Unraveling Fluid/Methane Seeps at the Cascadia Subduction Zone

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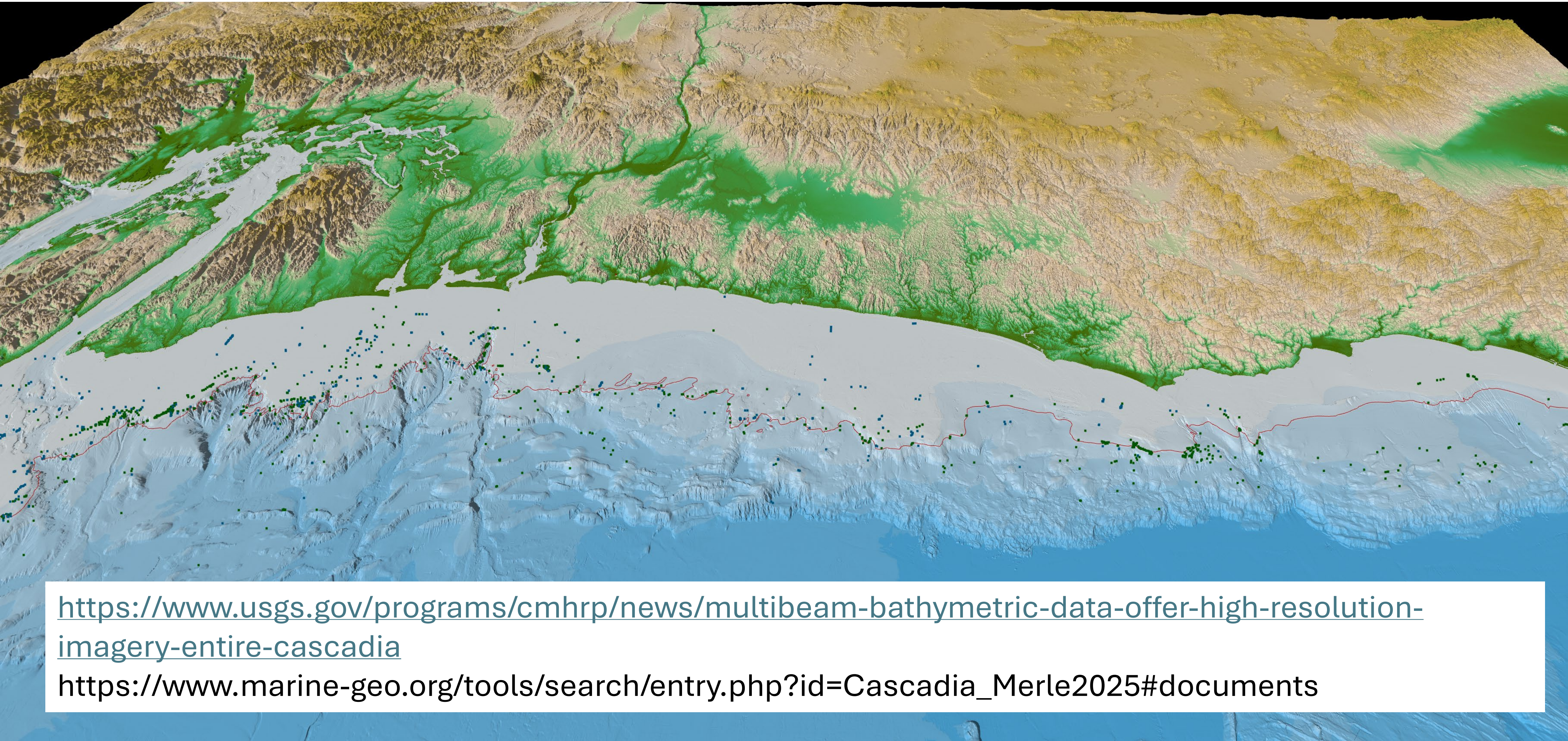


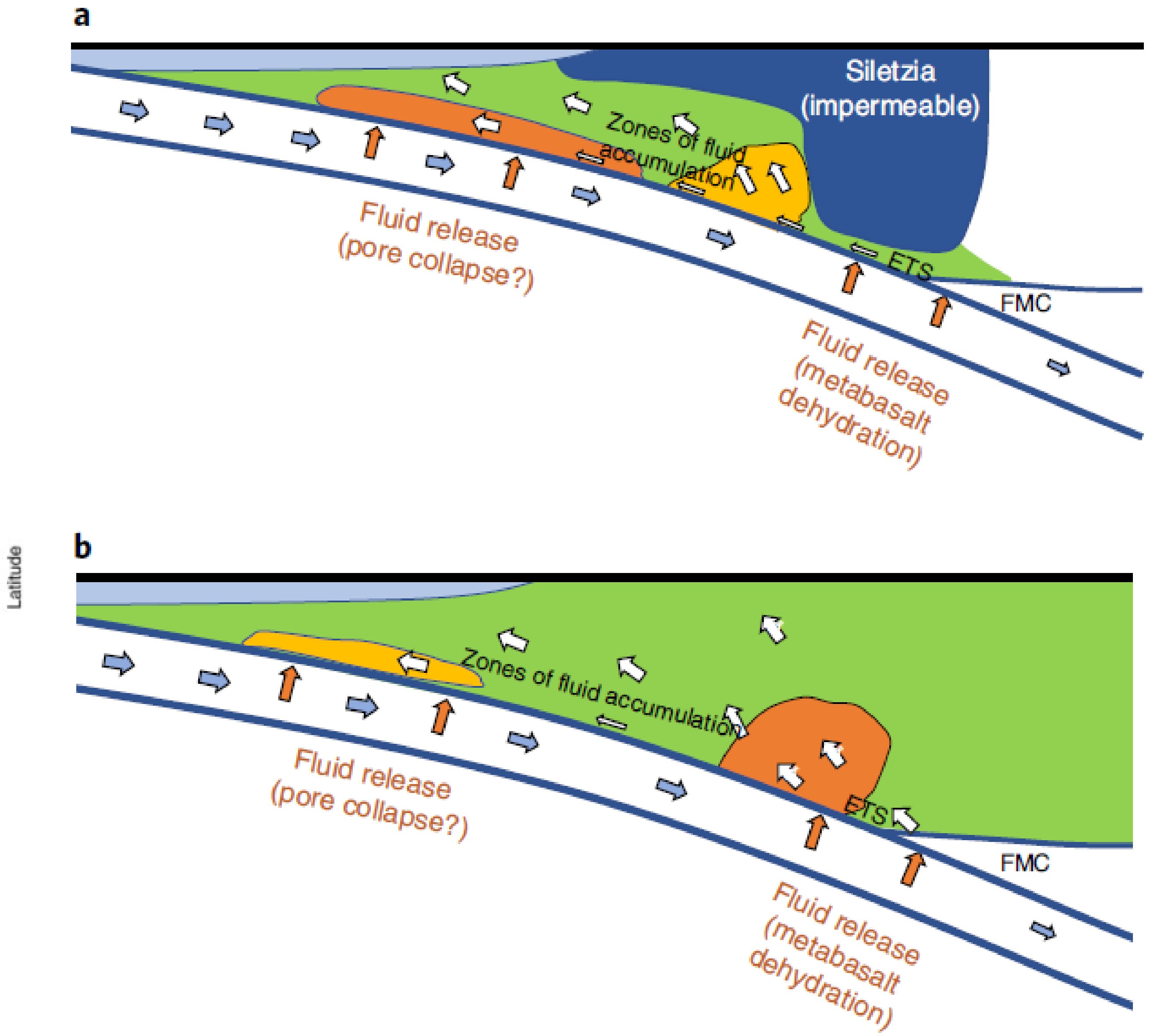
https://www.usgs.gov/programs/cmhrp/news/multibeam-bathymetric-data-offer-high-resolution-imagery-entire-cascadia
https://www.marine-geo.org/tools/search/entry.php?id=Cascadia_Merle2025#documents

