With THANKS to the Captains, mates, officers and all the crews of all 4 vessels for OUTSTANDING SATs & GREAT SCIENCE!!

SBP29 Installations on the R/Vs SALLY RIDE, NEIL ARMSTRONG, THOMAS G. THOMPSON & USCGC HEALY (WAGB-20):

Highlights & Learnings, including “Apples-to-Apples" Comparisons to Other SBP Systems

Daniel “DanO” Orange*, James Gibson & Eli Silver

U.C. Santa Cruz (**also* Integral Consulting / ONE {Oro Negro Exploration LLC})

Tolu Akande, & Anand Hiroji, University of Southern Mississippi

Charles Holland & Tim Sonnemann Portland State University

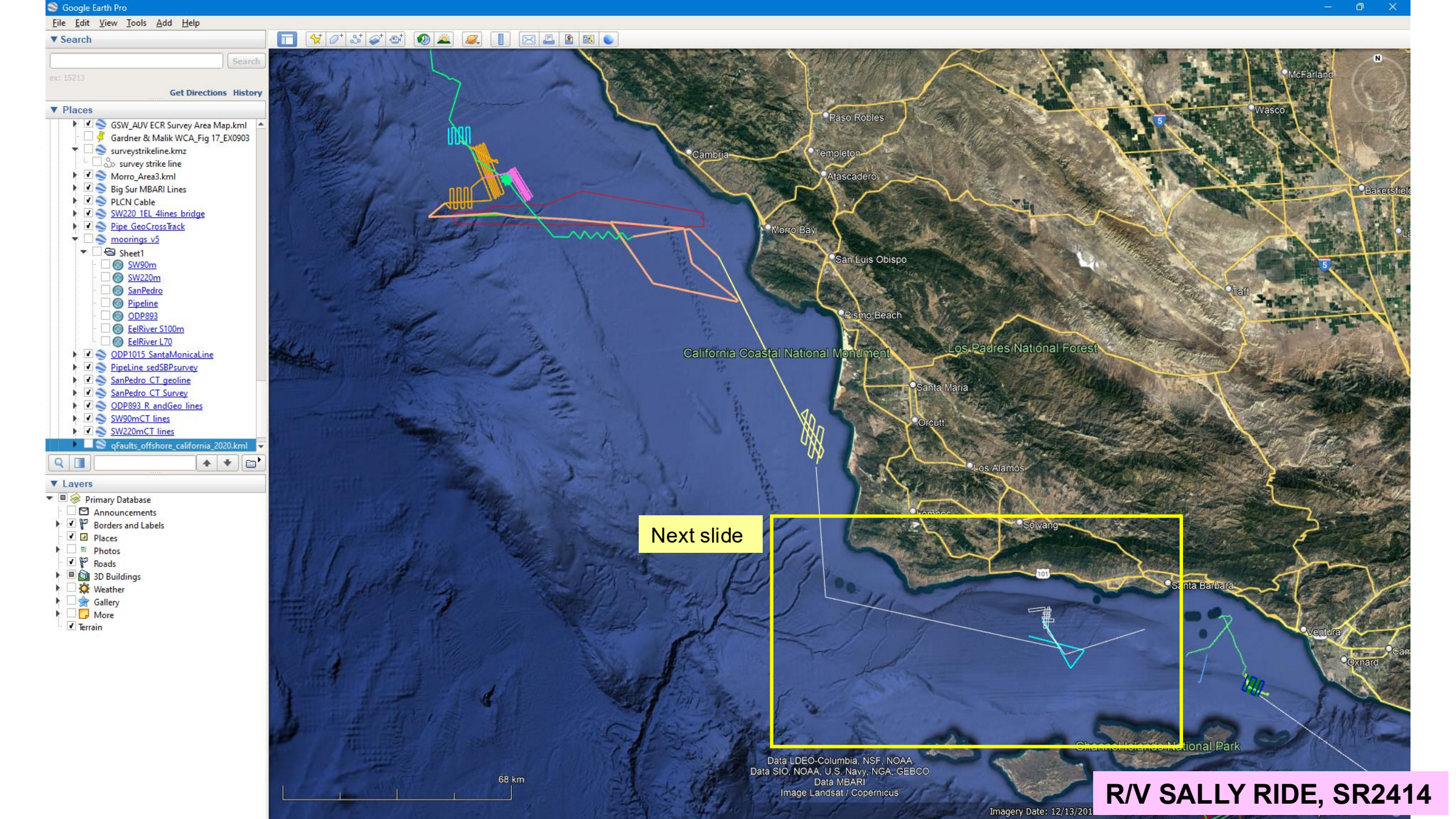
Bjørnar Langli, Kongsberg

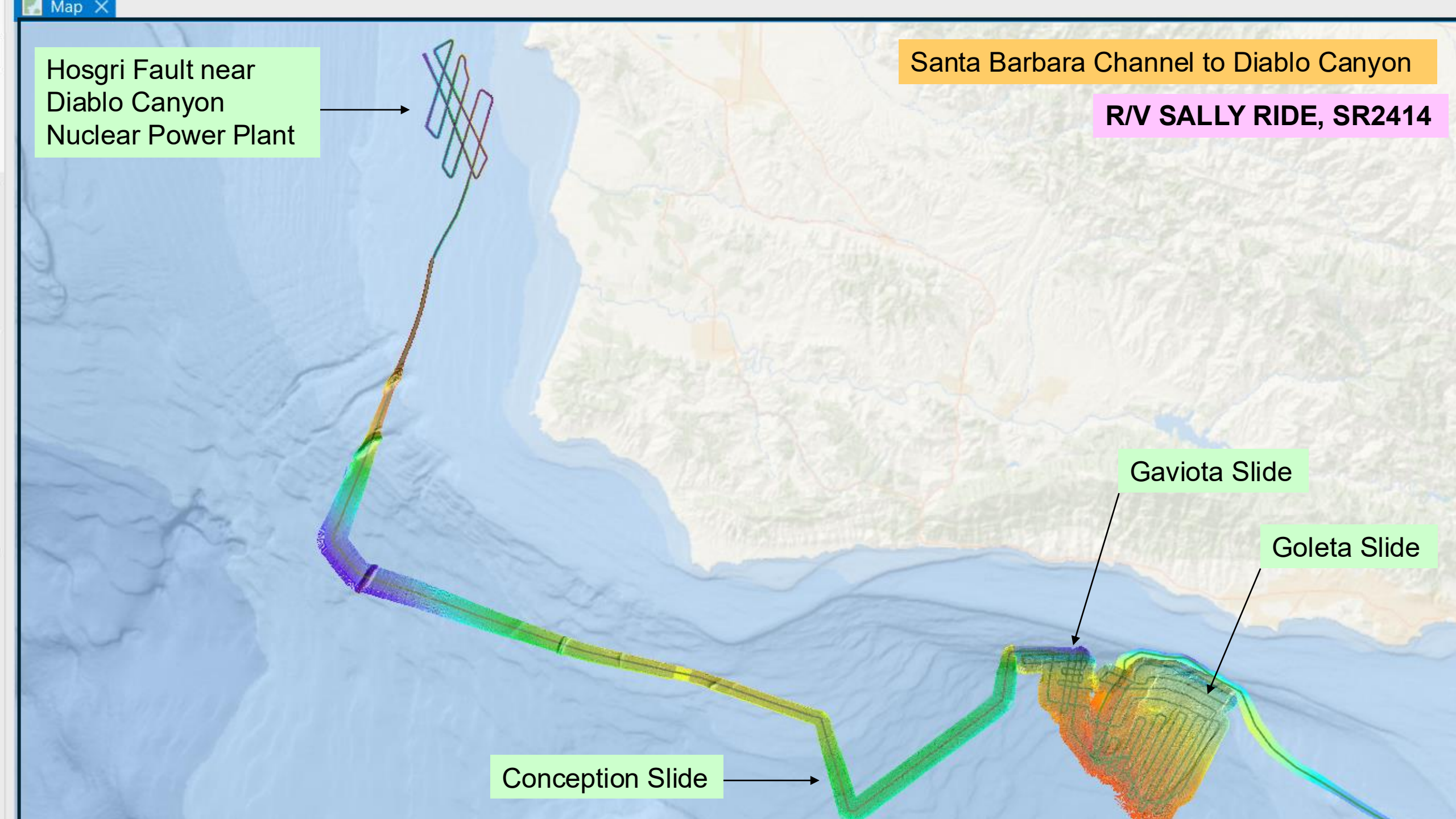
Jared Kluesner & Boe Derosier U.S. Geological Survey

