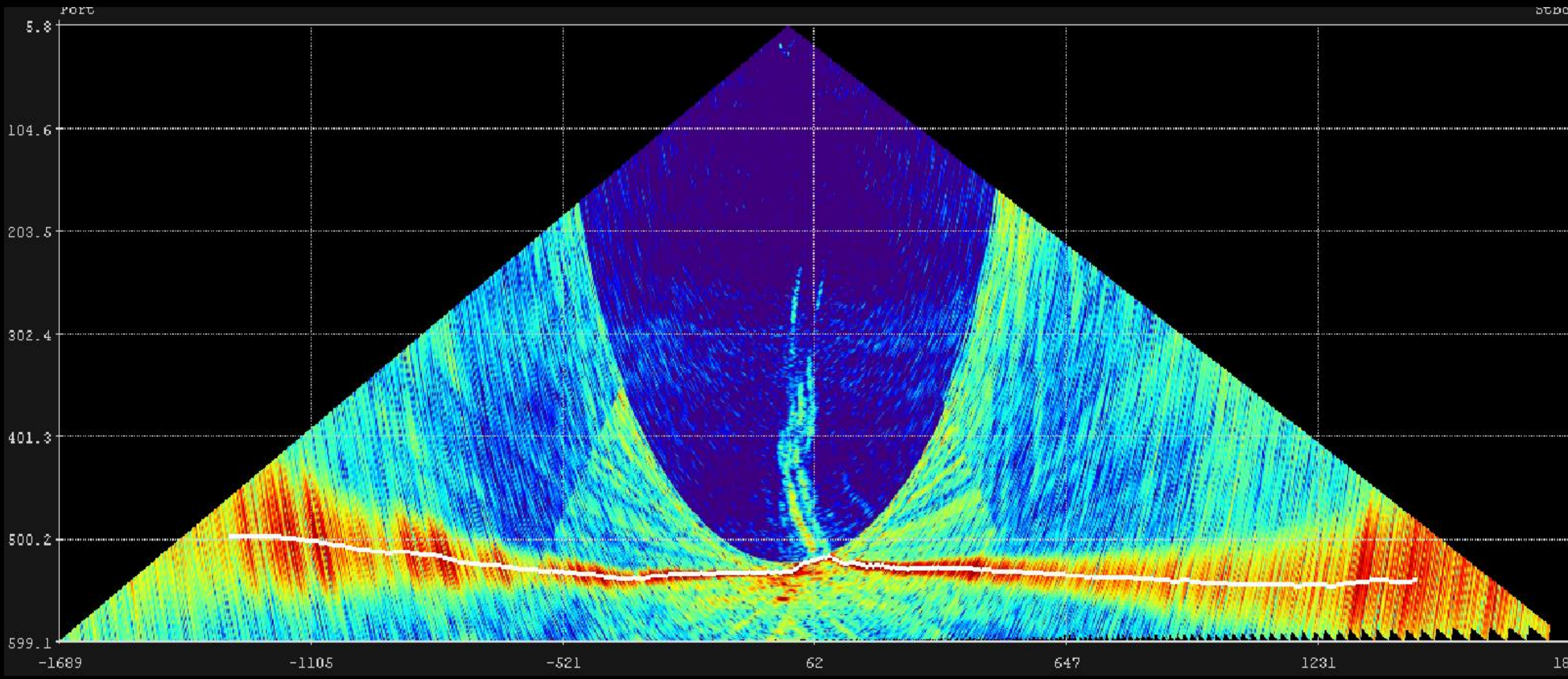
GLOBAL WARMING COMES TO THE WASHINGTON COAST.



SO, why would seismologists care about this?

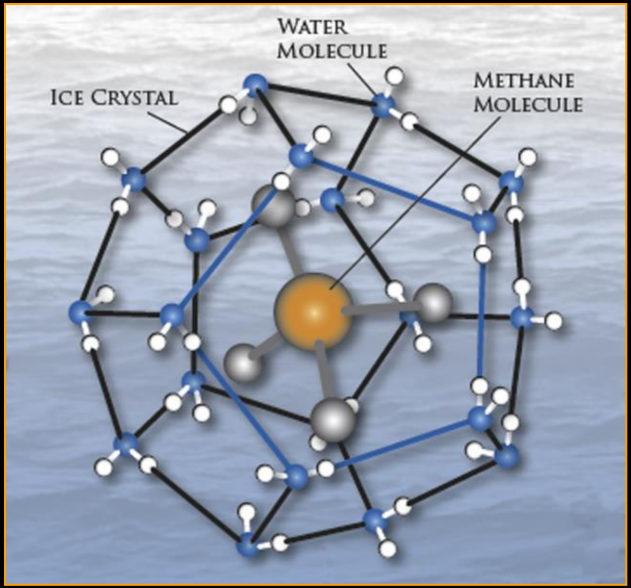
A Quick Look at
Current Studies of Heat, Fluid and Methane Fluxes on the Washington Portion of the Cascadia Margin

A TEAM Approach, consisting of:

Evan Solomon, Susan Hautala, Marie Salmi, Rob Harris, Rick Berg, Una Miller, Tor Bjorklund, and me.

Where underlined names are students who are actually carrying the heavy end of the work load.

Background on Gas Hydrates



Hydrate contains small cages of water molecules that house guest gas molecules.

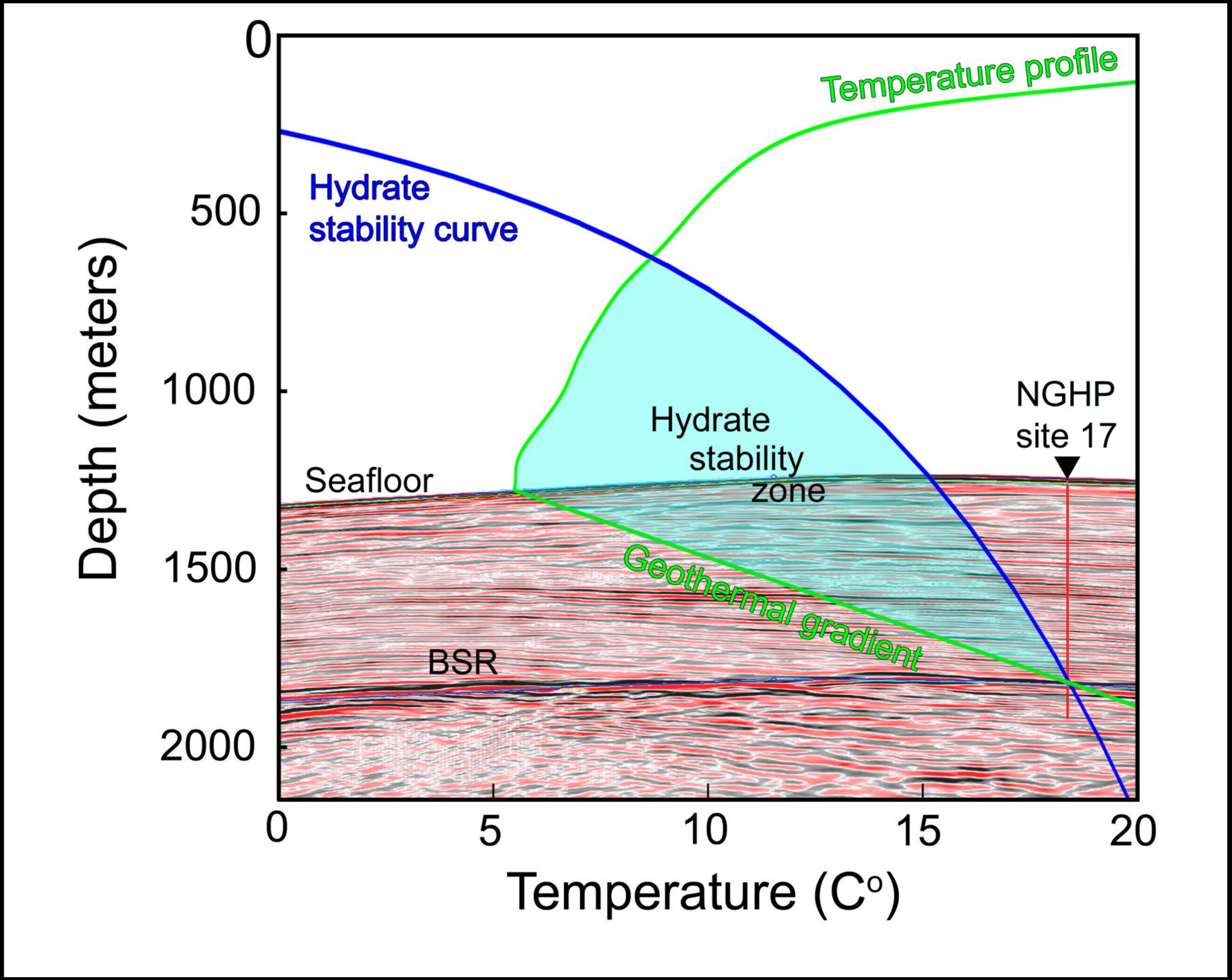
The gas is mostly methane.

HYDRATE – the ICE that BURNS.

In general, 1 cm^3 of gas hydrate contains 164 cm^3 of CH_4 and 0.8 cm^3 of freshwater.

