Gas Hydrate Geohazard Challenges Infrastructure Concerns

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Presentation Objective

This presentation will include a systematic review of drilling and conventional oil and gas production challenges associated with gas hydrate in both marine and Arctic permafrost settings, as well as an analysis of operational intervention techniques to address gas hydrate-related geohazard concerns.

Technical Review - Contents

1. Gas Hydrate Geohazard
   - "Naturally Occurring Processes" vs. "Operational Geohazards"
2. Gas Hydrate Operational Geohazards
   - Drilling Related Geohazards – GOA and Alaska
   - Facilities & Completion Geohazards – Gumusut, Alaska, Others
3. Summary and Recommendations

1. Gas Hydrate Geohazards

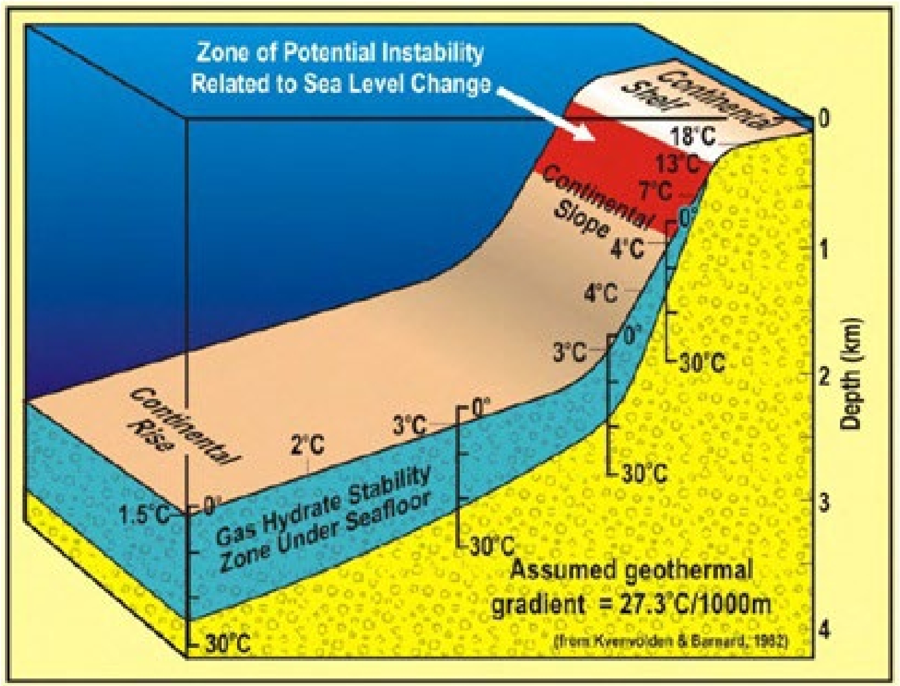
"Naturally Occurring Processes"

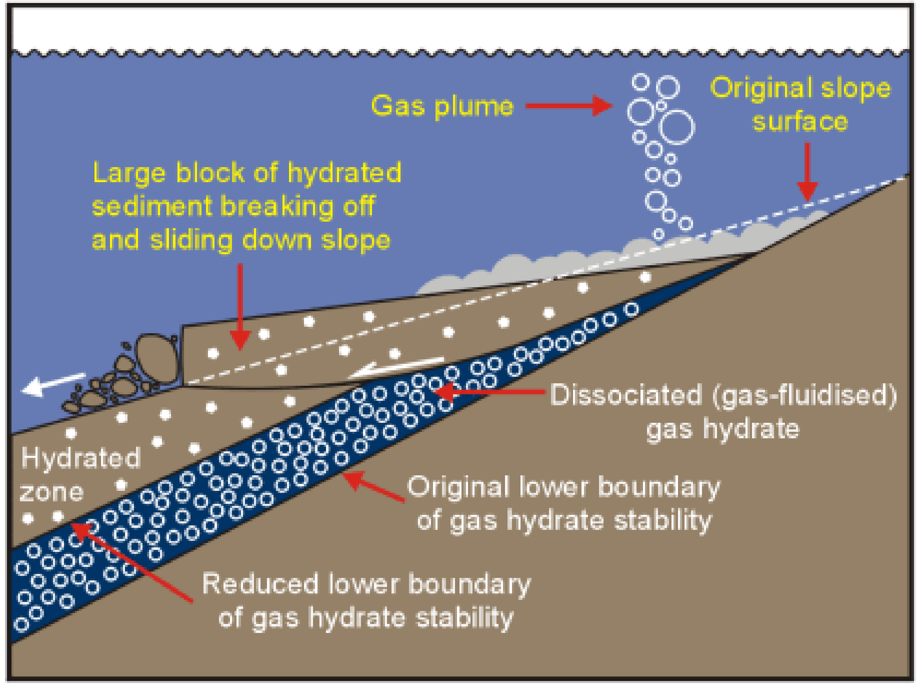
"Operational Geohazards"

Gas Hydrate Related Geohazards

Naturally Occurring Processes

The presence of gas hydrate increases the mechanical strength of the sediment; however, the dissociation of hydrate releases free gas and excess pore water, which may substantially reduce the geomechanical stability of the affected sediment, leading to large-scale mass wasting.





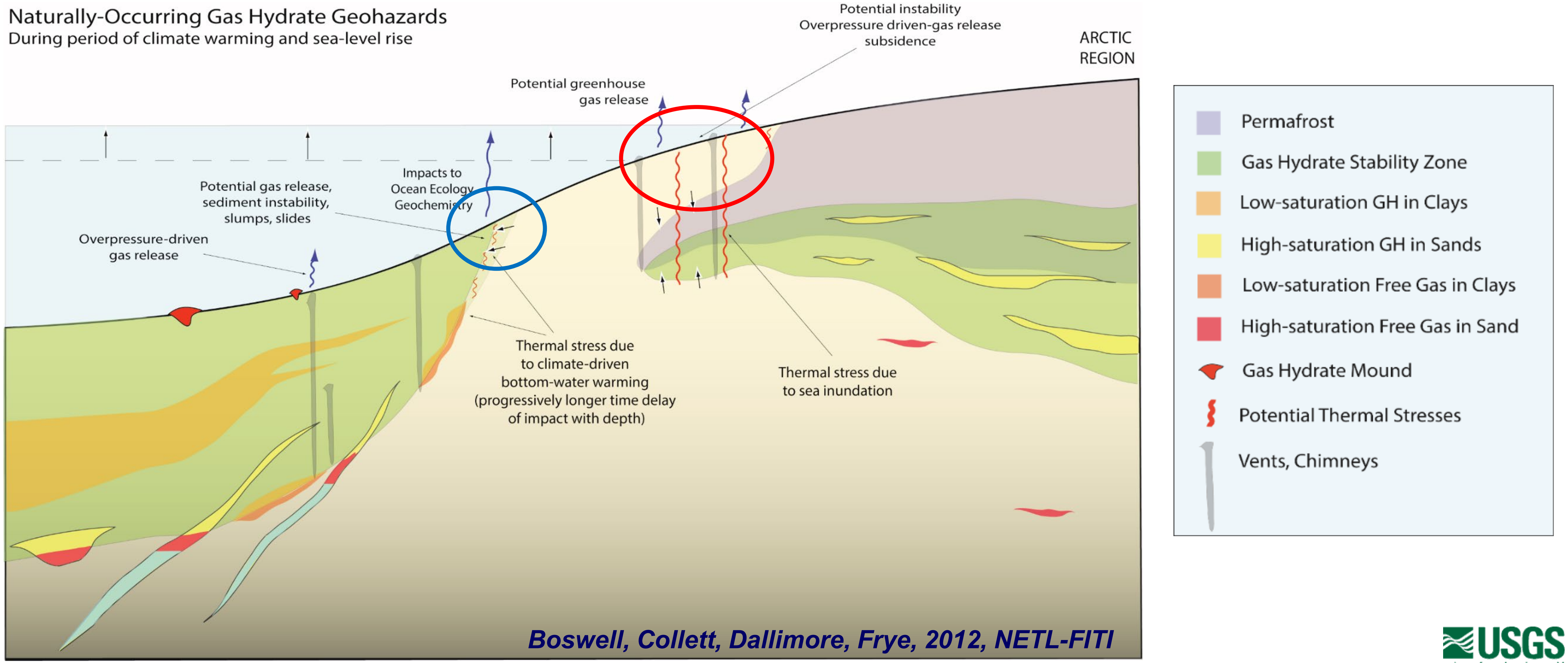
Slope failure mode as originally Proposed by McIver, R.D., 1982

McIver, R.D., 1982, Role of naturally occurring gas hydrates in sediment transport: American Association of Petroleum Geology Bulletin, v. 66, p. 789-792.

Gas Hydrate Related Geohazards

Naturally Occurring Processes

Gas hydrate geohazards induced solely from "naturally occurring processes"



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Gas Hydrate Related Geohazards
Operational Geohazards

***"Operational Geohazards"* triggered by human activities**

Geohazards associated with oil and gas production activities:

- Shallow foundational issues related to the installation of infrastructure
- Drilling and well-installation hazards that are encountered by wells targeting deeper horizons ("drilling through")
- Hazards associated with producing warm hydrocarbons from deeper stratigraphic sections through shallow gas hydrate-bearing intervals ("producing through")
- Geomechanical failure of reservoirs during production of gas hydrate-bearing intervals ("producing from")

