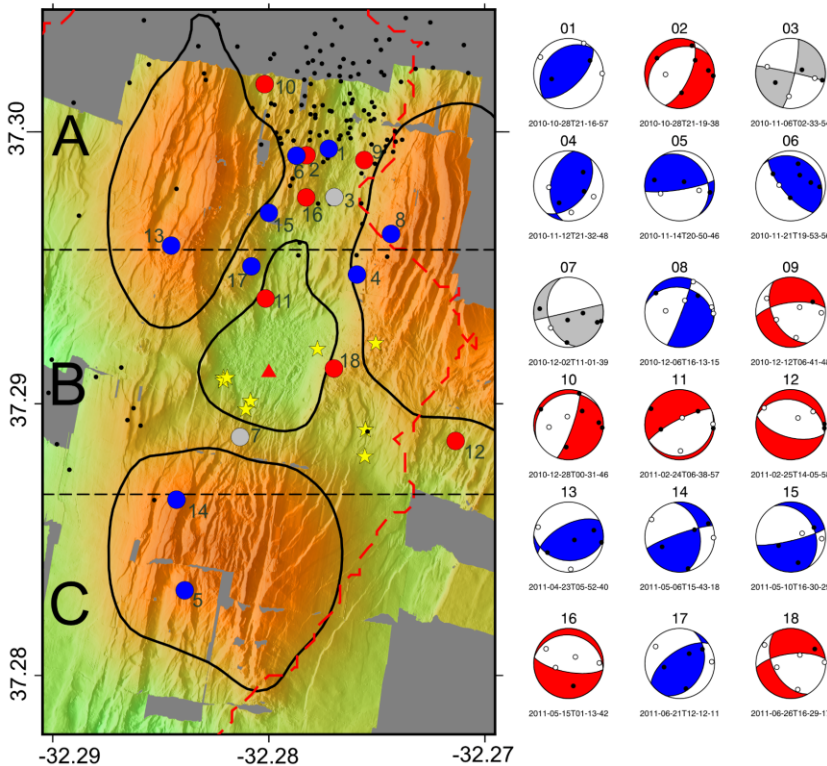
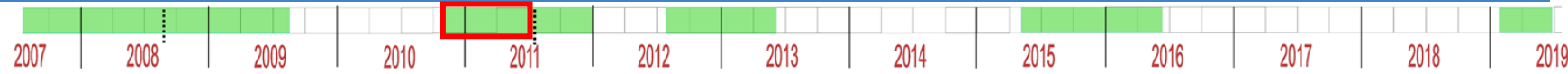
2010-2013

- The locus of the seismicity moved gradually South
- Strong alignment along the trace of F1b fault.

Post-2015

- Locus of the seismicity had shifted significantly.
- Events appeared to align along a pipe-like structure.