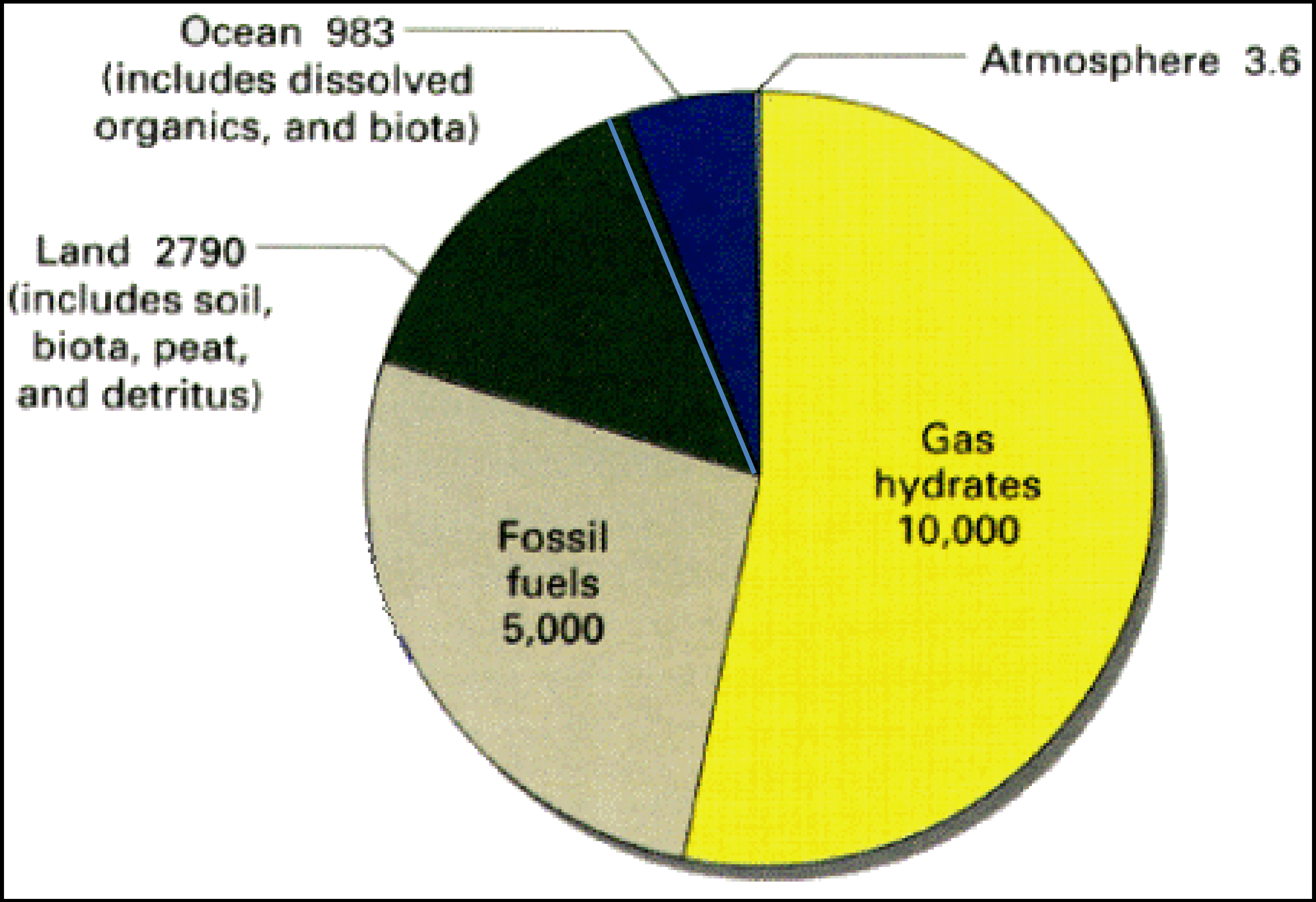
A little hydrate produces a LOT of methane.

Gas Hydrate Stability



Upper limit >300 m in the Arctic and about 500 m in lower latitudes

Stability depends on pressure, temperature, and CH_4 concentration



Estimates of the Size of the global Gas Hydrate Reservoir on continental margins.

CRITICAL TAPER MODEL 61

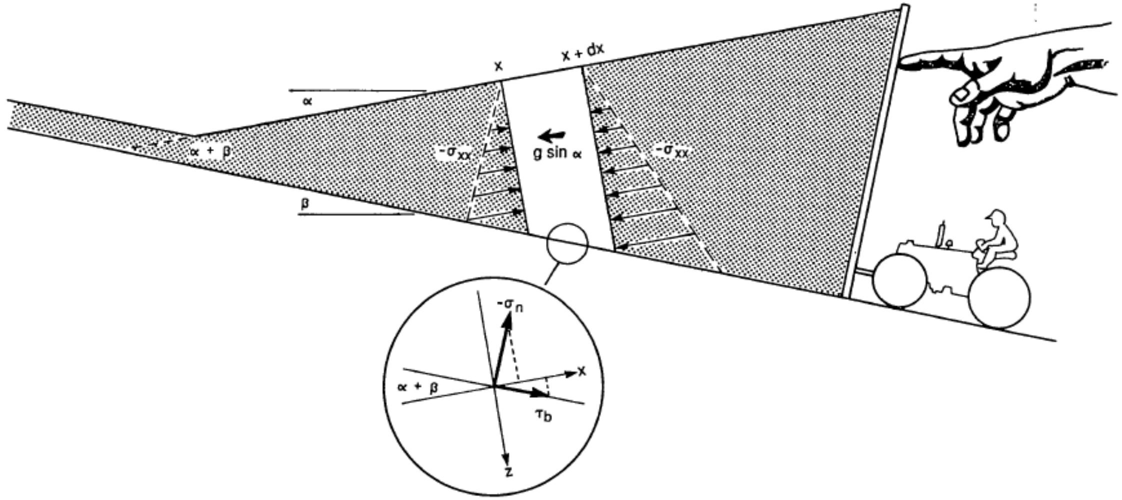


Figure 6 Schematic diagram illustrating the horizontal balance of forces on an element of a bulldozer wedge.

The 'old' view of accretionary prisms.

Without fluid.

Or with fluid.

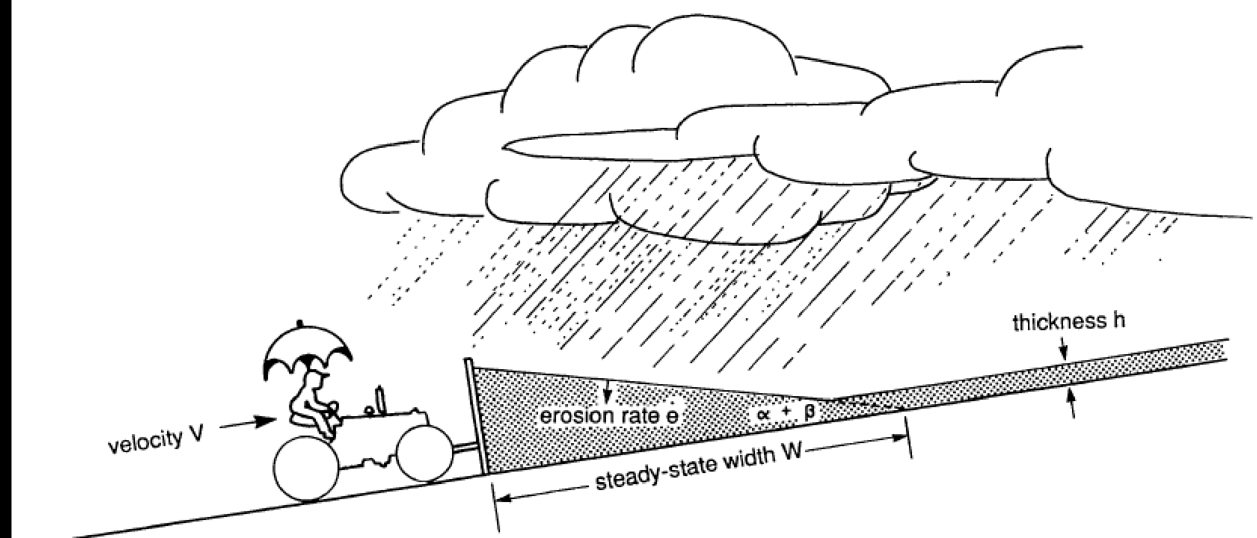


Figure 5 An eroding wedge attains a dynamic steady-state width given by $\dot{e}W = hV$.

A more modern view of accretionary prisms, Costa Rica.