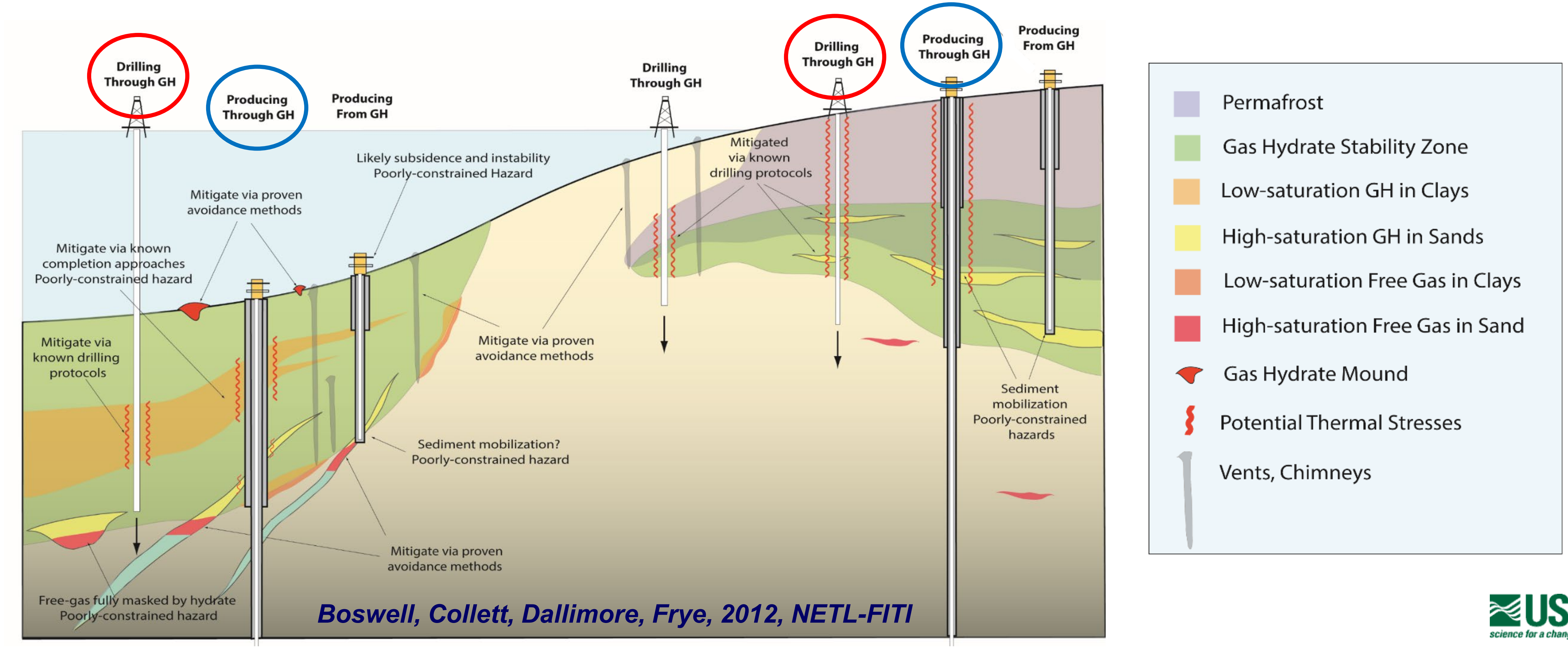
These hazards exist in both deepwater and permafrost-associated settings

Gas Hydrate Related Geohazards

Operational Geohazards

"<u>Operational geohazards</u>" triggered by human activities

Drilling associated hazards and hazards associated with producing hot hydrocarbons through shallow gas hydrates

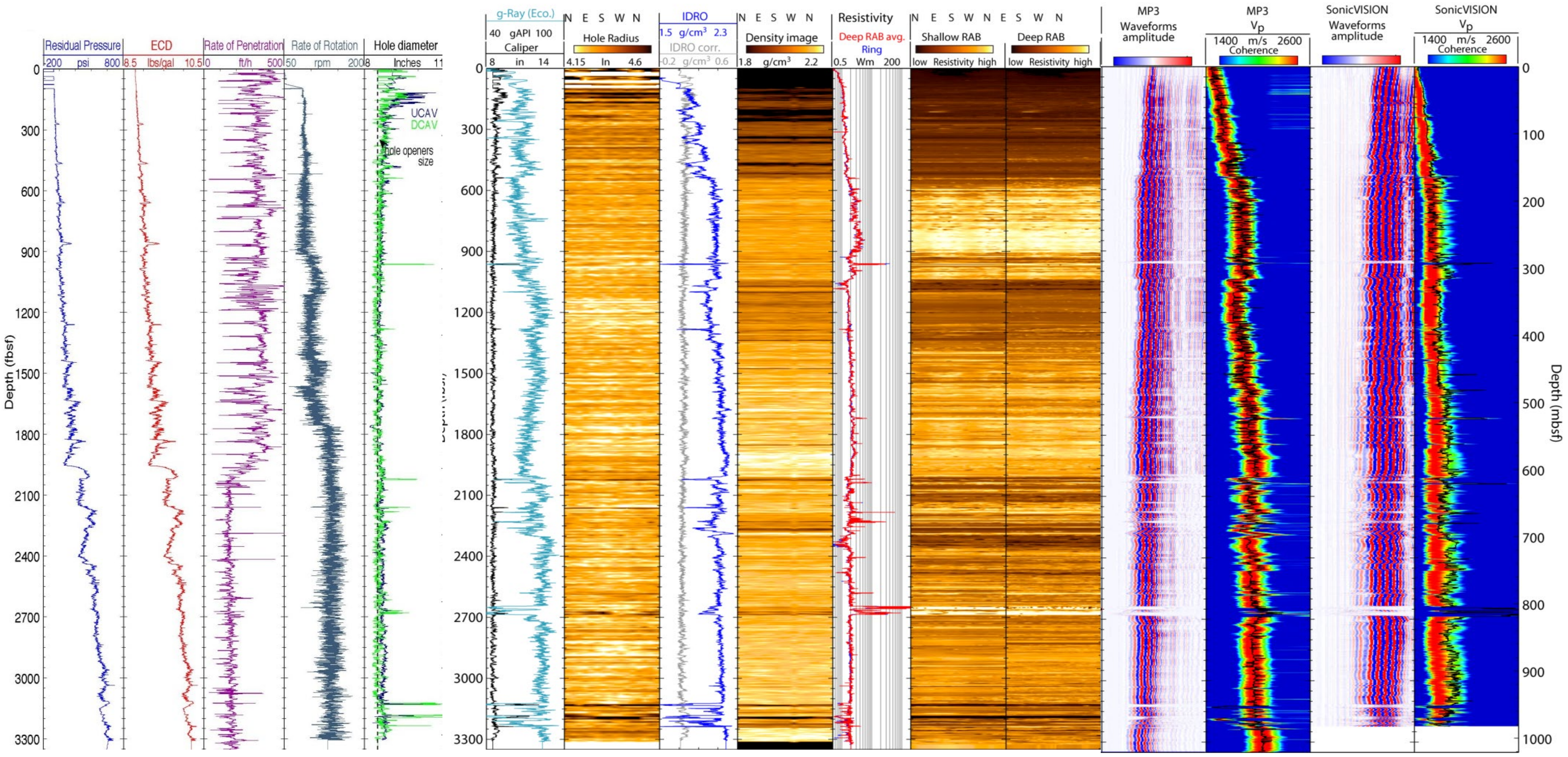


2. Gas Hydrate Operational Geohazards

- Drilling Related Geohazards – GOA, Alaska, Others

Gas Hydrate Related Geohazards

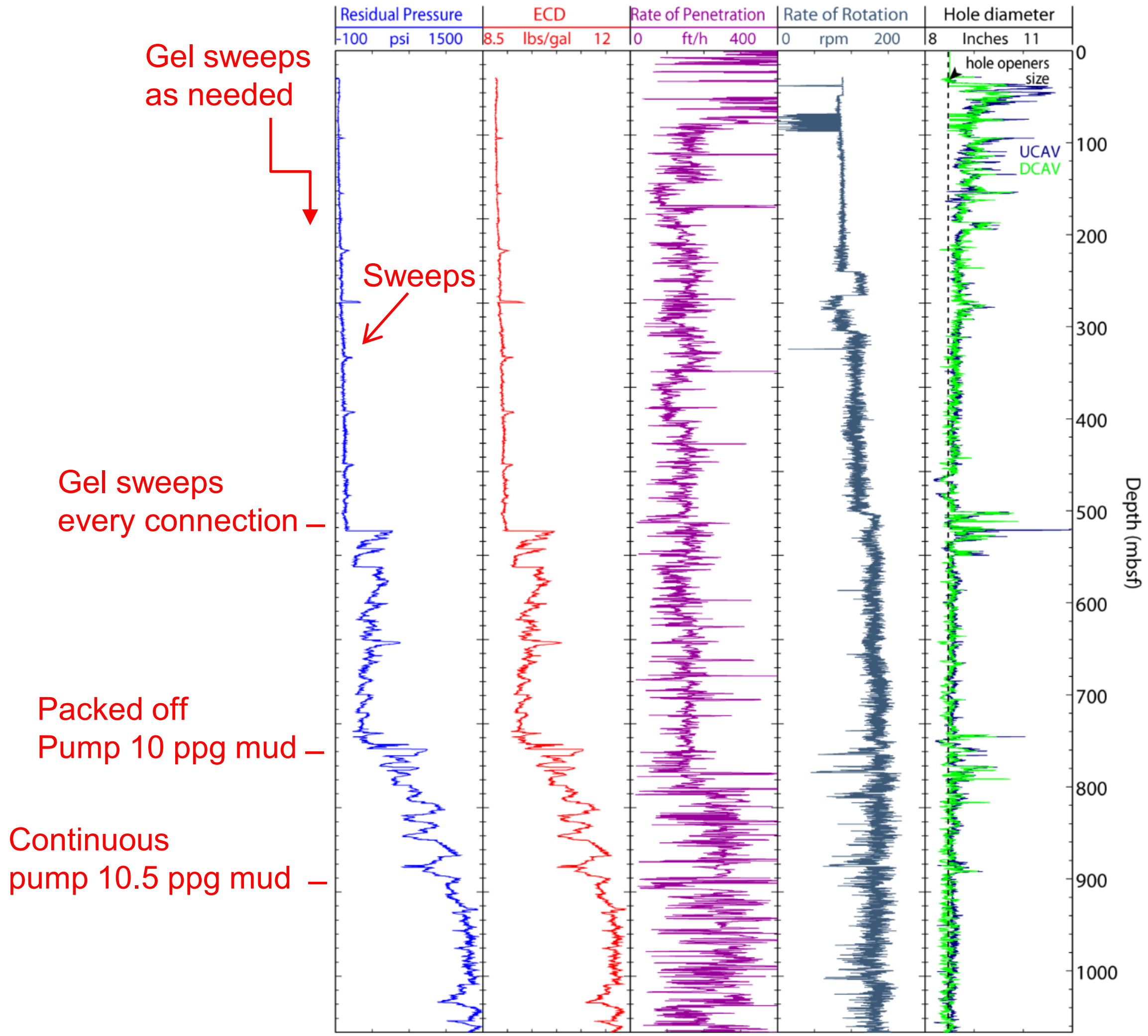
Operational Geohazards – GOA (marine) JIP Leg II – Walker Ridge 313



