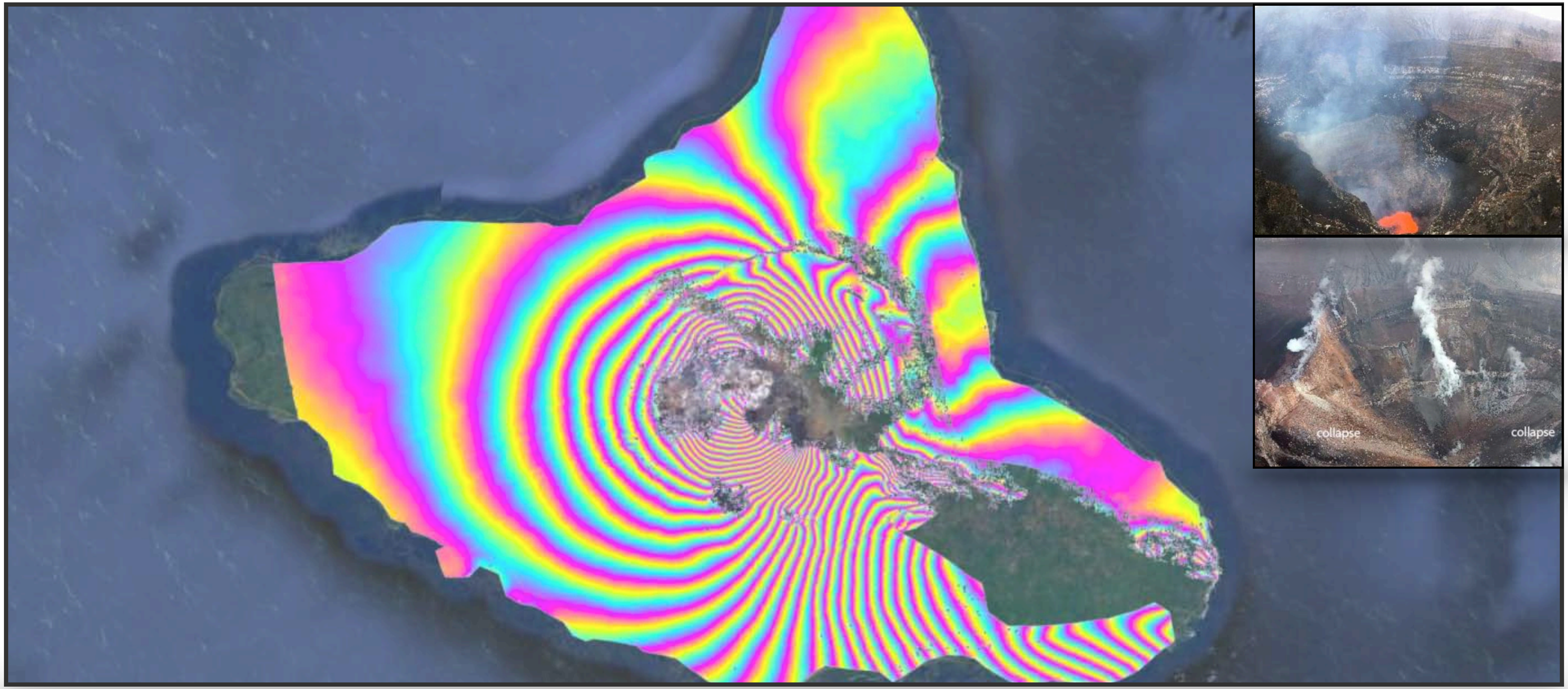
From prodigious volcanic degassing to caldera subsidence and quiescence at Ambrym: the influence of regional tectonics



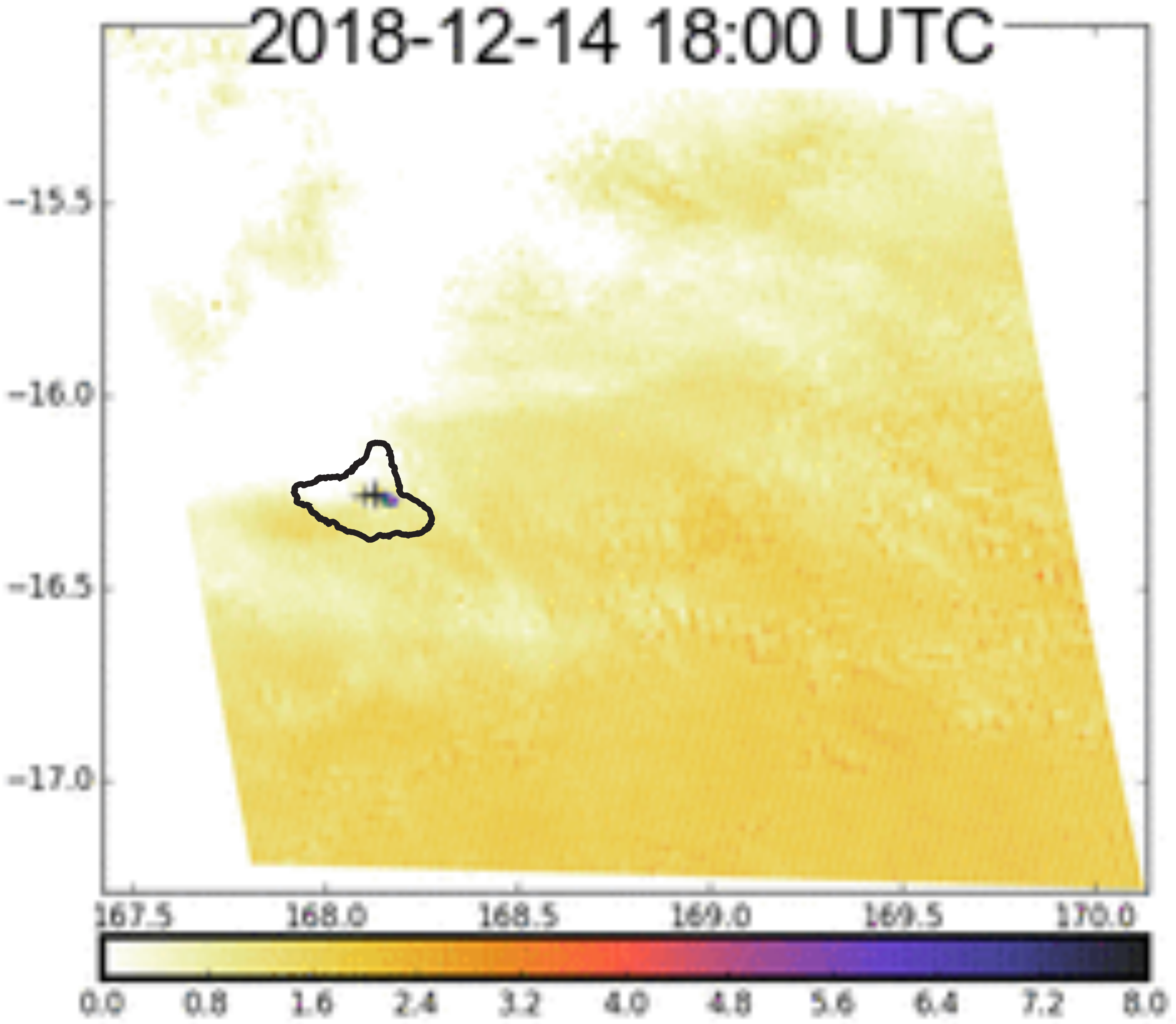
Tara Shreve, Raphaël Grandin, Marie Boichu, Esline Garaebiti, Valérie Ballu, Francisco Delgado, Frédérique Leclerc, Martin Vallée, Nicolas Henriot, Sandrine Cevuard, Dan Tari, Pierre Lebellegard, and Bernard Pelletier

Lamont-Doherty Earth Observatory
Columbia University | Earth Institute

2018 Kilauea summit caldera collapse

Neal, et al. 2019

…but if we don’t have summit-mounted cameras?



Himawari-8

Why is the Ambrym December 2018 event important?

- Through the joint analysis of **8 earth observation satellites,** we observe **caldera ring-fault activation** and **caldera-wide subsidence** caused by magma reservoir draining into the SE Rift zone

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Shreve, et al. 2019. *Scientific Reports,* in press.

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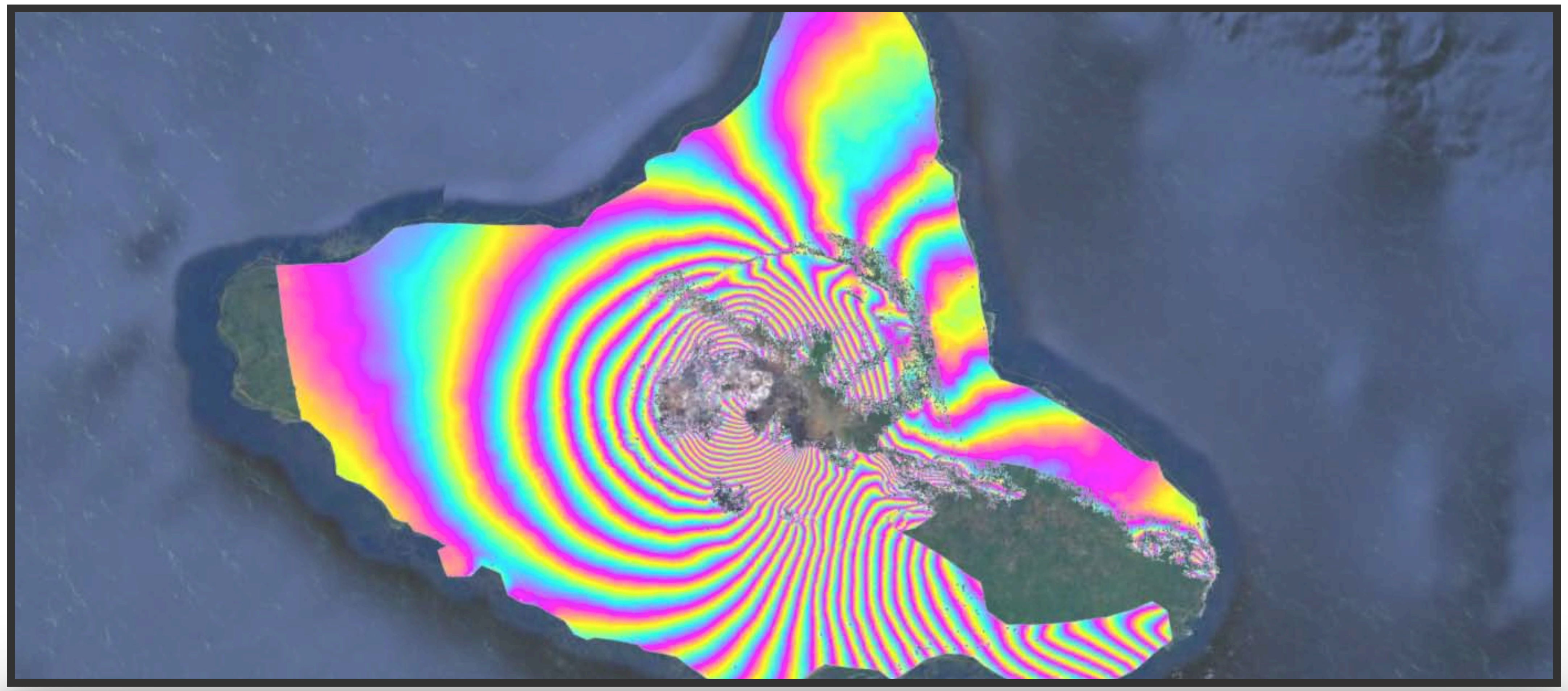
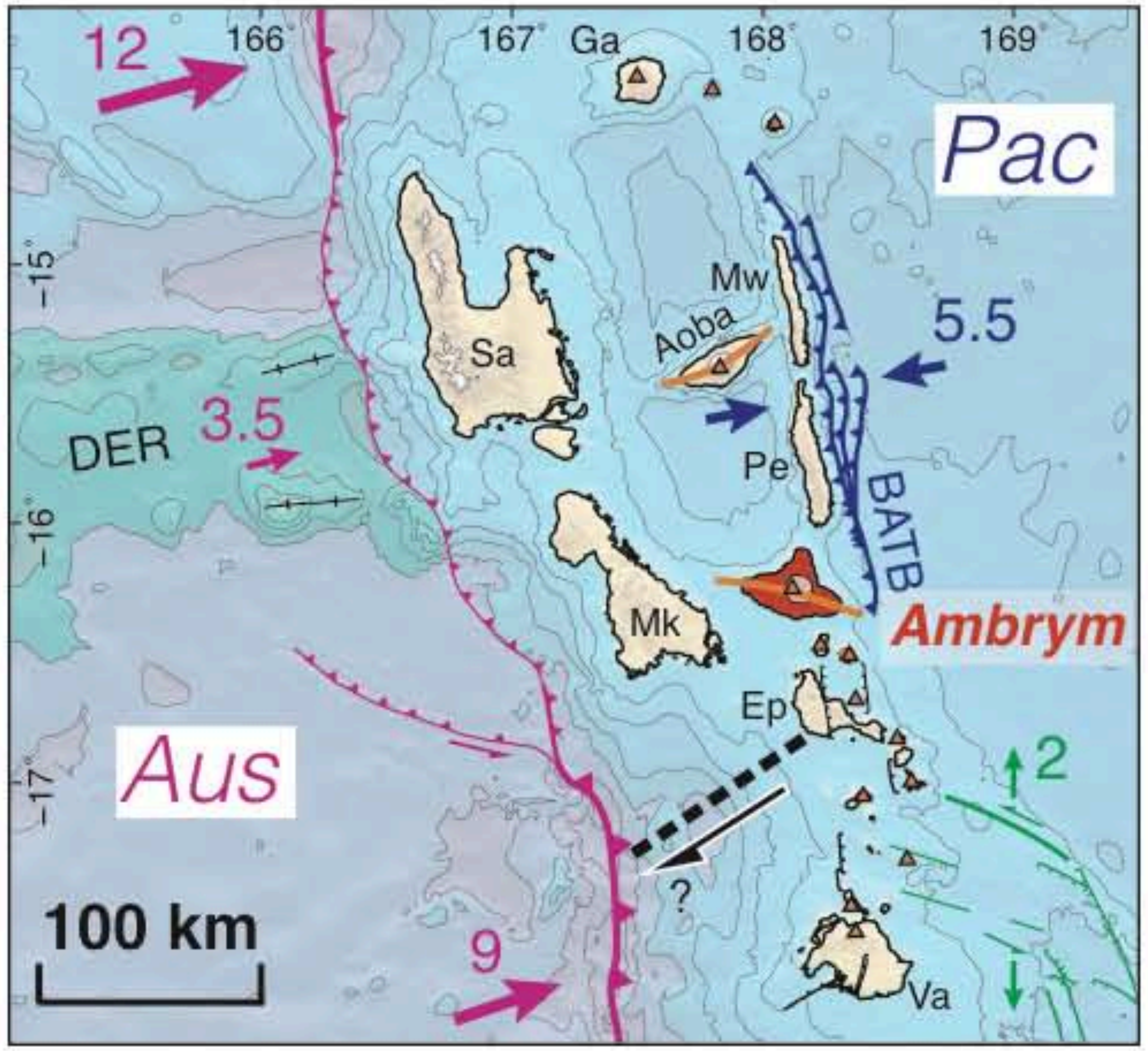
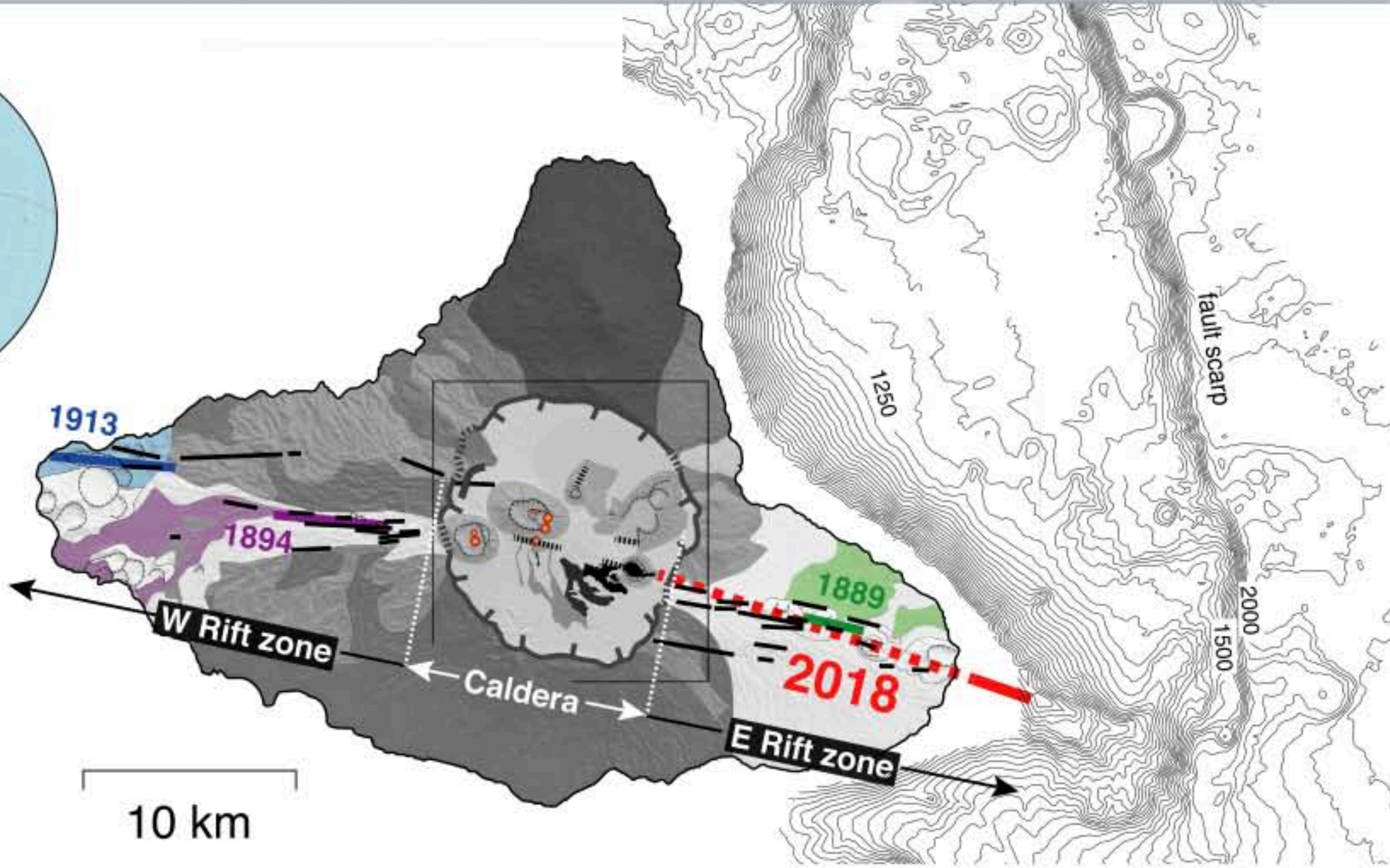