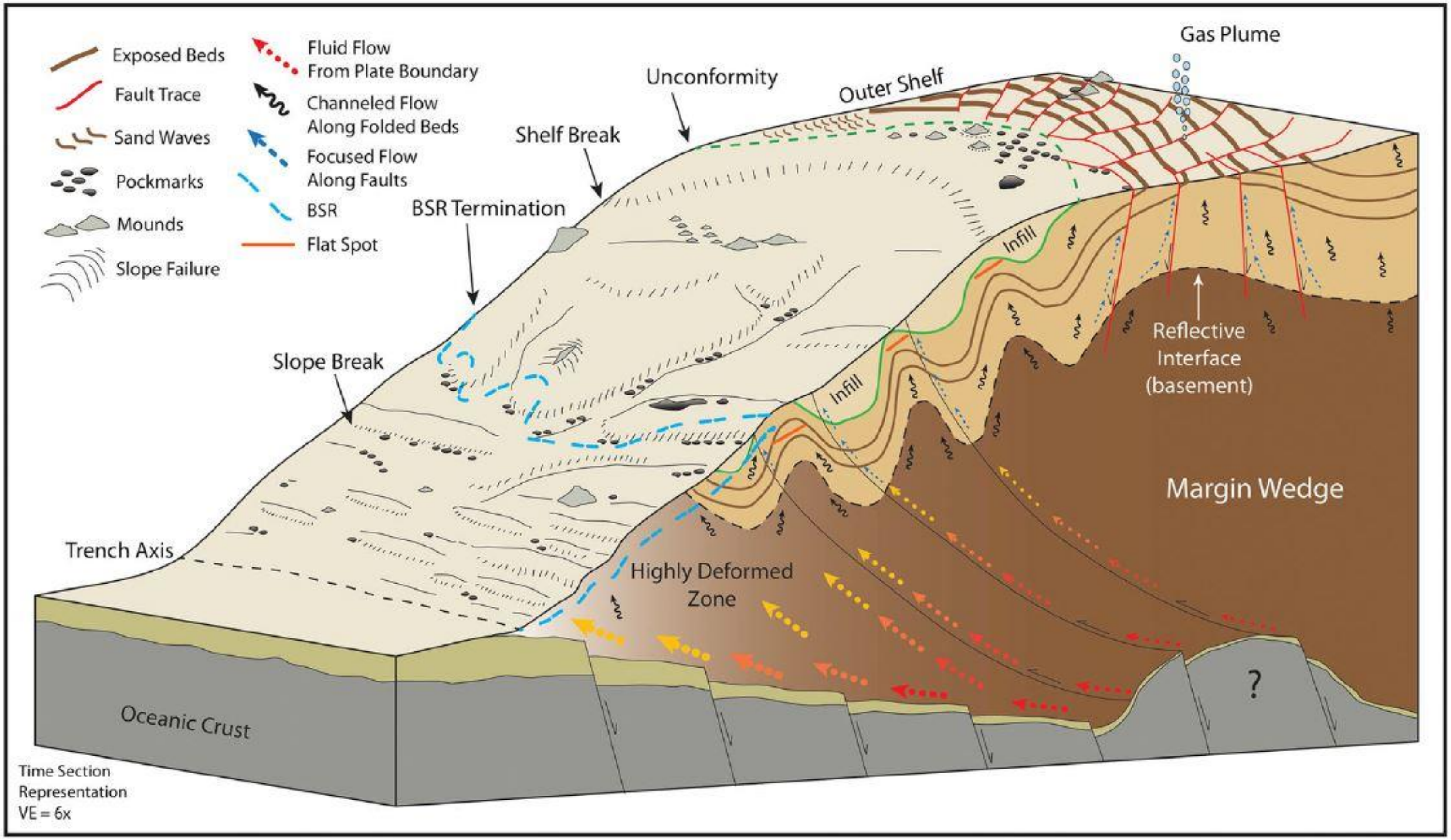
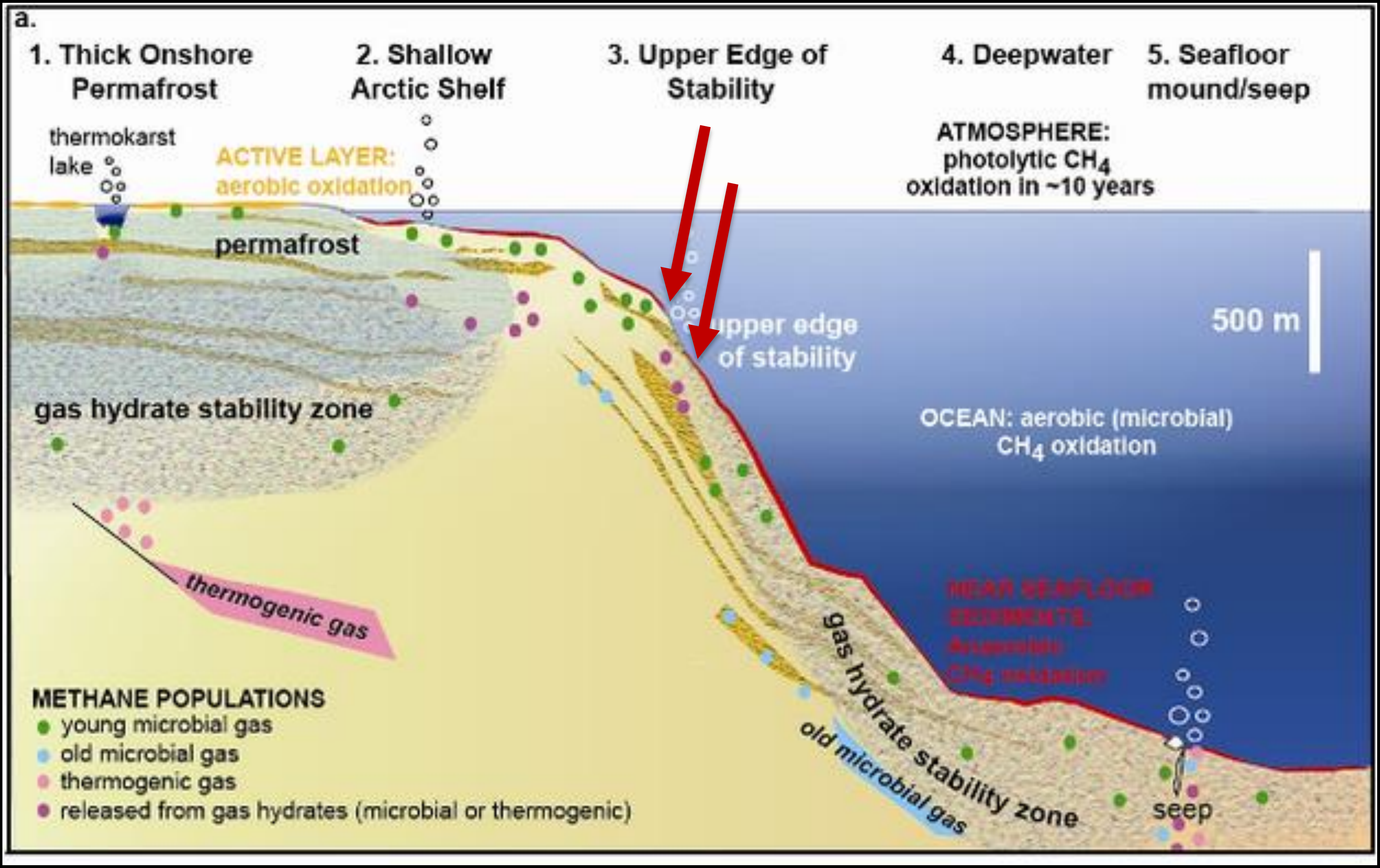


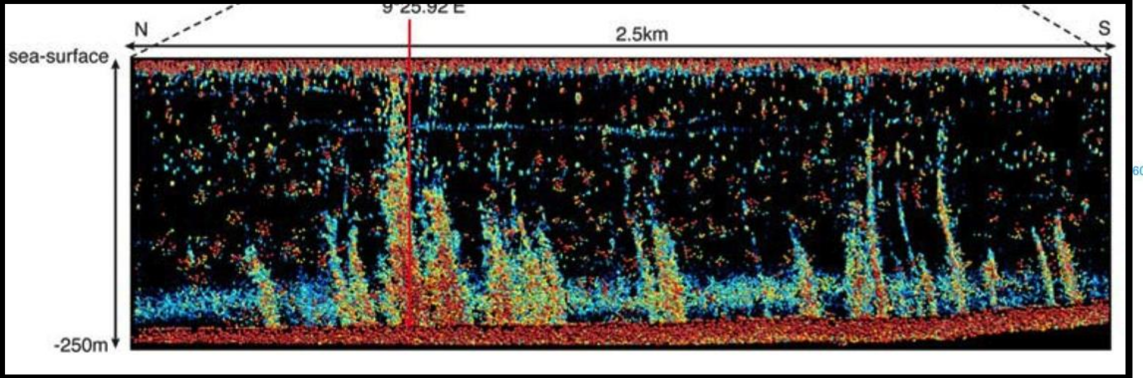
Figure 15. Conceptual 3-D block diagram of fluid flow paths and seafloor seepage features within the CRISP survey area. Locations of seafloor seepage features are strongly dependent on folds and fault patterns. Exposed beds on the outer shelf highlight dense faulting through a large anticline. Migrating fluids and gases use faults and folded stratigraphic horizons as conduits to the seafloor. Note increase in deformation to the east caused by the incoming Cocos Ridge.

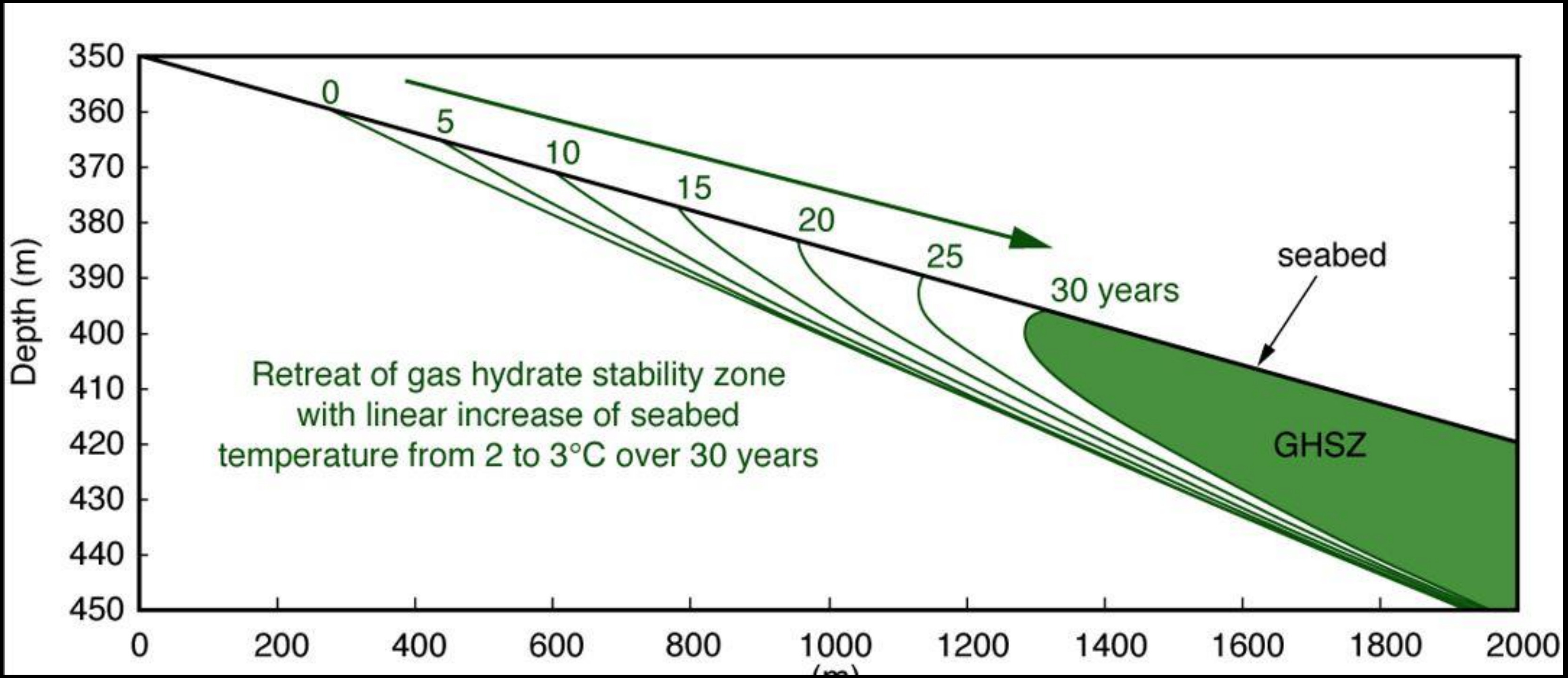
Now, add global warming, fluid flow and methane hydrates