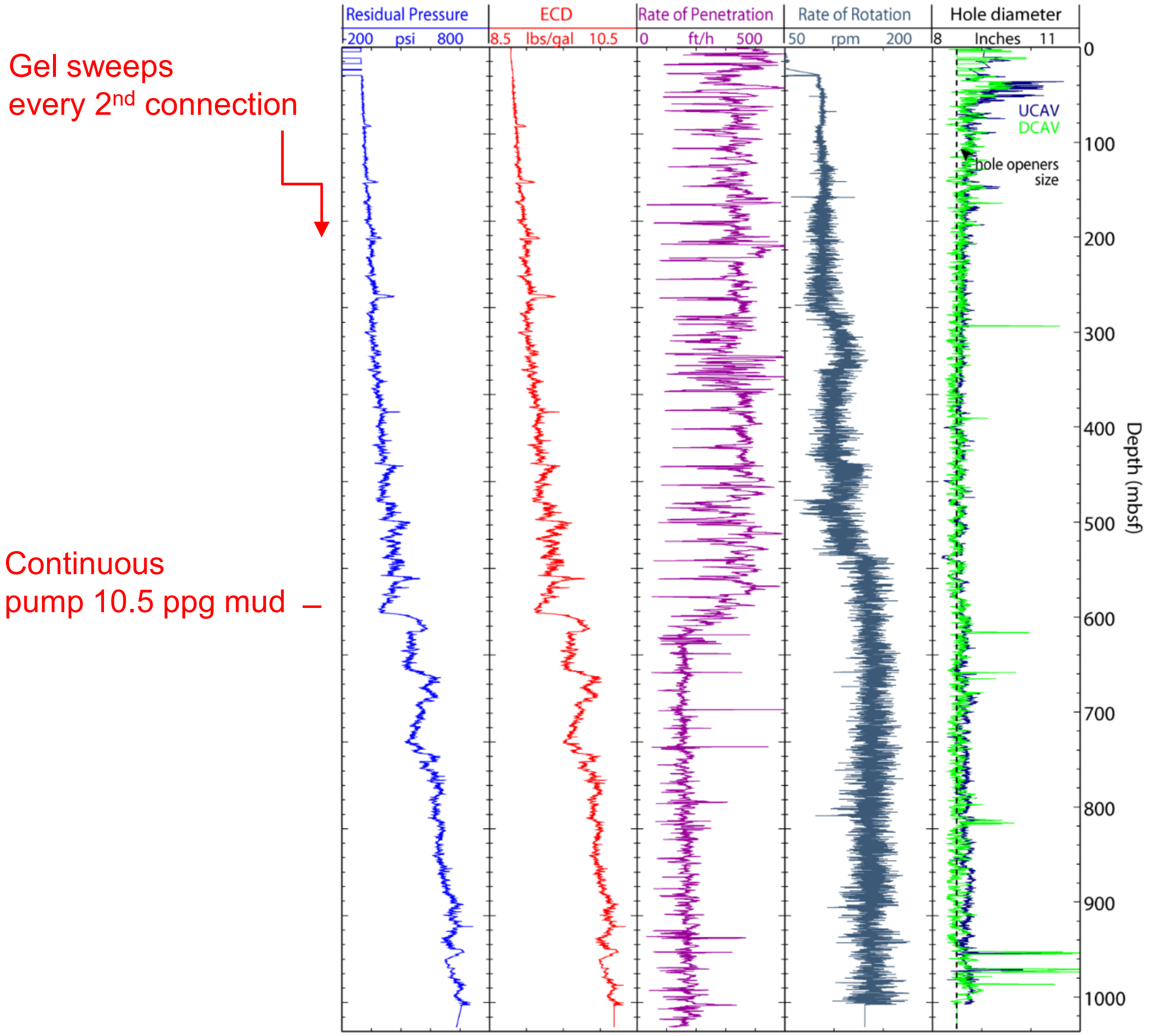
Gas Hydrate Related Geohazards

Operational Geohazards – GOA (marine) JIP Leg II – Walker Ridge 313

Walker Ridge 313 G
Drilling from "zero" to TD
ROP Target 350 ft per hour, gel sweeps as needed
Reduce ROP to 180 ft per hour



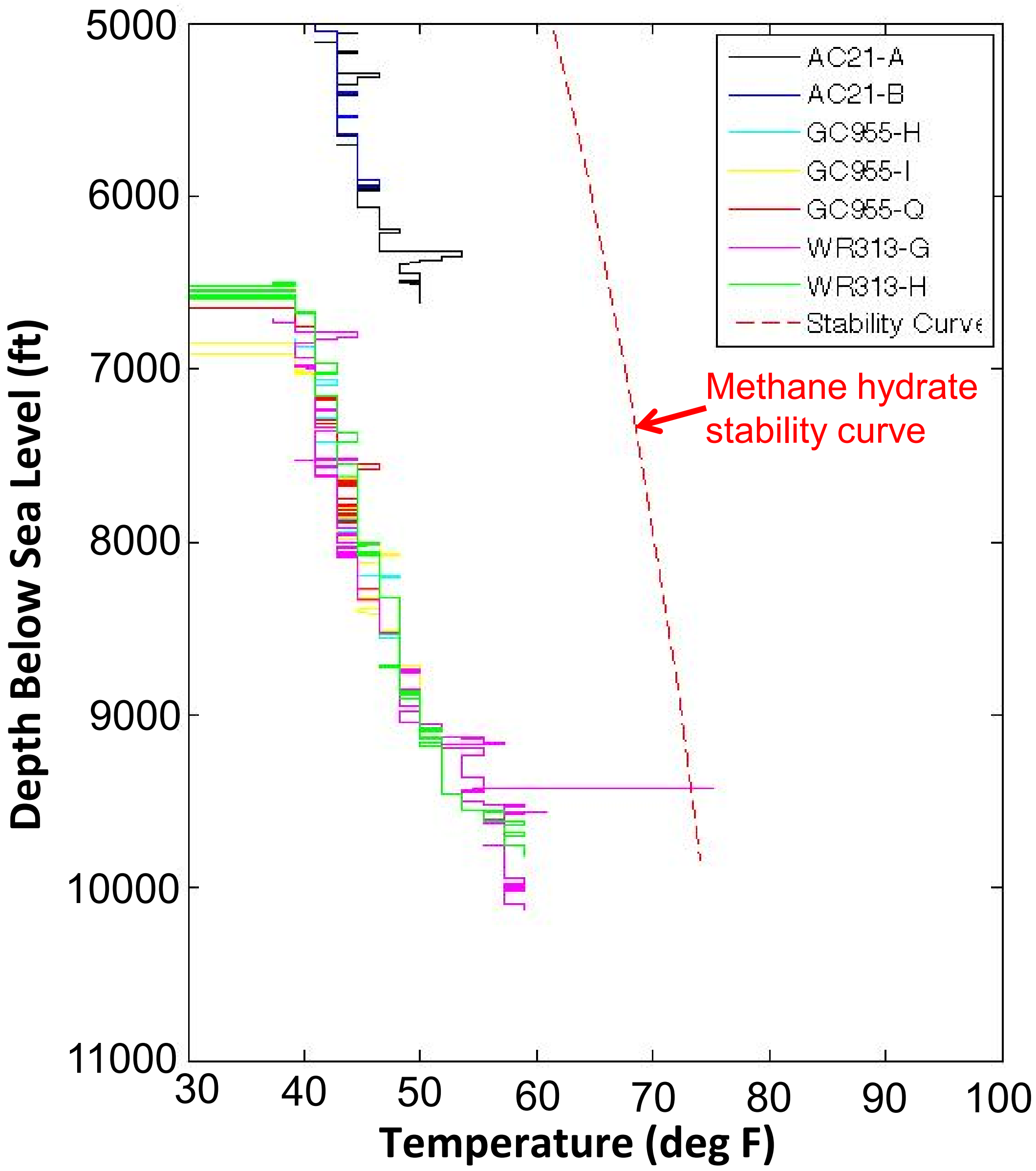
Walker Ridge 313 H
Drilling from "zero" to 2000 ft (610 m)
ROP Target 350 ft per hour, gel sweeps every 2nd connection
Drill from 2000 ft (610 m) to TD, reduce ROP to 180 ft per hour

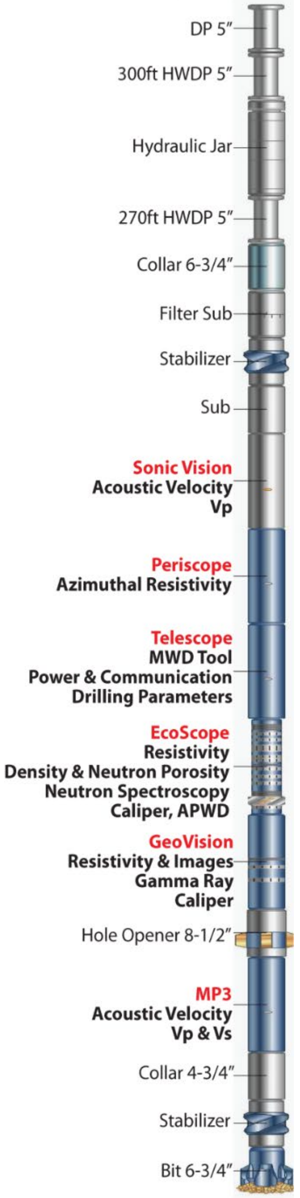


Gas Hydrate Related Geohazards

Operational Geohazards – GOA (marine) JIP Leg II – Walker Ridge 313

GOA JIP Leg II Downhole LWD temperatures and methane hydrate stability curve





Courtesy Ann Cook (The Ohio State Univ)