Cascadia Subduction Zone

Fluids in the Forearc

- **Three-dimensional inversions of data from nearly 400 long-period magnetotelluric sites, including 64 offshore**
- **Fluid Storage and Transport Control by Siletzia: Fluids accumulate in metasedimentary units above the subducting plate while the mafic rocks of Siletzia remain relatively impermeable. This indicates that Siletzia acts as a barrier to fluid migration, forcing fluids to escape up-dip along the megathrust, which influences fluid transport and storage across the Cascadia forearc**
- **Distinct Fluid Accumulation Zones: Fluid concentrations in the Cascadia forearc crust tend to peak at slab depths of 17.5 and 30 km. These depths suggest that metamorphic processes control fluid release, and the impermeable nature of the Siletzia block directs the escape of dehydration fluids along specific structural paths**
- **Influence of Forearc Lithology on Fluid Dynamics: Variations in lithology, especially the presence of impermeable Siletzia, play a critical role in controlling fluid accumulation and transport pathways. This lithological control is linked to variations in effective stress and fluid pressure along the megathrust, affecting seismic behavior and potentially influencing episodic tremor and slip events**
- **Underthrust Accretionary Complex and Siletzia Geometry: Accretionary complex material is being underthrust beneath the Siletzia terrane, driving uplift of the Coast Ranges. The 3D geometry of Siletzia revealed that it acts as a barrier, leading to localized accumulation of fluids at the edges and affecting the overall mechanical properties and seismic coupling of the subduction zone**

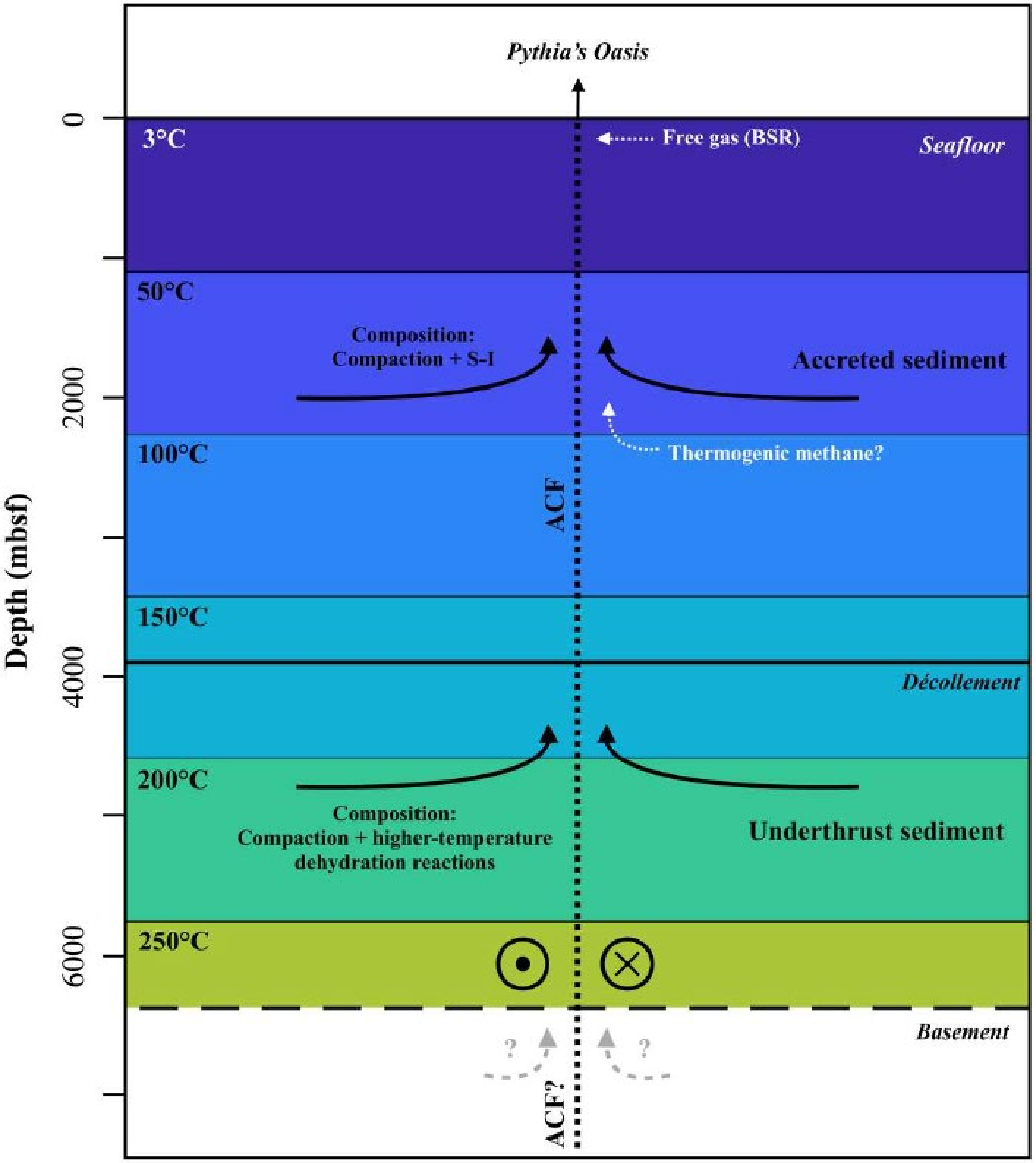
Fluid transport and storage in the Cascadia forearc influenced by overriding plate lithology

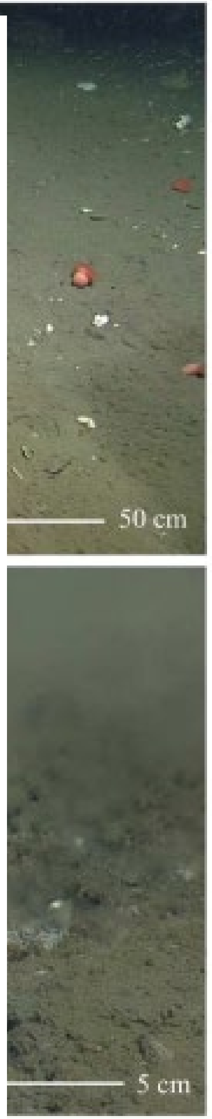


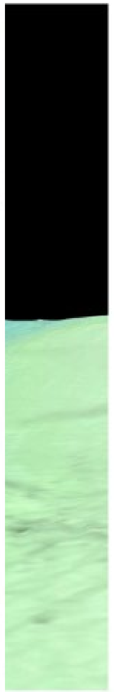
Cascadia Subduction Zone

Pythias Oasis

- Samples are extremely enriched in the minor elements boron (6026.4 µM) and lithium (275.5 µM): ~15 times that of their concentrations in seawater
- Geothermal gradients calculated using BSR geothermal gradients correspond to near-seep heat flow values of 83 to 222mWm−2
- ACF is inferred to intersect the plate boundary, near lithostatic pore pressures along the plate boundary would be sufficient to drive fracture permeability and the elevated flow rates observed at Pythia's Oasis. While this mechanism would eventually alleviate local fluid pressures along the décollement, fluids could be sourced from anywhere that is overpressured within the system (across and along strike), potentially enabling flow for sustained periods.
- "While we do not know whether Pythia's Oasis is the only seep of its kind, it is possible that similar seeps exist along the three strikeslip faults in the central CSZ."







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imaged during a
r and reveal gas
iompson in 2015