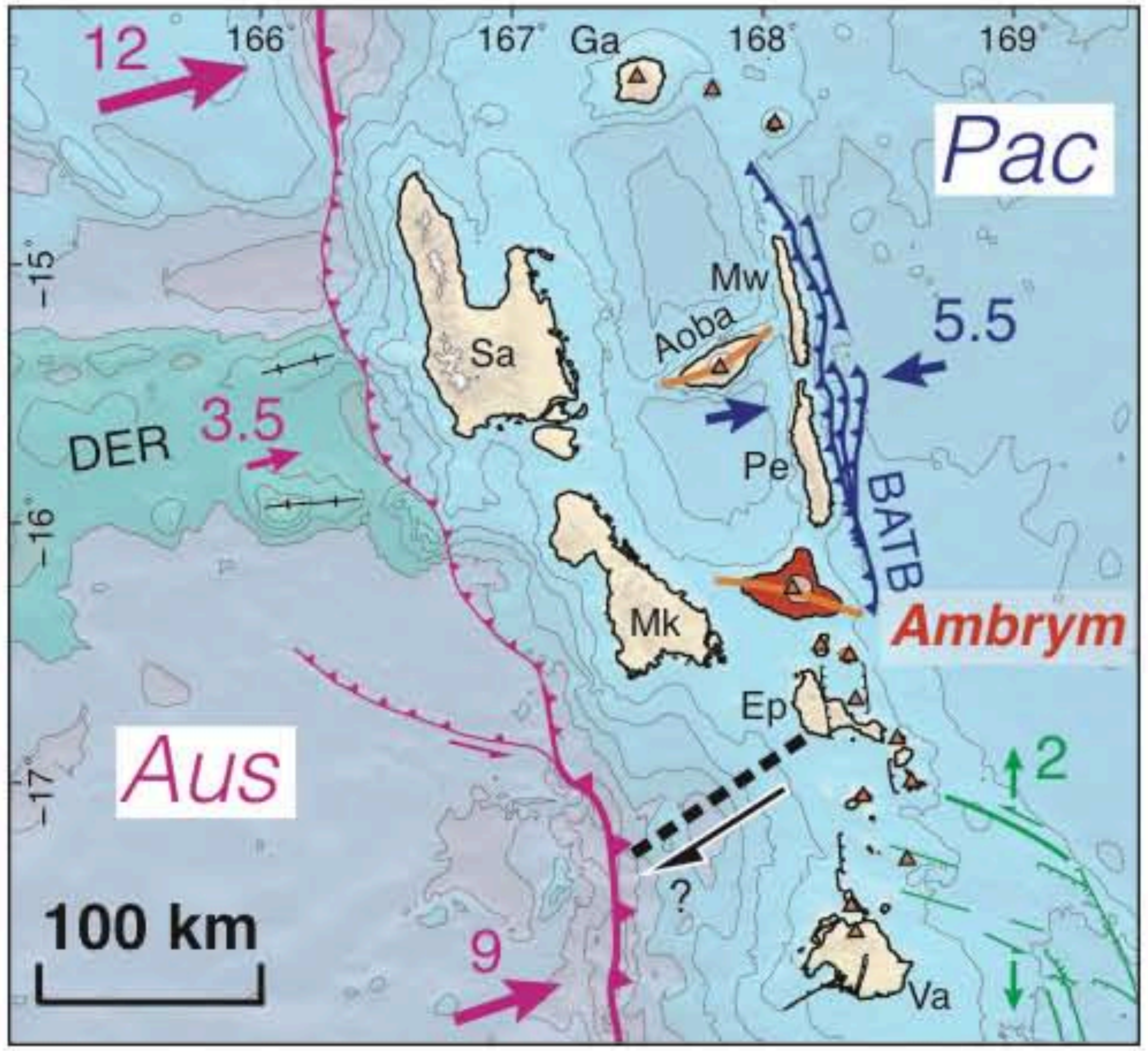
- Investigate how regional tectonic stresses control magma transport and **progressive caldera subsidence** at broad, basaltic calderas

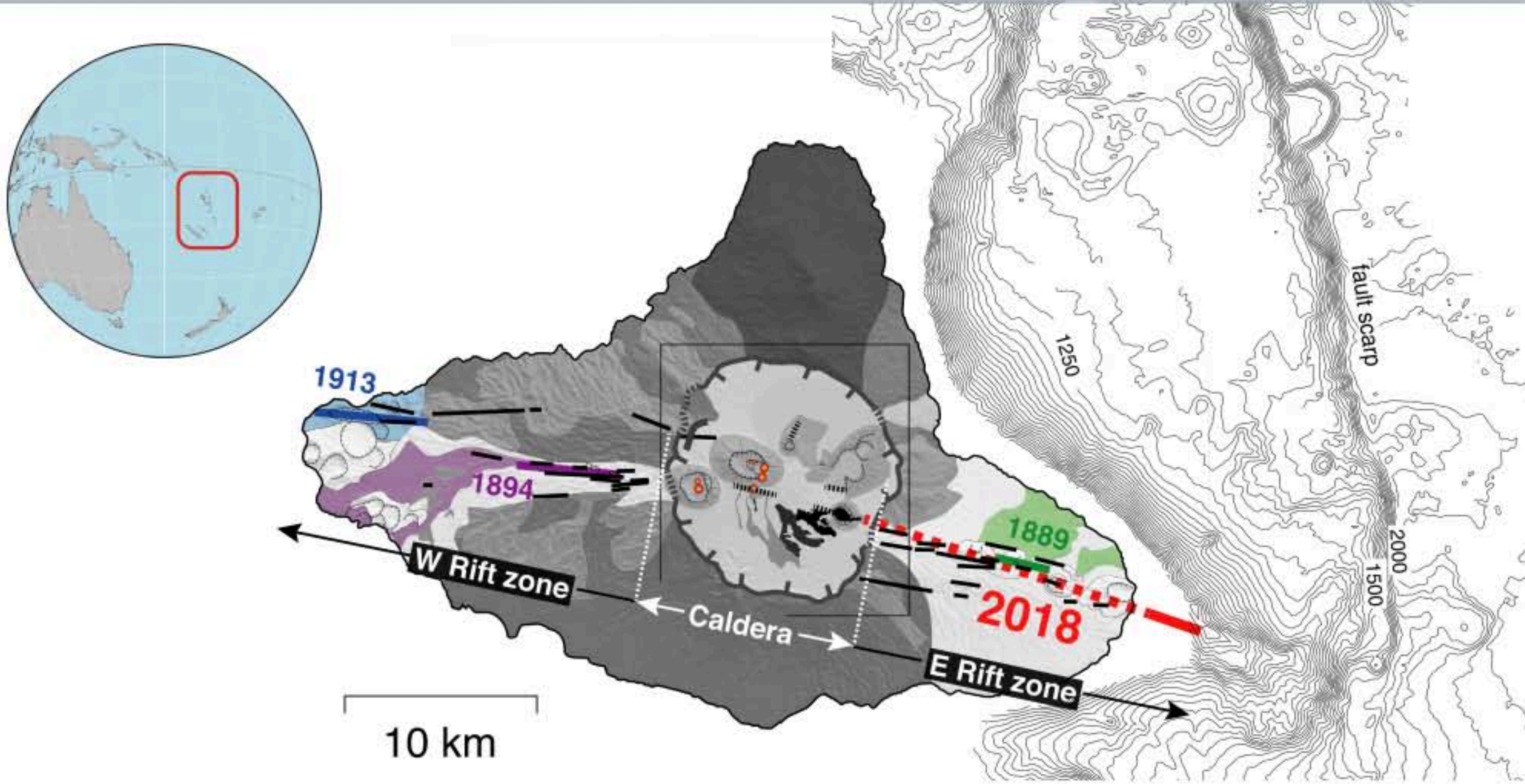




Adapted from McCall, 1970 and Lagabrielle, et al 2003

- Located in **central portion of Vanuatu Subduction Zone**, which is perturbed by the **collision of D'Entrecastetaux Ridge**
- **Close proximity to back thrust,** whose end terminates east of Ambrym Island
- Basaltic volcanic island that hosts a **12 km-wide caldera** with two main craters
- Both **intra-caldera** (lava lakes, fissure eruptions) and **extra-caldera** (rift intrusions, phraetomagmatic eruptions) **activity**





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Tectonics

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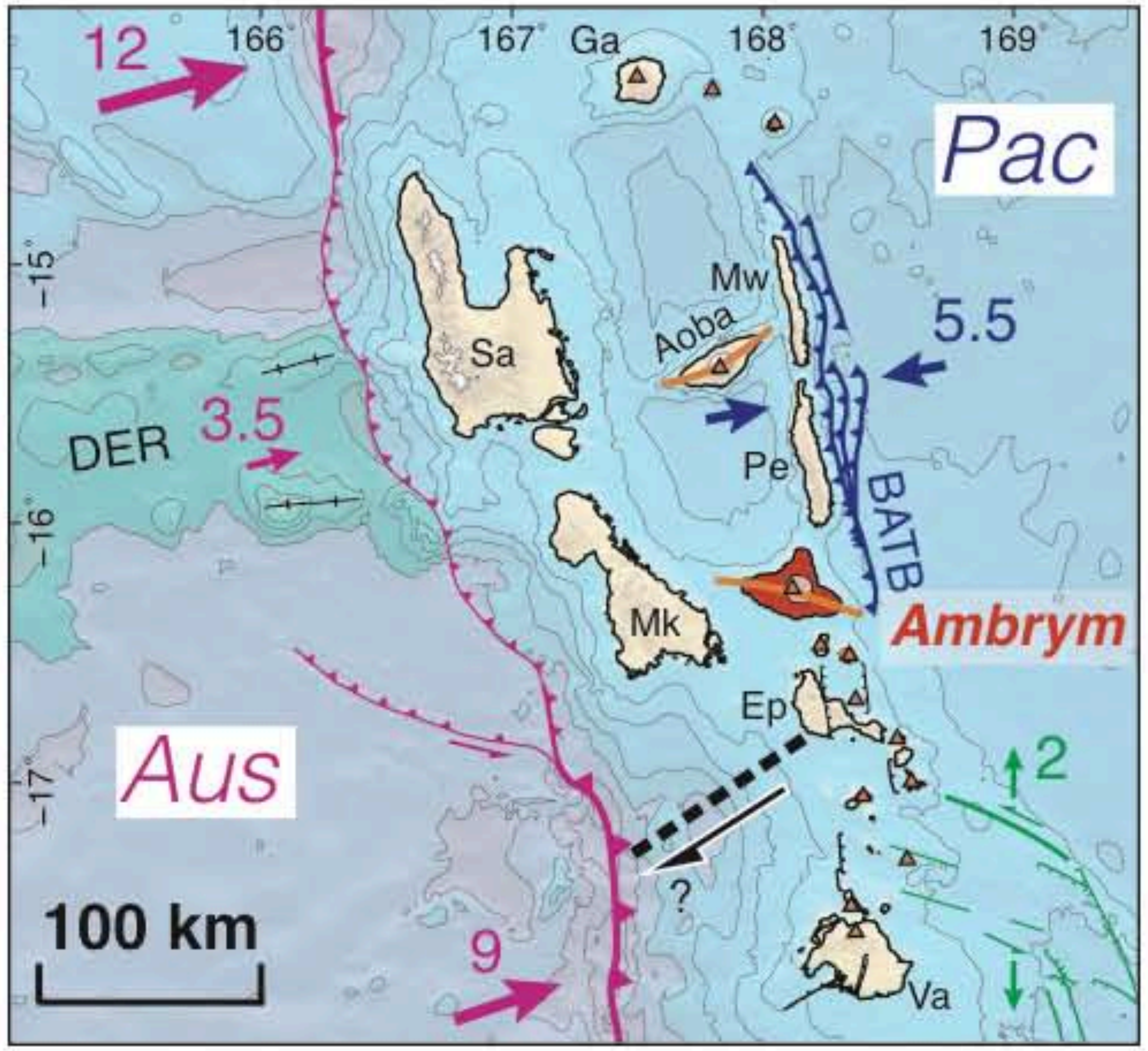