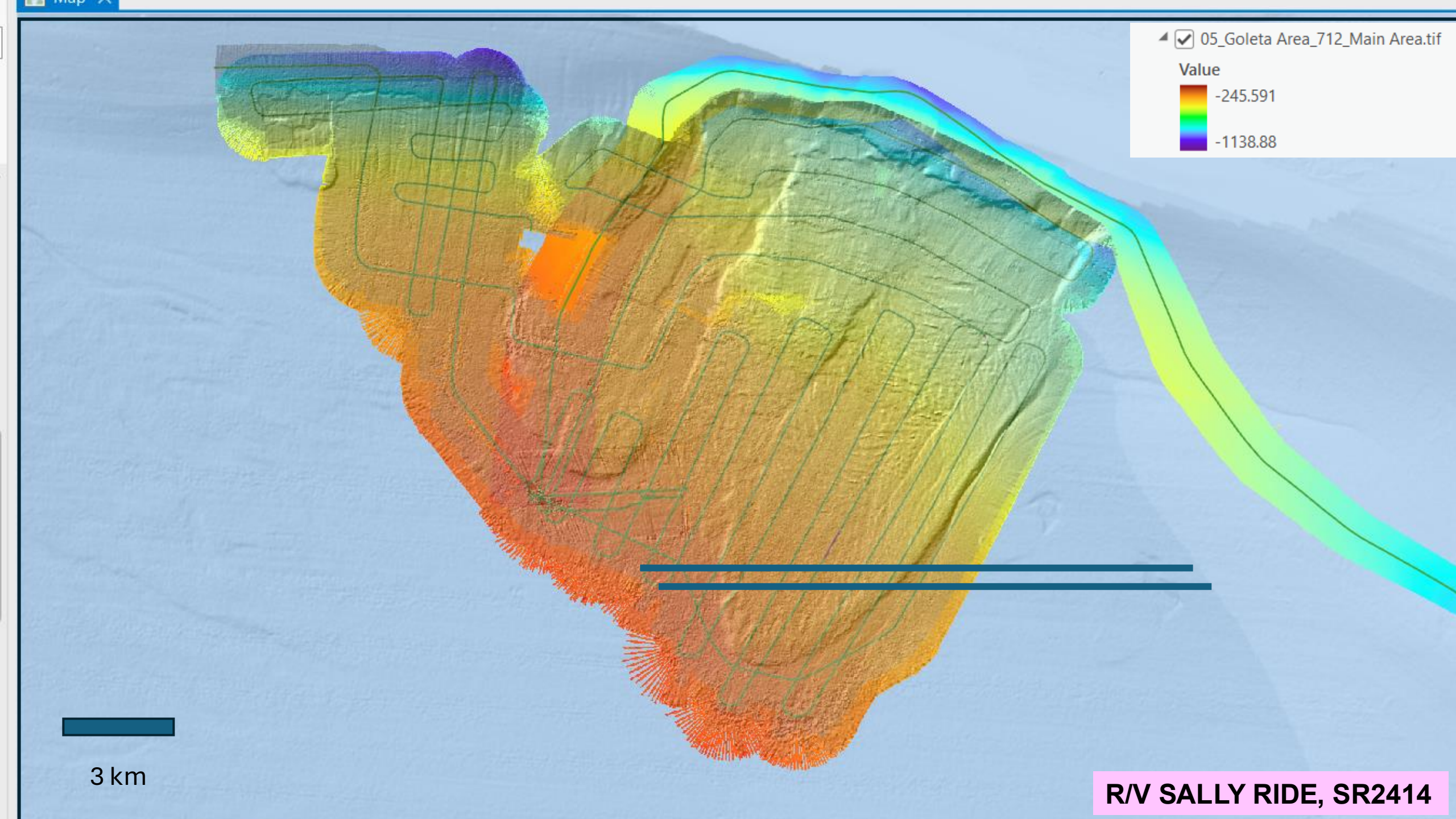
Clay Whittaker, (NAVO [ret.])

Madeleine C. Lucas & Kyle Becker University of Washington

SBP29s:
3° x 6° - R/Vs SALLY RIDE, NEIL ARMSTRONG, USCGC HEALY
3° x 3° - THOMAS G. THOMPSON
(TGT “Hammerhead” gondola; others flush to hull; HEALY through 2cm Titanium)

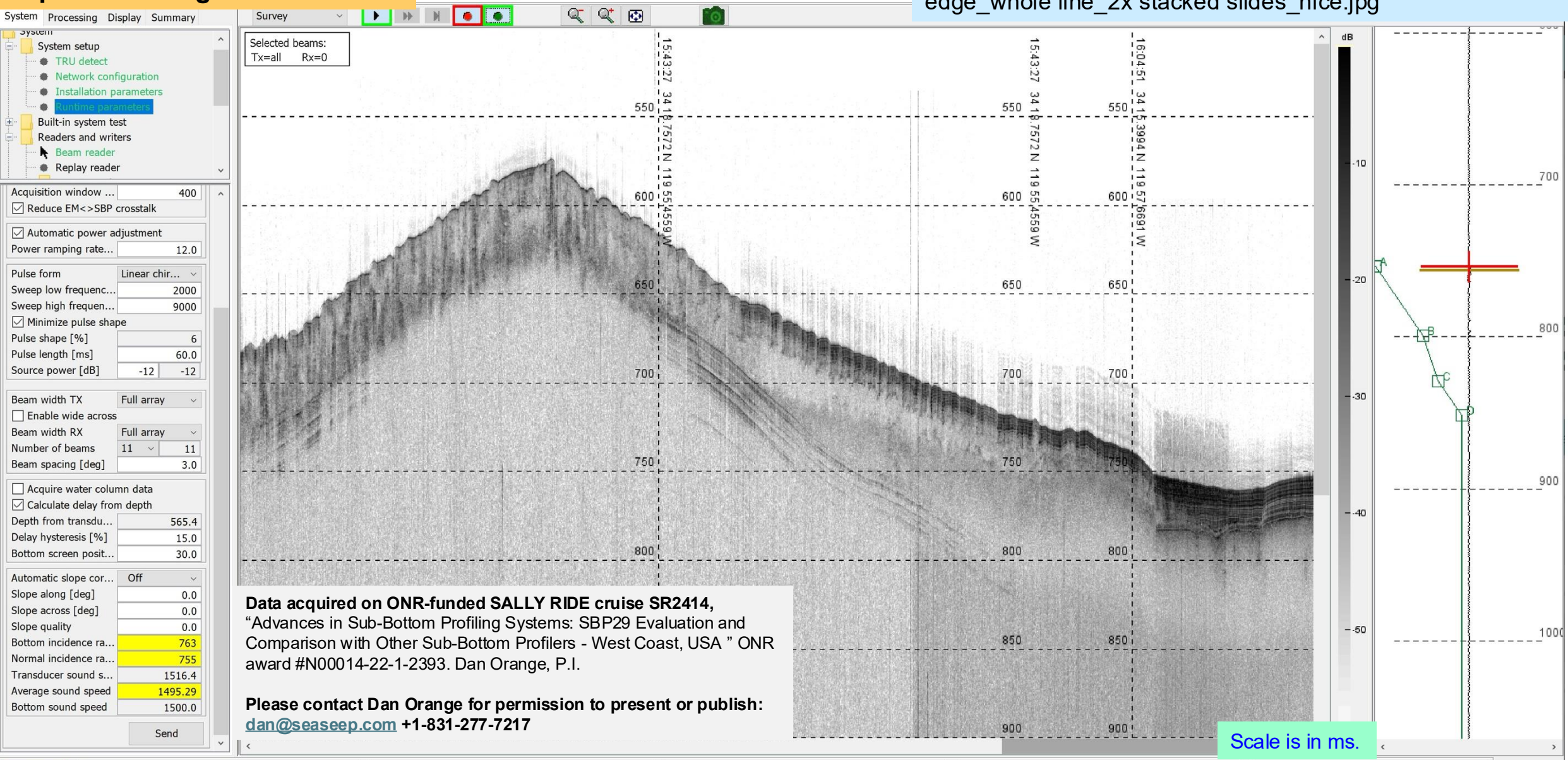

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surveystrikeline.kmz
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Pipe_GeoCrossTrack
moorings_v5
Sheet1
SW90m
SW220m
SanPedro
Pipeline
ODP893
EelRiver S100m
EelRiver L70
ODP1015_SantaMonicaLine
PipeLine_sedSBPsurvey
SanPedro_CT_geoline
SanPedro_CT_Survey
ODP893_R_andGeo_lines
SW90mCT_lines
SW220mCT_lines
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Atascadero
Morro Bay
San Luis Obispo
Pismo Beach
California Coastal National Monument
Los Padres National Forest
Santa Maria
Orcutt
Los Alamos
Solvang
Santa Barbara
Ventura
Oxnard
Channel Islands National Park
McFarland
Wasco
Taft
Bakersfield
Next slide
68 km
Data LDEO-Columbia, NSF, NOAA
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Data MBARI
Image Landsat / Copernicus
Imagery Date: 12/13/201
R/V SALLY RIDE, SR2414


Map
Hosgri Fault near
Diablo Canyon
Nuclear Power Plant
Santa Barbara Channel to Diablo Canyon
R/V SALLY RIDE, SR2414
Gaviota Slide
Goleta Slide
Conception Slide


05_Goleta Area_712_Main Area.tif
Value
-245.591
-1138.88
3 km
R/V SALLY RIDE, SR2414

Dip Line through Goleta Slide.