The high-volume,
: located ~380 m
ring ROPOS dive
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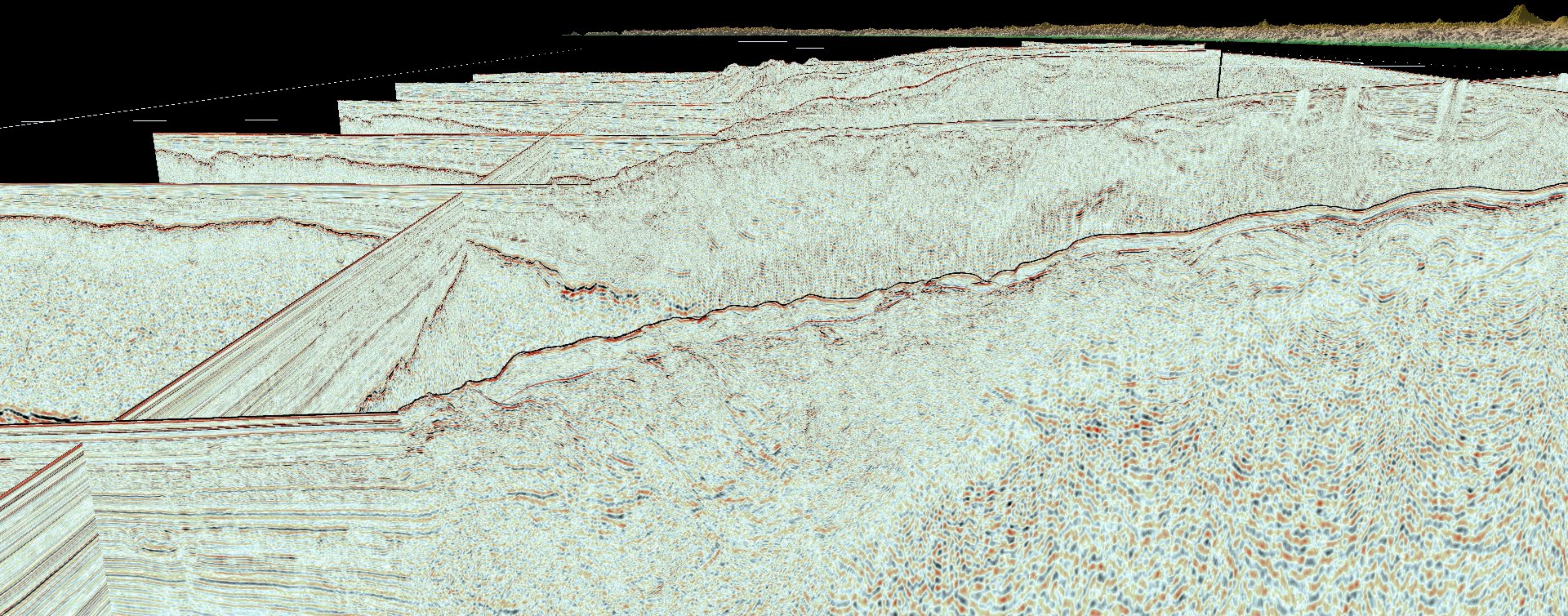
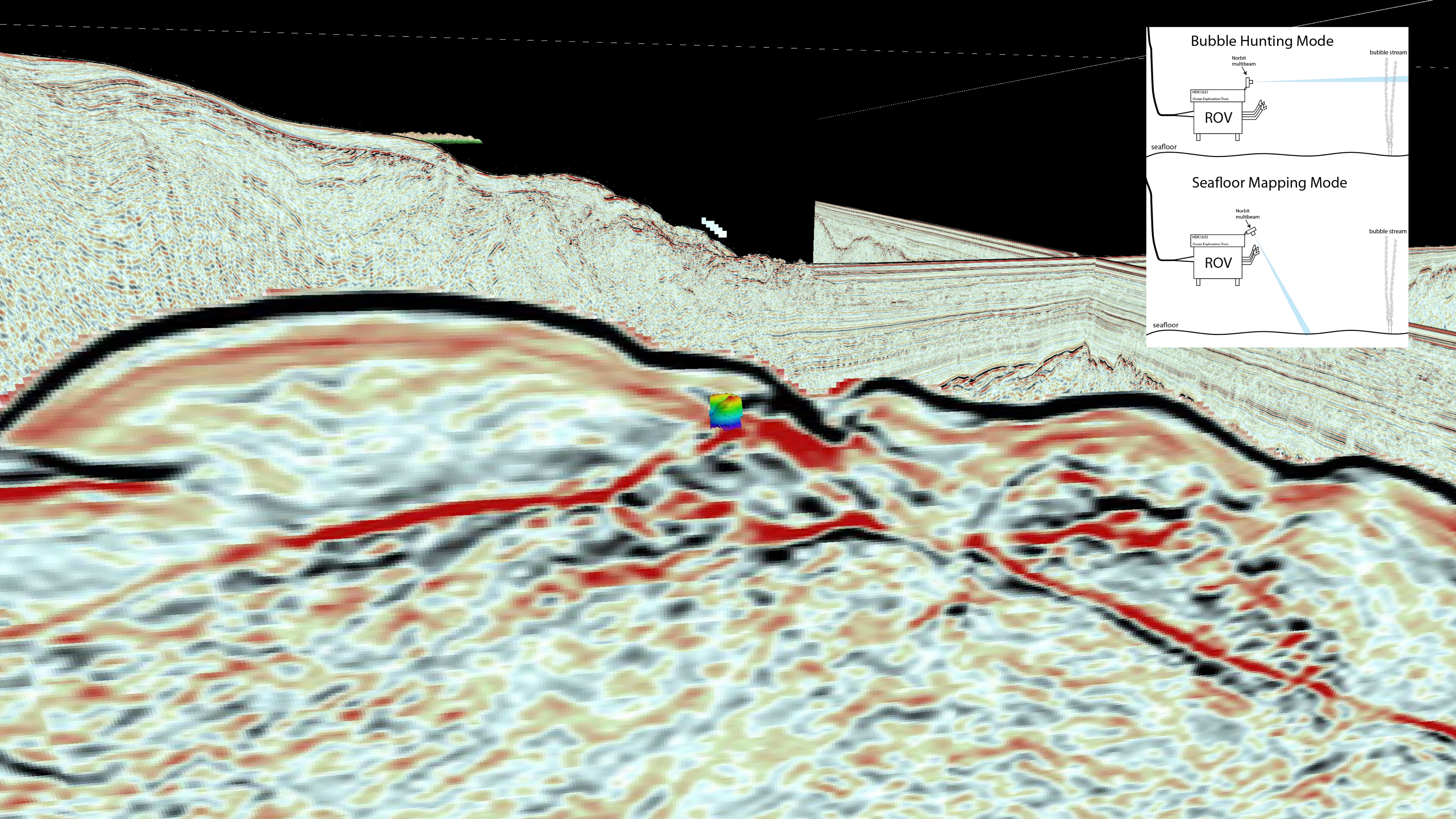
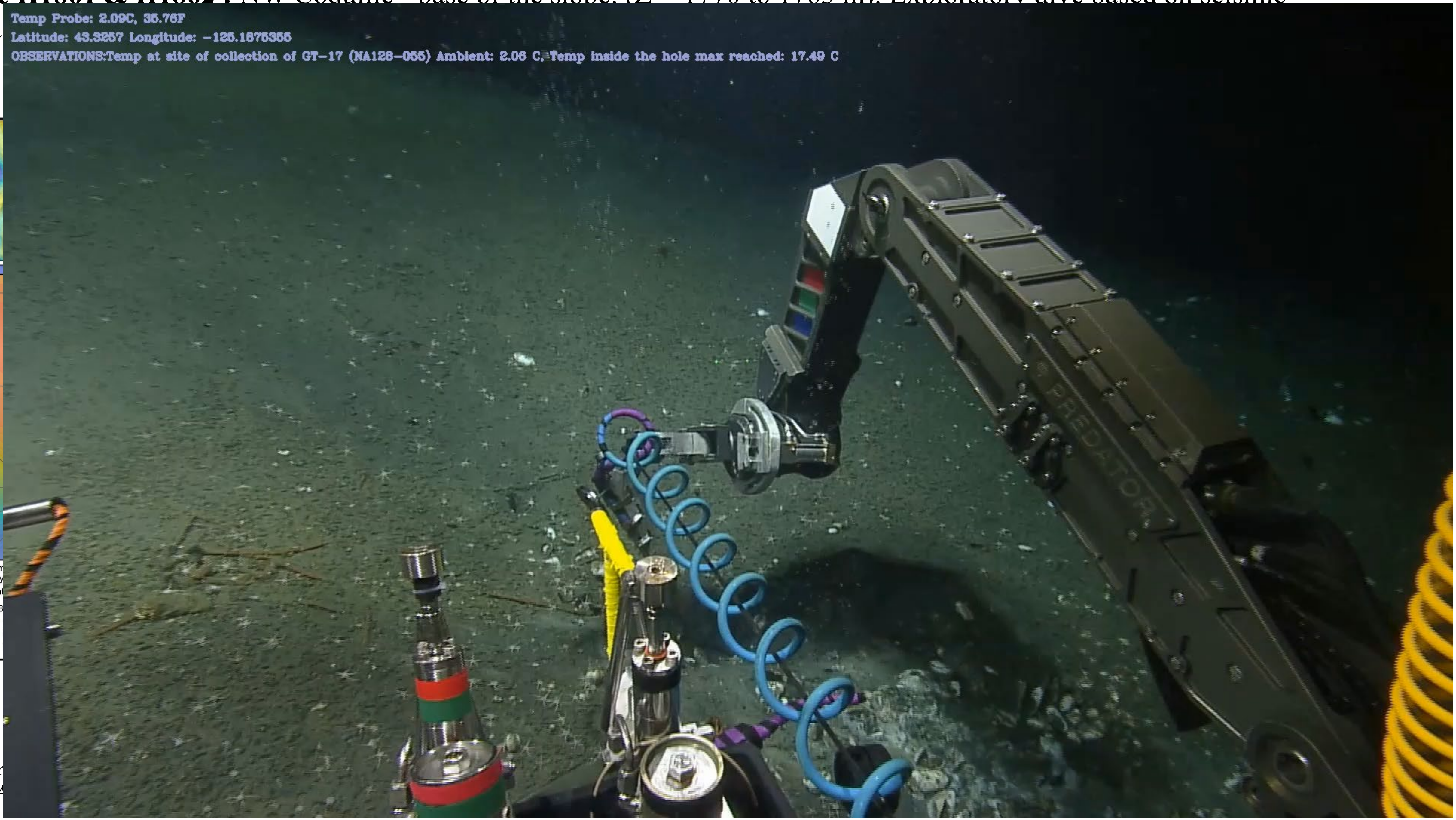