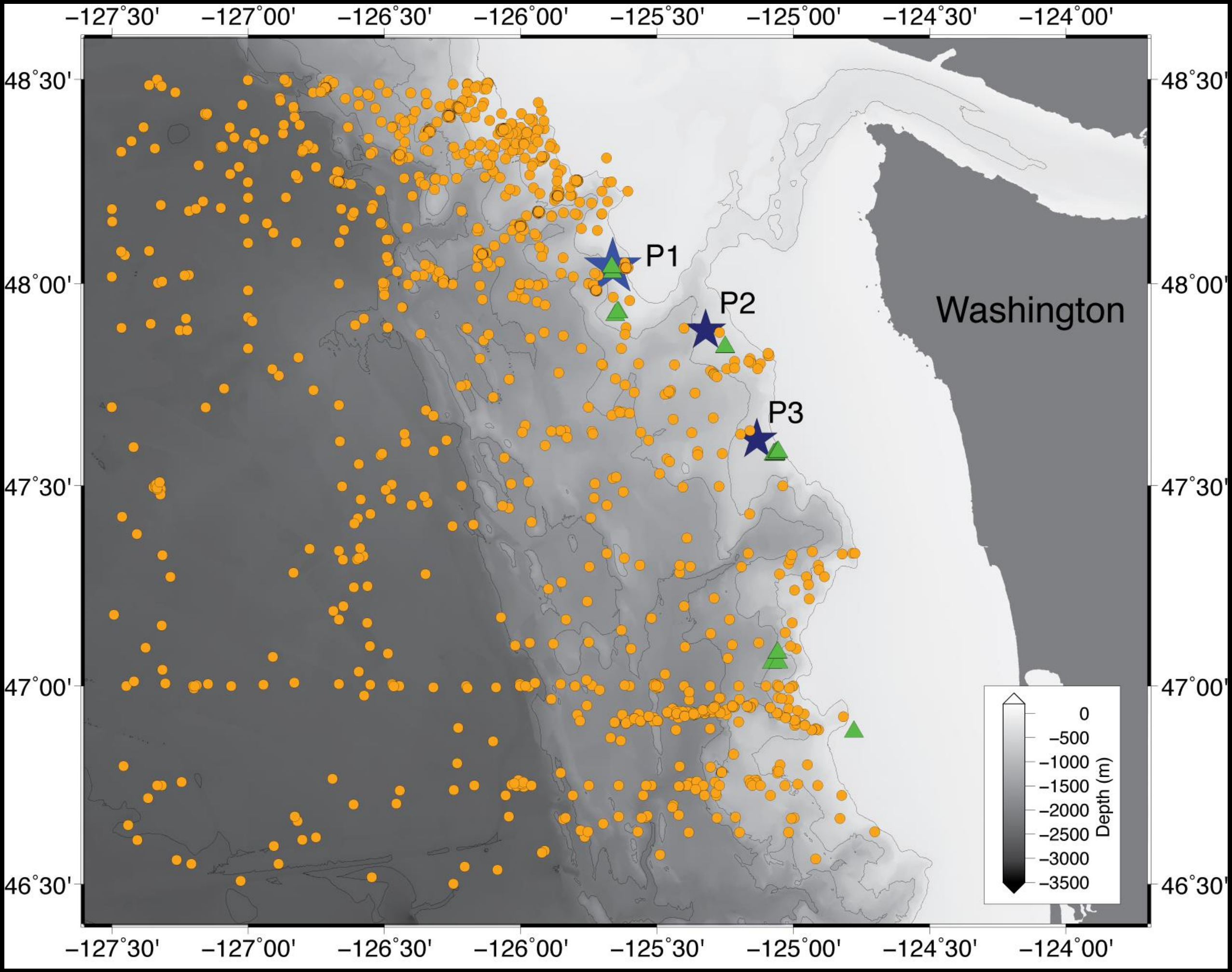
And you get a very complex and dynamic environment

Previous Studies Have Suggested Possible Gas Hydrate Dissociation Offshore Spitsbergen



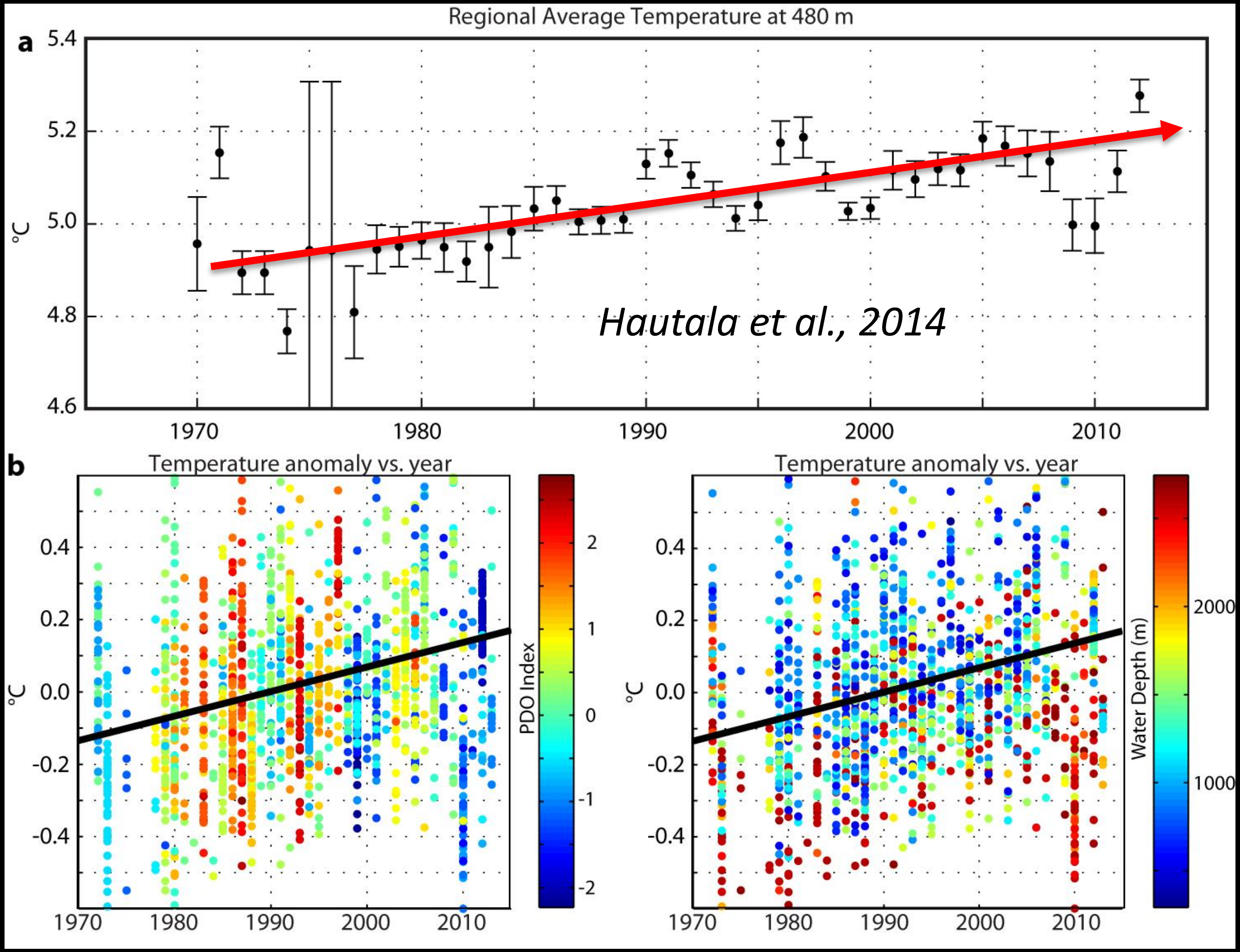


What About Intermediate Water Warming at Mid-Latitudes? - **like the CASCADES**



Hautala, S., E. Solomon, HP Johnson, U.K. Miller., published 2014, GRL

Recent analysis of 6,596 CTD casts along the Washington continental margin also shows a warming of bottom water (400-600 m) over the past 50 years.



Bottom Water Warming on the Washington continental margin,

At 500 meters water depth.