Filename: 2024-08-23_1615_Goleta slide dip line_approaching edge_whole line_2x stacked slides_nice.jpg



Data acquired on ONR-funded SALLY RIDE cruise SR2414,
"Advances in Sub-Bottom Profiling Systems: SBP29 Evaluation and Comparison with Other Sub-Bottom Profilers - West Coast, USA " ONR award #N00014-22-1-2393. Dan Orange, P.I.

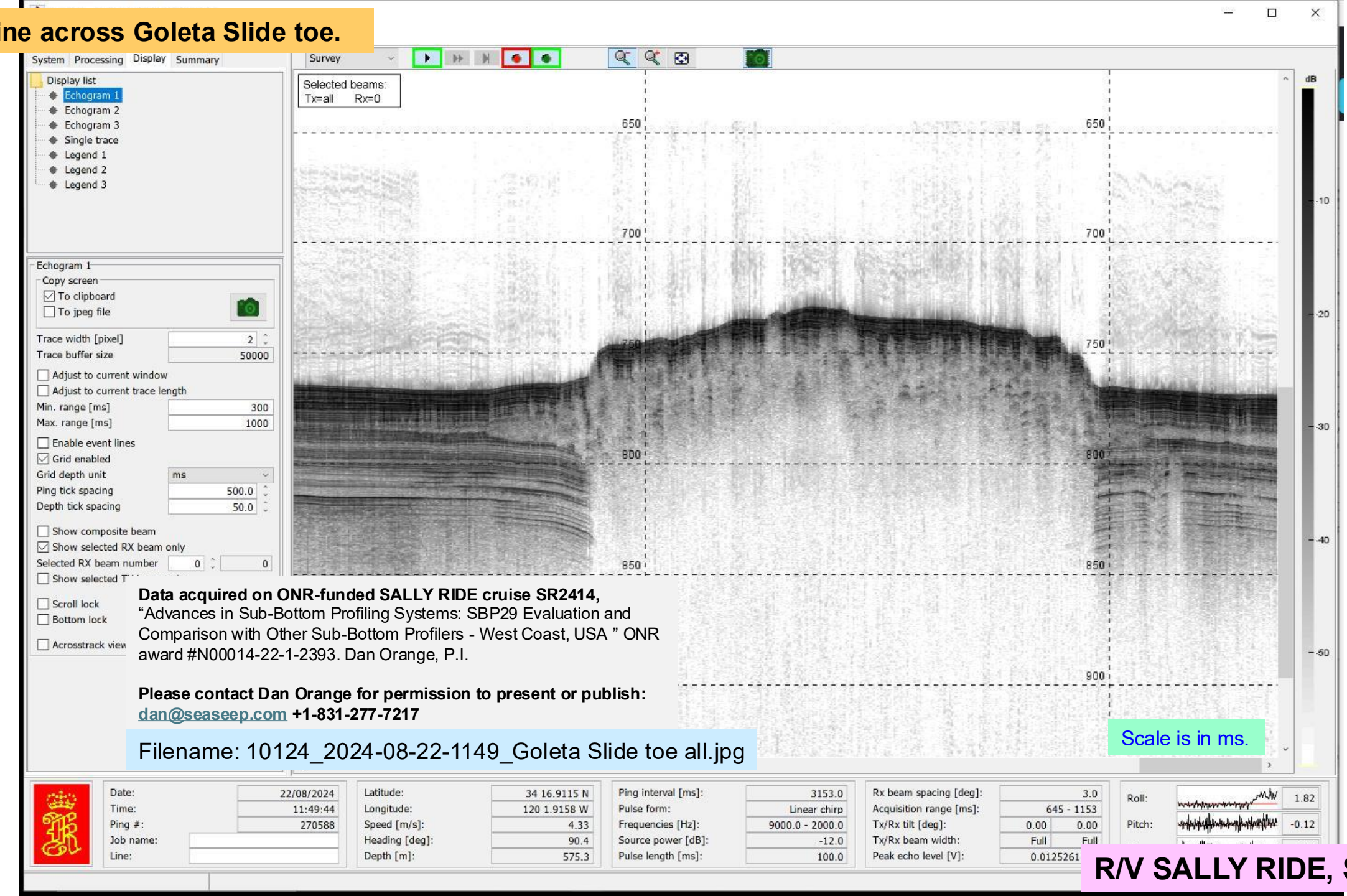
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dan@seaseep.com **+1-831-277-7217**

Scale is in ms.

Date:	22/08/2024	Latitude:	34 14.6792 N	Ping interval [ms]:	2871.0	Rx beam spacing [deg]:	3.0	Roll:	1.21
Time:	16:14:01	Longitude:	119 57.6459 W	Pulse form:	Linear chirp	Acquisition range [ms]:	596 - 1064	Pitch:	0.15
Ping #:	276439	Speed [m/s]:	5.14	Frequencies [Hz]:	9000.0 - 2000.0	Tx/Rx tilt [deg]:	0.00 0.00		
Job name:		Heading [deg]:	27.0	Source power [dB]:	-12.0	Tx/Rx beam width:	Full		
Line:		Depth [m]:	563.8	Pulse length [ms]:	60.0	Peak echo level [V]:	0.0099360		

R/V SALLY RIDE, SR2414

Strike Line across Goleta Slide toe.