Bubble Hunting Mode
Norbit multibeam
bubble stream
HERCULES
Ocean Exploration Trust
ROV
seafloor
Seafloor Mapping Mode
Norbit multibeam
bubble stream
HERCULES
Ocean Exploration Trust
ROV
seafloor

Dive H1861 & H1862 : NW Coquille - base of the slope. (Z = 1770 to 1763 m). Exploratory dive based on seismic data



Repor
NOAA

Warm Seep from MG2104-PD16

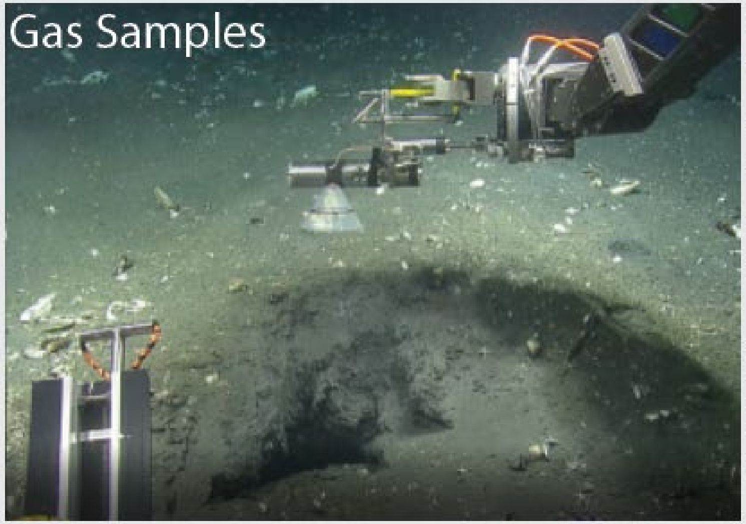
Geochemical A

NA128 - Cascadia Margin 2021
E/V Nautilus and ROVs Hercules and Argus
Gastight bottles extracted: Anson Antriasian
Mass spectrometer runs: Anson Antriasian

SAMPLE	Site	3He/4He
		R/Ra
NA128-047-GT17-1	Warm Seep #1	0.07
NA128-55-GT17-1	Warm Seep #2	0.07
NA128-57-GT5	Warm Seep #3	0.07

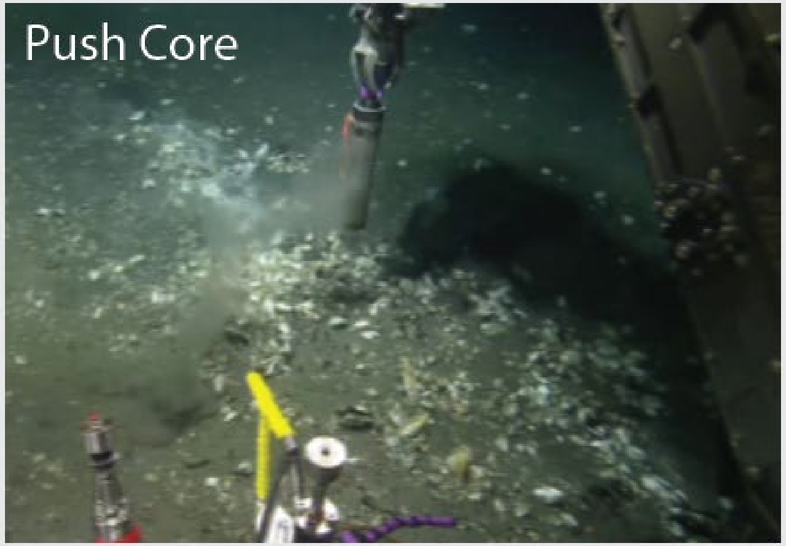
ROV Sampling

Fluid escaping the seafloor was sampled using a snorkel and modified gas tight sampler.



Gas bubbles escaping the seafloor were sampled using a funnel attached to a gas tight sampling device.

Geochemical analysis of gas samples presented to the left



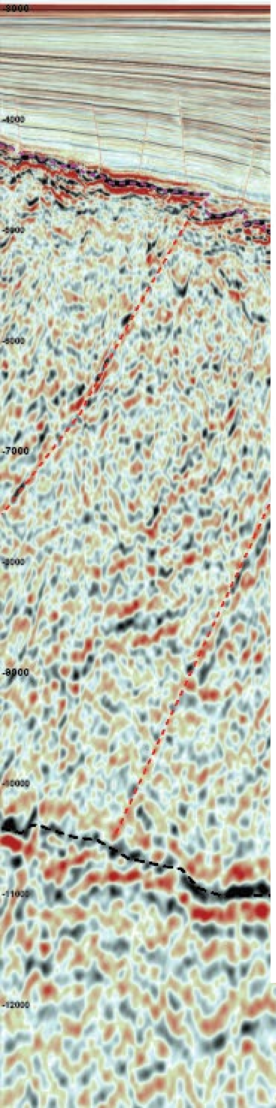
Push cores (~12cm in length) were collected at sediments adjacent to fluid escape sites. These sites were host to extensive clam beds and bacterial mats.

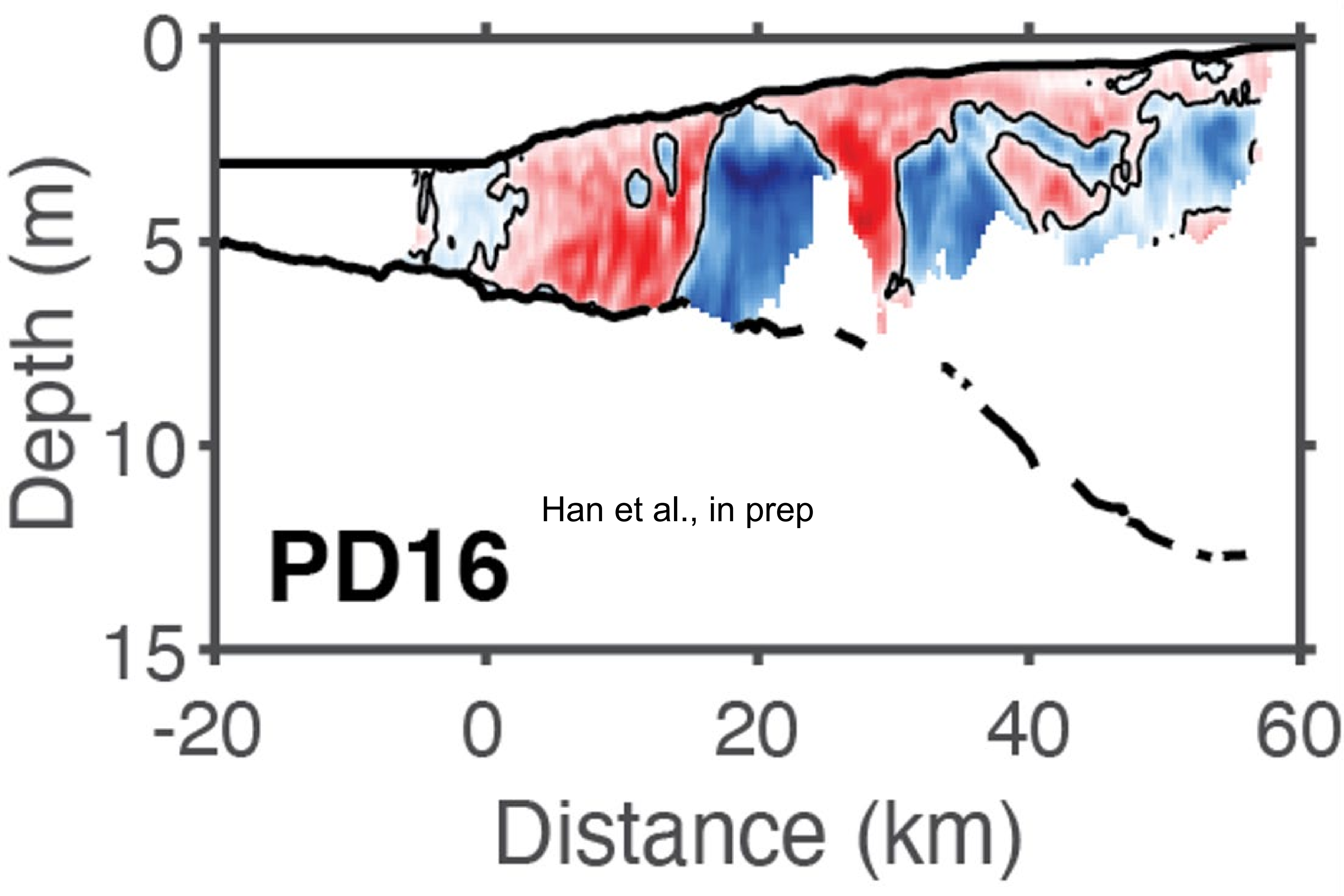
Geochemical analysis of pore waters extracted from push cores are presented to the left.