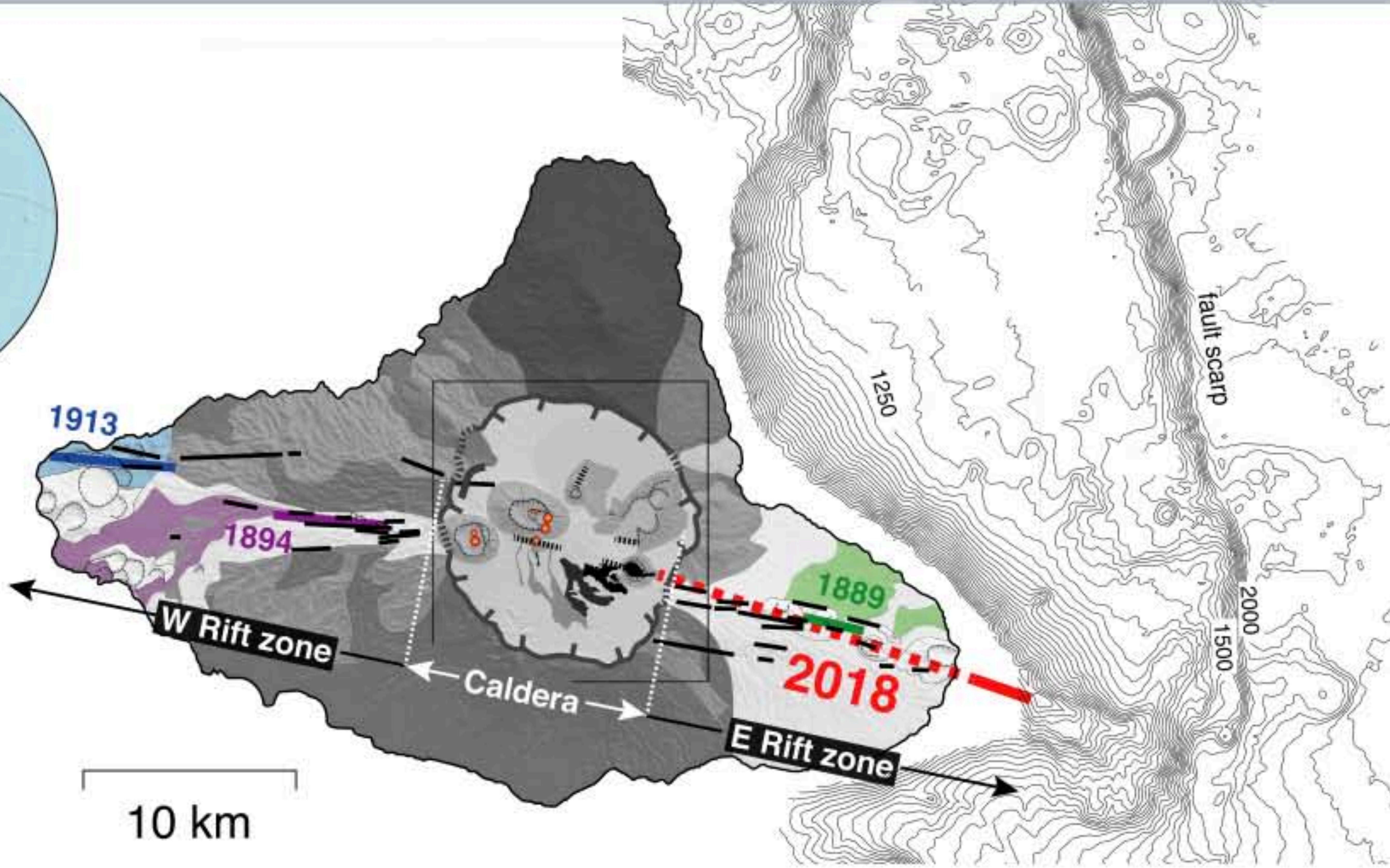

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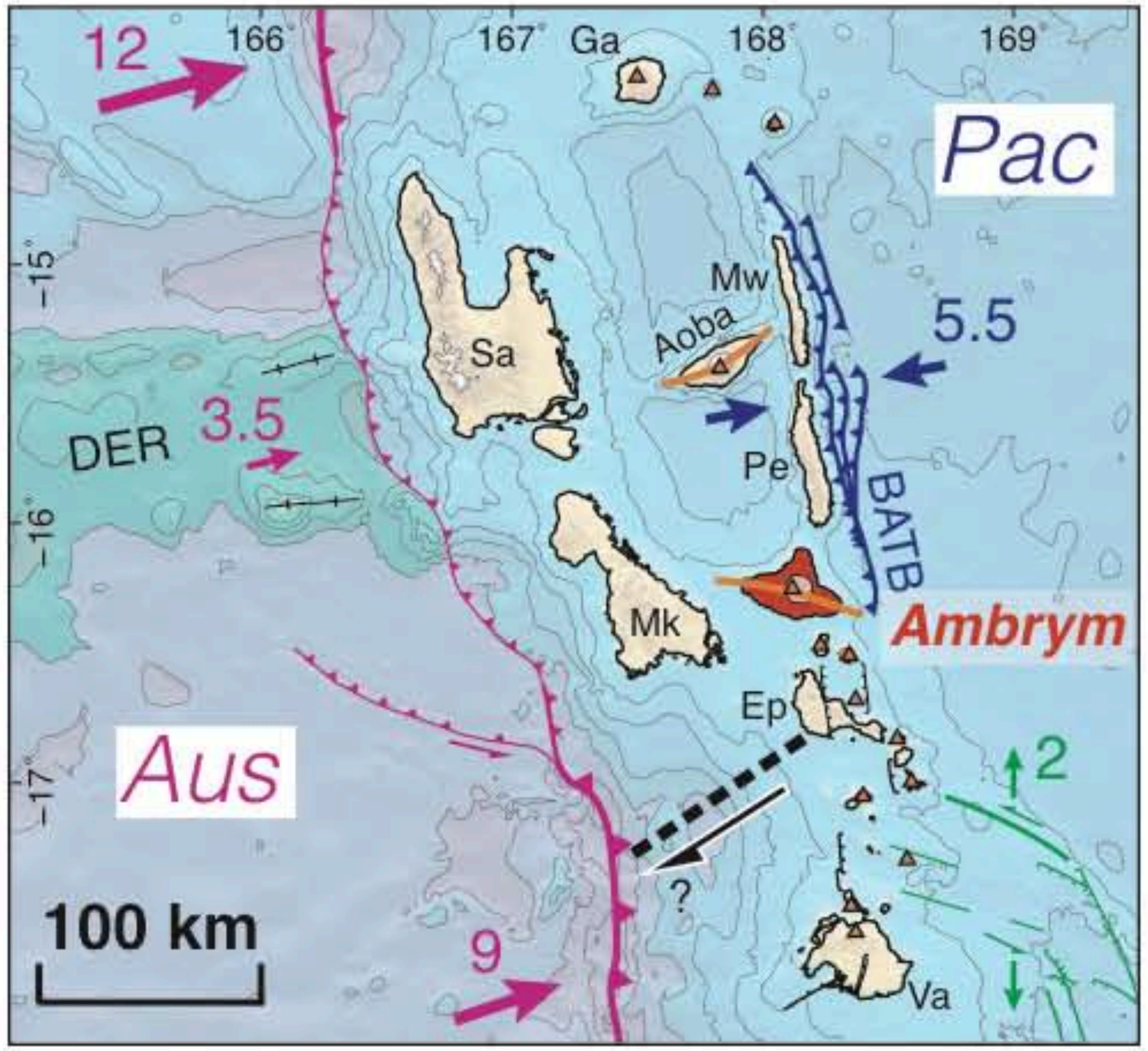

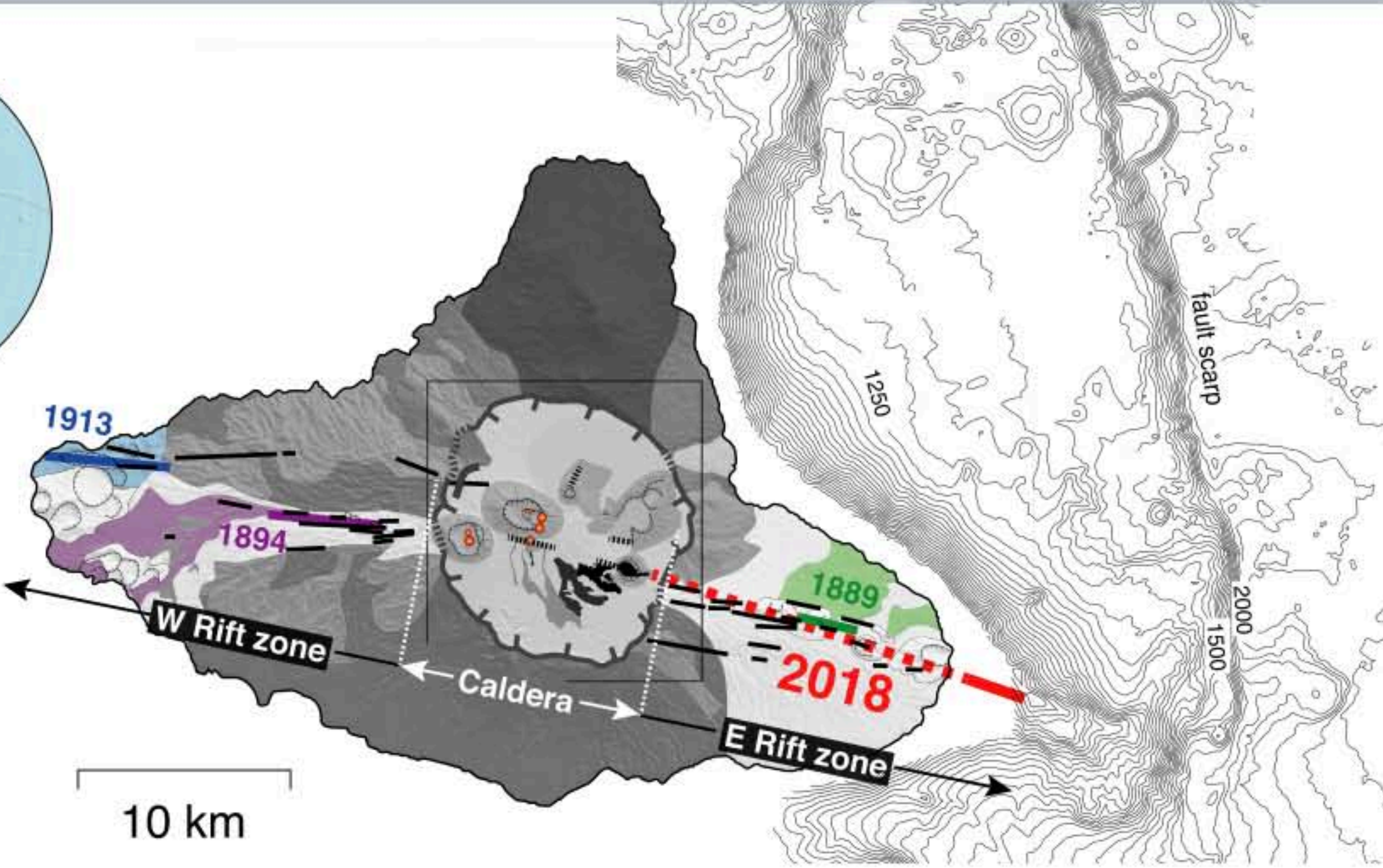

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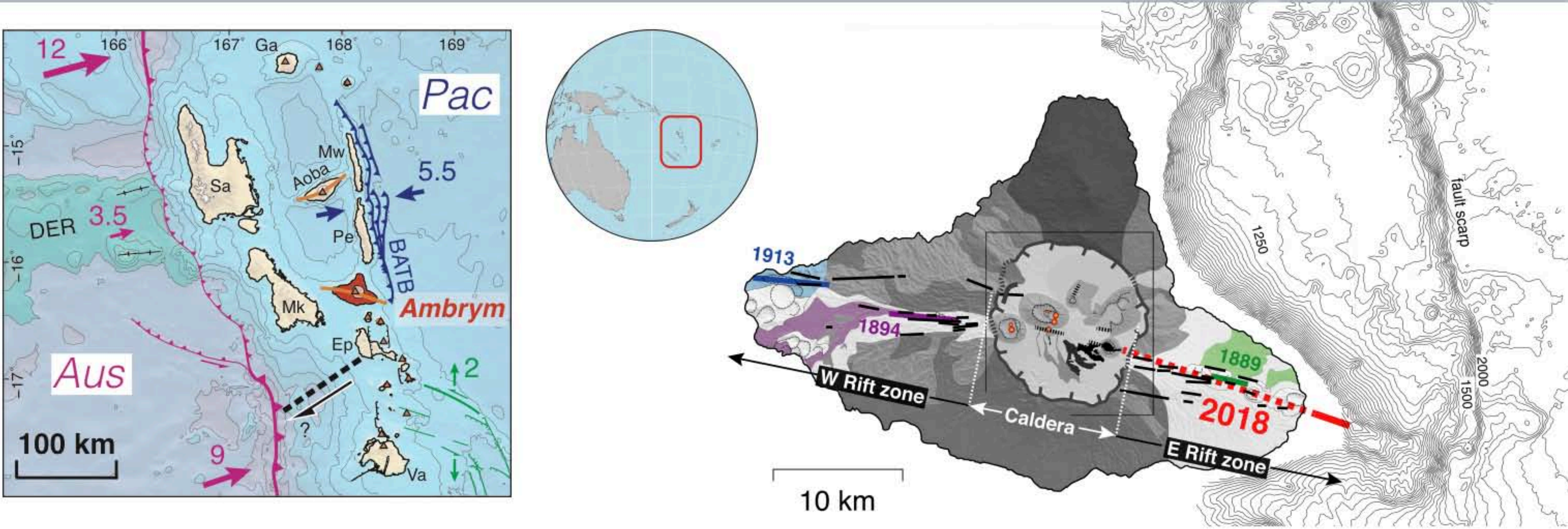

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December 2018 Eruption

Phase 1

- Intra-caldera fissure eruption, lava flow, crater collapse, lava lake drainage

Phase 2

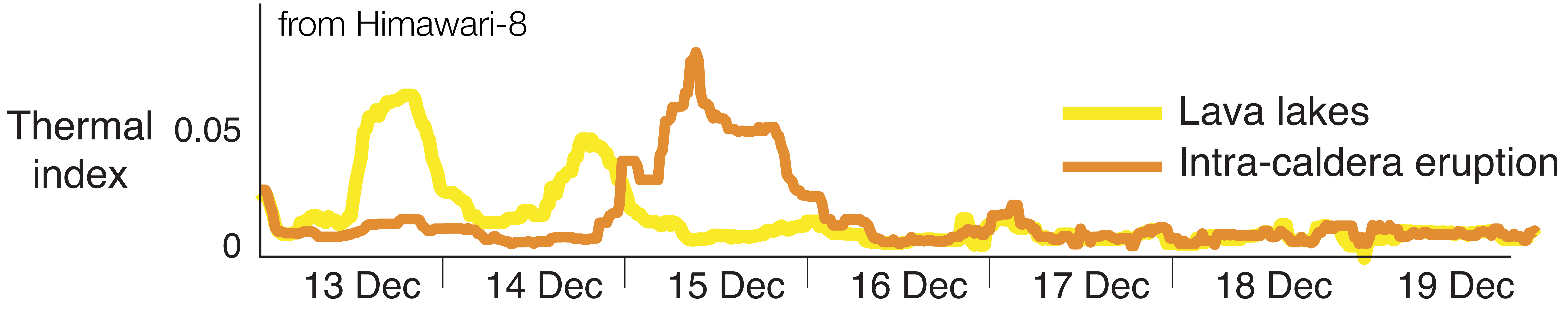
- Migrating seismicity, extra-caldera rift intrusion, caldera ring-fault activation and subsidence

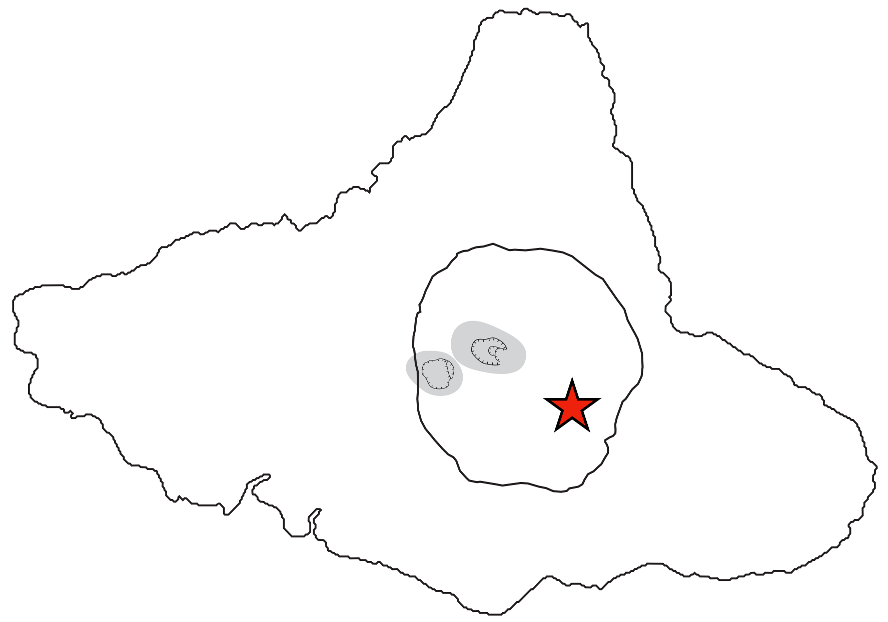
Phase 3

- Continued submarine eruption and caldera subsidence, no lava lake activity, decreased degassing

Phase 1

- **Intra-caldera fissure eruption, lava lake drainage,** lava flow, crater collapse