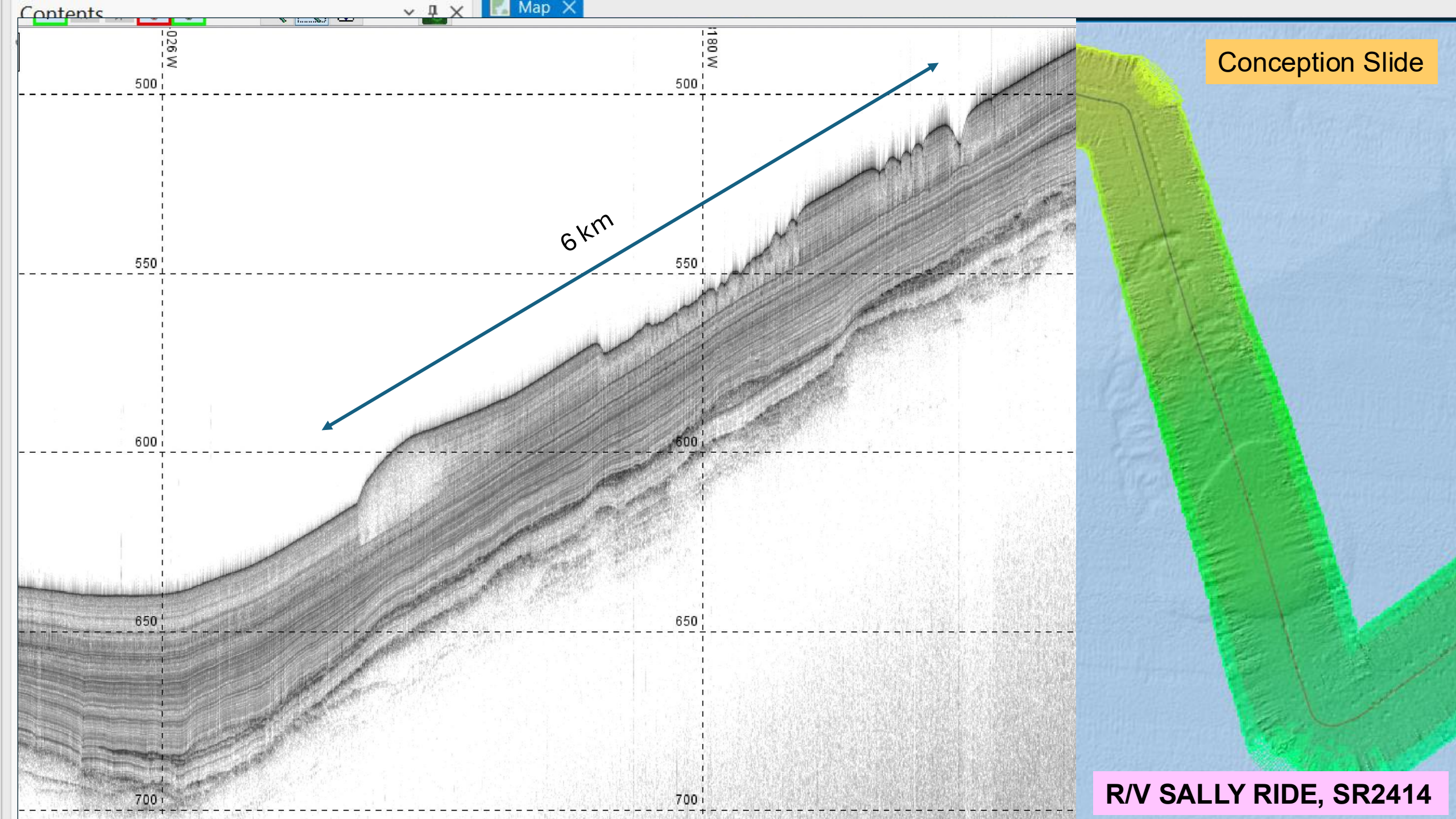
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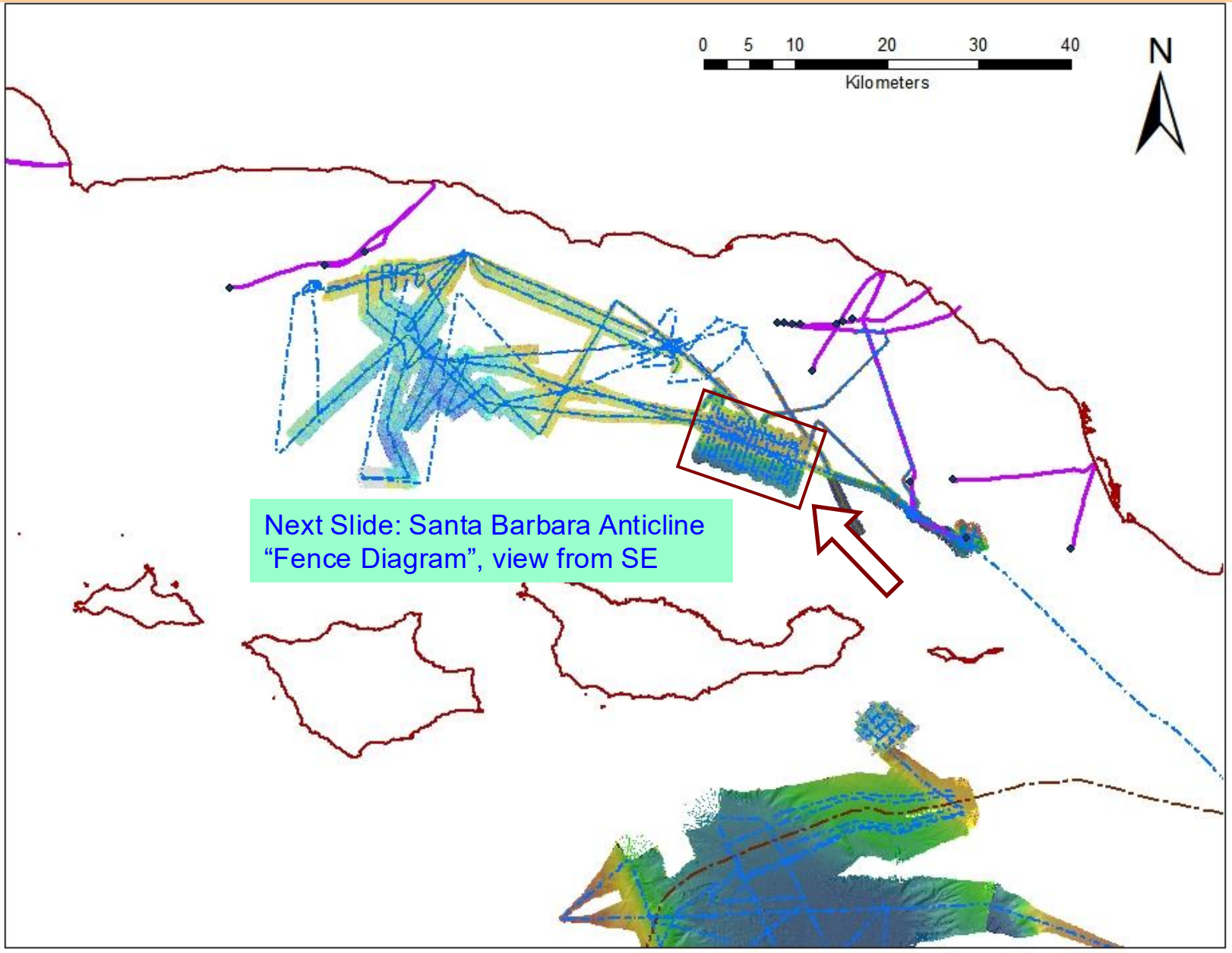
Filename: 10124_2024-08-22-1149_Goleta Slide toe all.jpg

Scale is in ms.

R/V SALLY RIDE, SR2414


Contents
Map
026 W
180 W
500
550
600
650
700
6 km
Conception Slide
R/V SALLY RIDE, SR2414

SALLY RIDE SR2207 As-shot. Santa Cruz Basin, Sponge Reef, and Santa Barbara Channel.

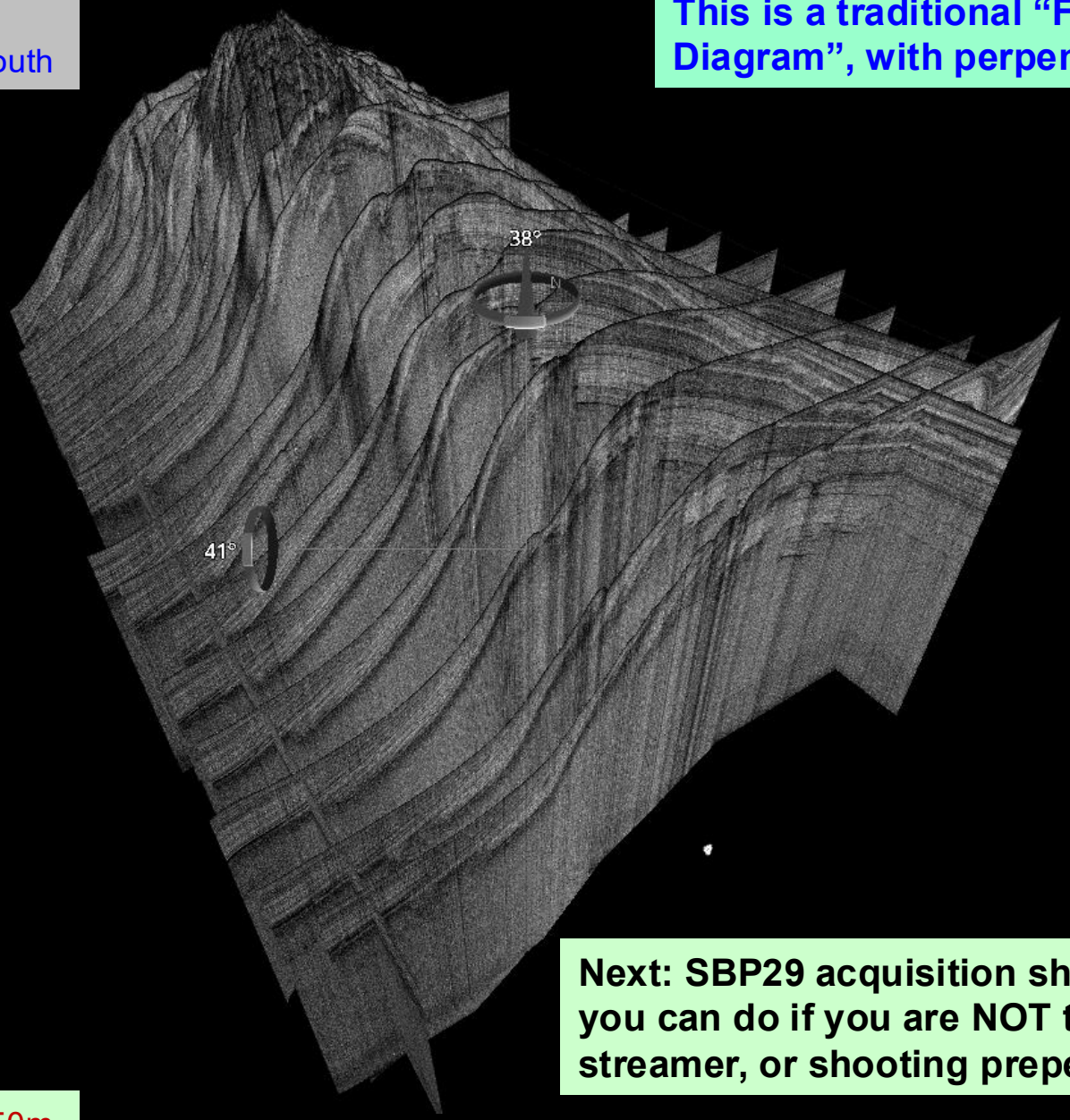


Orange, et al., (FEMME, 2023) SBP29: a Quantum Leap in Sub-Bottom Profiling

R/V SALLY RIDE, SR2414

SALLY RIDE SR2207 Santa Barbara Anticline Fence Diagram.