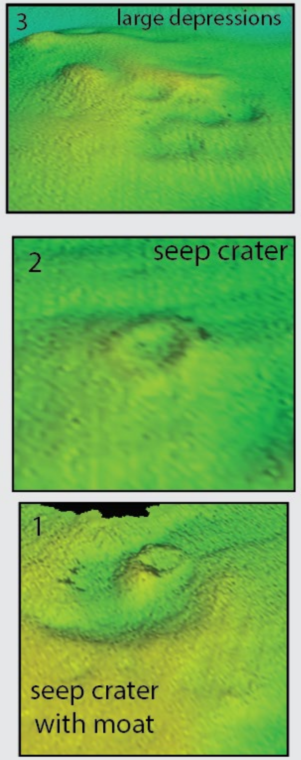
CASIE21 Seismic Data - PreStack Depth Migration

Multi-channel seismic reflection profile MGL2104 PD16 collected during the CASIE21 expedition.

- A decollement is imaged in PD16
- Seismic data reveal a thick (>2km of the margin.
- Seaward vergent thrust faults are
- Prominent bottom simulating ref
- A BSR anomaly, deflection upwar
- BSR anomaly is nearly continuous regime (remove the BSR).
- Large landslide deposits are imag







Meters

smic data reveled the

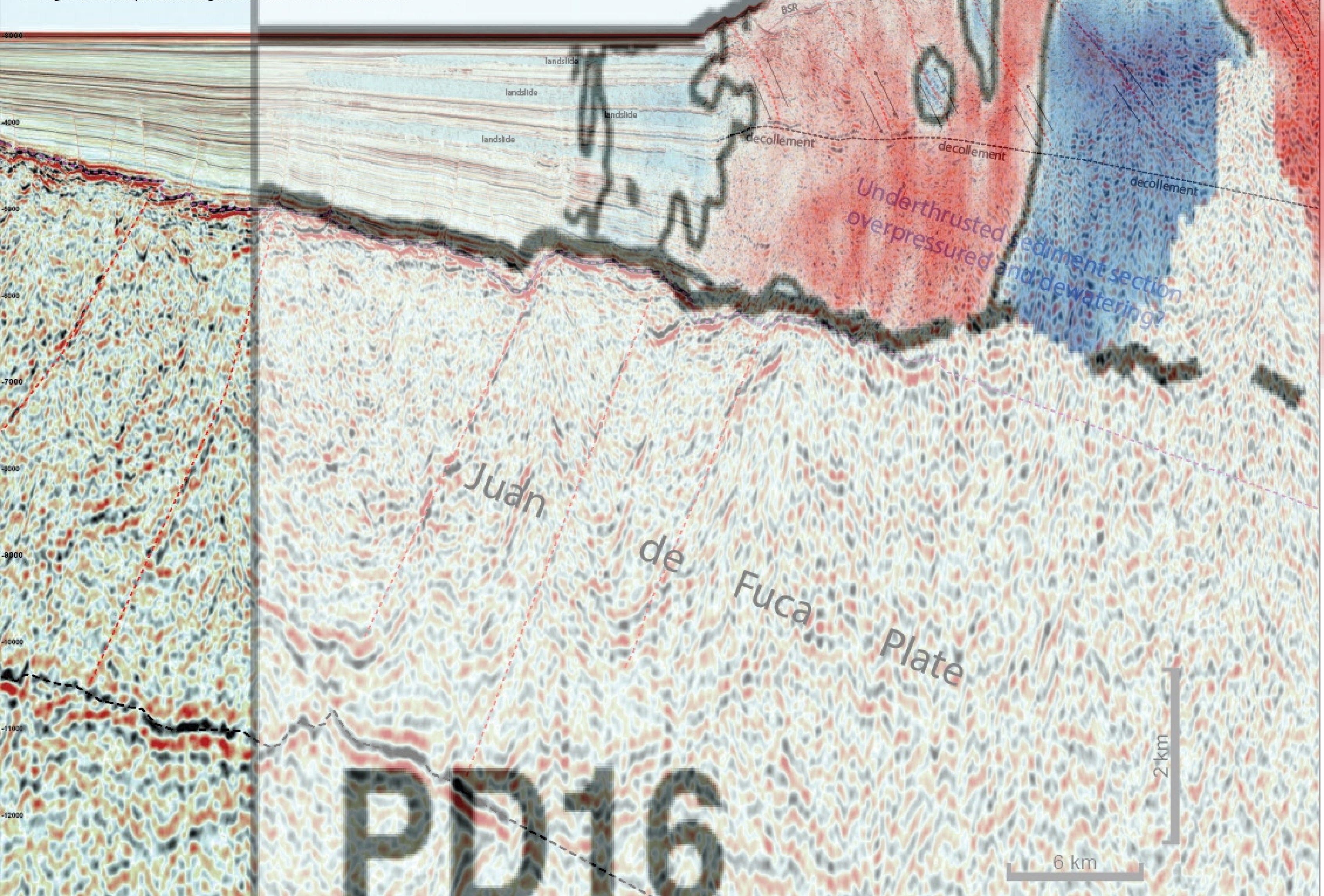
mpling of gasses and fluids
tiple emission sites.
adjacent to sampled warm
oor expulsion features.
expulsion features are

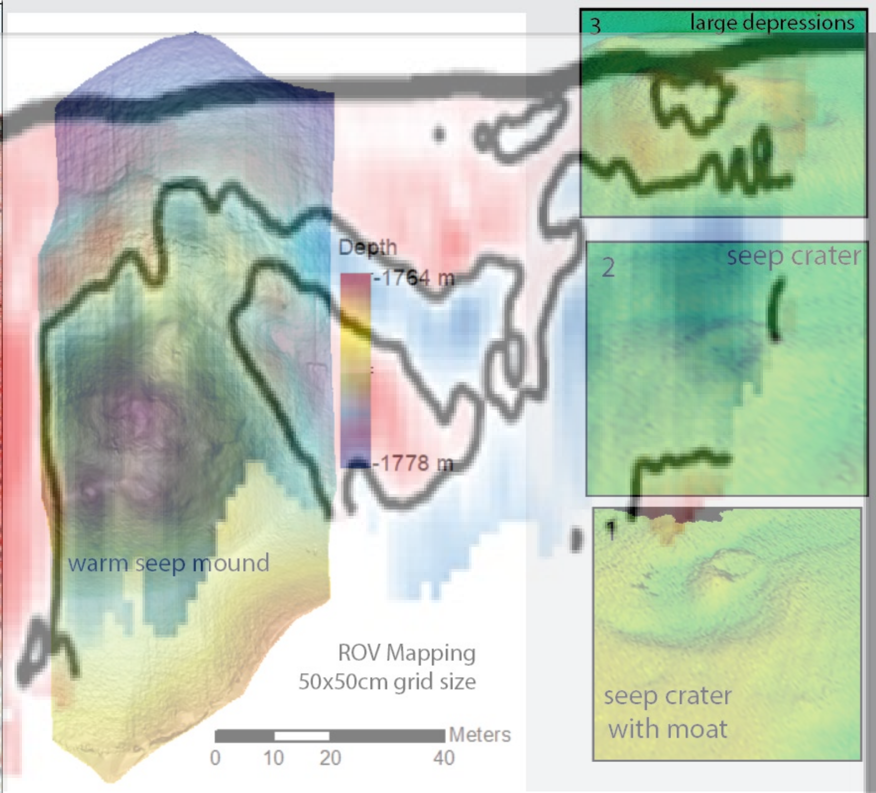
pressure environment
the megathrust?
warm seep.