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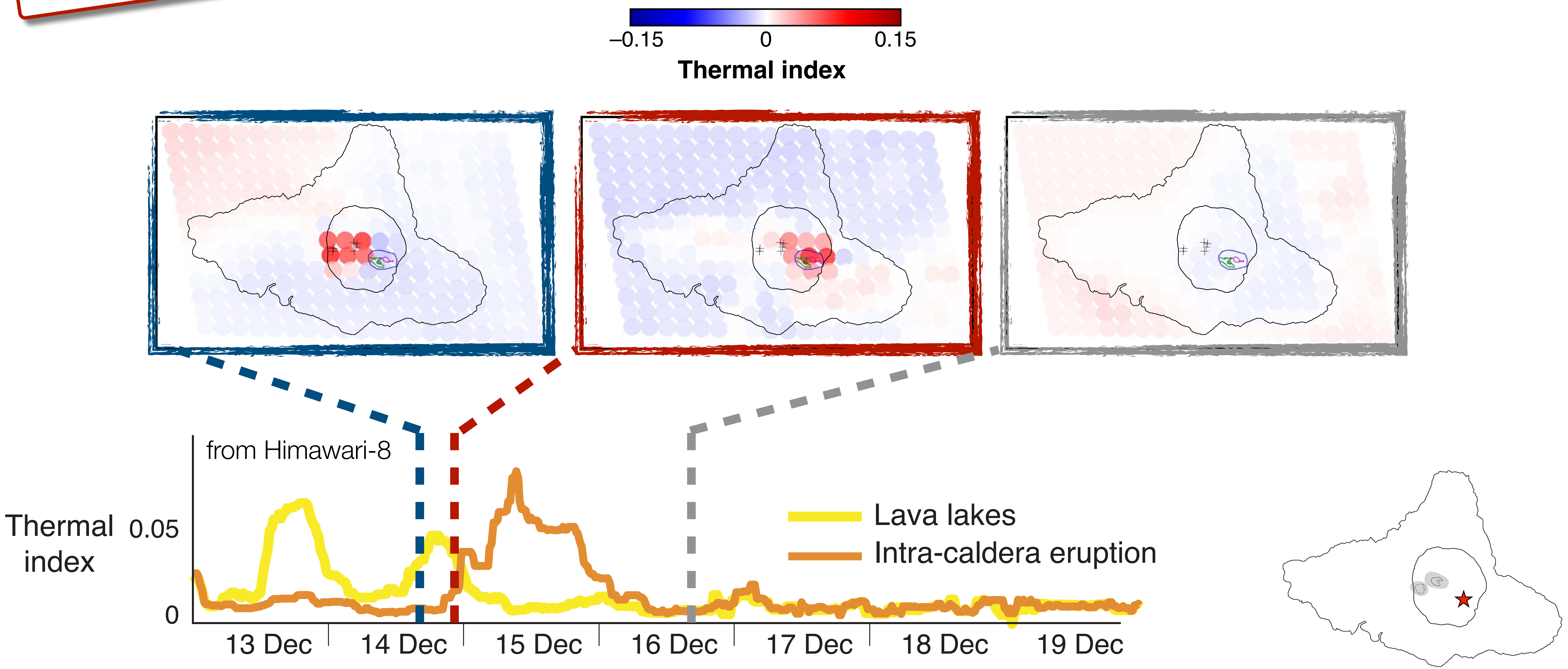
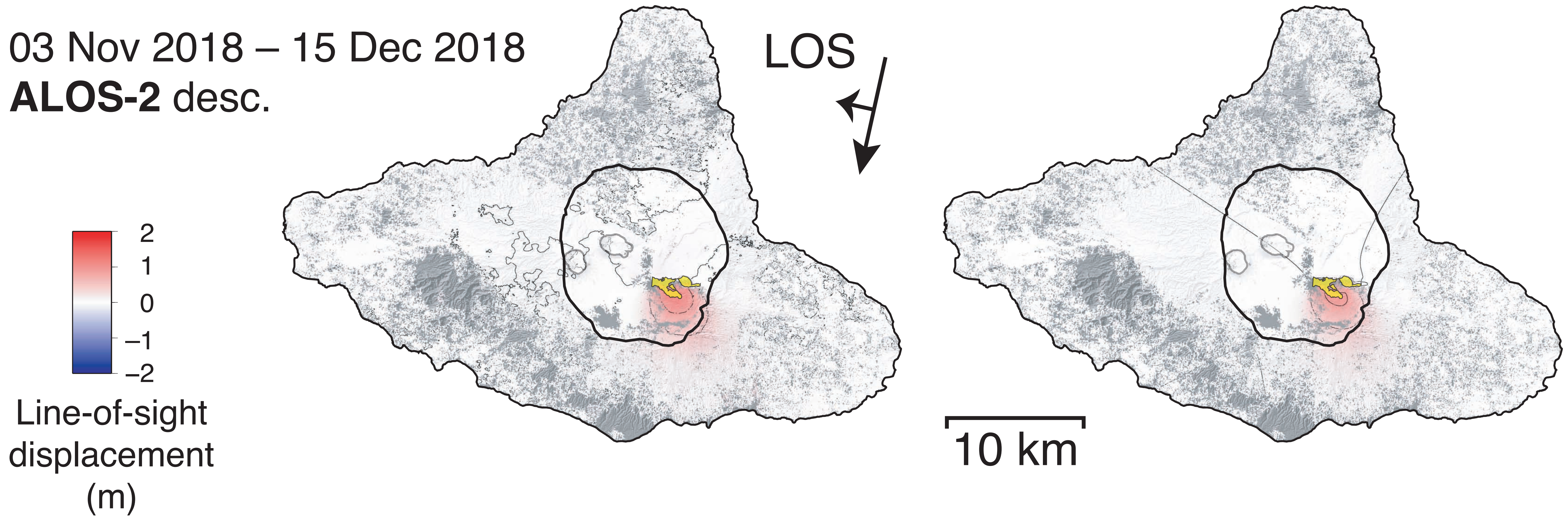


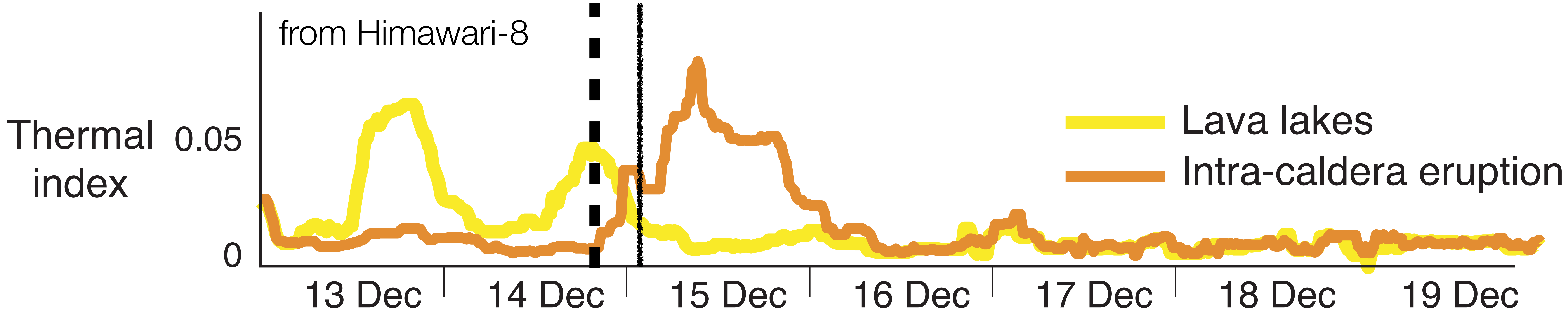
Phase 1

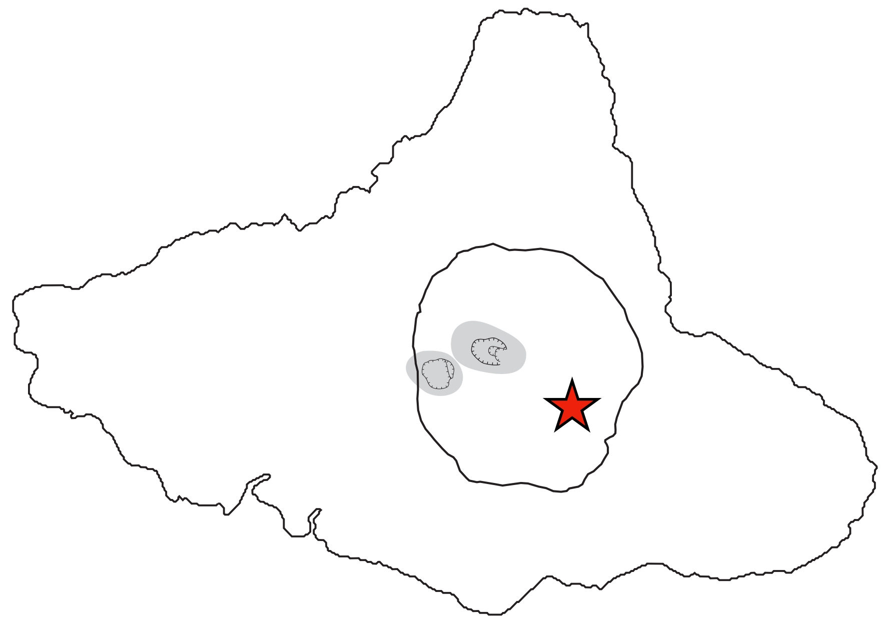
- **Intra-caldera fissure eruption, lava lake drainage,** lava flow, crater collapse

- **Non-linear inversion** used to find first-order geometry
- Dike dipping **~40°S**
- 34 x 10^6 m^3 **intruded magma**

Data **Synthetic**







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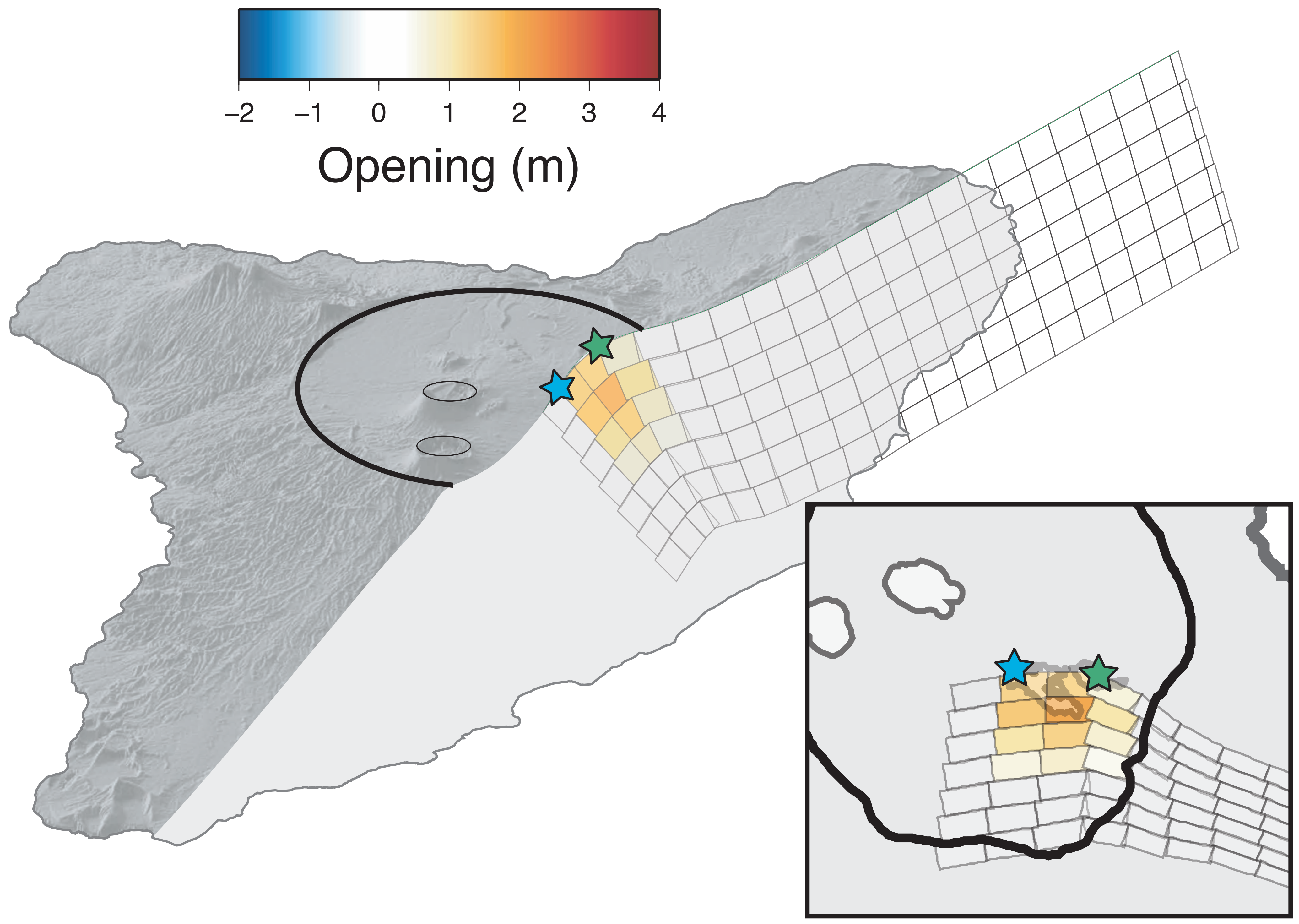

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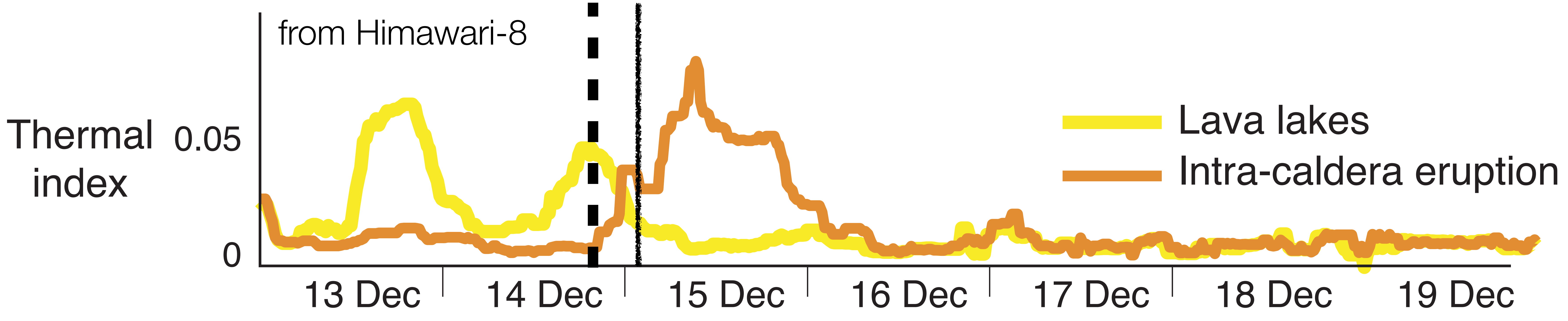