Perspective
View from South



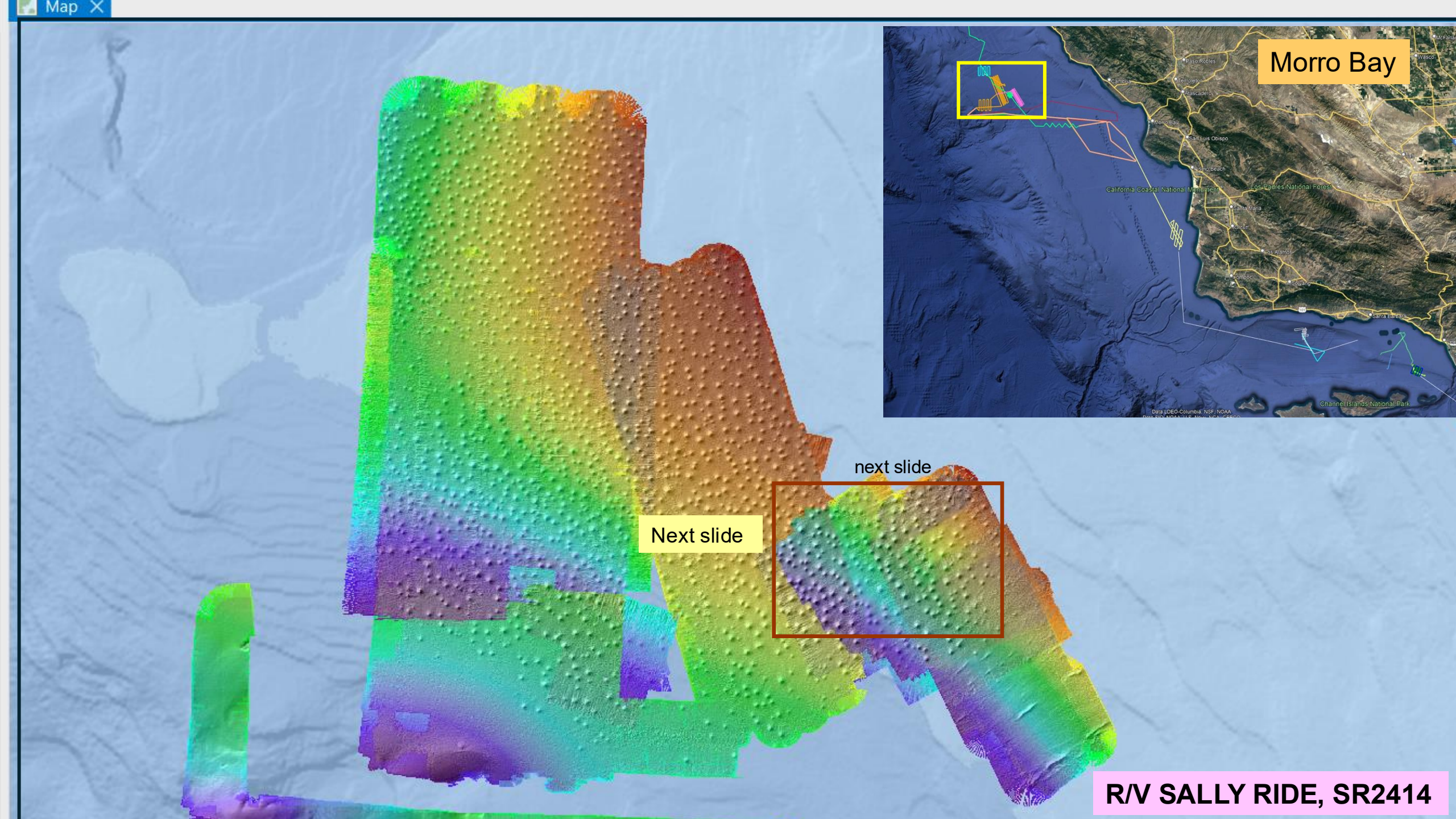
This is a traditional "Fence Diagram", with perpendicular lines.

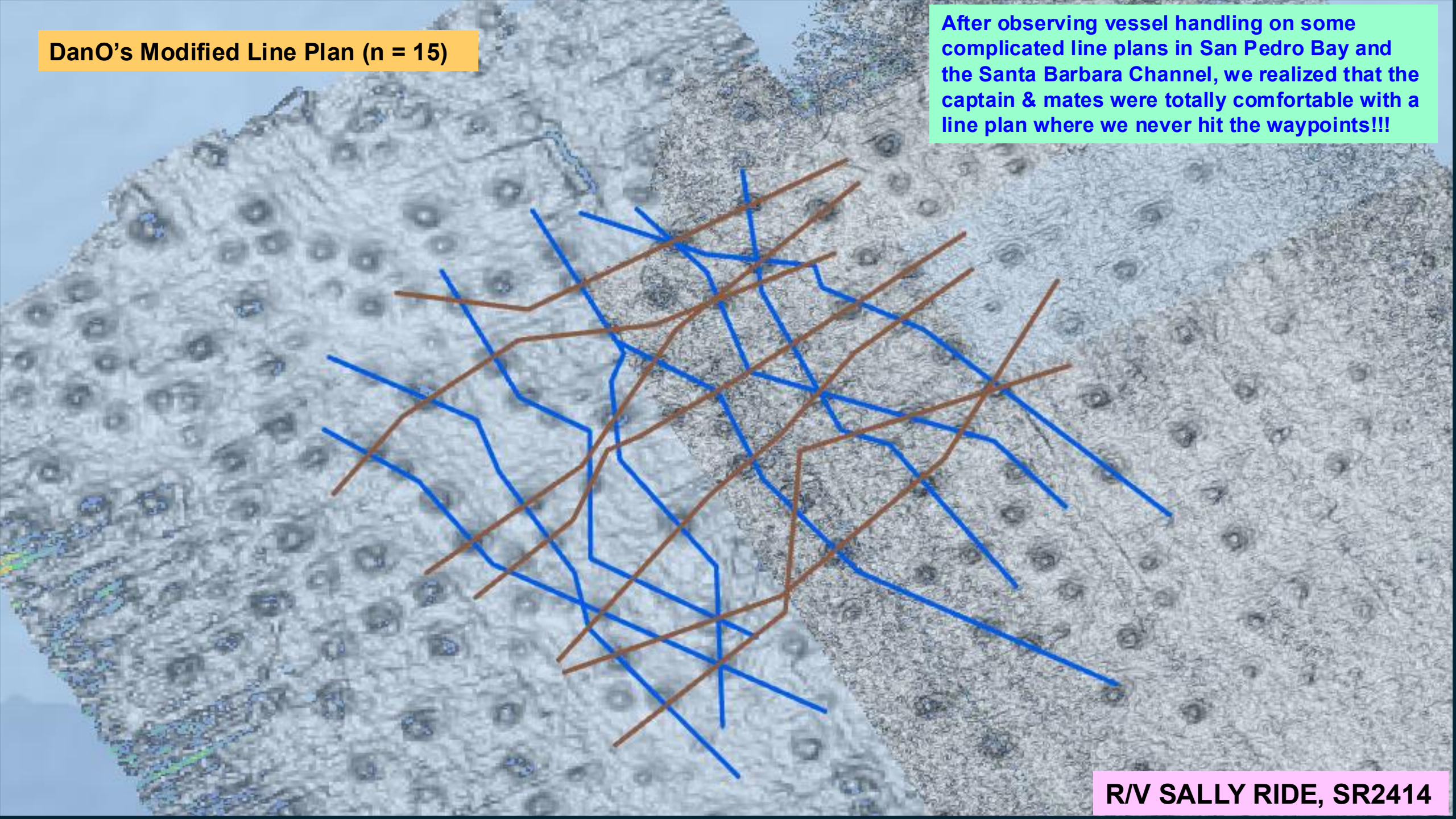
Next: SBP29 acquisition showcasing what you can do if you are NOT towing a streamer, or shooting prependicular lines.