CASIE21 Seismic Data - PreStack Depth Migration

Multi-channel seismic reflection profile MGL2104 PD16 collected during the CASIE21 expedition.

- A decollement is imaged in PD16 from base of imbricate thrust faults within the accretionary wedge.
- Seismic data reveal a thick (>2km thick) section of marine sediment being underthrusted and subducted along with the Juan de Fuca Plate at this section of the margin.
- Seaward vergent thrust faults are imaged as the dominant structure accommodating sediment accretion and deformation.
- Prominent bottom simulating reflectors (BSR) are imaged in the seismic sections and indicate high concentrations of methane in accreted sediments.
- A BSR anomaly, deflection upwards, located ~15km landward of the deformation front indicated the migration of warm fluid into the shallow subsurface.
- BSR anomaly is nearly continuous across the warm seep suggest that the current warm seep is young and has not had enough time to alter the thermal regime (remove the BSR).
- Large landslide deposits are imaged seaward of the deformation front.

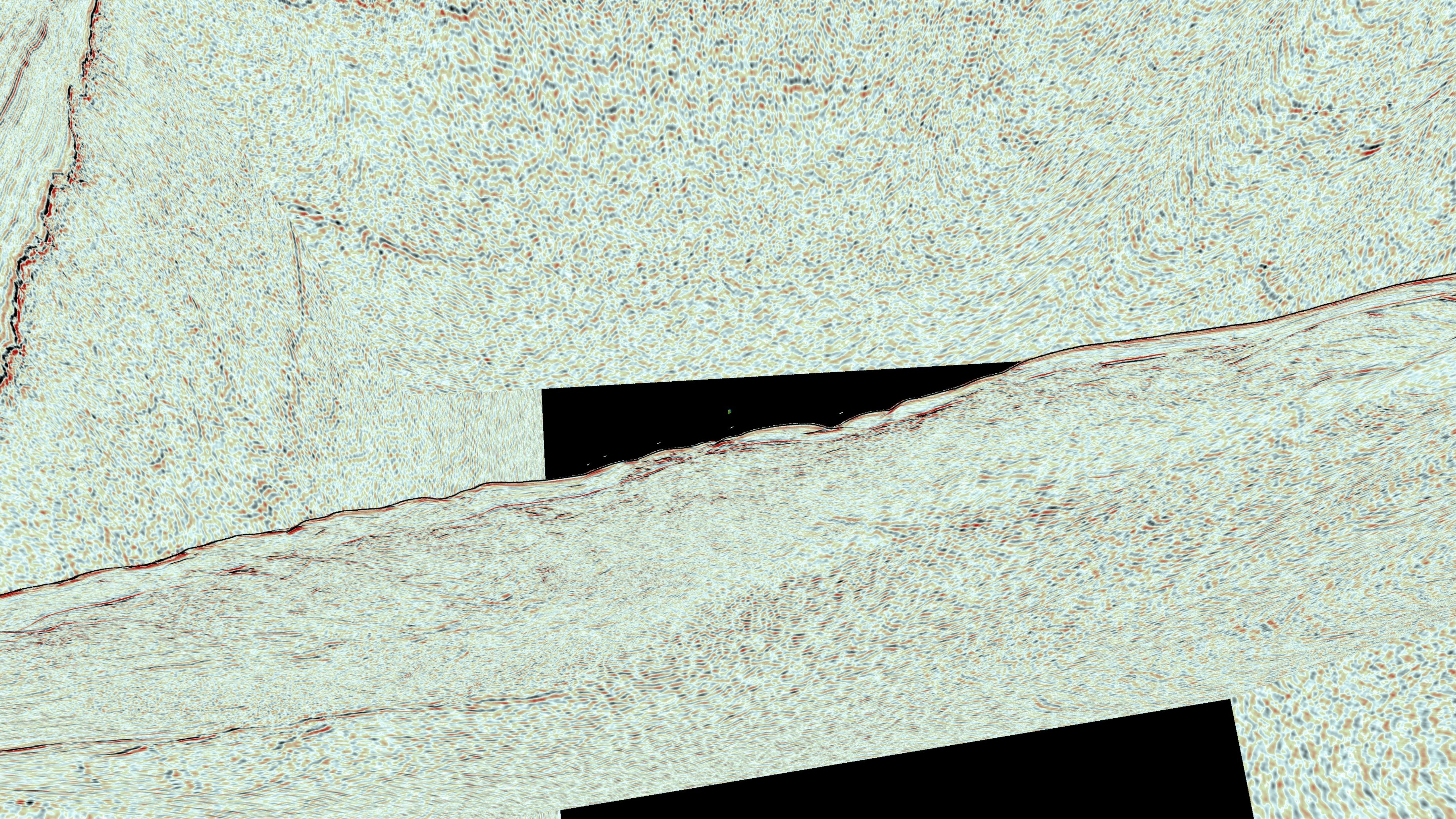


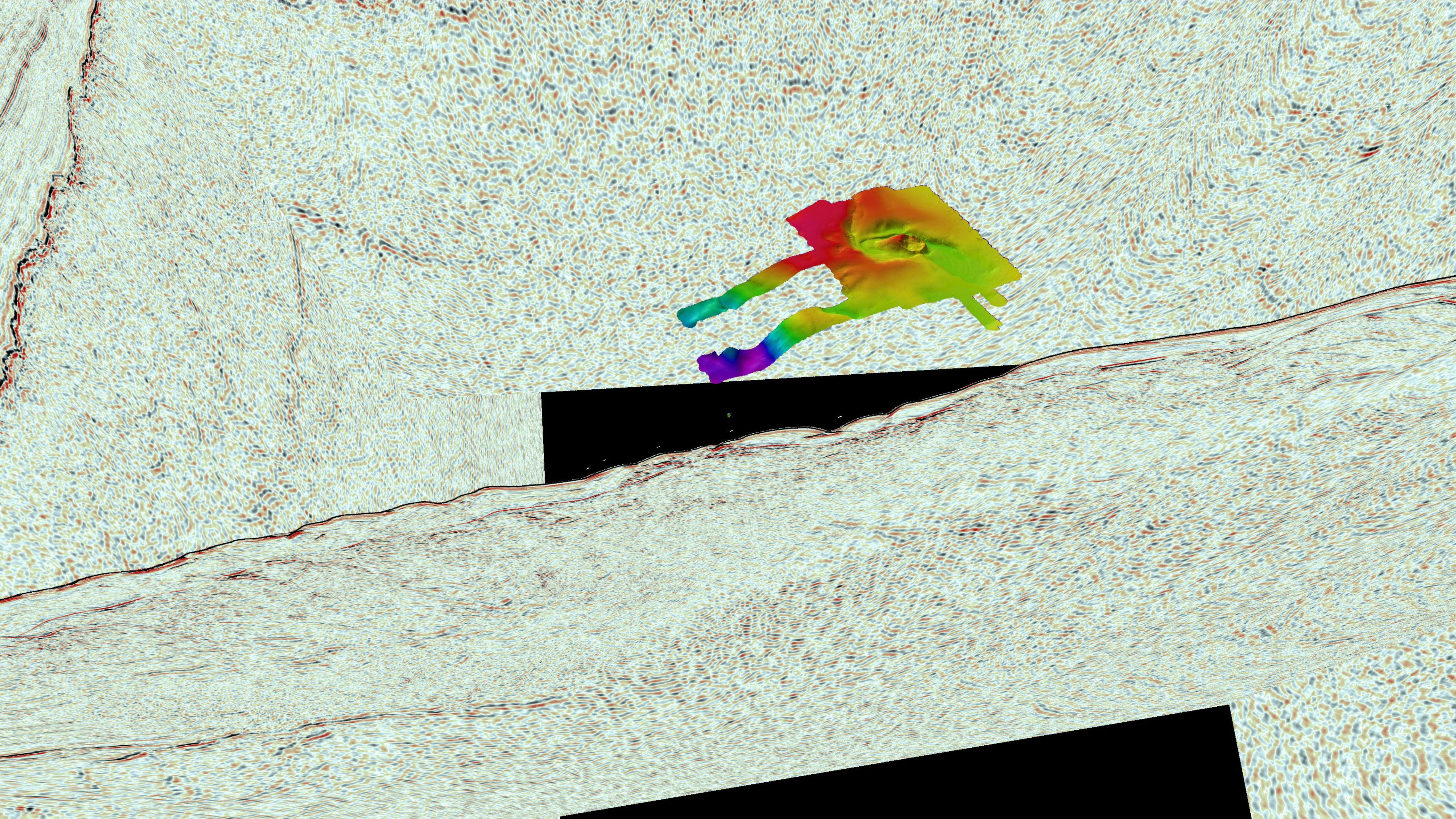


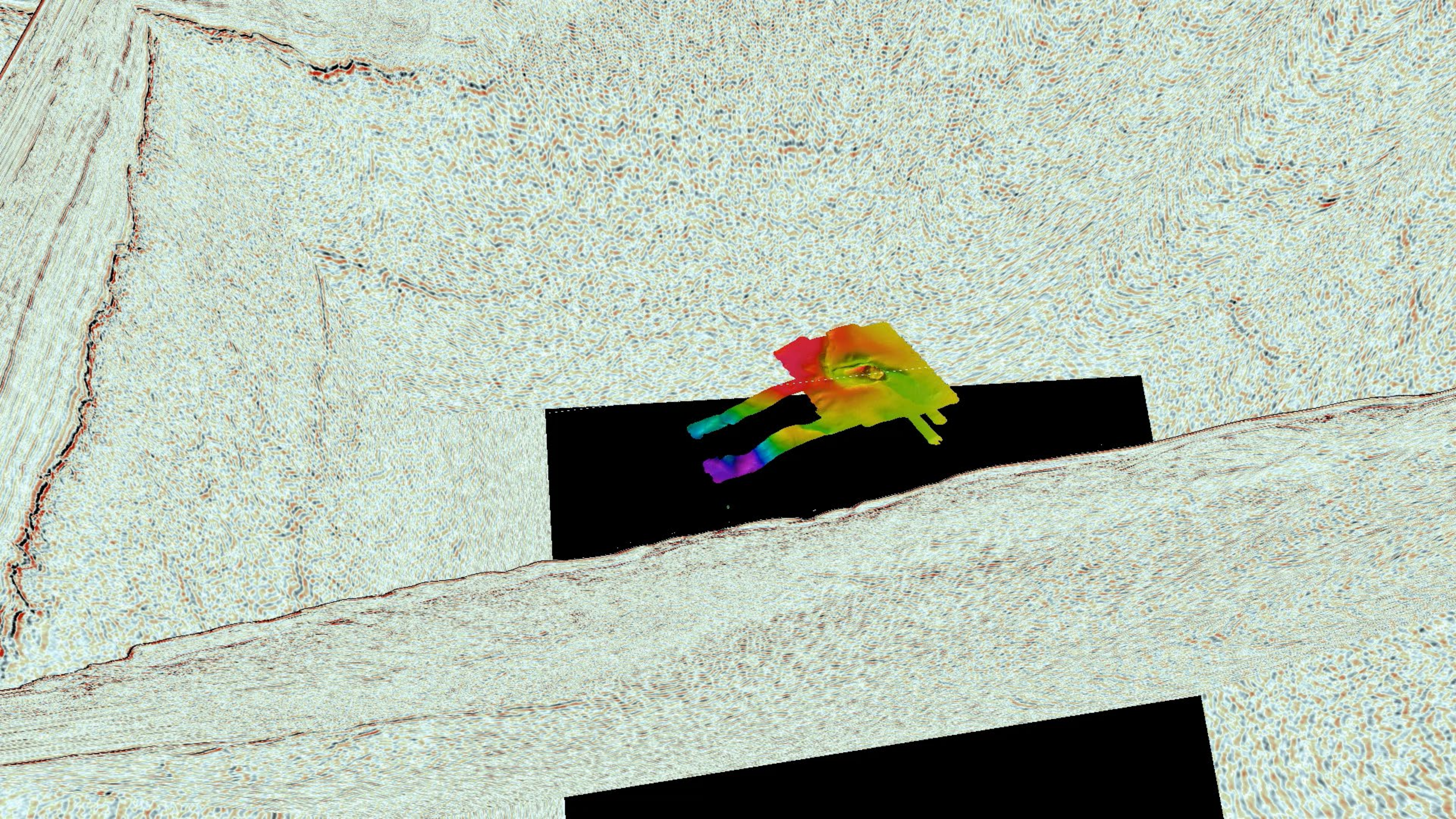
A BSR anomaly imaged in seismic data reveled the location of a warm fluid seep.

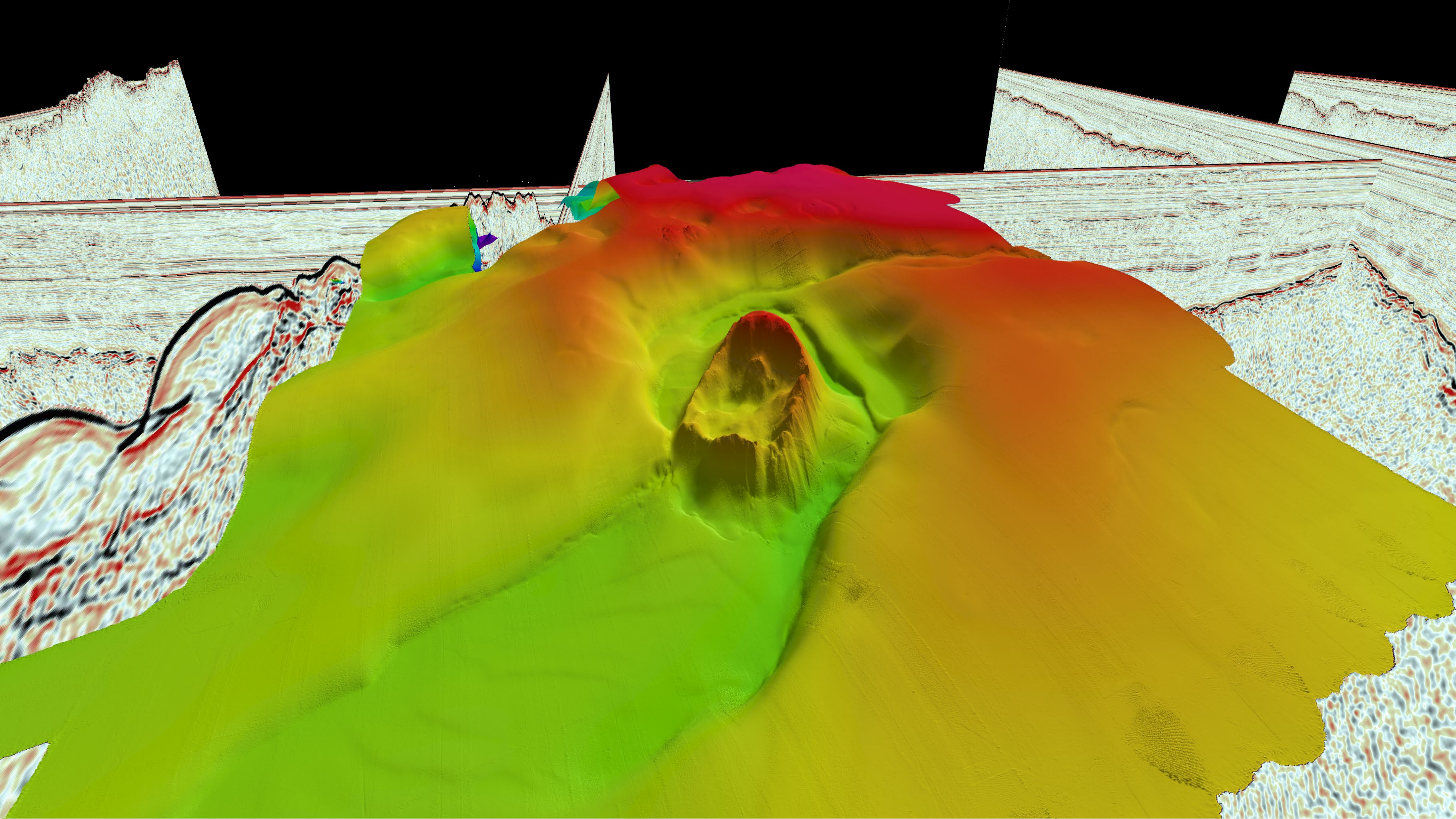
ROV dives allowed for the sampling of gasses and fluids escaping the seafloor at multiple emission sites. Additional seafloor mapping adjacent to sampled warm seep indicate pervasive seafloor expulsion features. How many of these seafloor expulsion features are releasing warm fluid?

How does this high pore fluid pressure environment affect the effective stress on the megathrust?
We need a cool name for this warm seep.