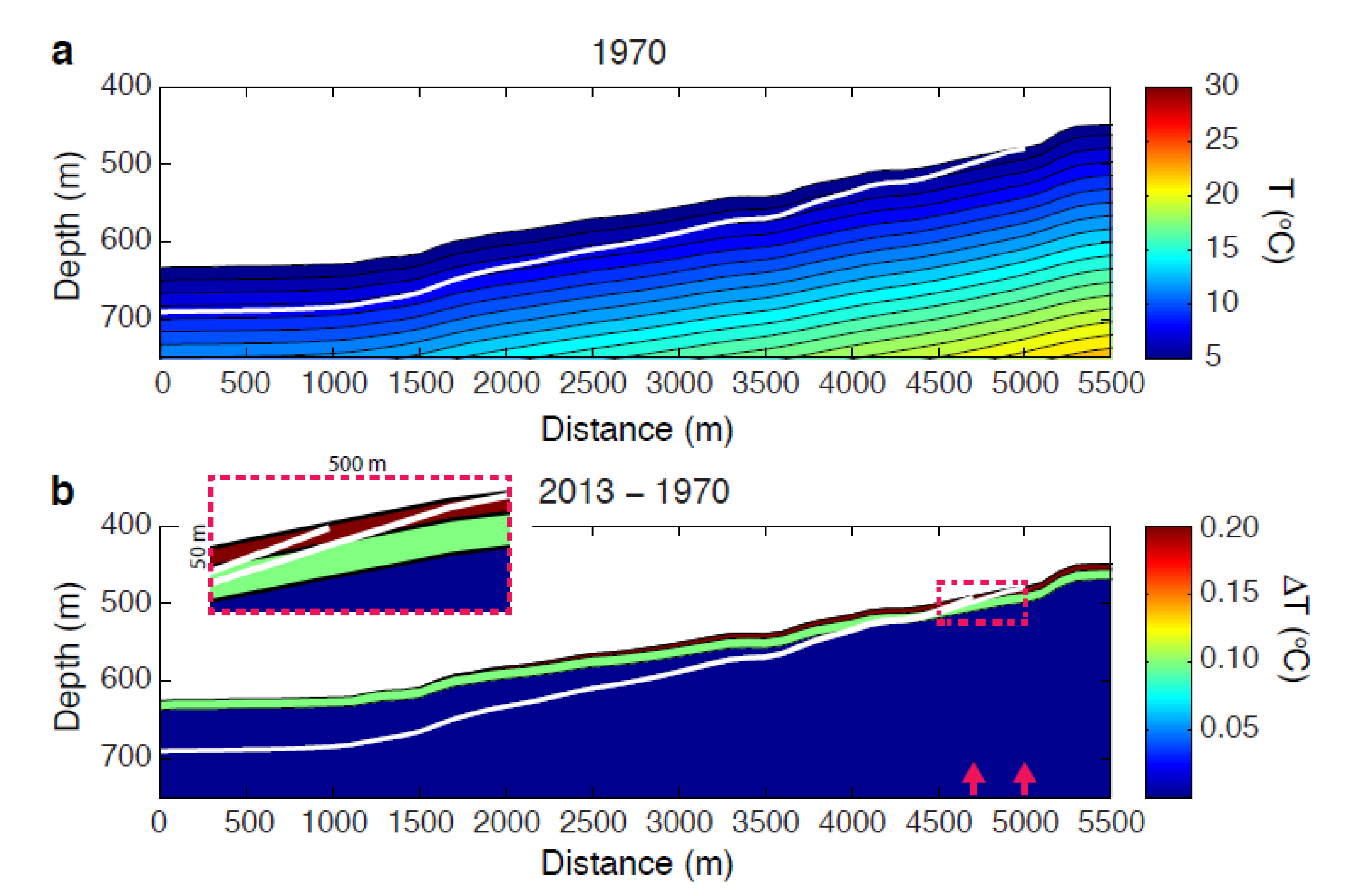
The upper depth limit of hydrate stability

Over 44 year record, this is warming of about 0.3 °C

Bottom waters have been warming over the past 40 years

Upper limit of gas hydrate stability is at 500 m water depth along the WA margin

On the WA Cascadia margin, this is the equivalent of moving the upper limit of hydrate stability – **downward by 50 meters and horizontally by about 1 kilometer.** Depending on the margin slope.



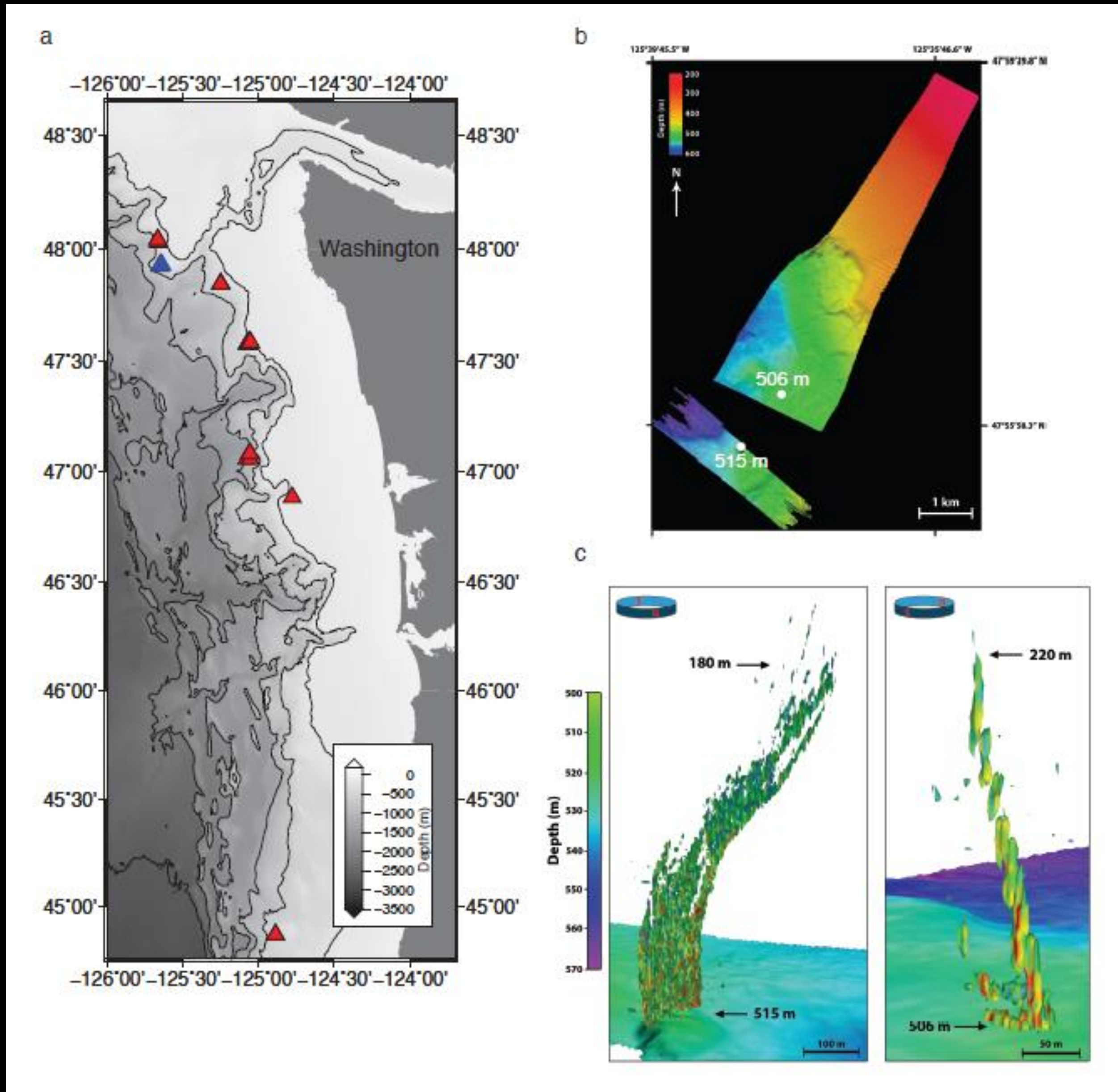
That releases a LOT of methane!

1. So we have a potential driving function – warming water off the Cascadia Margin at the right (500 m) depths.

2. The NEXT question is – do we observe the expected RESPONSE to that driving force? i.e., methane plumes at the upper stability depth?

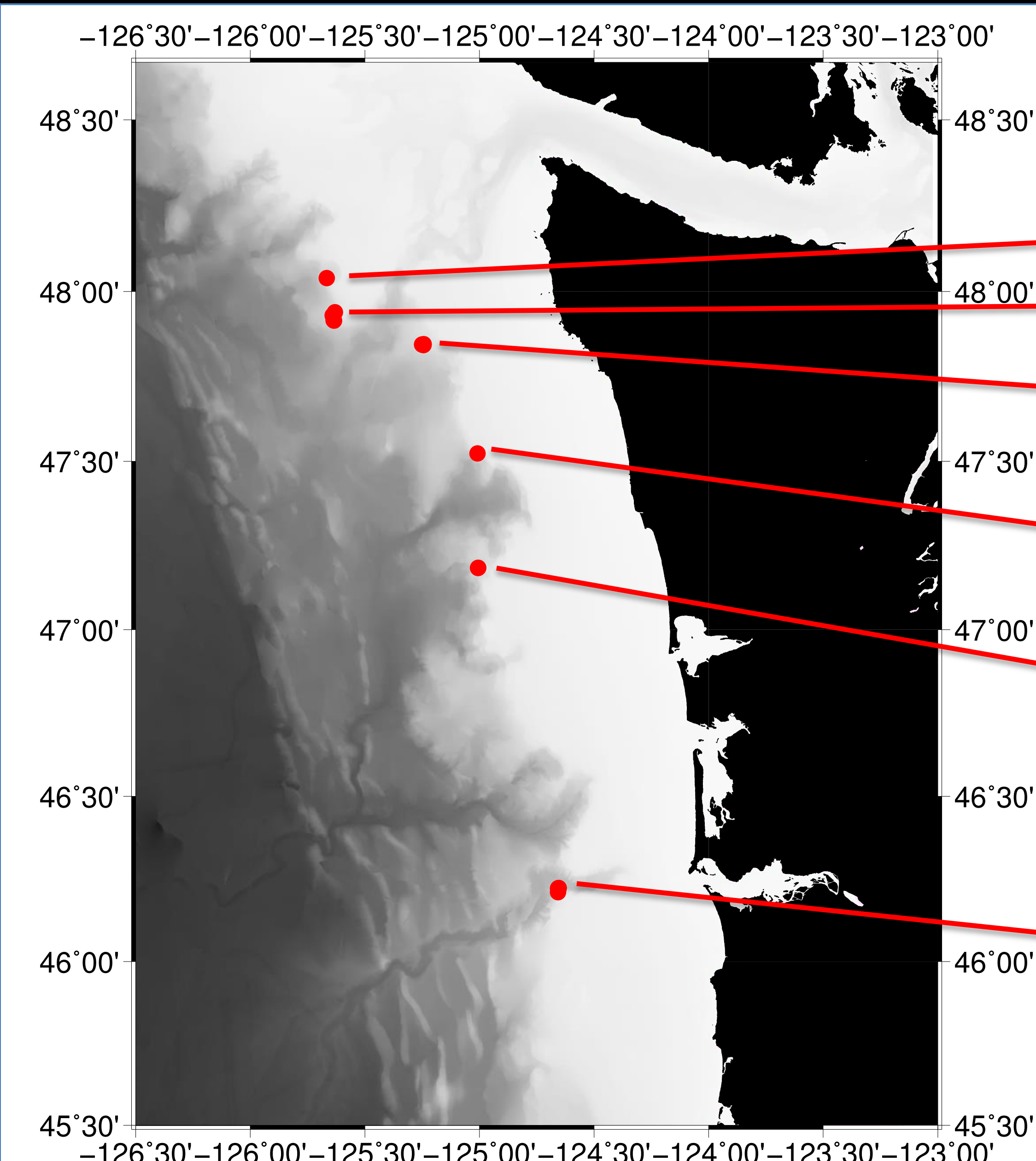
3. And then, the FINAL piece of the puzzle, are the observed methane emissions (at 500 m depth) related to hydrate decomposition?