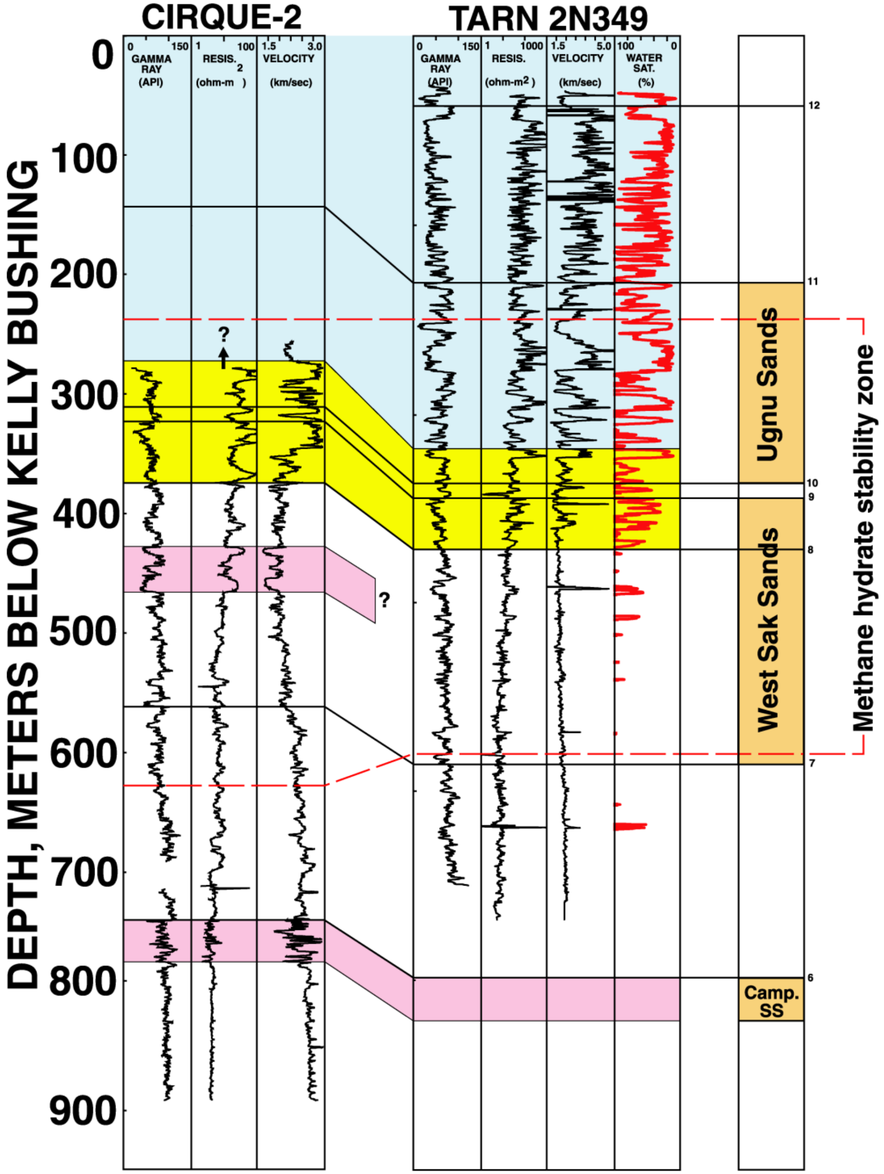
Gas Hydrate Related Geohazards

Operational Geohazards – GOA (marine) JIP Leg II – GC955-Q “Gas Flow”

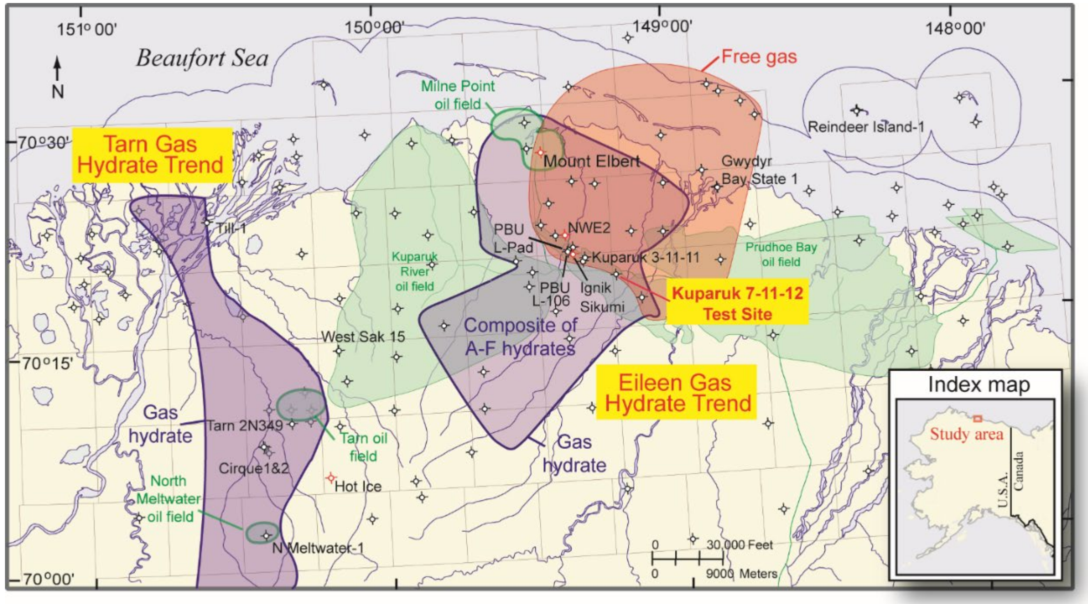
Date	TIME	GC955-Q DETAIL OF OPERATIONS AND REMARKS
April 27, 2009	0:00	Drill 6 3/4" x 8 1/2" hole section F/ 8065' to 8,078' w/ 10.5ppg. @ 00:15 drill into **gas bubble** causing the well to kick. Line up on 13.0 ppg Kill mud and displace 10.5ppg w/ 120 bbls of 13.0 ppg Kill mud leaving 15 bbls in pipe for displacement.
	1:00	ROV monitor well for 1 hour. Well static.
	2:00	POOH @ a reduced speed F/ 8,078' to 6,723' ROV noticed **well start flowing**. Note tight spots @ 7,857', 7,678' w/ 10-12K over pull -- ***SWABBED GAS***
	4:30	Line up on 16.0 ppg mud and displaced drill pipe, installed bop & TIH F/ 6,723' to 7,305'. Tagged up w/ 15K.
	6:00	Displaced two annulus volumes @ 7,305' w/ 16.0ppg. No observed flow.
	6:30	POOH @ a reduced speed F/ 7,305" to 6,660' bit 93' inside hole.
	7:30	ROV monitor well for 1 hour. Well STARTED FLOWING, PUMP 50 BBLS OF 16.0 PPG @ 6,660'. No Flow.
	10:30	Pumped two annulus volumes @ 7,563' w/ 16.0ppg. No Flow
	12:00	Continue POOH @ reduced speed F/ 7,563'
	16:00	BHA @ surface. Service break and lay out same.
April 28, 2009	0:00	Trip into the hole with the cement assembly, 0020 hrs ROV guided bit into well, tih & tagged @ 6,860', made up TD & washed from 6,860' to 6,923', continue tih to 7,400'.
	3:00	Held JSA & TBT, fill lines & test same to 3K - good, perform cmt job - pump 35 bbl, 16.0 ppg spacer followed by 47.5 bbl, 16.4 ppg cmt followed by 6 bbl, 16.0 ppg spacer & spot in place with 115 bbls of seawater - 500' cmt plug from 7,400' to 6,900', cmt in place @ 0430 hrs
	4:30	POOH from 7,400' to 6,343'.
	19:00	MMS has given approval of completion, Recover ROV to surface. **At 20:00 complete GC955-Q**

Gas Hydrate Related Geohazards

Operational Geohazards – Alaska (permafrost) Tarn Gas Hydrate Trend



Cirque-1 (February 29, 1992): While drilling the Cirque-1 well, a shallow (710 m) free-gas zone was encountered, which subsequently blew out the well. This gas zone is overlain by a thick gas-hydrate-bearing interval (250-350 m), which also contributed to the gas flow and blowout. The blowout occurred while tripping the drill string – *swabbed gas into the well*. The operator reported that after the blowout, the gas flow continued in an episodic manner, which is indicative of a gas hydrate blowout. The use of heavy-weight CaCl kill mud made the problem worse!



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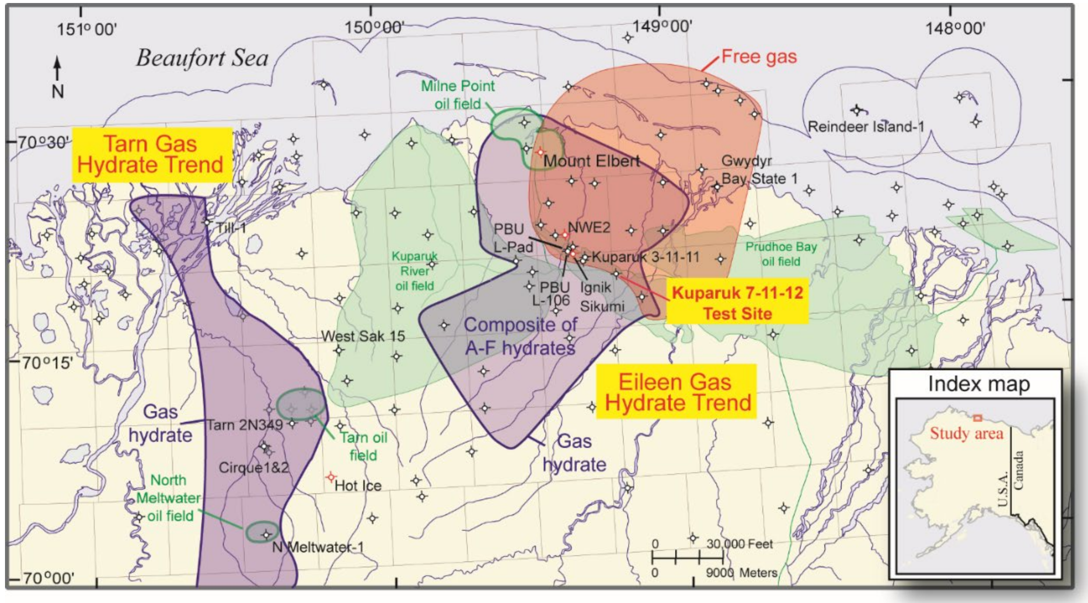
Gas Hydrate Related Geohazards

Operational Geohazards – Alaska (permafrost) Eileen Gas Hydrate Trend

Prudhoe Bay Unit Z-7 (May 14, 1990): While drilling the Prudhoe Bay Unit Z-7 well we observed two significant gas shows at a depth of 628m and 638m, which correlate with previously identified gas hydrate units. After drilling to a depth of 1756 m the bit was tripped to the surface to run casing. Upon reentering the hole the gas hydrate units had sloughed into the borehole and the previously drilled interval from 620m to 756m had to be redrilled.



Milne Point Unit K-25 (May 14, 1990): While drilling the Milne Point Unit K-25 well, gas hydrates were encountered at 662m, 710m, 716m, and (?) 841m. Gas flow lowered mud weights from 11 ppg to 7.8 ppg, mud weights were built back to 11.5 ppg; however, with little affect on gas flow. After drilling and setting the surface casing 1,200m, gas cut mud and water was noted bubbling around the casing and the conductor pipe. Cement evaluation logs revealed poor cement bond in the gas-hydrate-bearing intervals.