Dipline spacing ~650m

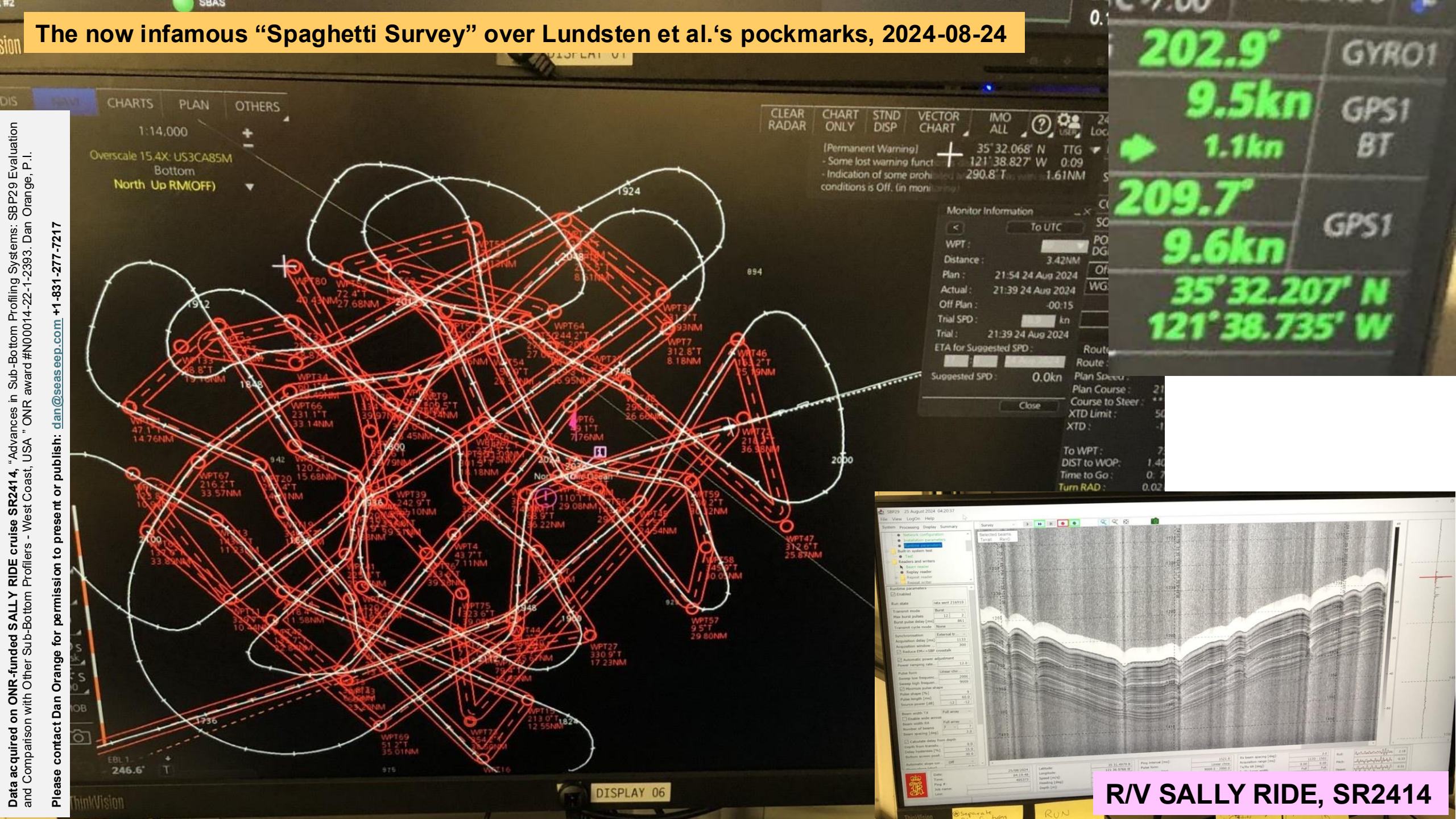
Orange, et al., (FEMME, 2023) SBP29: a Quantum Leap in Sub-Bottom Profiling

R/V SALLY RIDE, SR2414


Map
Morro Bay
Paso Robles
Cambria
Templeton
Atascadero
Morro Bay
San Luis Obispo
Pismo Beach
California Coastal National Monument
Los Padres National Forest
Santa Maria
Orcutt
Los Alamos
Solvang
Santa Barbara
Channel Islands National Park
Data LDEO-Columbia, NSF, NOAA
next slide
Next slide
R/V SALLY RIDE, SR2414


DanO's Modified Line Plan (n = 15)
After observing vessel handling on some complicated line plans in San Pedro Bay and the Santa Barbara Channel, we realized that the captain & mates were totally comfortable with a line plan where we never hit the waypoints!!!
R/V SALLY RIDE, SR2414

The now infamous “Spaghetti Survey” over Lundsten et al.‘s pockmarks, 2024-08-24

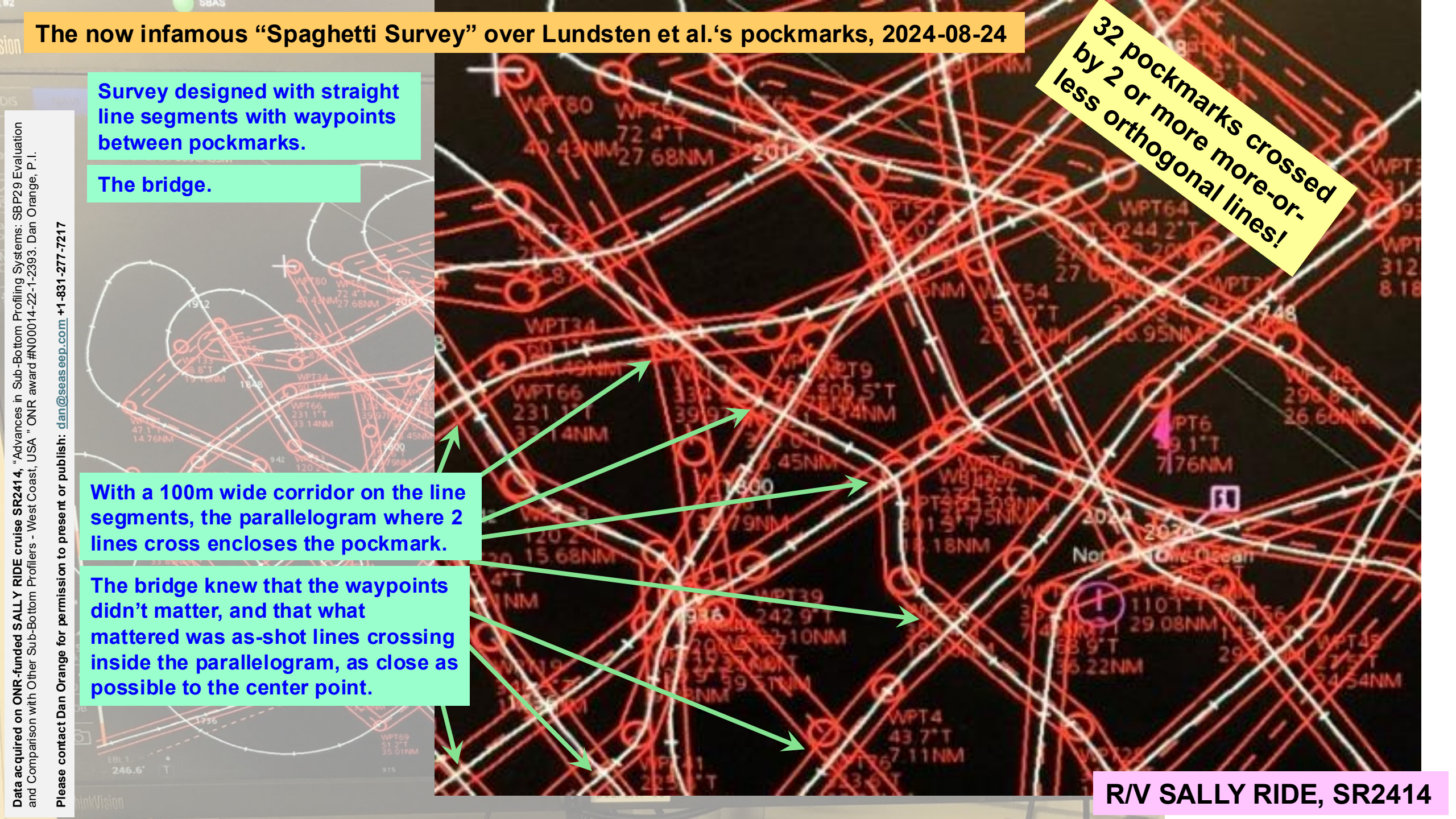


Data acquired on ONR-funded SALLY RIDE cruise SR2414, “Advances in Sub-Bottom Profiling Systems: SBP29 Evaluation and Comparison with Other Sub-Bottom Profilers - West Coast, USA ” ONR award #N00014-22-1-2393. Dan Orange, P.I.