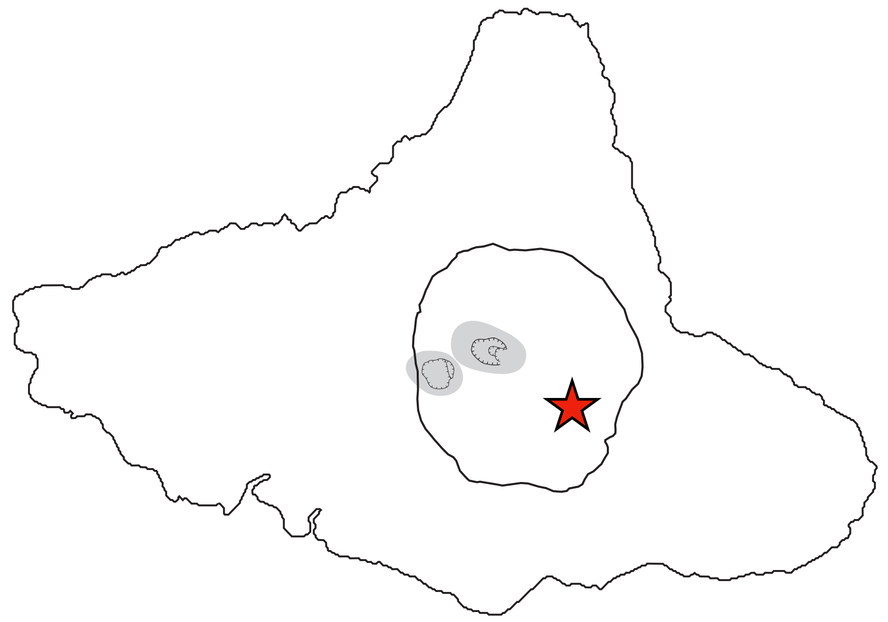

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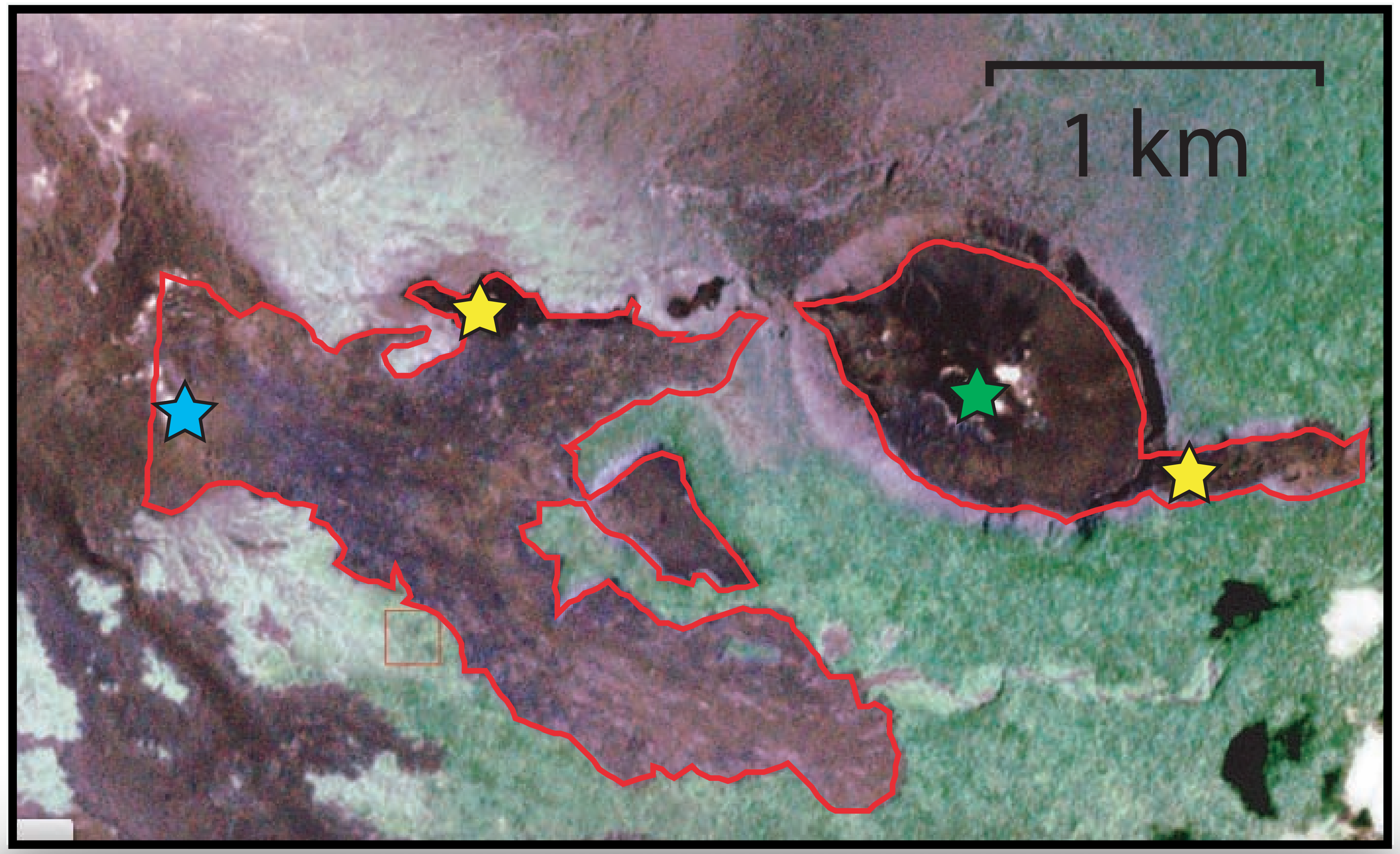
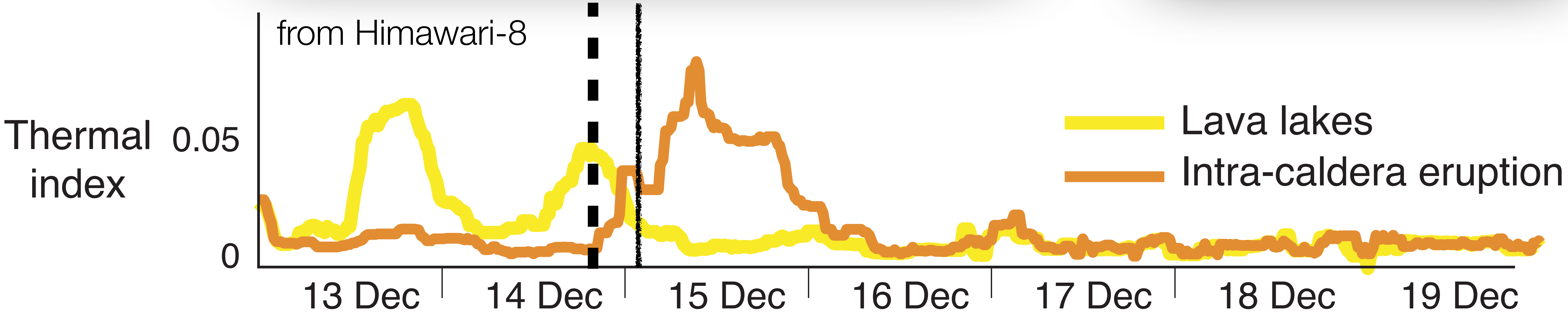
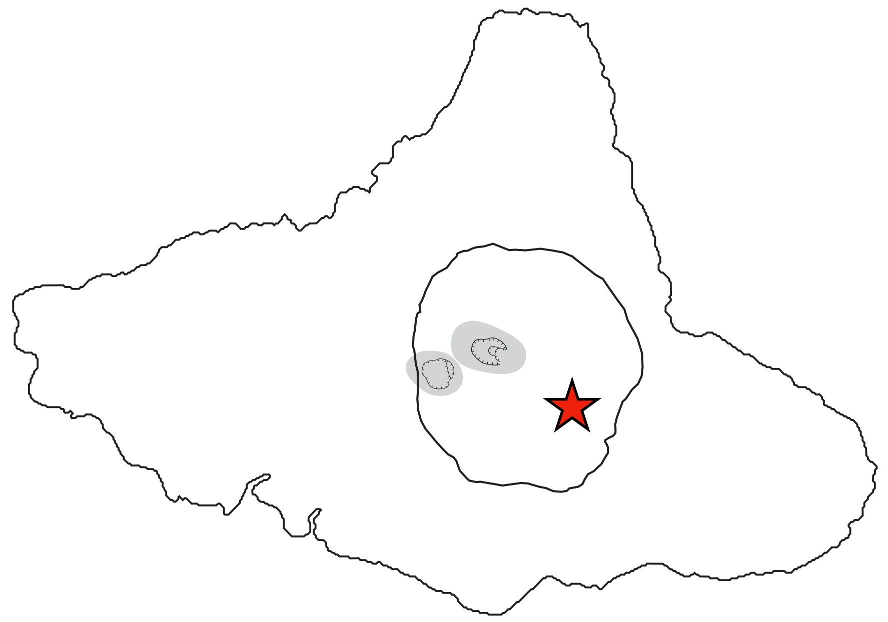
Planets Optical Satellite Image, Jan 31 2019



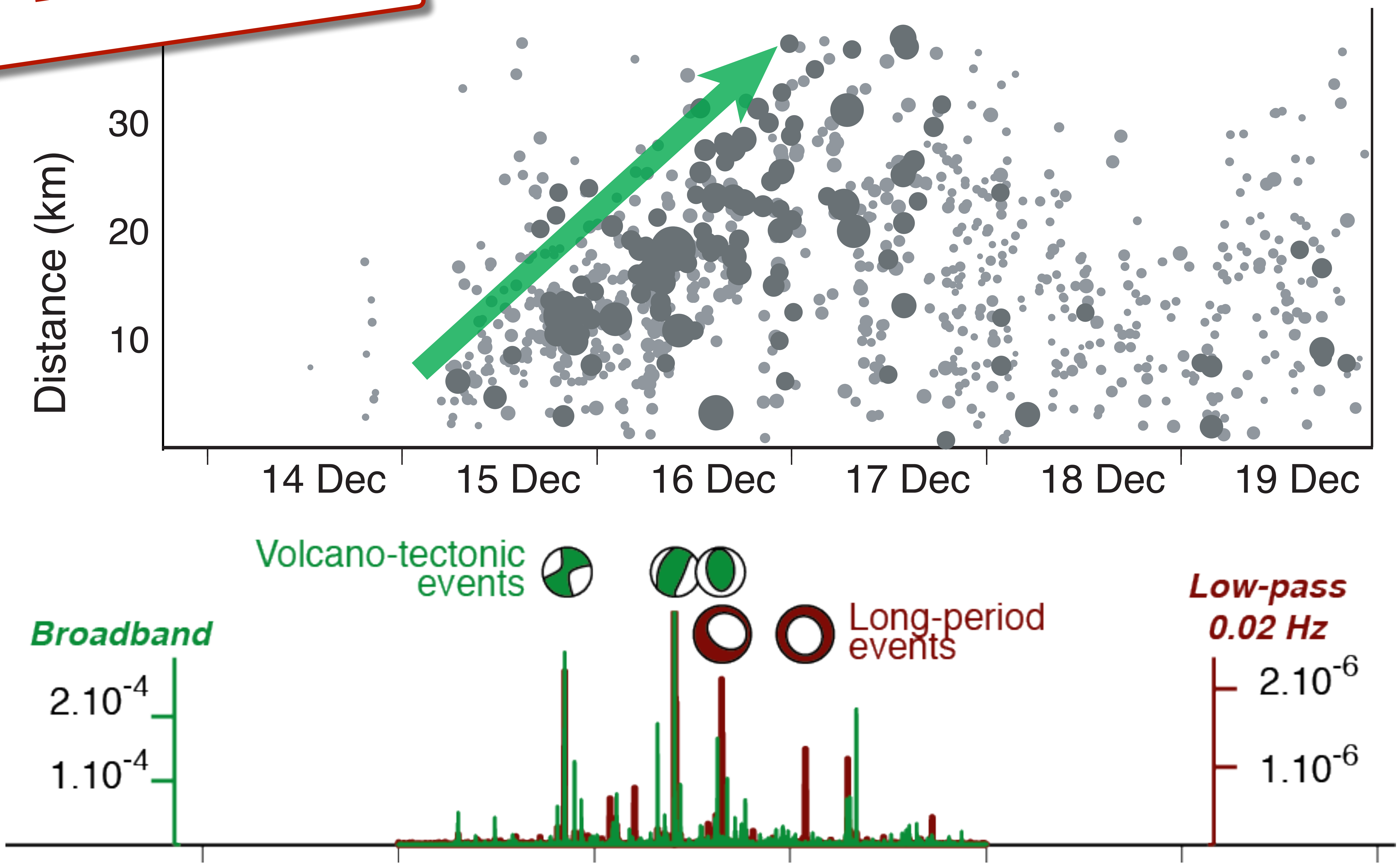
© Nial Peters

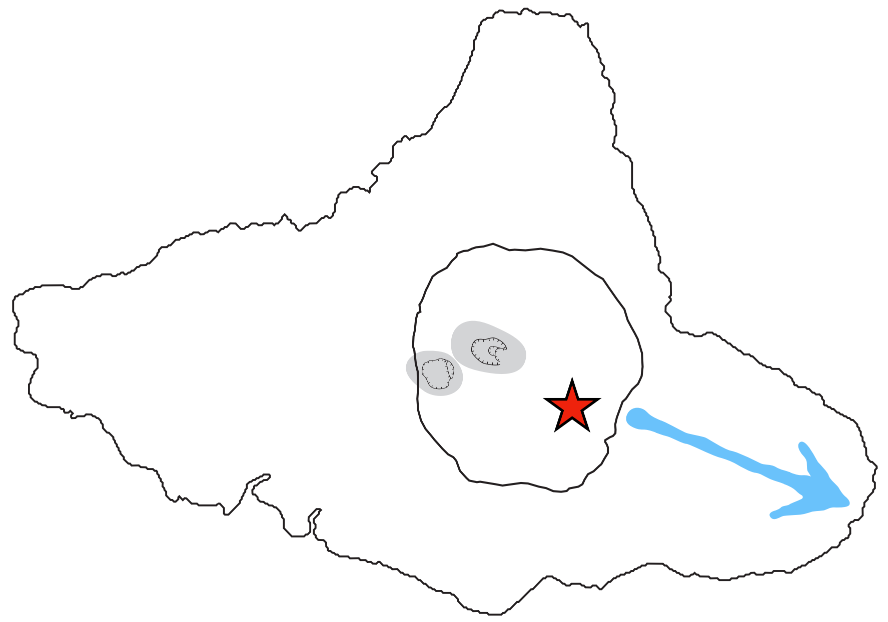




Phase 2

- **Migrating seismicity, LP events,** extra-caldera rift intrusion, caldera ring-fault activation and subsidence





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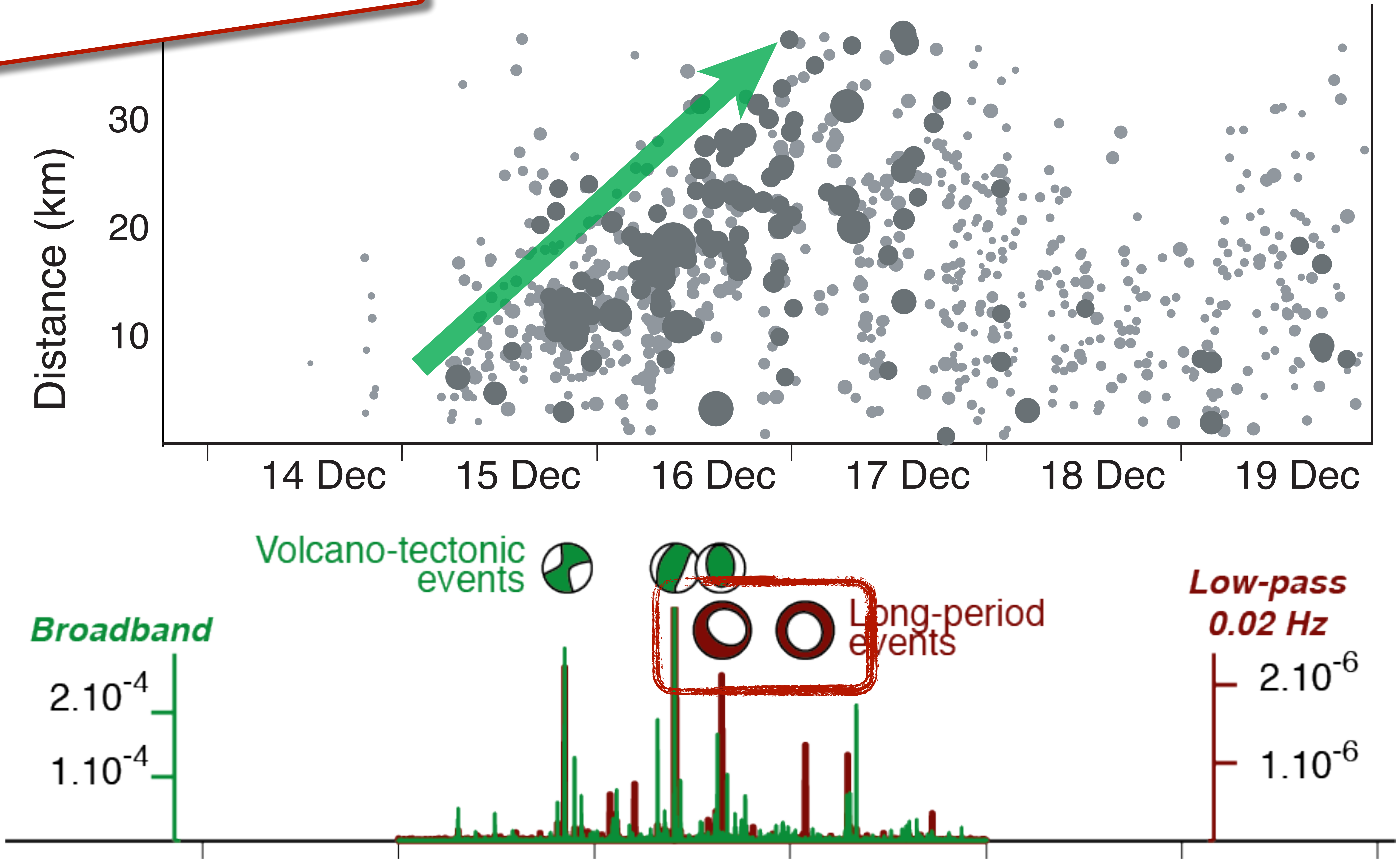
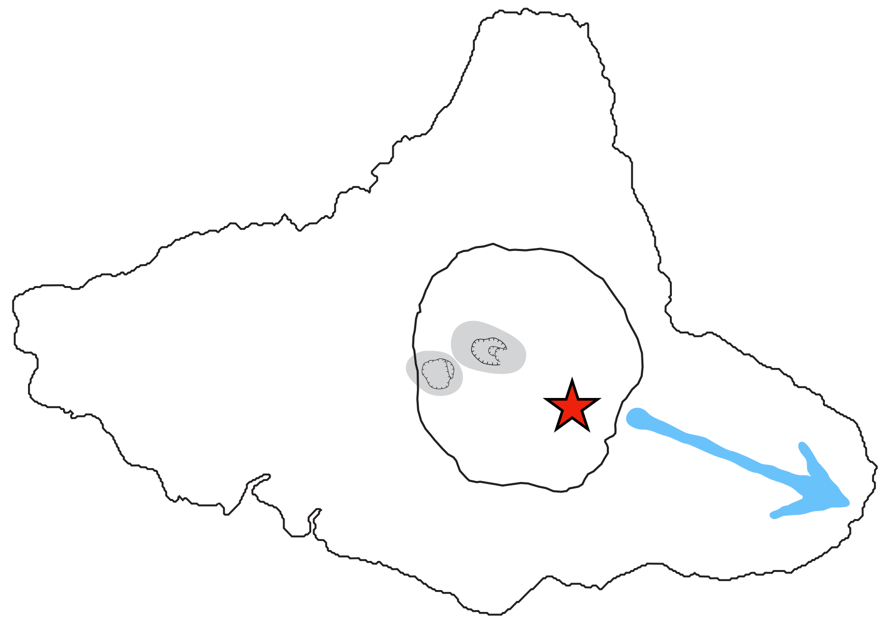