Techniques Used to <u>Prevent</u> Gas Hydrate Dissociation

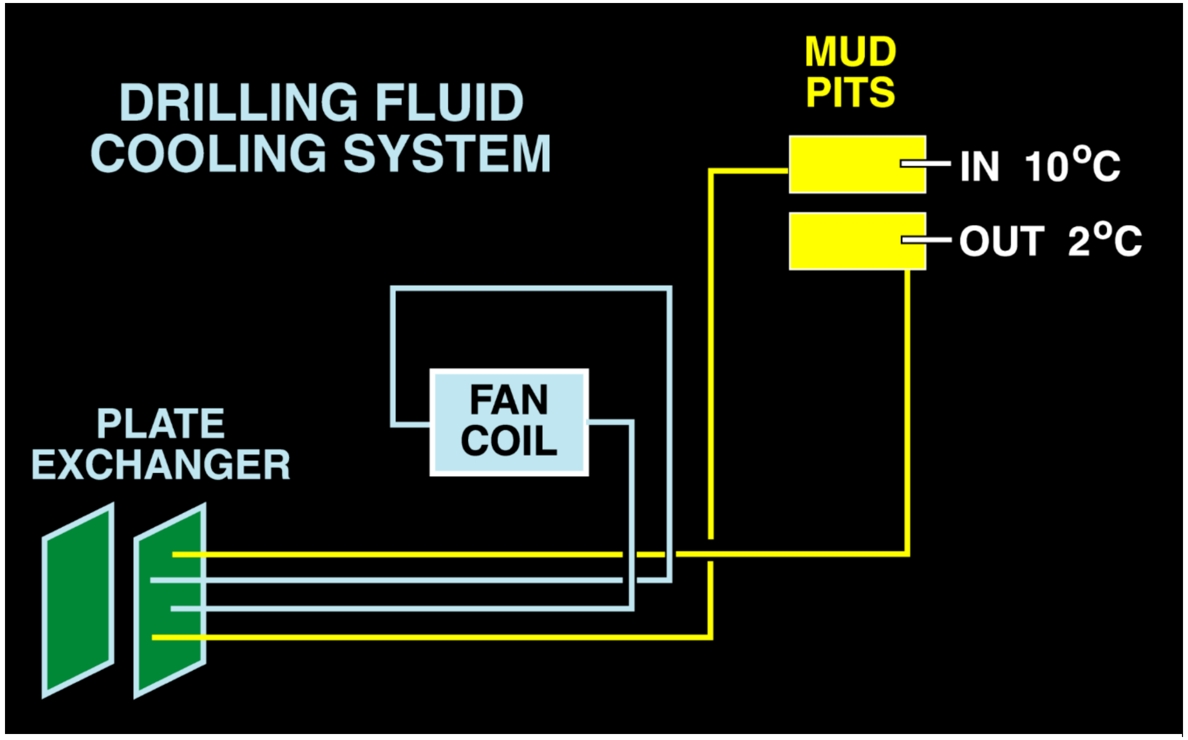
Operational Geohazards

- Reduce the temperature of the drilling fluids
- Increase the mud density/weight ?
- Increase mud circulation, maintaining turbulent flow
- Run casing after penetrating gas hydrate zone
- Use cement with low heat of hydration
- Use small downhole drilling motors to reduce mud temperatures
- Use mud additives to stabilize gas hydrates

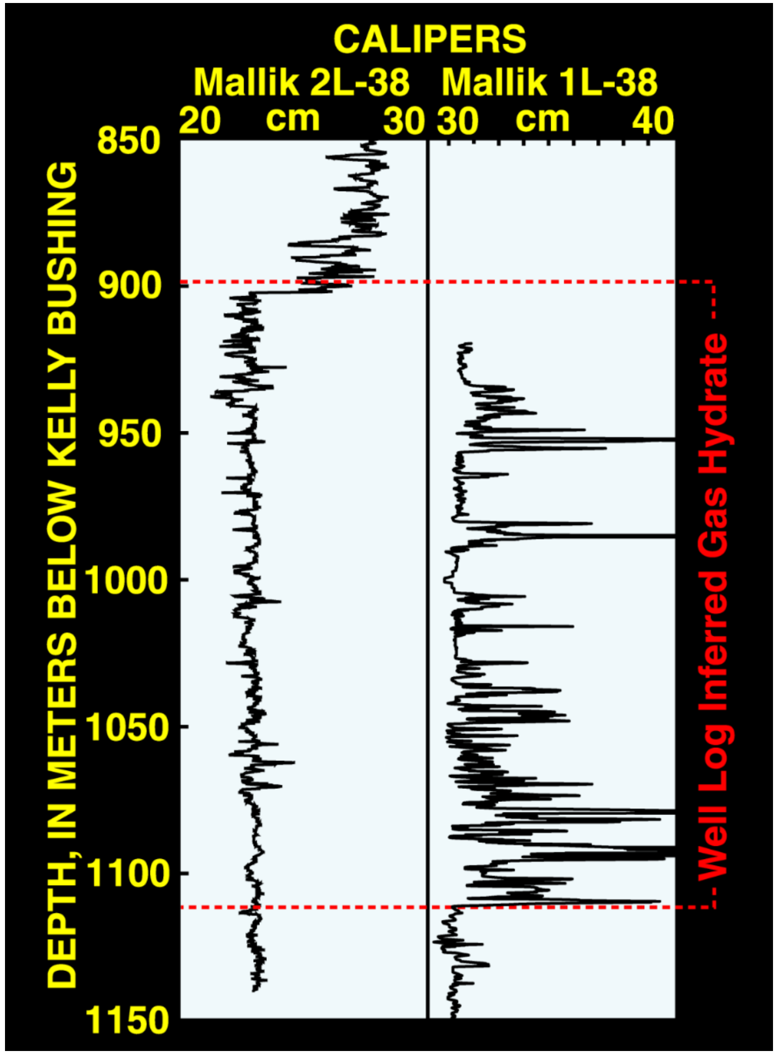
Note specific geologic and engineering requirements

Techniques Used to Prevent Gas Hydrate Dissociation

Operational Geohazards



Parameter	Target	Hold Point(s)
Mud Temperature (Suction Pit)	20°F	Min: 15°F*
Mud Temperature (Possum Belly)	≤32°F	Max: 35°F**
Flow Rate	800 GPM	N/A



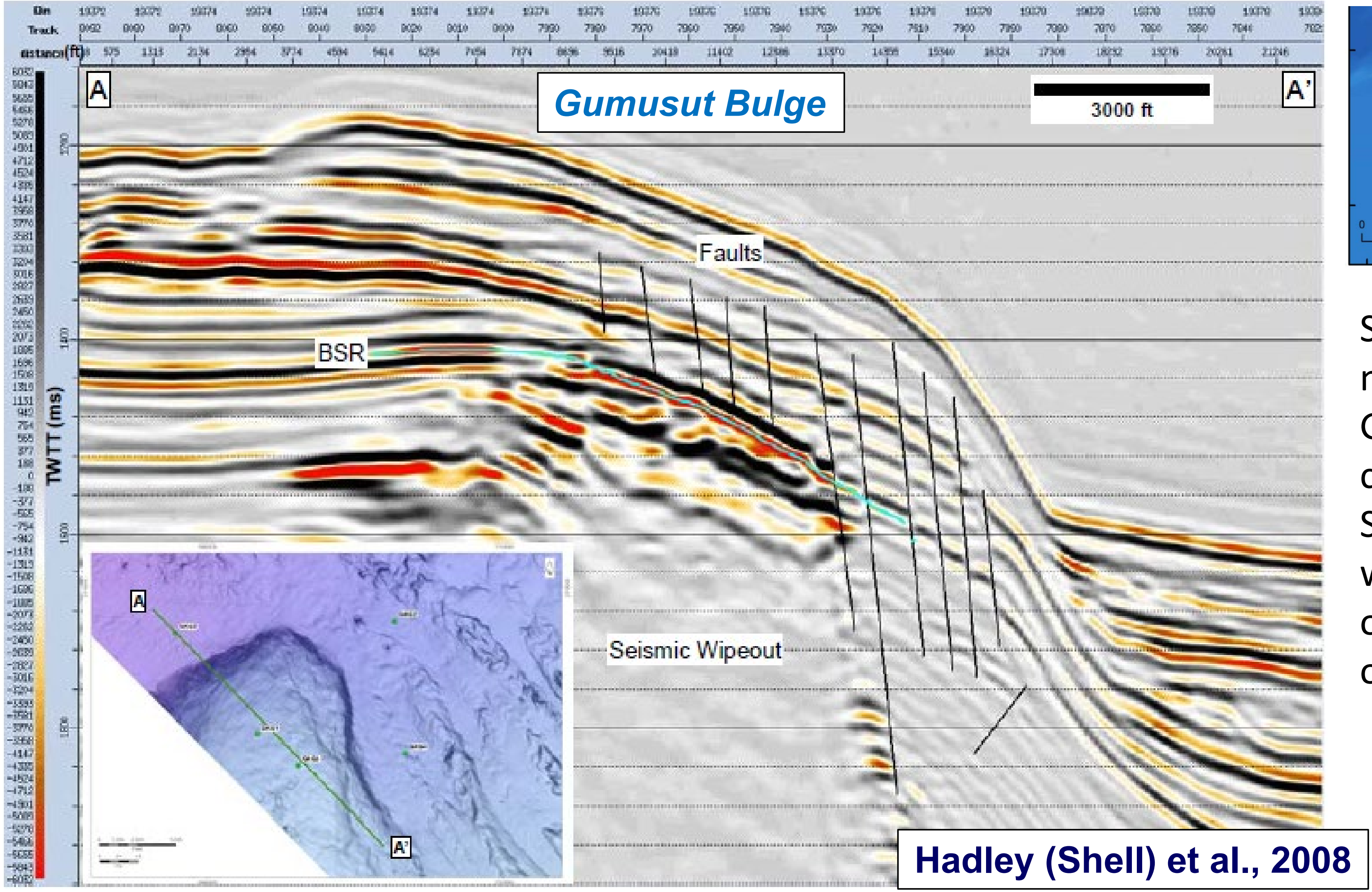
Arctic Alaska Drilling Mud Chiller System and caliper log analysis of impact on gas hydrate dissociation in the Canadian Mallik 2L-38 and Mallik 1L-38 wells

2. Gas Hydrate Operational Geohazards

- Facilities & Completion Geohazards – Gumusut and Alaska

Conventional Production Associated Hazards

Malaysia Gumusut-Kakap Project (2006)



Shell BHD encountered numerous geohazards at the Gumusut-Kakap Field on the continental slope offshore Sabah, Malaysia associated with the development and operation of a conventional oil field.