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R/V SALLY RIDE, SR2414

The now infamous “Spaghetti Survey” over Lundsten et al.‘s pockmarks, 2024-08-24



Survey designed with straight line segments with waypoints between pockmarks.

The bridge.

With a 100m wide corridor on the line segments, the parallelogram where 2 lines cross encloses the pockmark.

The bridge knew that the waypoints didn’t matter, and that what mattered was as-shot lines crossing inside the parallelogram, as close as possible to the center point.

32 pockmarks crossed by 2 or more more-or-less orthogonal lines!

R/V SALLY RIDE, SR2414

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SBP29 25 August 2024 01:37:51

Filename: 10124_20240825_0136_Pockmark spaghetti survey_line 4_eval symmetry_Display_zoom_ms.jpg

File View LogOn Help

System Processing Display Summary

Display list
- Echogram 1
- Echogram 2
- Echogram 3
- Single trace
- Legend 1
- Legend 2
- Legend 3

Echogram 1

Copy screen
- [x] To clipboard
- [ ] To jpeg file

Trace width [pixel]: 1
Trace buffer size: 50000
- [ ] Adjust to current window
- [ ] Adjust to current trace length
Min. range [ms]: 1120
Max. range [ms]: 1500
- [ ] Enable event lines
- [x] Grid enabled
Grid depth unit: ms
Ping tick spacing: 500.0
Depth tick spacing: 30.0
- [ ] Show composite beam
- [x] Show selected RX beam only
Selected RX beam nu... 0 0
- [ ] Show selected TX beam only
- [ ] Scroll lock
- [ ] Bottom lock
- [ ] Acrosstrack view

Survey

Selected beams:

Line 4 through Lundsten et al., 's Pockmark AUV Survey Area

Scale is in ms.

Assuming a sediment accumulation rate of 18.3 cm/ky (Dobbs et al., 2023) these pockmarks have persisted in the same location (!!) for 275,000 years!!!

20 ms = ~15m

1230 1290 1320 1350 1380

dB -10 -20 -30 -40

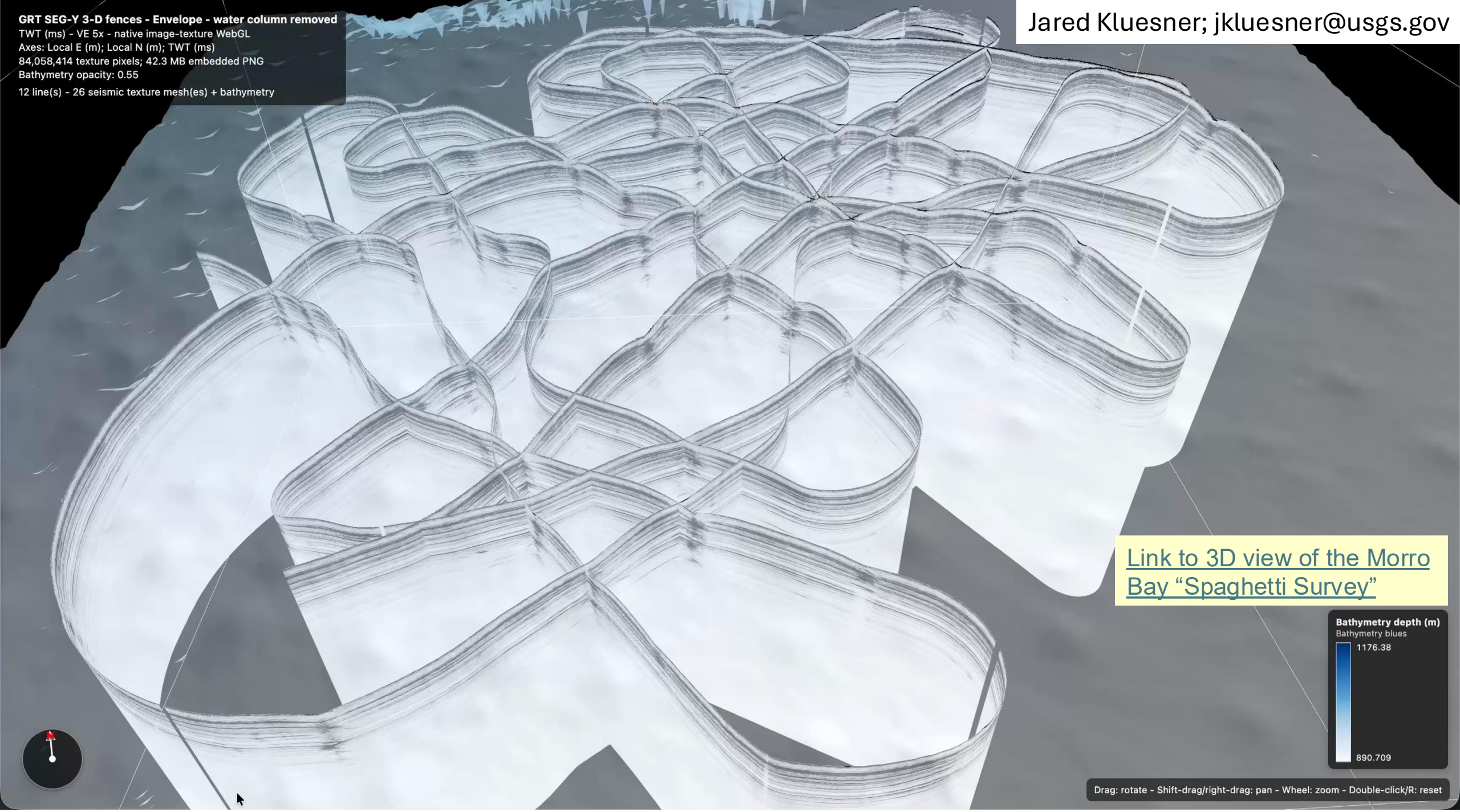
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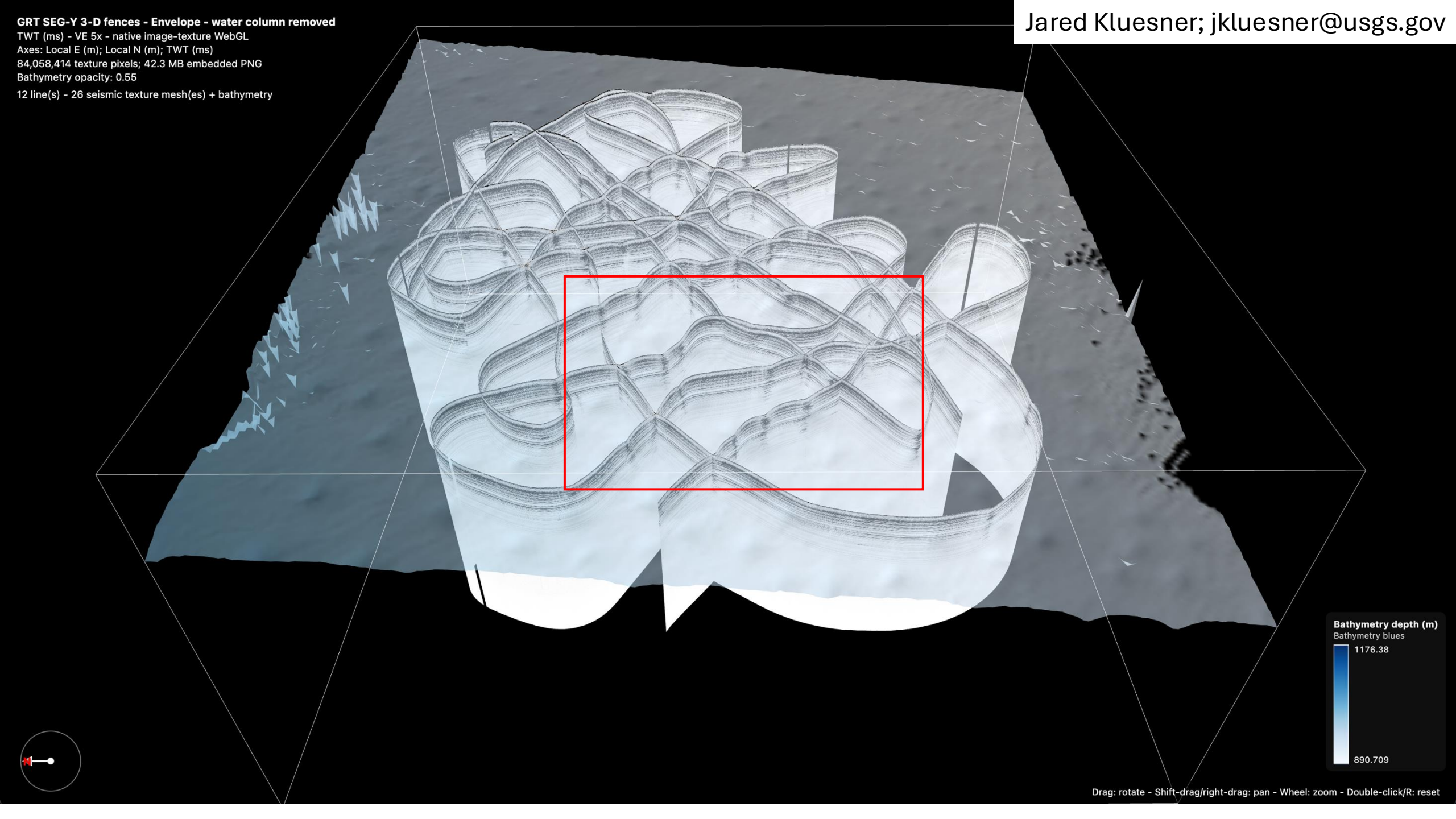
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WD = 938m
8.9 kts.
Chirp down 9 – 2 kHz
Pulse length = 60ms