- Reservoir volume loss and/or caldera ring faulting
- **> 10 LP events** in 48 hours



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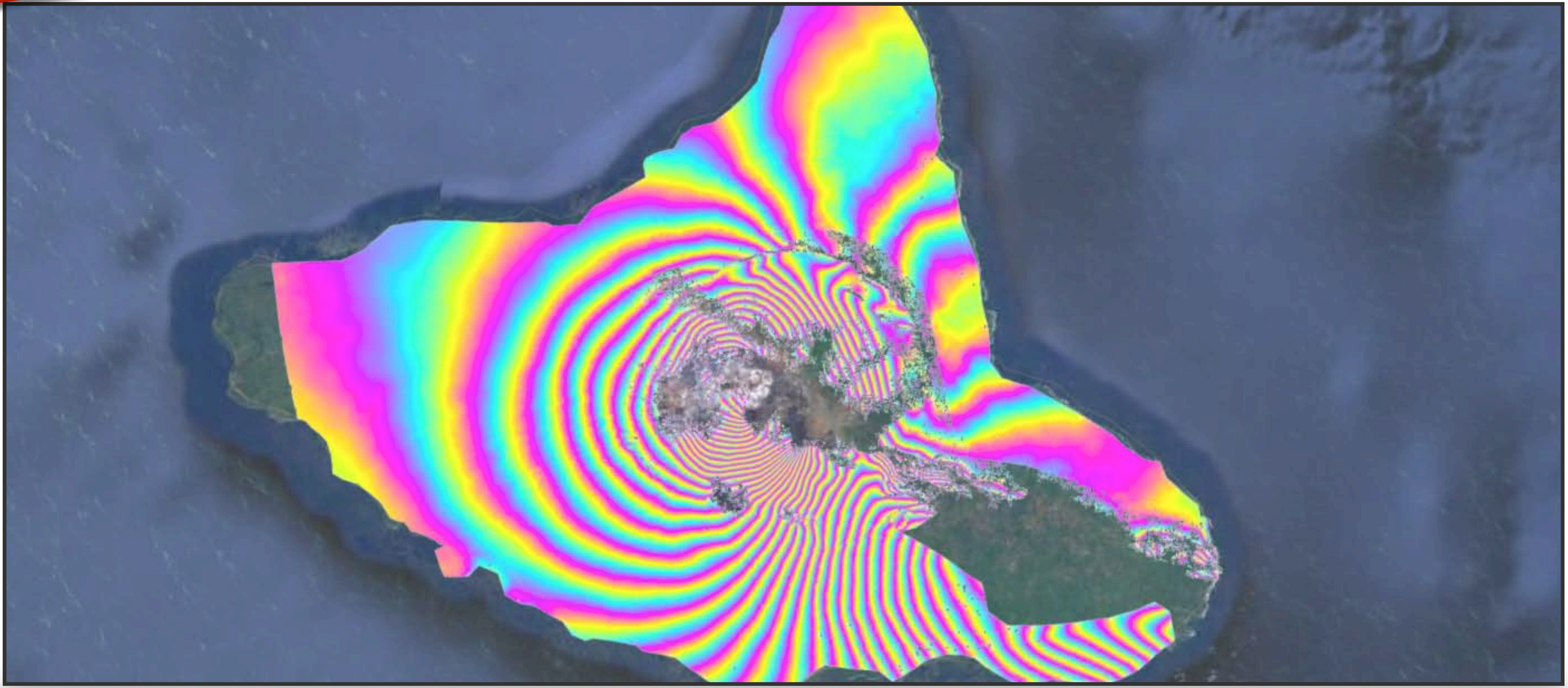

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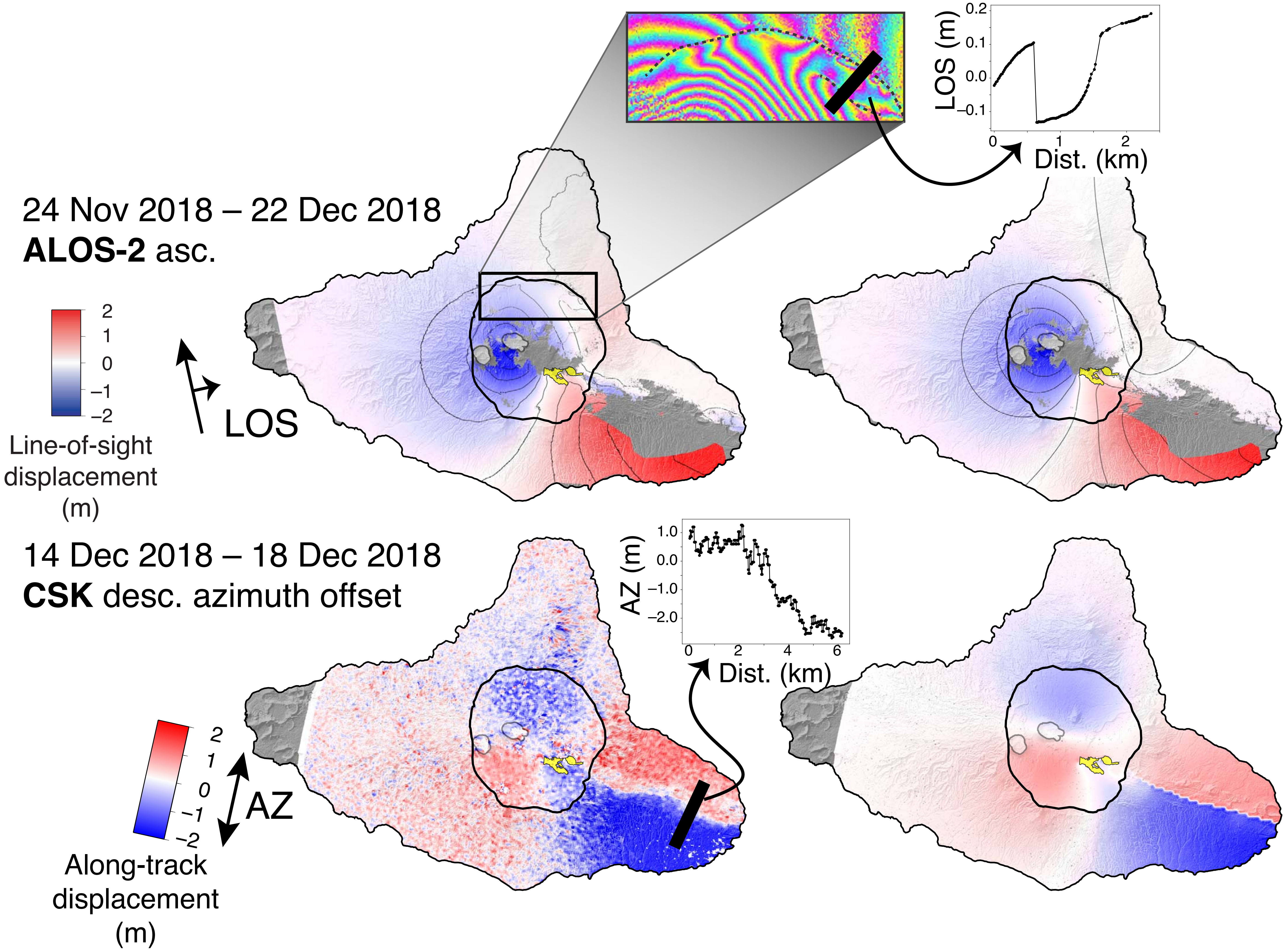
- Dike dipping **~70°S**
  - 475 ± 60 x 10^6 m^3 **intruded magma**
- Symmetrical point source at **4.5 km depth**
  - -213 ± 20 x 10^6 m^3 **volume change**
- Up to **20 cm** of displacement **along caldera-ring fault**



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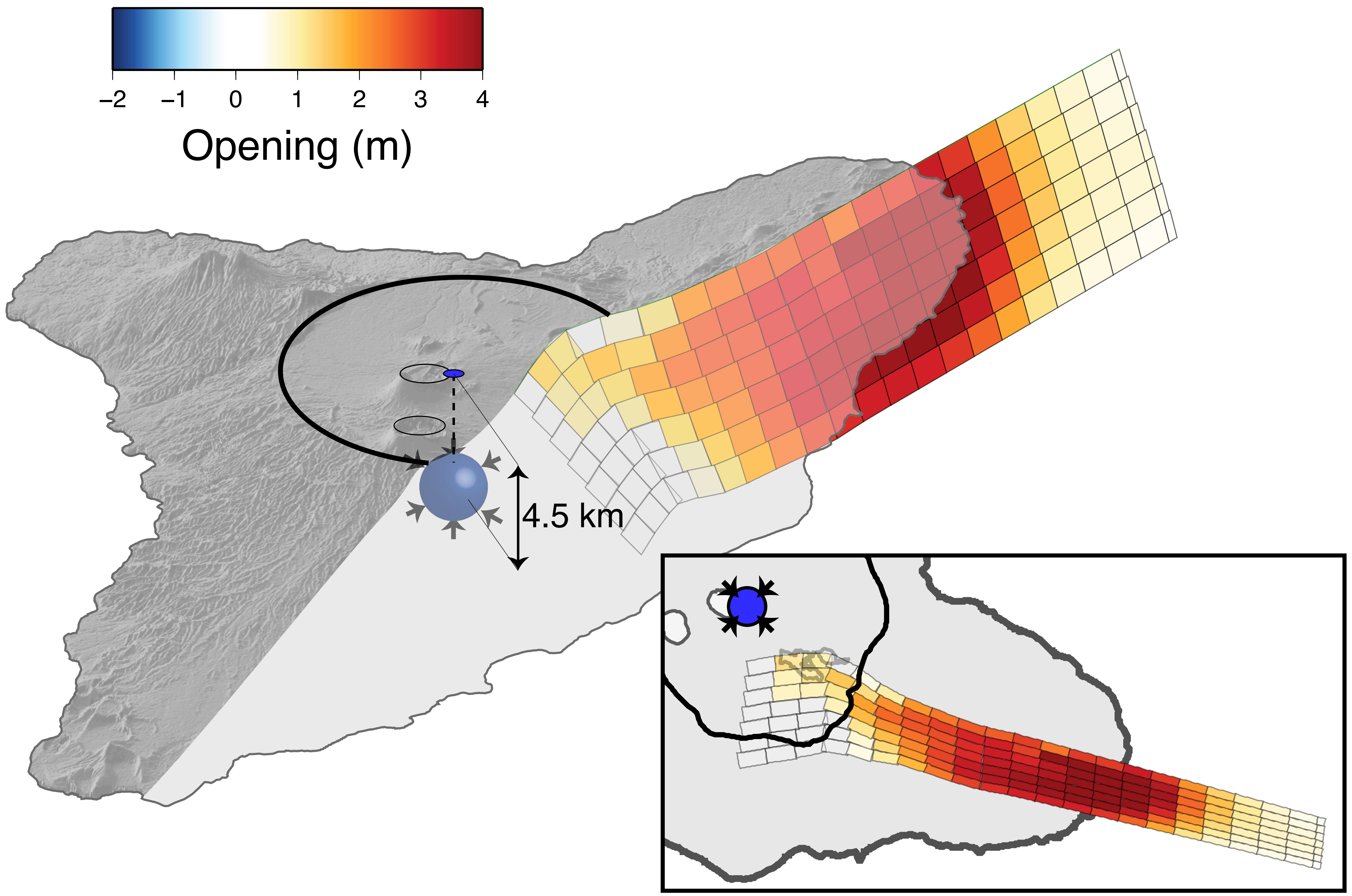

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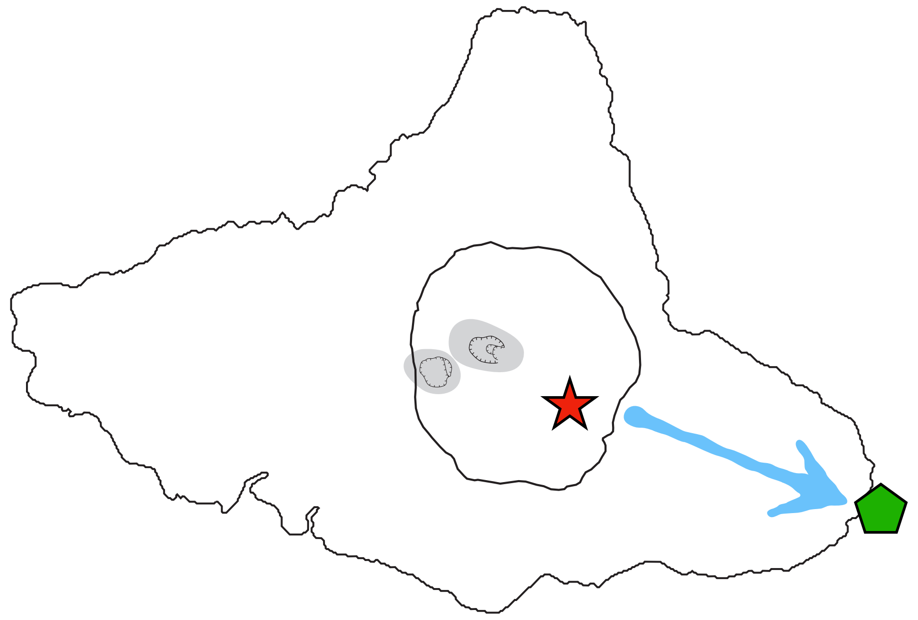
- **Basaltic pumice** found on east coast beaches in December and January



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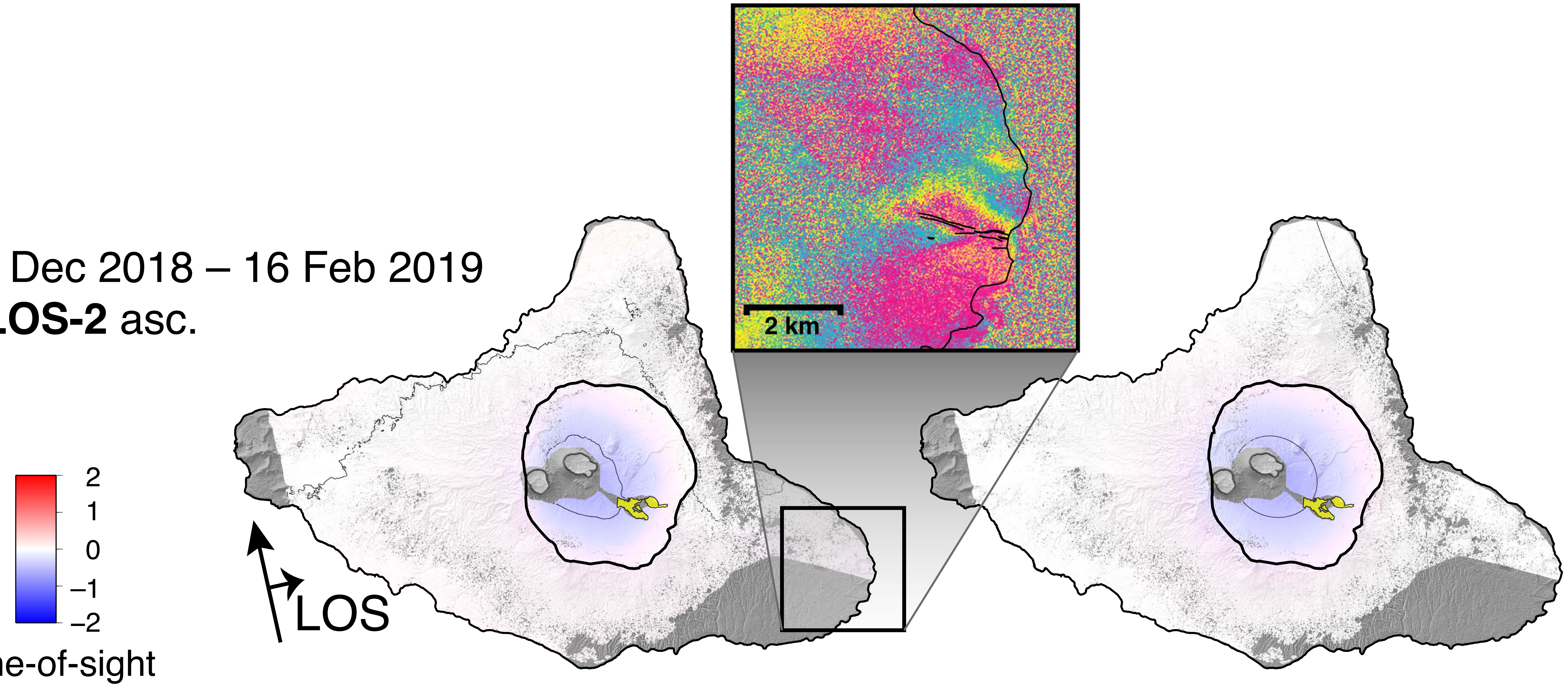
- **Localized deformation** along SE coast