Conventional Production Associated Hazards
Malaysia Gumusut-Kakap Project (2006)

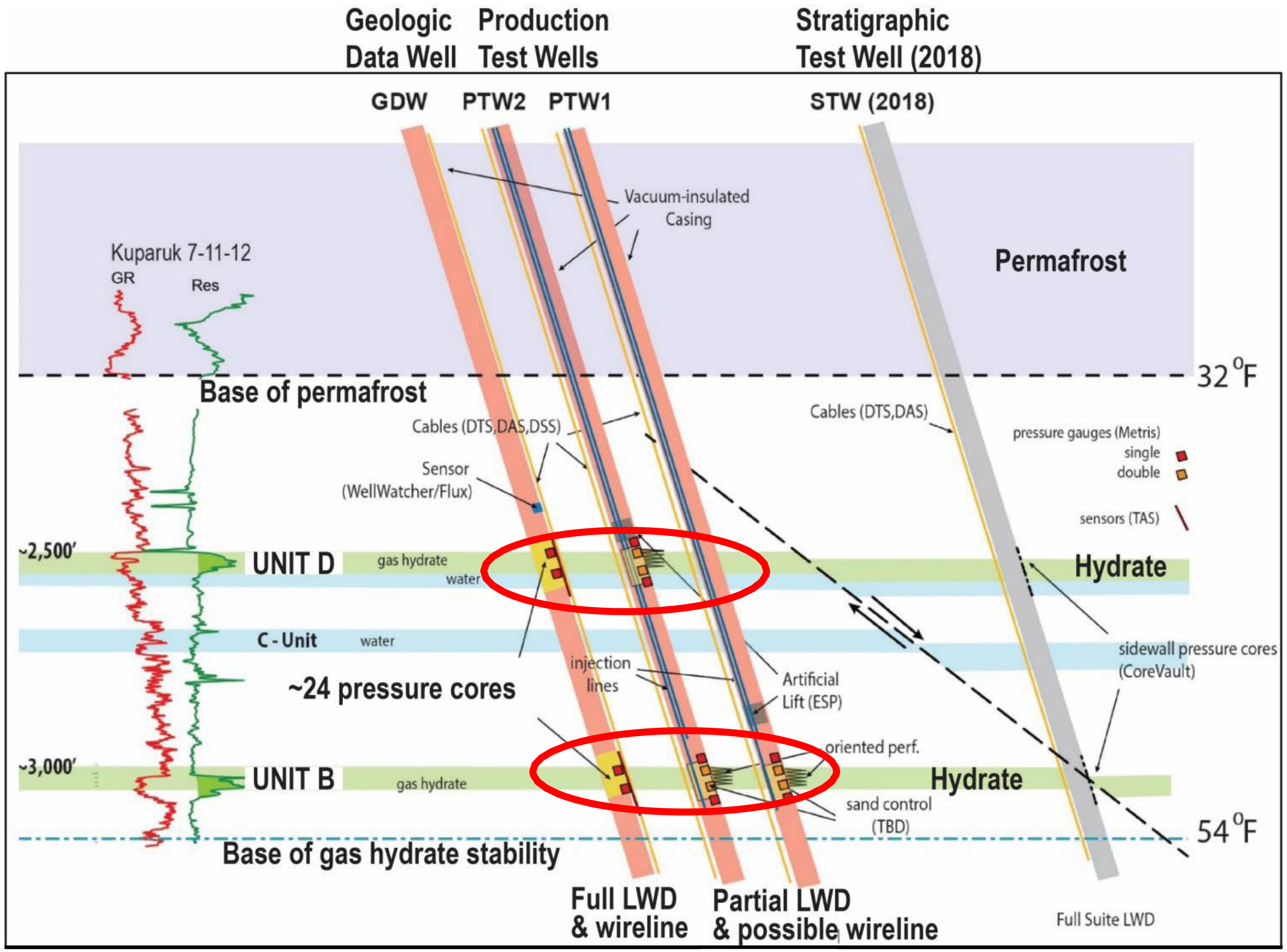
Project Results:

- Early identification of geohazards using exploration 3D and high resolution deep-tow seismic surveys.
- Comprehensive geohazard and geotechnical investigation, using logging and pressure coring.
- Mode of occurrence of hydrates (in near vertical veins).
- Hydrate found at all locations (structure I to structure II GH).
- Tension leg platforms (TLP) and Spar development concepts with deviated wells were rejected because of integrity of TLP foundations and hydrate dissociation sediment subsidence could lead to casing and production tubing problems. A subsea development with a semi-submersible floating production system host was ultimately selected.

Hadley (Shell) et al., 2008

Alaska Gas Hydrate Production Field Experiment

Extended Gas Hydrate Production Testing



- Assess technologies to safely produce hydrates
- Focusing on sub-permafrost gas hydrate sedimentary sections, with pressure core and well log data acquired in 2022
- Long-term (~10 months) production test started in September of 2023
- Production through stepwise depressurization, continuous monitoring, sampling of produced fluids and gas (USGS)
- Advanced, pressure/temperature gauges and distributed temperature, acoustic, and strain sensing and 4D VSP & CWT monitoring of reservoir changes during production; VSP and DTS analysis with CSM
- Includes hazards (land subsidence) monitoring

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Test Well Monitoring

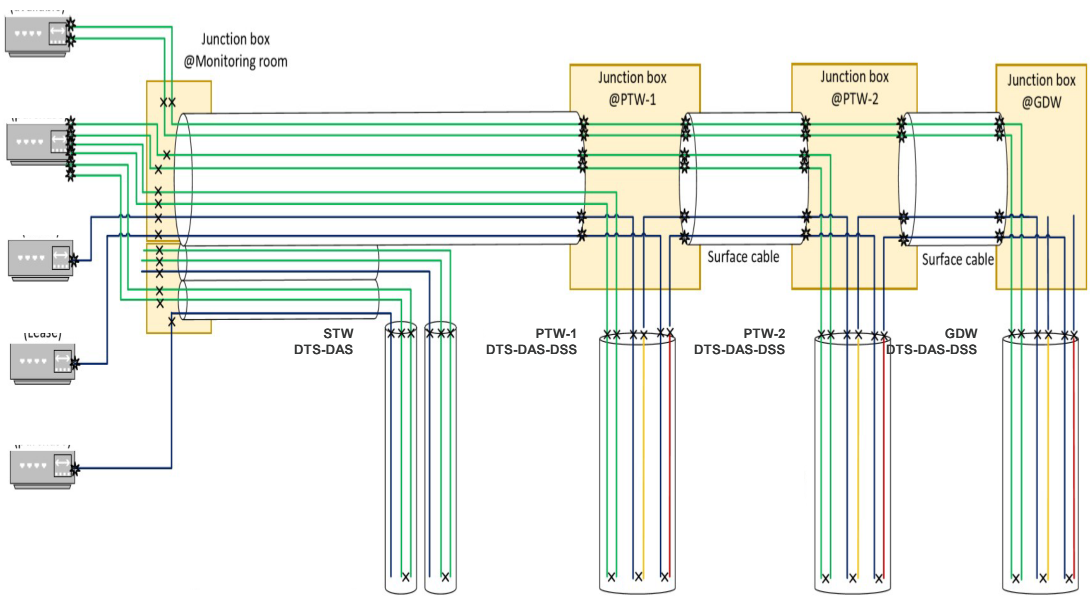
Distributed and Gauge Based Systems

TYPES OF DISTRIBUTED SENSING

Distributed Temperature Sensing (DTS) is the most widely used form of distributed sensing. It can precisely measure temperatures up to 300°C (570°F) every meter along the fiber to an accuracy of +/- 1°C (1.8°F) and a resolution to +/- 0.01°C (0.018°F).

Distributed Acoustic Sensing (DAS) effectively turns the fiber cable into a series of geophones (or microphones) to identify near wellbore injection and production, cross well monitoring, fluid densities, fluid migration, and casing leaks, and/or for early detection of equipment wear or failure. In addition, DAS is a cost-effective alternative to traditional vertical seismic profiles (VSPs). DAS offers thousands of sensor points and repeatable time-lapse imaging.

Distributed Strain Sensing (DSS) can help to determine casing deformation location and severity, or provide insight into stresses produced at perforations during stimulation.