Remember, there are methane emissions at EVERY depth on the Cascadia margin. What does chemistry tell us.



This is what we think that methane release looks like.

THOMPSON Cruise TN 314 October 2014



Site 1

Sites 2 & 3

Site 4

Site 5
(aka Tor’s Plume)

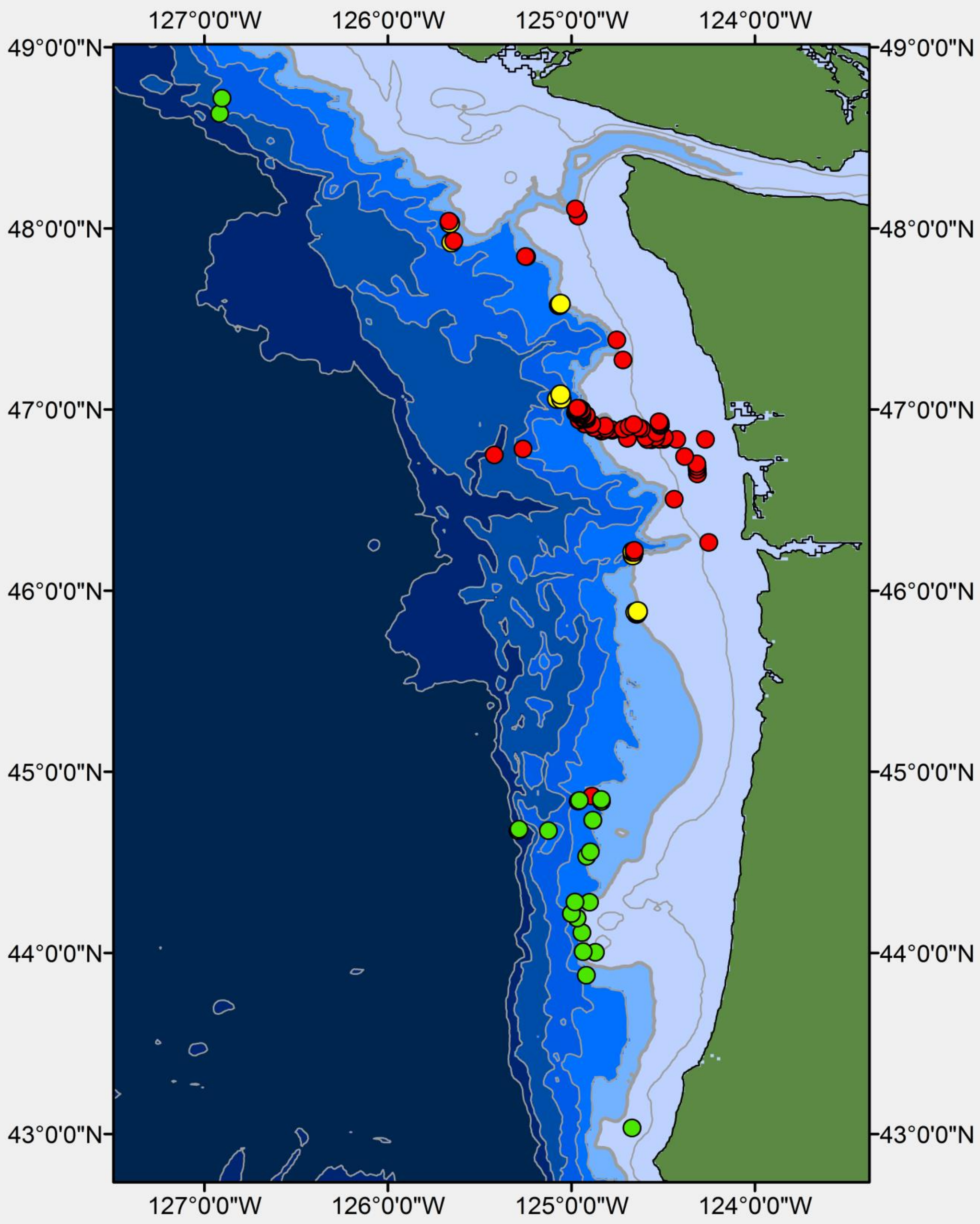
Sites 8 & 9

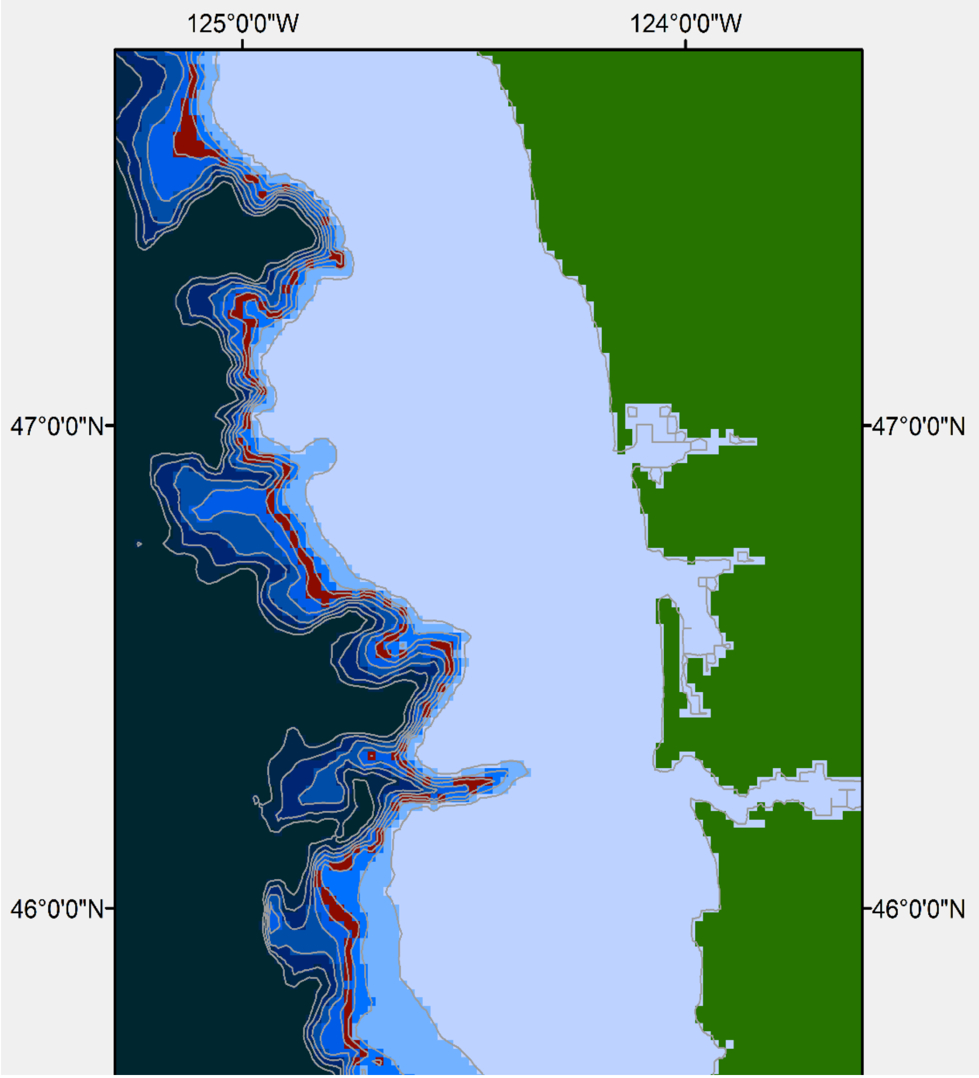
Site 6
(aka **Not Cassie’s Plume**)

Methane emission sites on Cascadia Margin, discovered over the past 10 years.

Total number of methane bubble streams discovered so far is 196 bubble streams, which translates into 106 distinct methane emission sites.