22 Dec 2018 – 16 Feb 2019
ALOS-2 asc.



Phase 3

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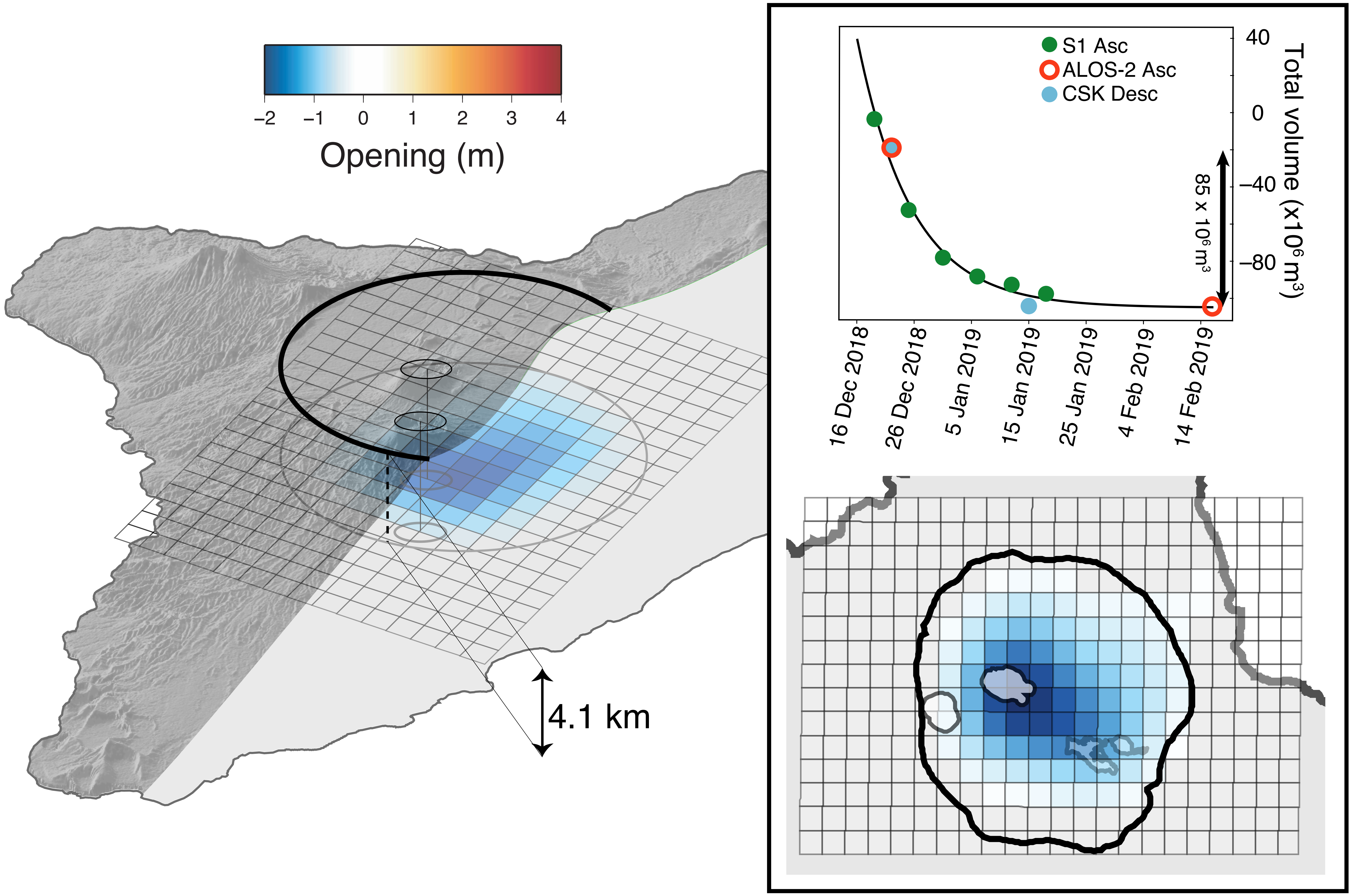
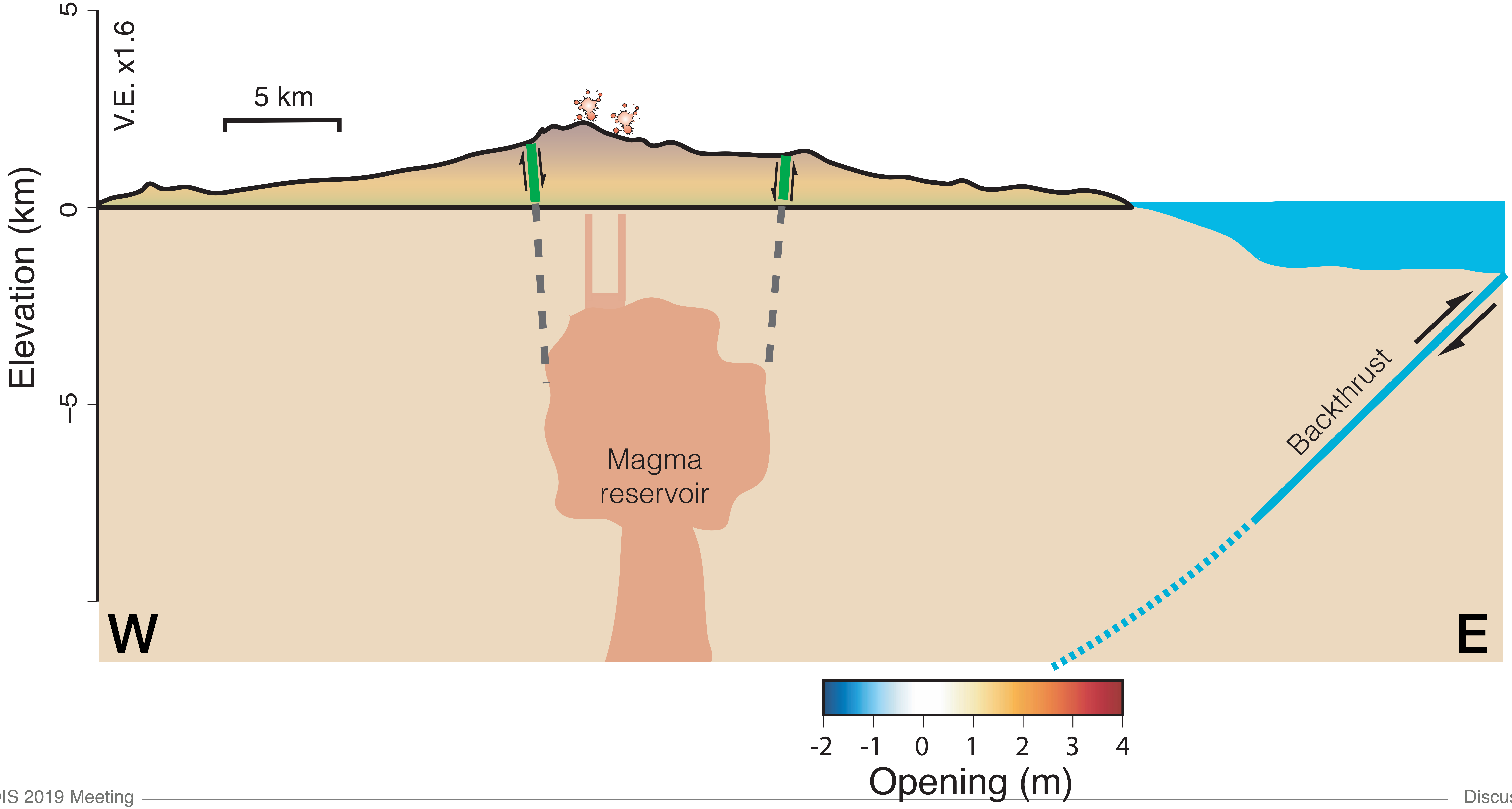
- Sill at **4.1 km depth**
  - -85 x 10^6 m^3 **volume change**
- **Exponentially decaying** subsidence



December 2018 Eruption — Conceptual Model



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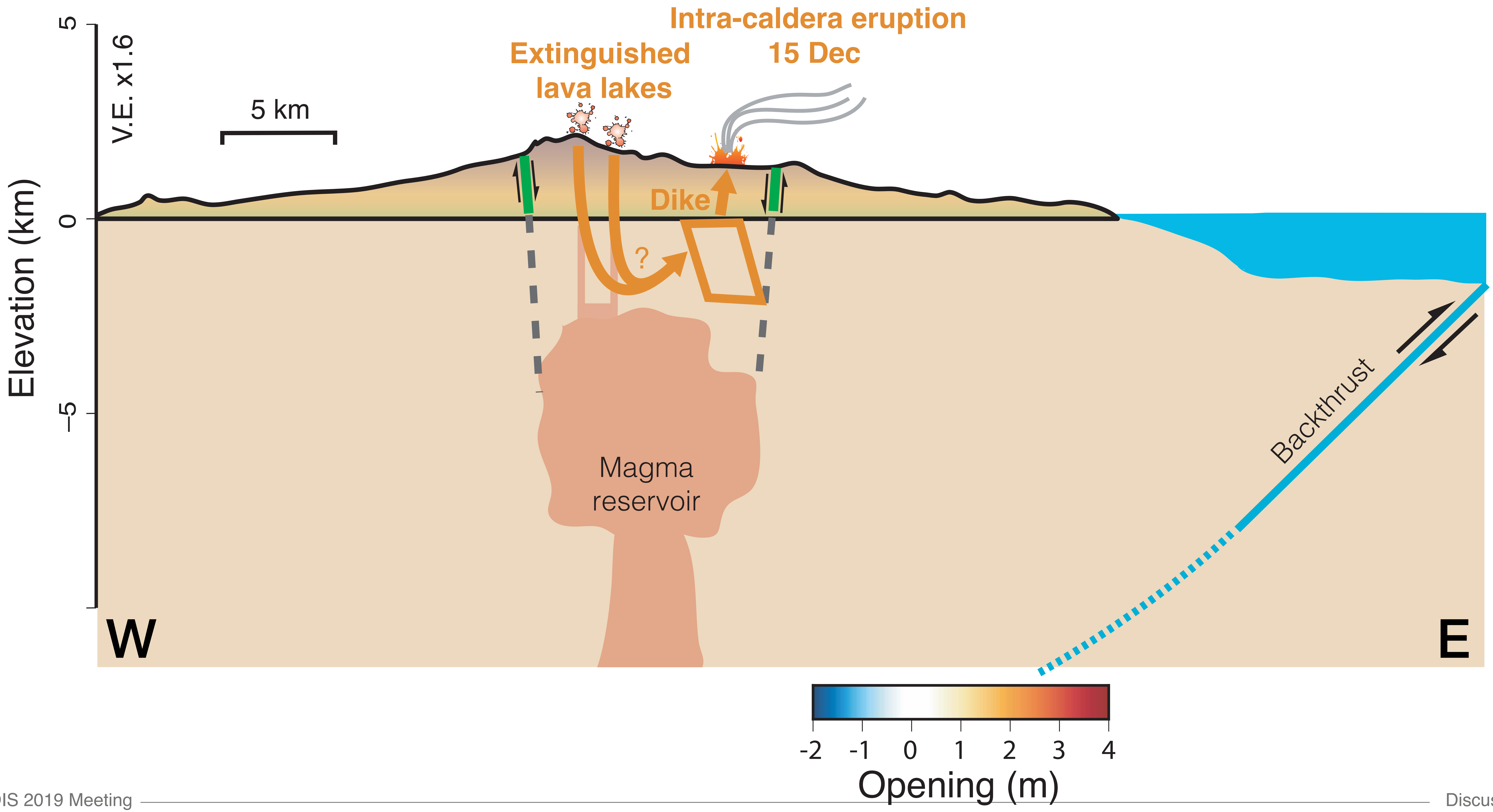

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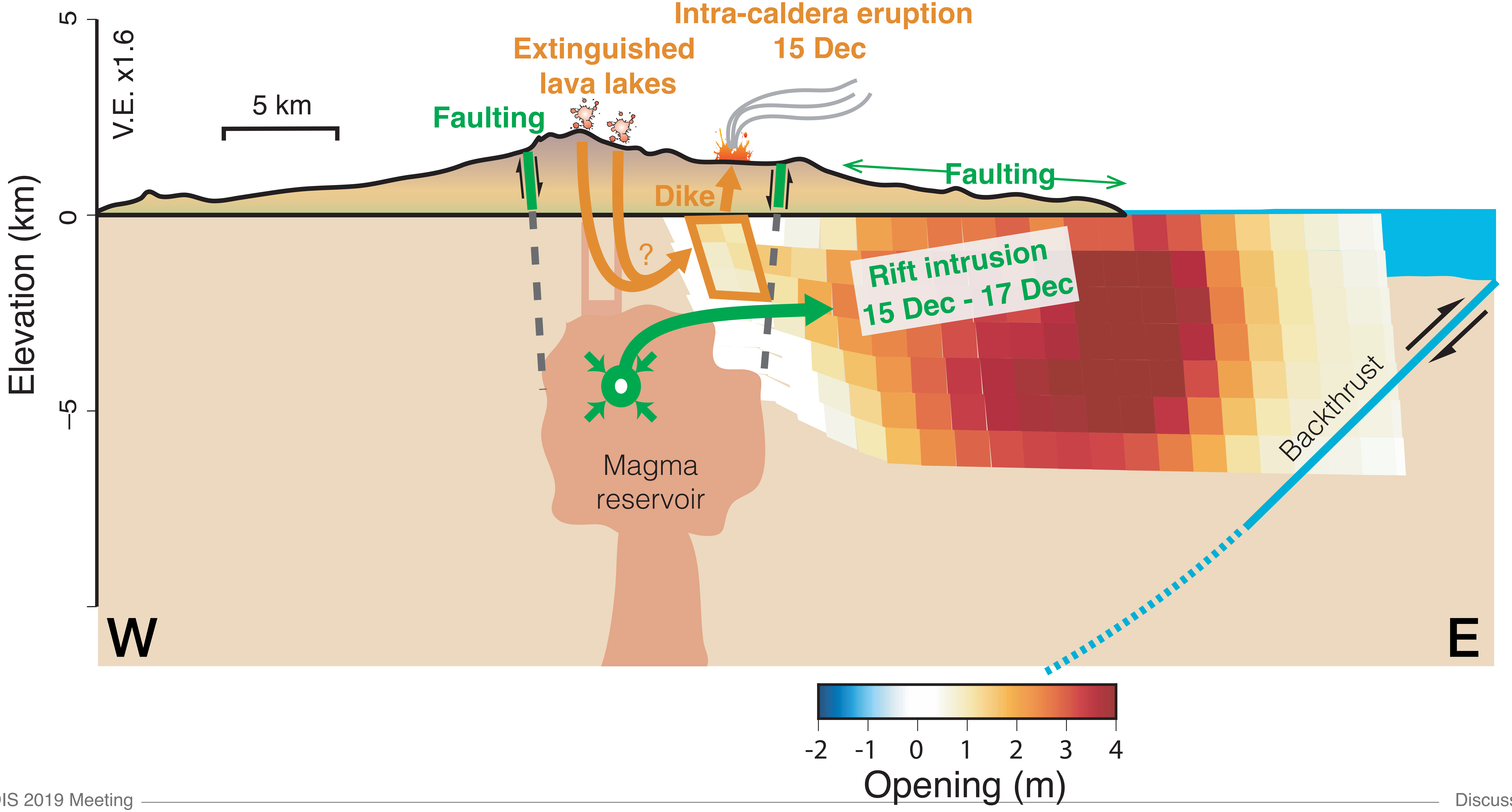