Alaska Gas Hydrate Production Field Experiment

Extended Gas Hydrate Production Testing Site

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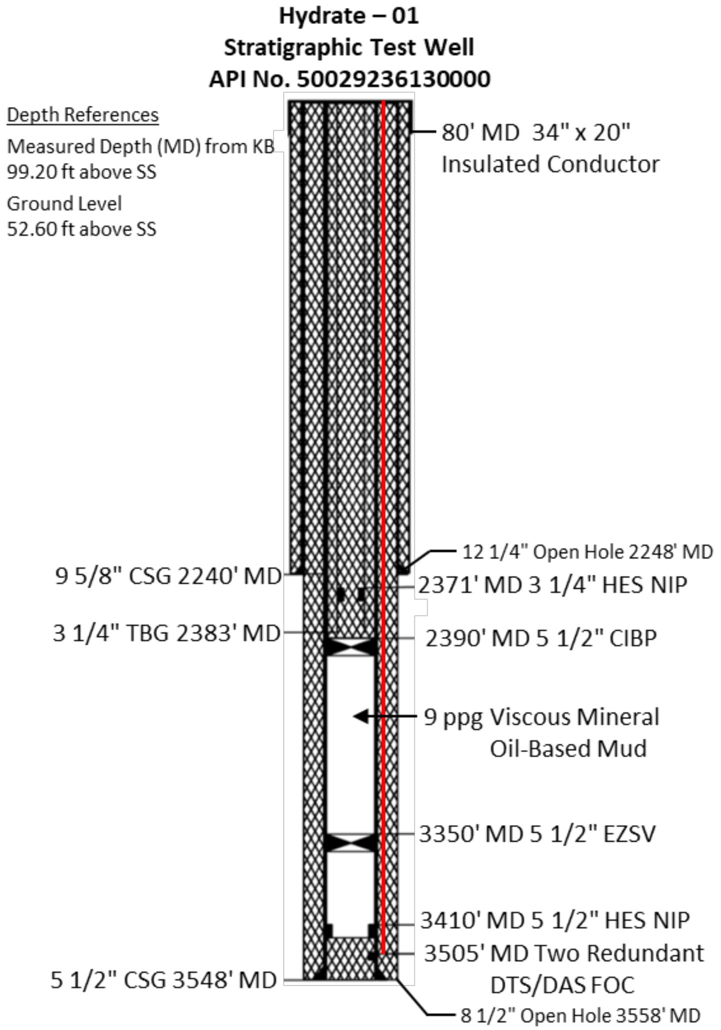
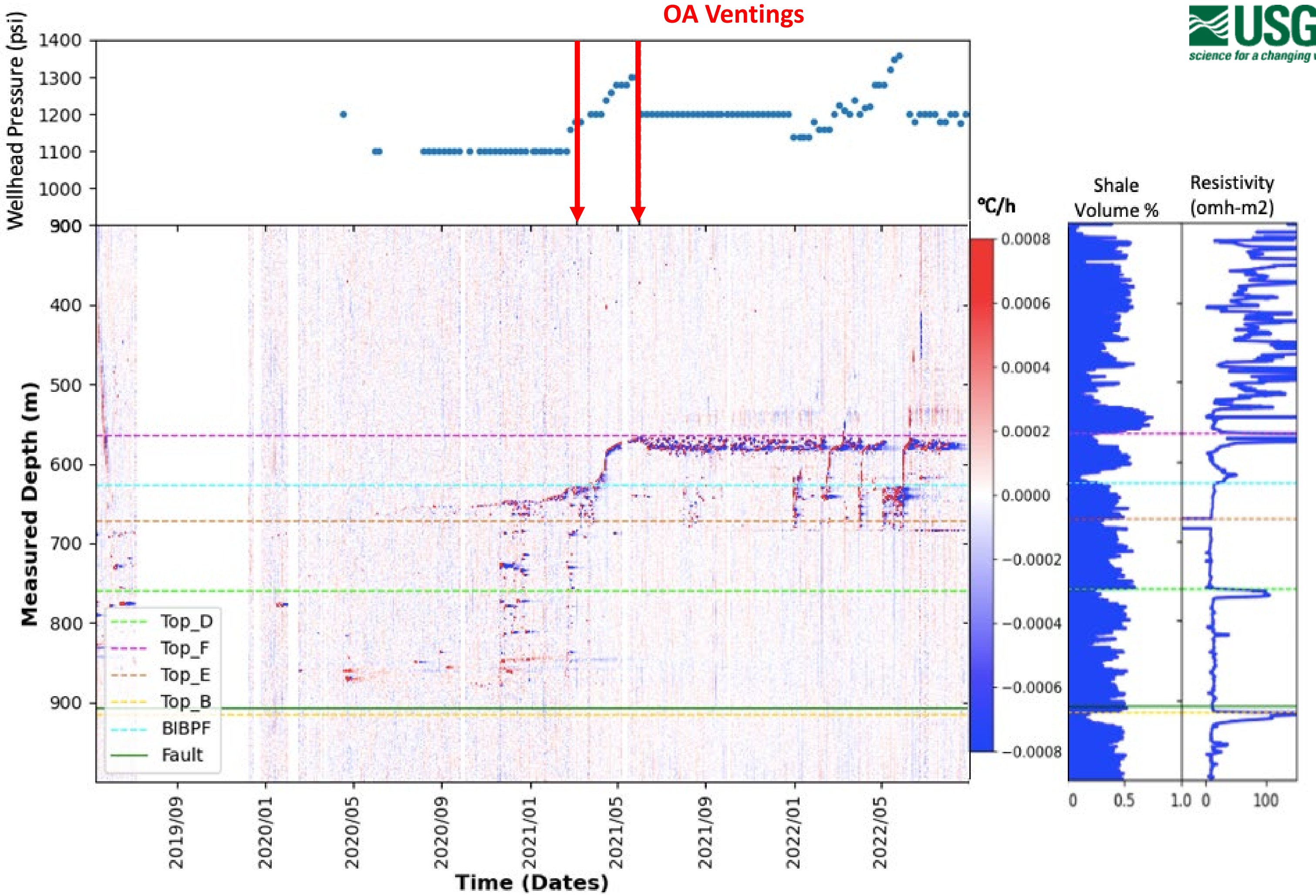
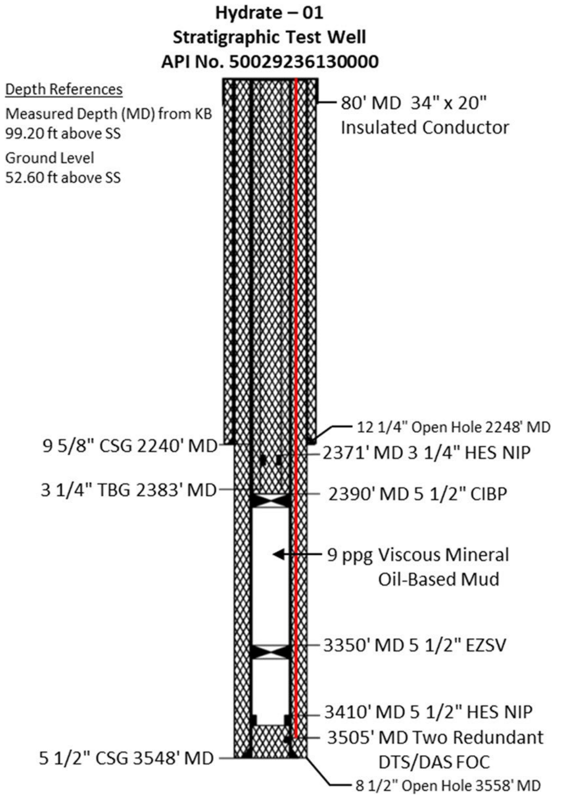
Alaska Permafrost and Gas Hydrate Well Integrity Studies

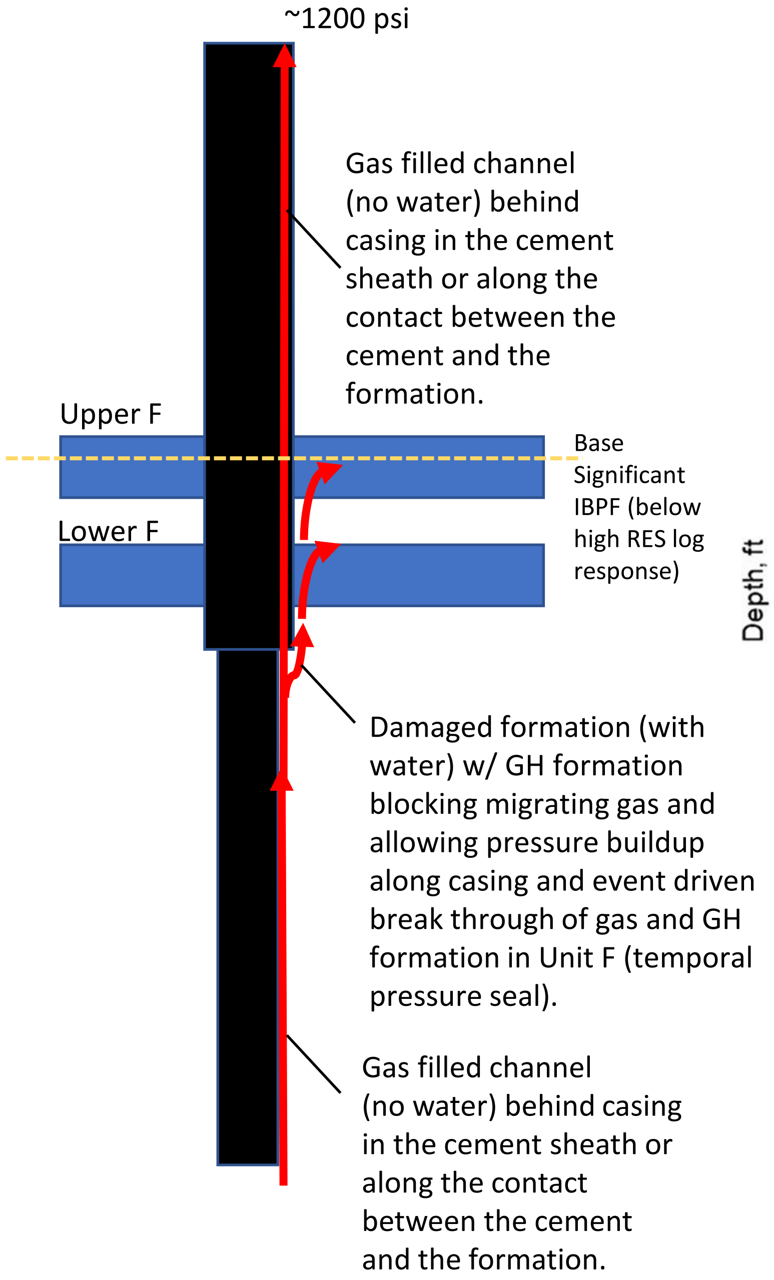
https://doi.org/10.2118/223111-PA

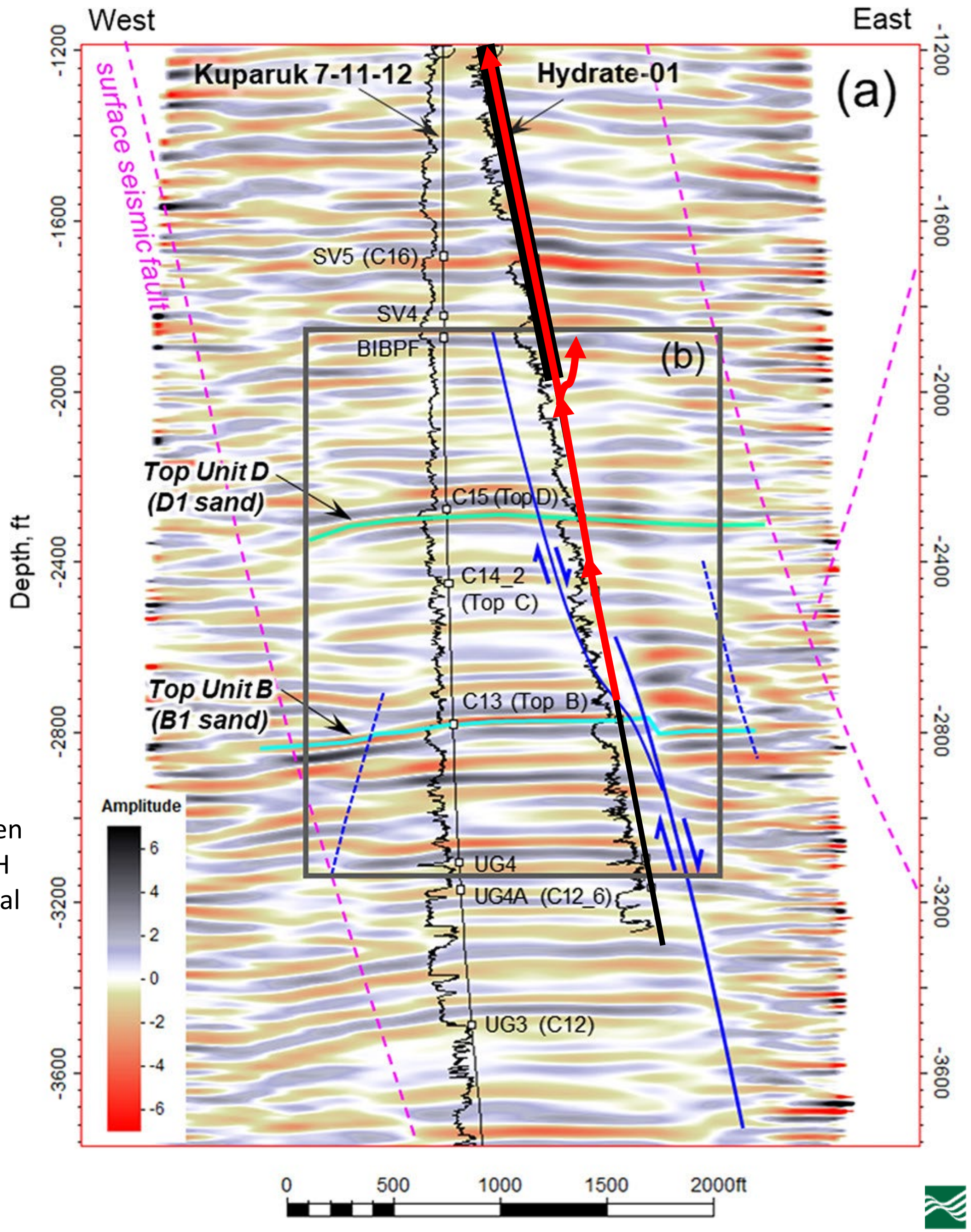




Hydrate-01 Waterfall DTS (temperature) display showing temperature changes over time with the graph at the top indicating outer annulus (OA) wellhead pressures and gas bleeding events where the OA pressure was vented.