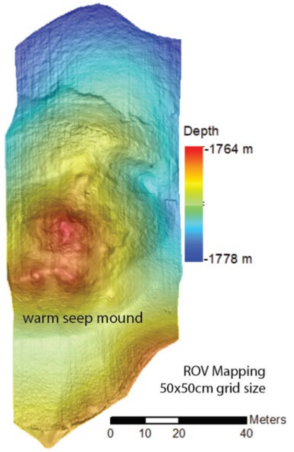


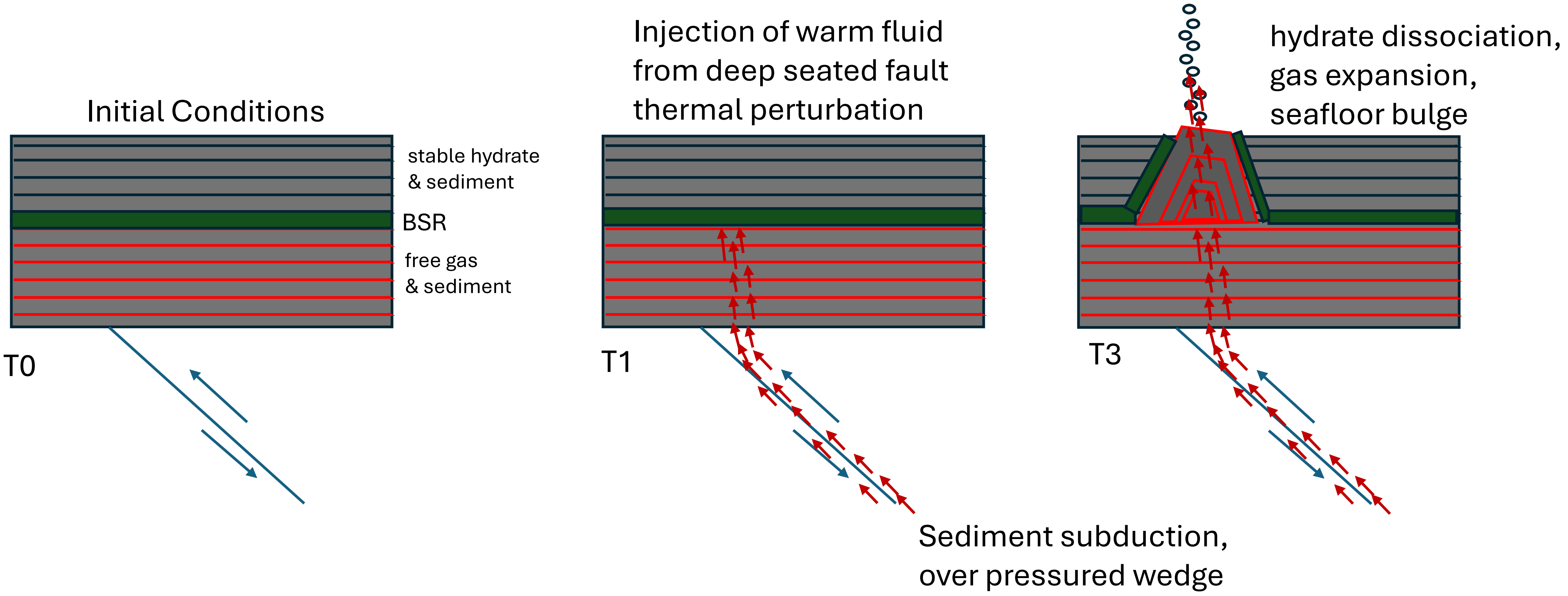






Conceptual Model for Crater Features





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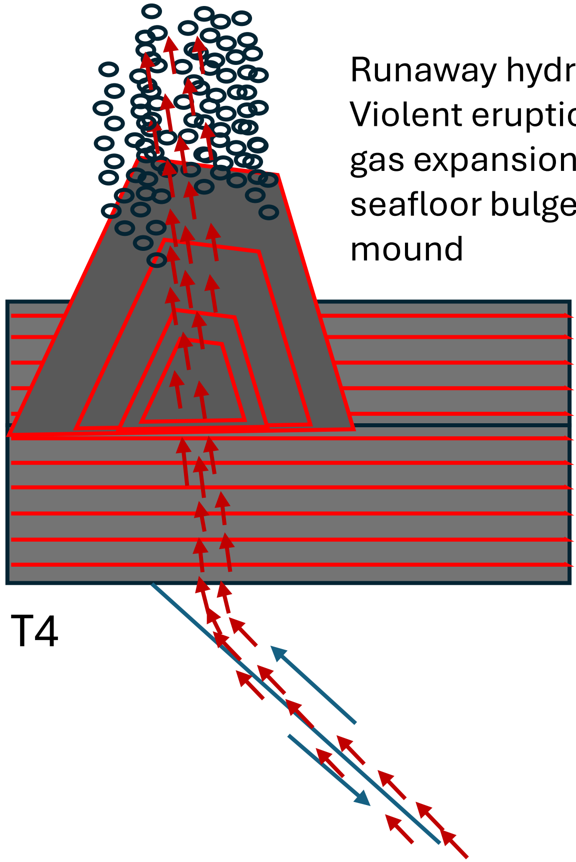
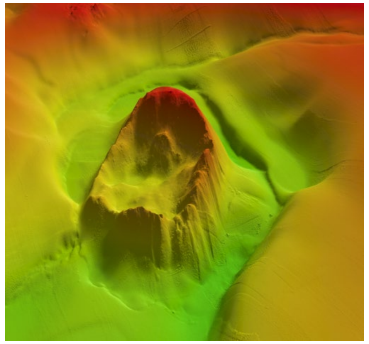
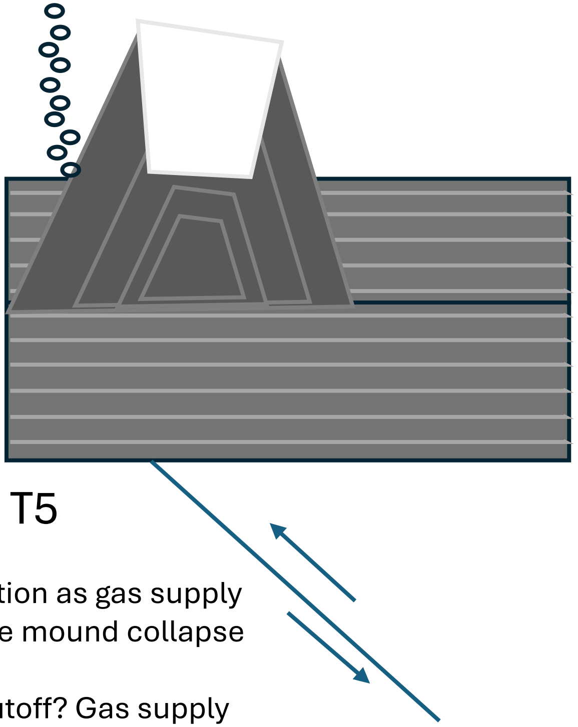


Runaway hydrate dissociation,
Violent eruption,
gas expansion, eruption,
seafloor bulge into giant
mound



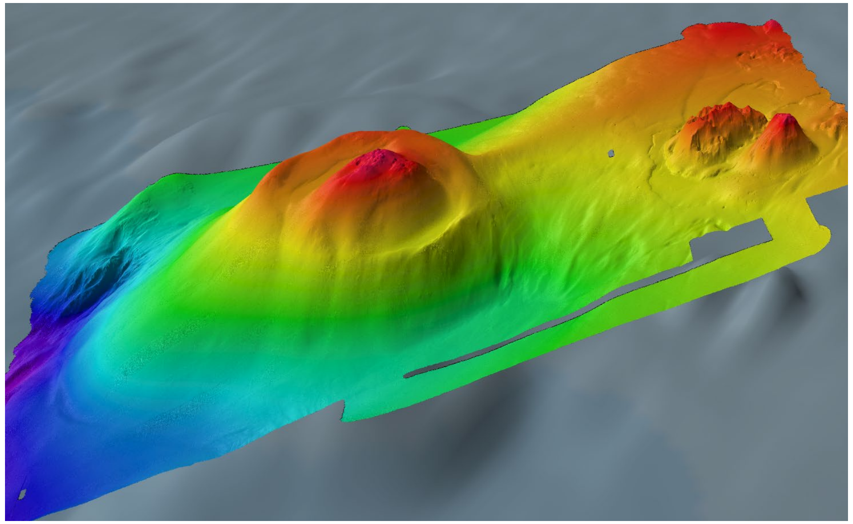


Depressurization as gas supply wanes and the mound collapse

Warm fluid cutoff? Gas supply exhausted?

Subsequent injection of warm fluid and gas expansion?

Resurgent dome indicates this.



THANK YOU

QUESTIONS?