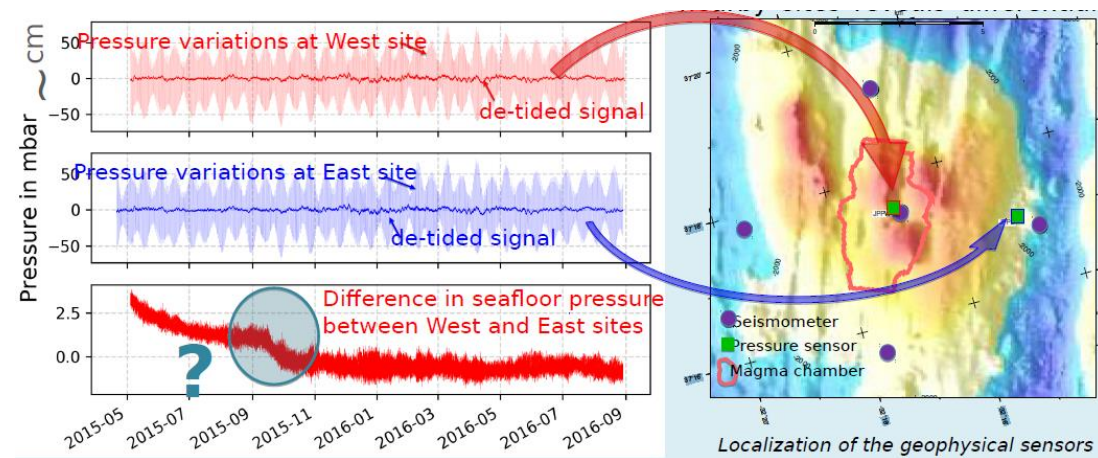
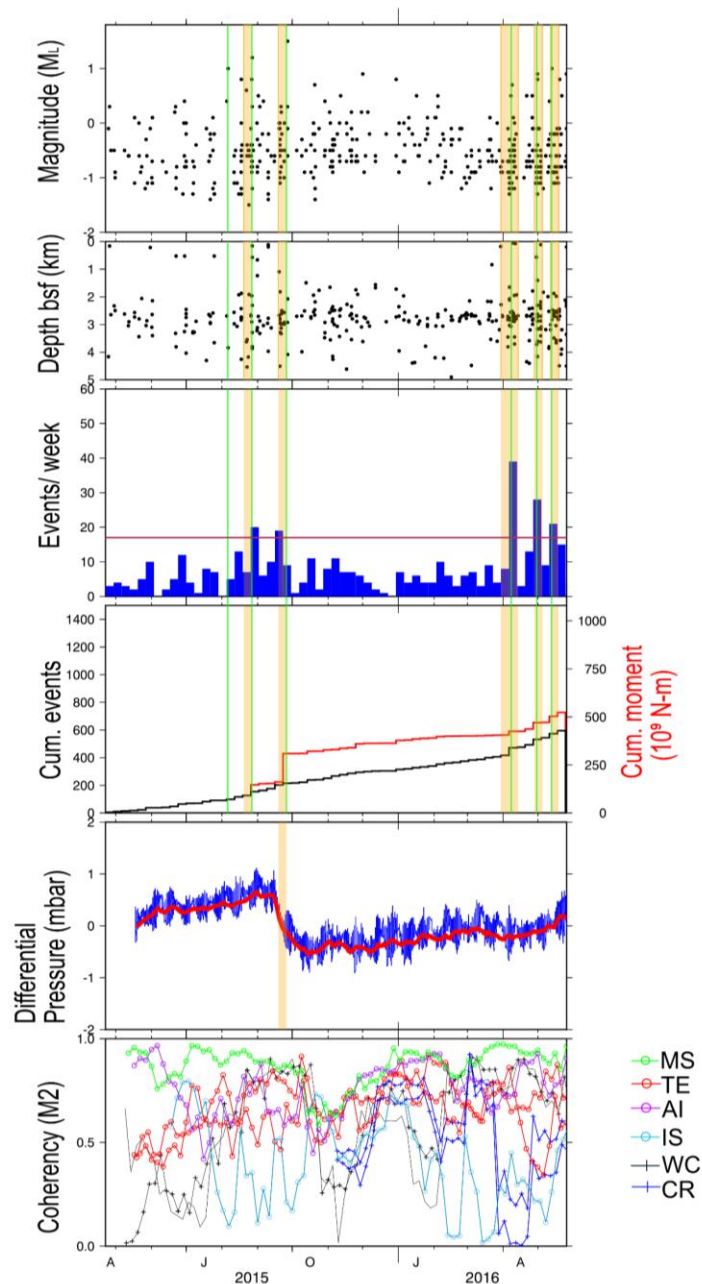




- 18 events from 2010 -2011
 - 9 thrust, 7 normal and 2 strike/slip mechanisms

- *No correlation with the seismically-imaged normal faults nor any obvious pattern in the source properties.*
- *Tectonic fault - related events probably get obscured in other periods by magmatism and hydrothermal cooling.*

Discussion: Correlation with September 2015 seafloor deformation event:



Pressure data from: Ballu et. al, EGU-2019

- Difference in seafloor pressure recorded at East and West side in September 2015
- Higher Seismic activity period observed in August to September 2015
- Lower coherence between in tidal pressure and hydrothermal fluid temperature observed in Late October and November 2015

Discussion: Effect of the AMC

Almost all events are located above the AMC reflector



AMC reflector defines the seismogenic layer

Few events located below the AMC reflector

- Post - 2015: close/outside the Eastern boundary of the AMC



Brittle lower crust present: possible to have a deep seismic event

- 2009 HSA period: within the later bound of the AMC



The location uncertainty covers most of the deep events

Deepening of the AMC of almost 1km is not possible in such time period