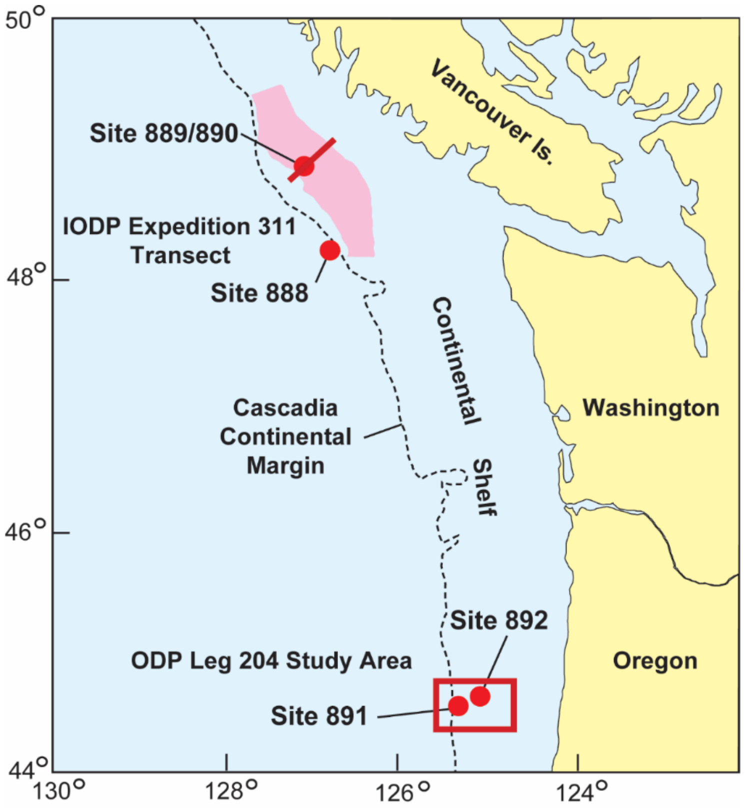


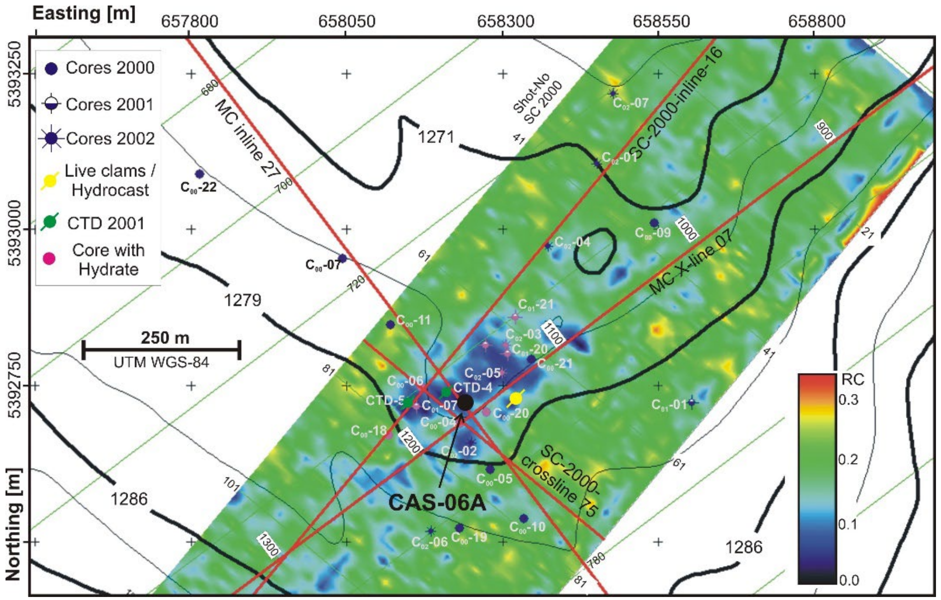


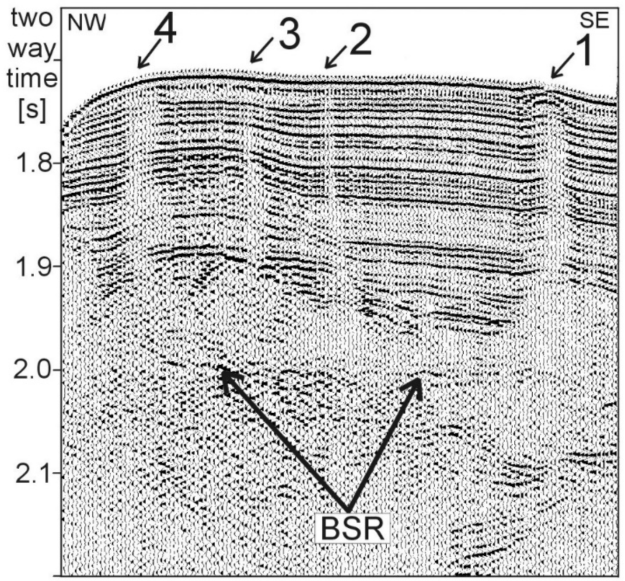
Note:
In the last month we are seeing the development of the same Temp and Pressure Response in the Dec-2022 completed Hydrate-02 well (note no know fault crossing).

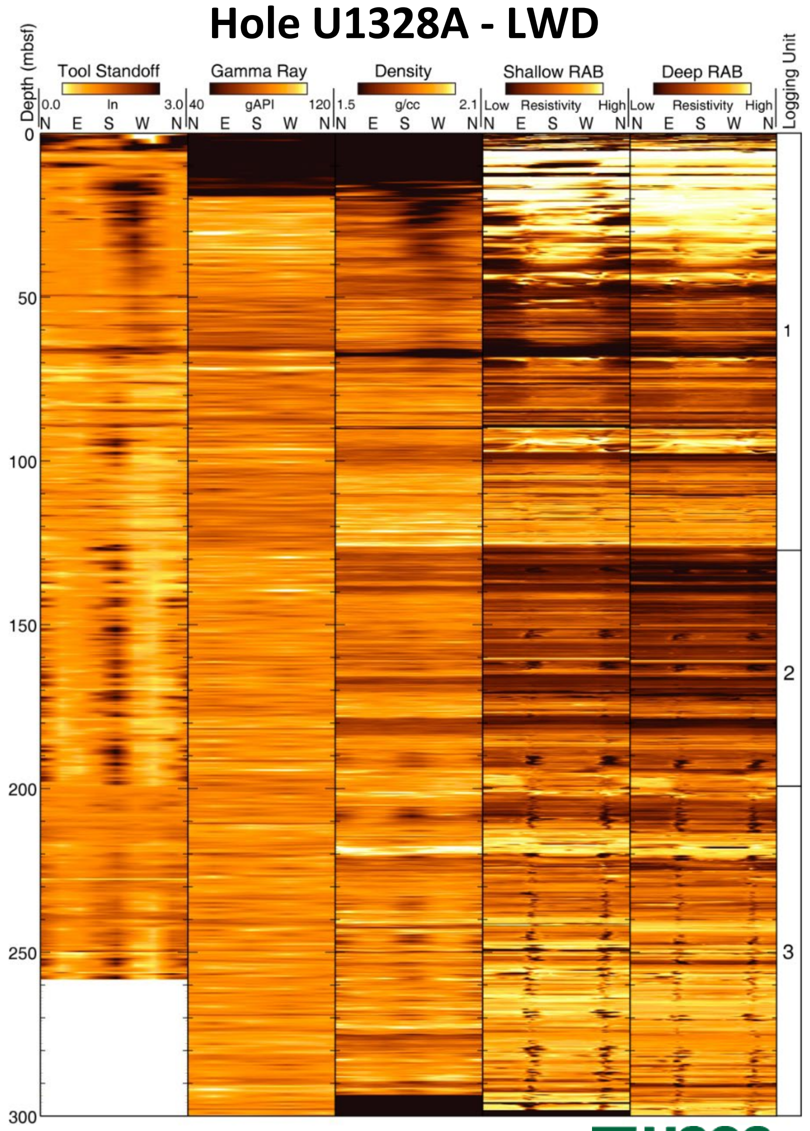
IODP Expedition 311 – Site U1328

Cold Vent Site CAS06A/B









Conduits for gas transport through gas hydrate stability zone, with concentrated hydrate occurrences near the sea floor

3. Summary and Recommendations

Summary and Recommendations

Findings and Intervention

Drilling Operations

- Conduct drilling hazard assessment.
- Document the need for advanced drilling and mud handling programs and systems.
- Highly concentrated gas hydrate accumulations are likely to be characterized by significant gas returns. The volume of gas will be limited to the amount of sediment disaggregated by the bit, provided the drilling fluid temperature is not elevated.
- Drill plans should be designed to distinguish between gas releases from hydrates and sustained gas flows from free-gas occurrences. Gas release from hydrate-bearing stratigraphic sections are often not controlled by heavy mud.
- Open-hole drilling operations (no riser) require the complete analysis of all the available LWD data (APWD pressure measurements, borehole temperatures, well log formation responses, acoustic borehole monitoring, etc.), drilling performance data, and ROV monitoring of the well head at the seafloor.

Summary and Recommendations
Findings and Intervention

Facilities & Completions (production-related concerns)

- Conduct geoscience studies (seismic data acquisition/analysis, pilot hole LWD, and core data acquisition/analysis) in support of field development planning.
- Gas hydrate and free-gas system analysis, mode and type of occurrence.
- Modeling physical and geomechanical response of free-gas and gas hydrate occurrences related to the production of hot fluids from underlying conventional oil and gas fields.
- Engineering development concepts that consider the integrity of seafloor structures and production casing/tubing, including distributed fiber-optic and gauge-based monitoring systems.