From Johnson, Miller, Salmi and Solomon, in prep, 2015



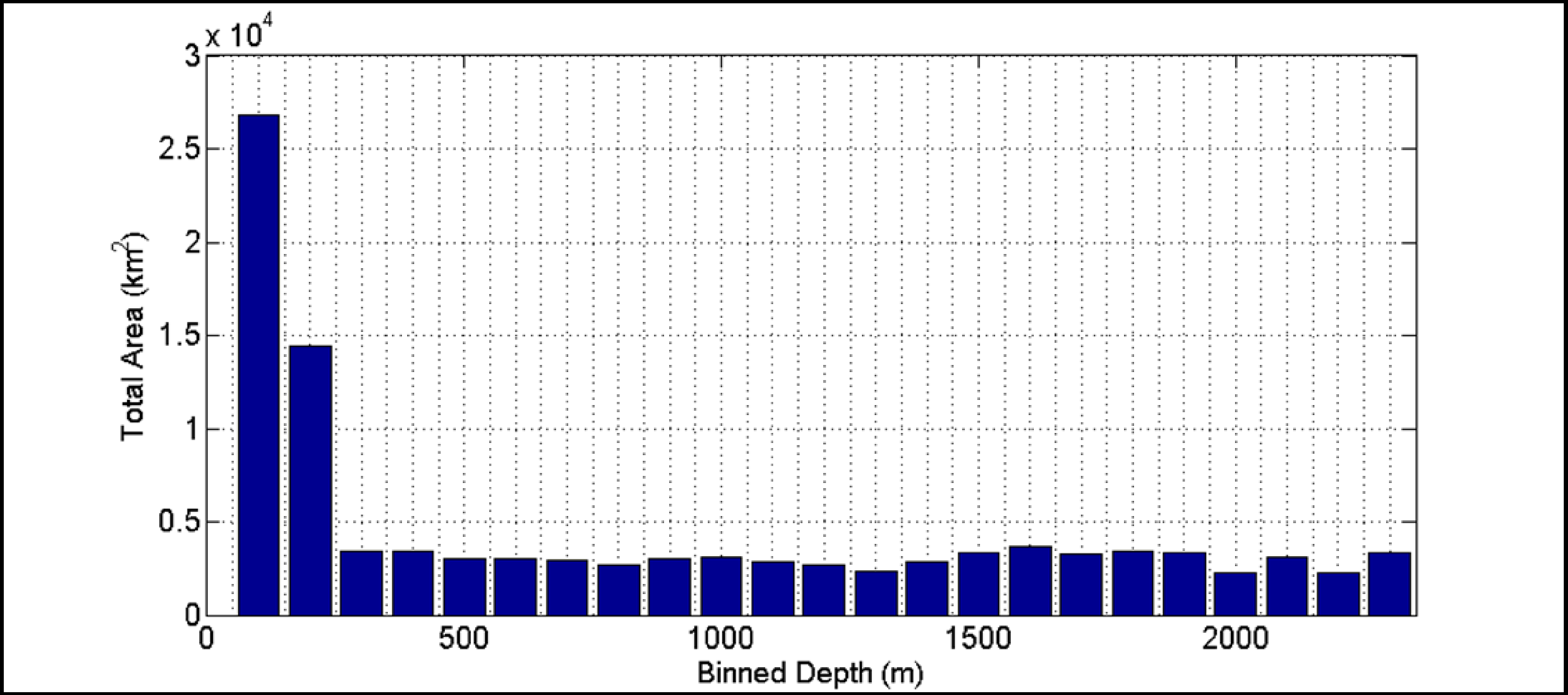


Depth intervals on a continental margin are very non-uniform.

The **shelf** (50 to 150 meters for Cascadia) has about 10X more area than the same depth interval of 450 to 550 meters at the **feather-edge of hydrate stability.**

Histogram showing the area of the Cascadia margin partitioned into 100m depth intervals, beginning at 50 m.

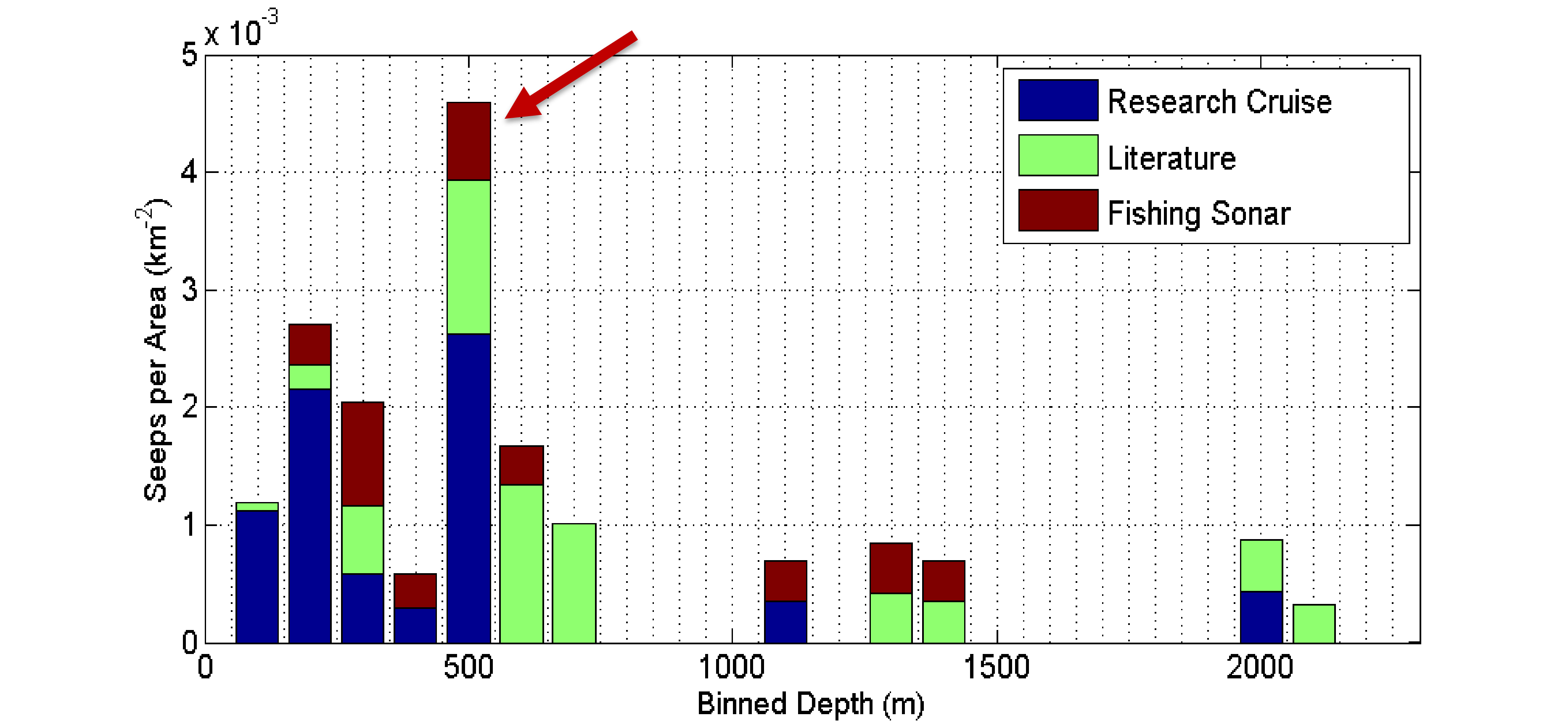
Note the shallow continental shelf has the largest partition of area (by a factor of 10).



What is the DEPTH of the methane plumes on the Washington/Oregon margins?

The upper stability depth of hydrate decomposition is 500 meters.

Histogram showing all emission sites on the Cascadia margin, with 300 m clustering and normalization by area. Color bar shows data source.



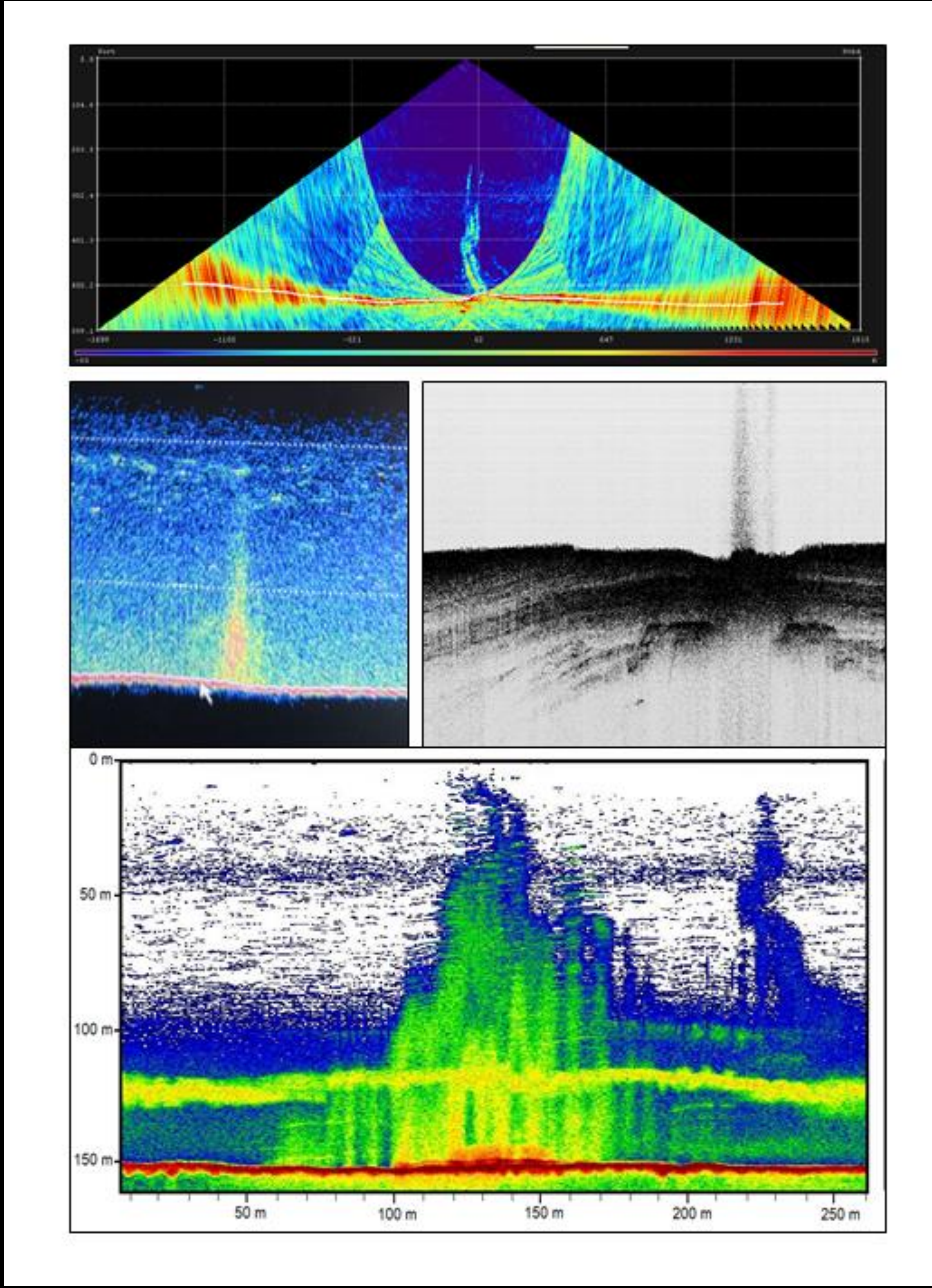
EXAMPLES OF ACOUSTIC IMAGES OF METHANE PLUMES - USING DIFFERENT TECHNIQUES AND FREQUENCIES.