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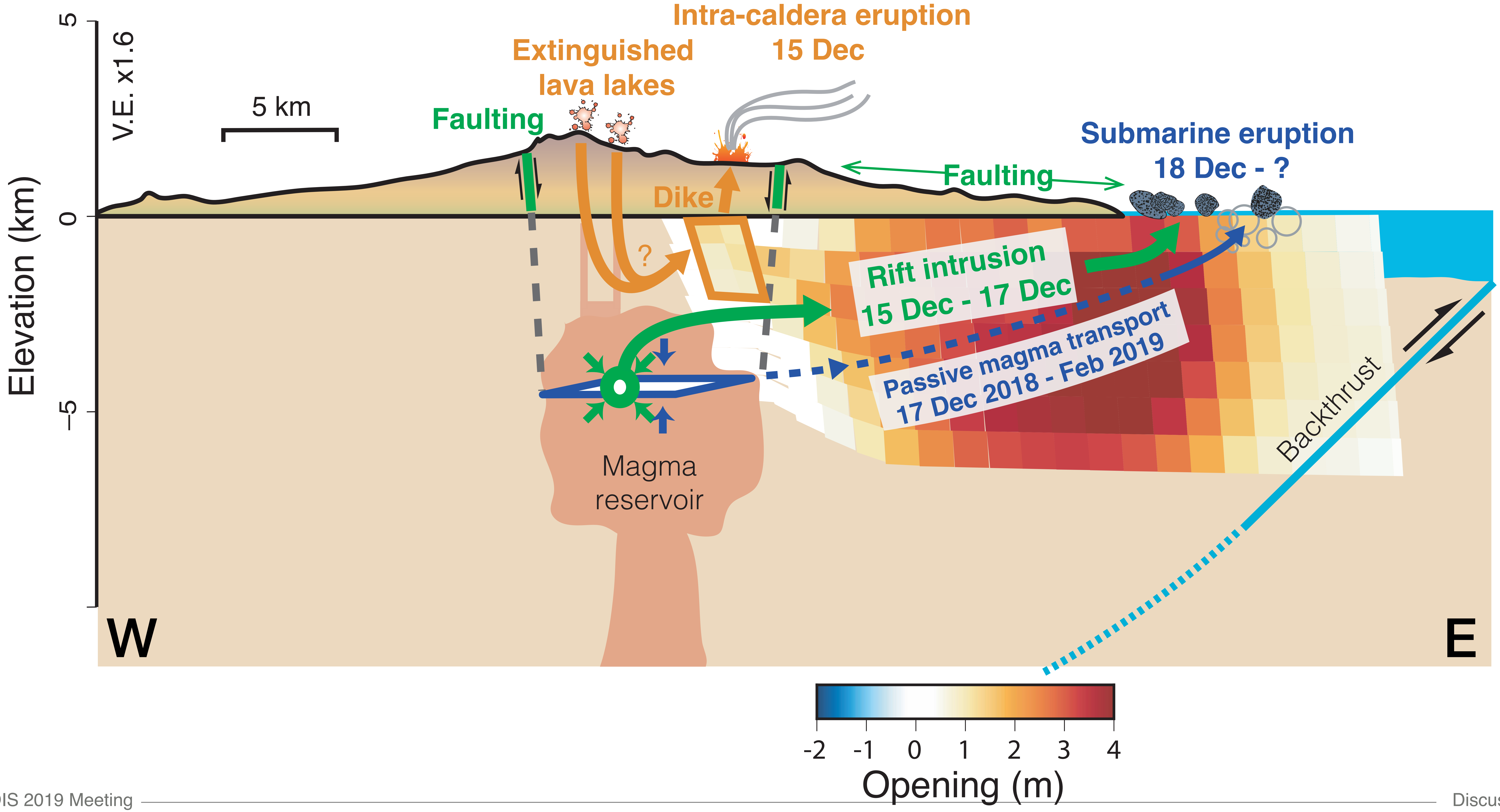

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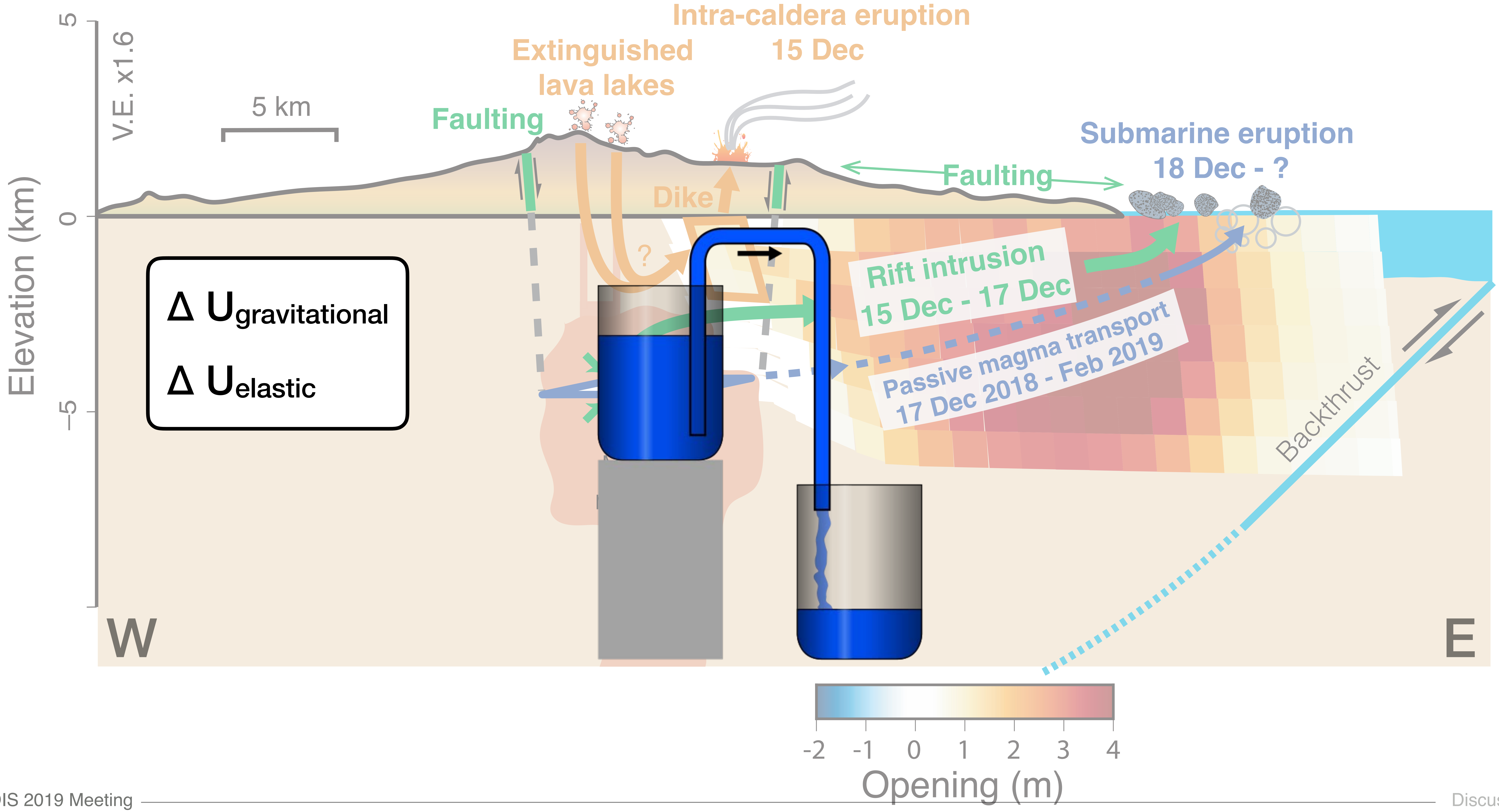

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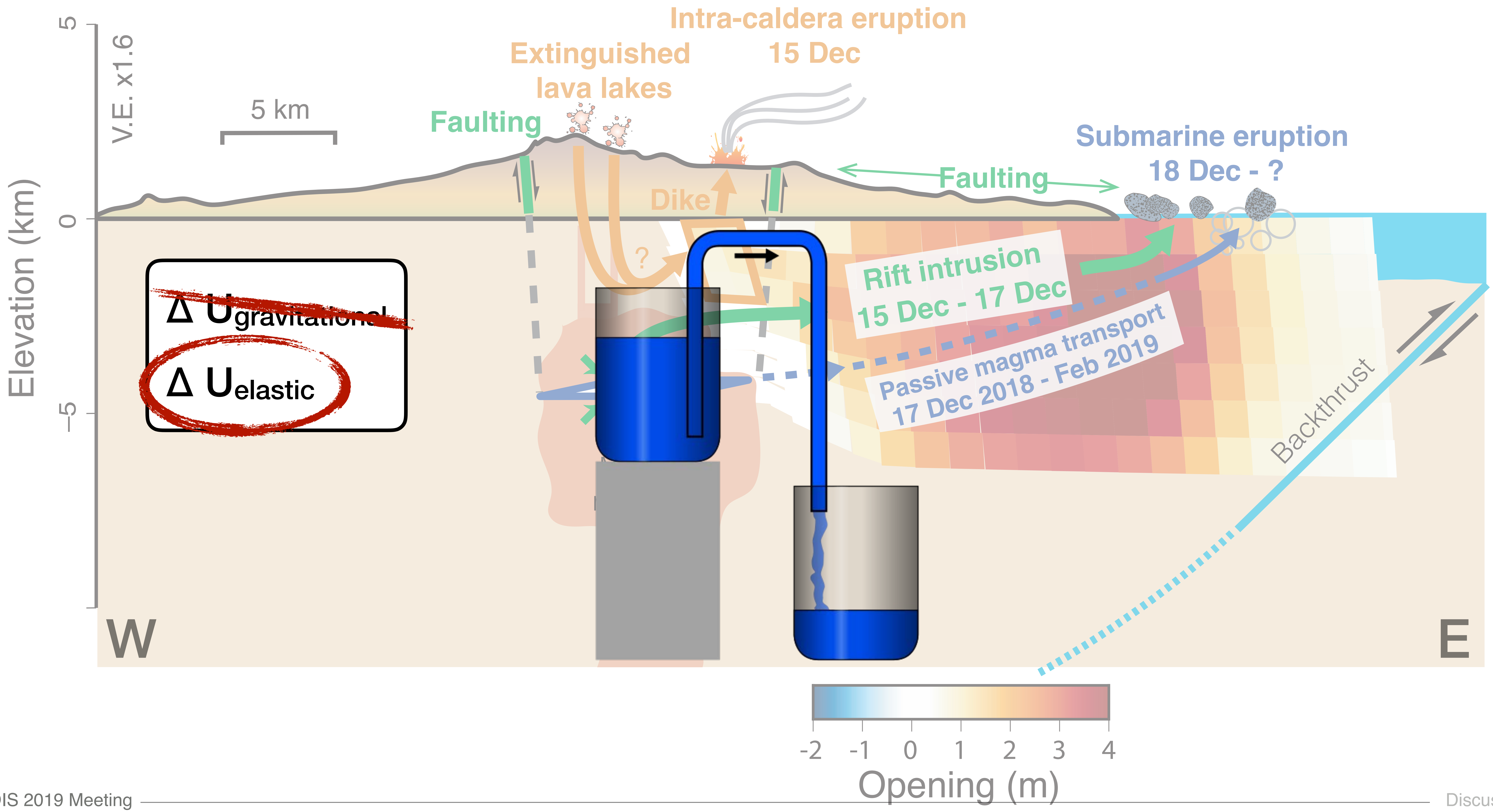

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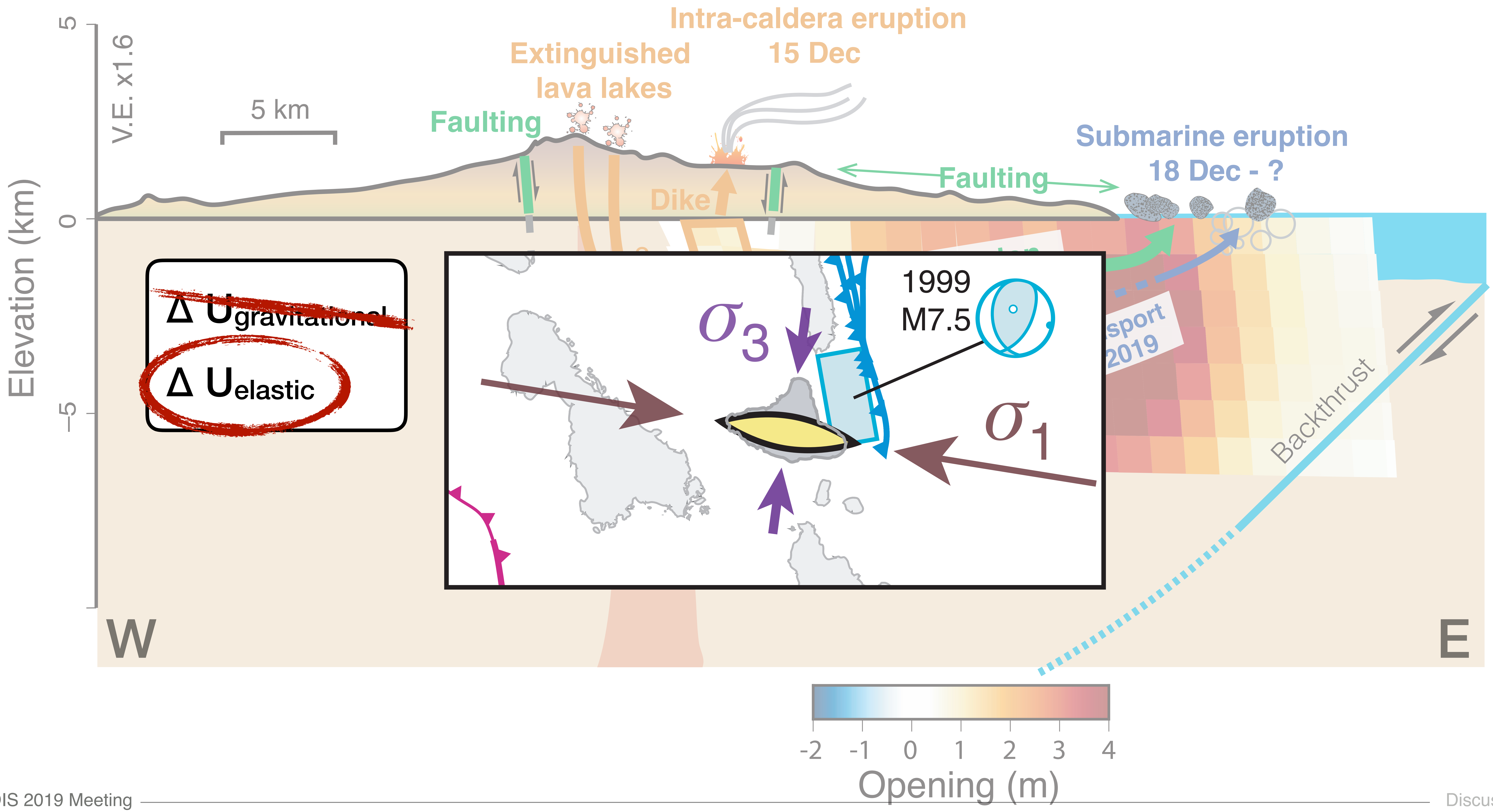

Conclusions

- ☑ This "siphon" effect resulting from tectonic stresses is able to **shut down degassing** and **thermal activity** at the surface

- ☑ Draining of Ambrym's laterally extensive central magmatic reservoir results in **caldera ring fault activation** and **meter-scale caldera subsidence**

- ☑ At **broad, basaltic caldera-rift systems**, **recurrent pumping** of magma into the rift zone may lead to **episodic caldera subsidence**, leaving **little geological trace** at the surface

Combining multi-sensory satellite datasets is an effective and efficient way to investigate volcanic unrest in remote regions

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Thank you for your time!

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