EM302 SWATH BATHYMETRY, 30 khz

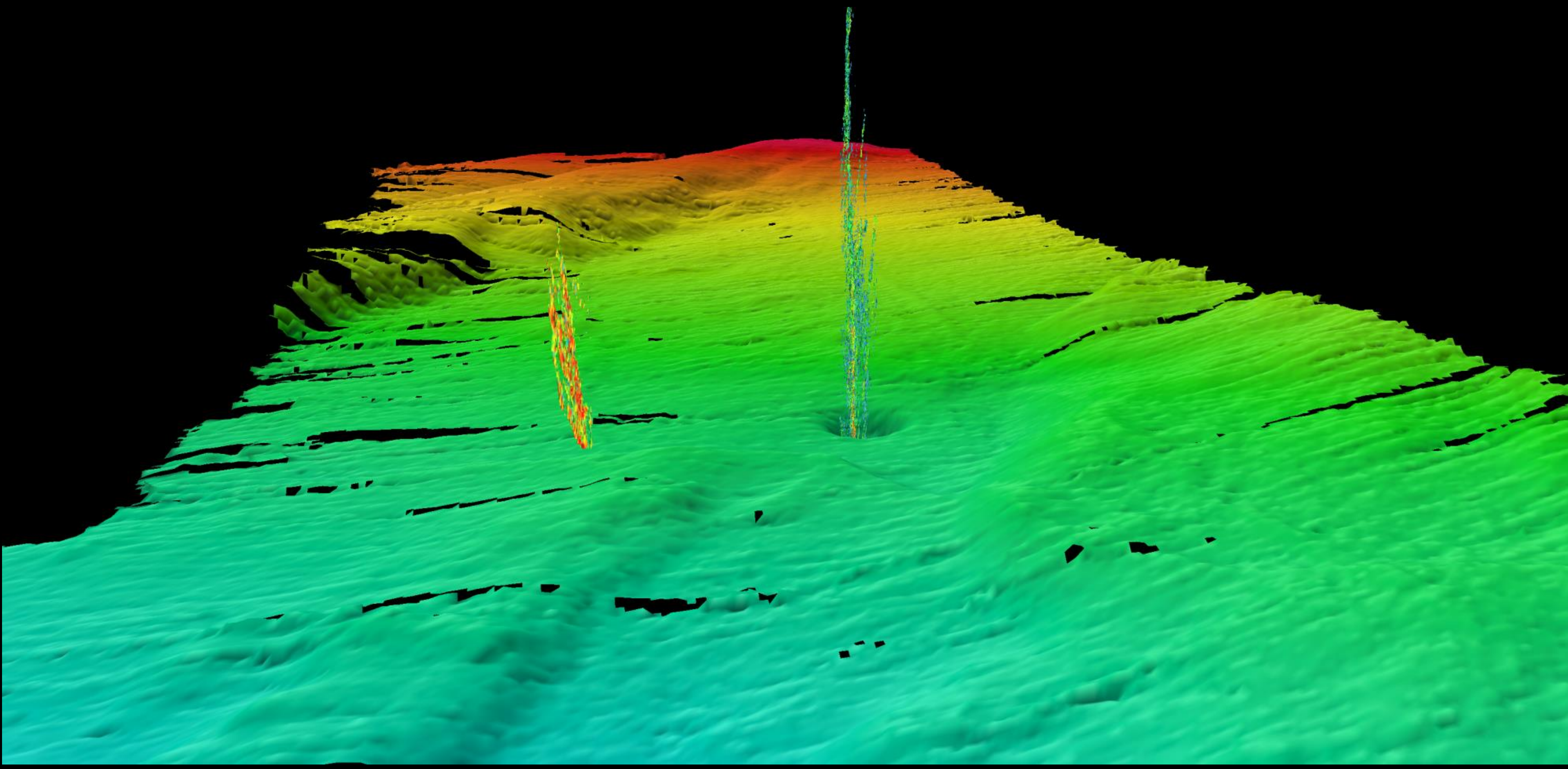
FISHERMAN’S SONAR, 30 to 60 khz.

3.5 khz CHIRP SONAR

200 khz RESEARCH SONAR.

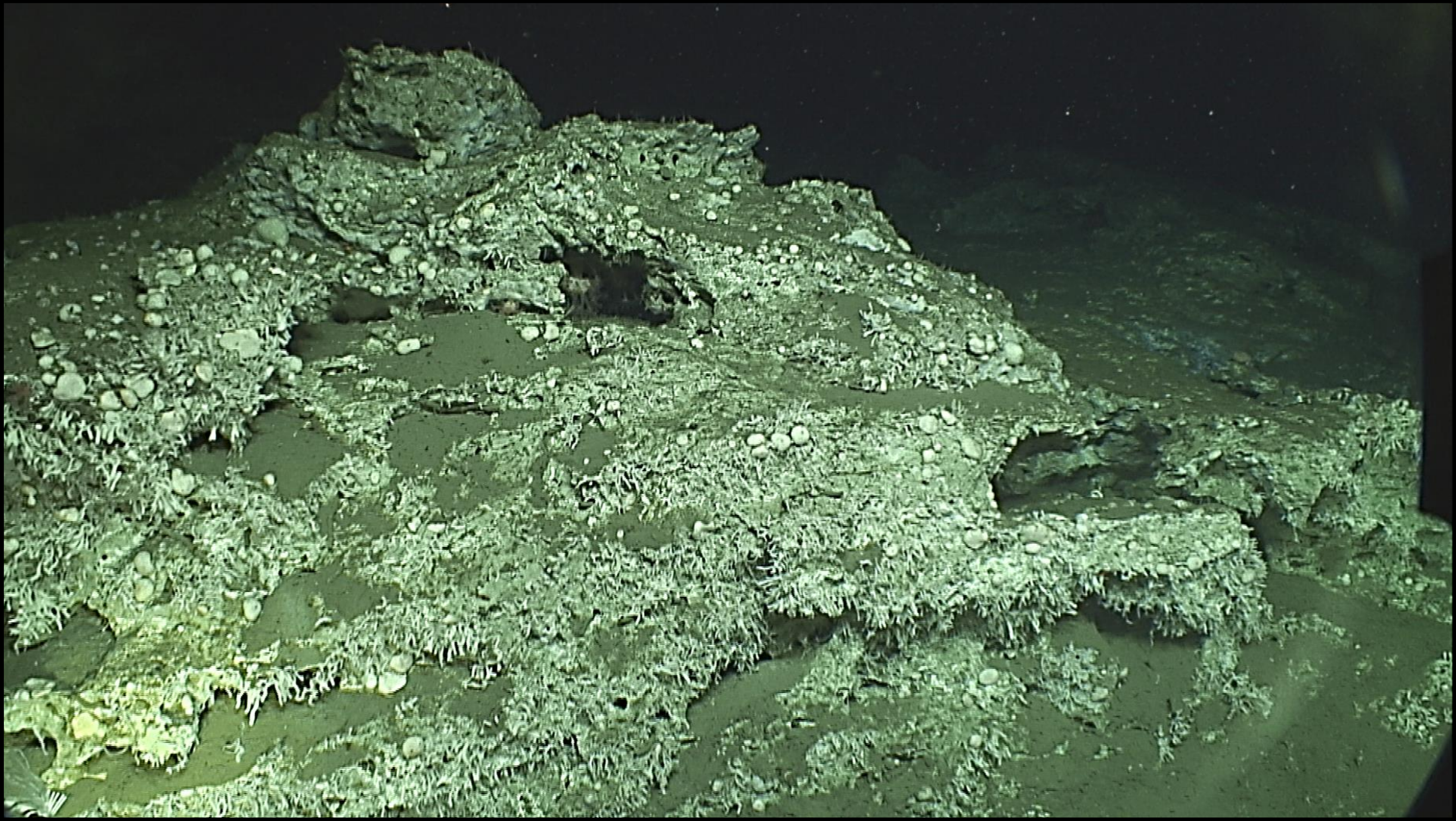


OR, you can be 'fancy' with EM302 acoustic imaging of the plumes



DEEPER, LONG-LIVED Sites of METHANE EMISSIONS on the seafloor are very 'busy', in terms of vent-specific biology.   These are NOT hydrate related.

A site where bacteria are using the methane that bubbles up from the seafloor and combines that carbon with Calcium from seawater and making (massive) carbonate deposits. Mound is about 3 meters high.



Estimates of Amount of Methane Released

<u>Assumptions:</u>

No methane in sulfate reduction zone, Dz = 5m, gas hydrate below. And Porosity = 63.4% and gas hydrate occupies 5% of pore space

As a result of gas hydrate dissociation since 1970, the hydrate-related methane flux off the WA margin today is ~1×10^{11} g CH_4/yr –

this is the same as the entire amount of CH_4 emitted during the Deepwater Horizon spill in the Gulf of Mexico.

If the IPCC AR4 scenario is correct, then 470 Tg of gas hydrate is susceptible to dissociation related to contemporary warming by the year 2100.

That is 6 Deepwater Horizon spills – <u>per year</u>.

Take-home message from talk….

Accretionary prisms are a lot more complicated that we used to think they were.

And therefore a lot more fun to work on.