Date:	25/08/2024	Latitude:	35 31.3276 N	Ping interval [ms]:	850.0	Rx beam spacing [deg]:	3.0	Roll:	1.35
Time:	01:37:03	Longitude:	121 38.9870 W	Pulse form:	Linear chirp	Acquisition range [ms]:	1133 - 1501	Pitch:	0.29
Ping #:	397140	Speed [m/s]:	4.47	Frequencies [Hz]:	9000.0 - 2000.0	Tx/Rx tilt [deg]:	0.00 0.00		
Job name:		Heading [deg]:	306.8	Source power [dB]:	-12.0	Tx/Rx beam width:	Full		
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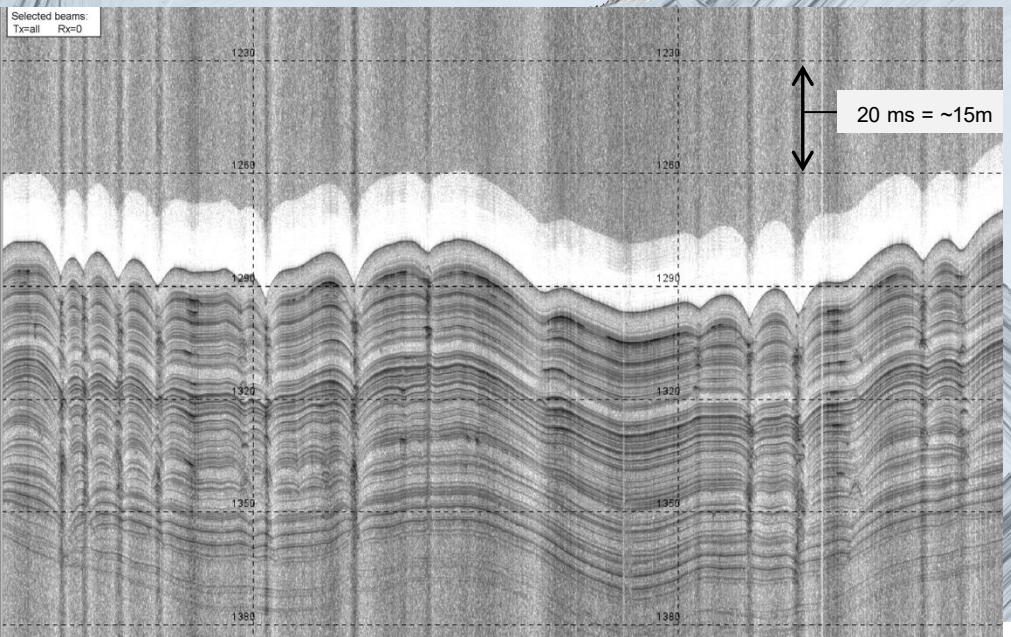
R/V SALLY RIDE, SR2414


GRT SEG-Y 3-D fences - Envelope - water column removed
TWT (ms) - VE 5x - native image-texture WebGL
Axes: Local E (m); Local N (m); TWT (ms)
84,058,414 texture pixels; 42.3 MB embedded PNG
Bathymetry opacity: 0.55
12 line(s) - 26 seismic texture mesh(es) + bathymetry
Jared Kluesner; jkluesner@usgs.gov
Link to 3D view of the Morro Bay “Spaghetti Survey”
Bathymetry depth (m)
Bathymetry blues
1176.38
890.709
Drag: rotate - Shift-drag/right-drag: pan - Wheel: zoom - Double-click/R: reset


GRT SEG-Y 3-D fences - Envelope - water column removed
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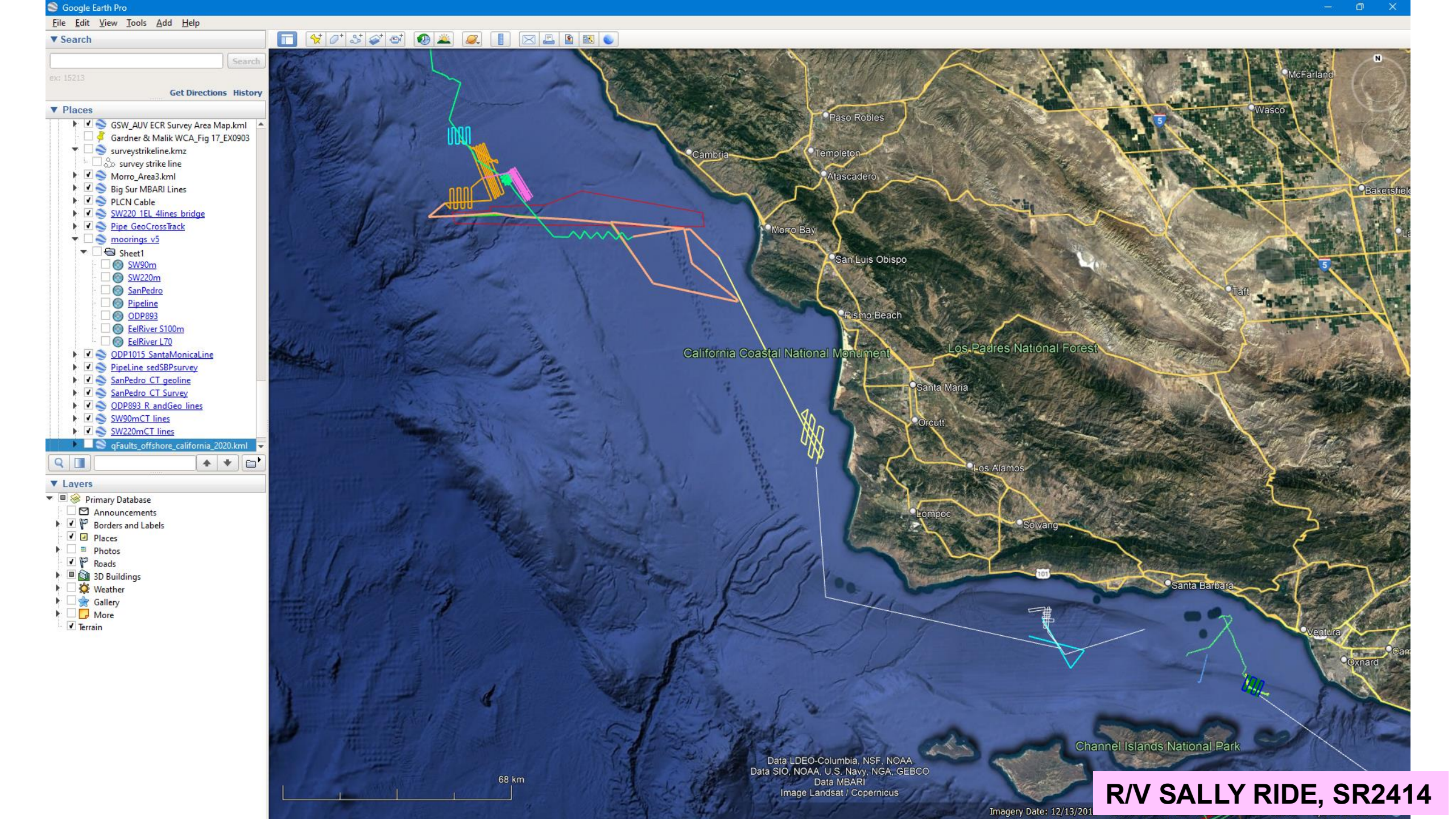
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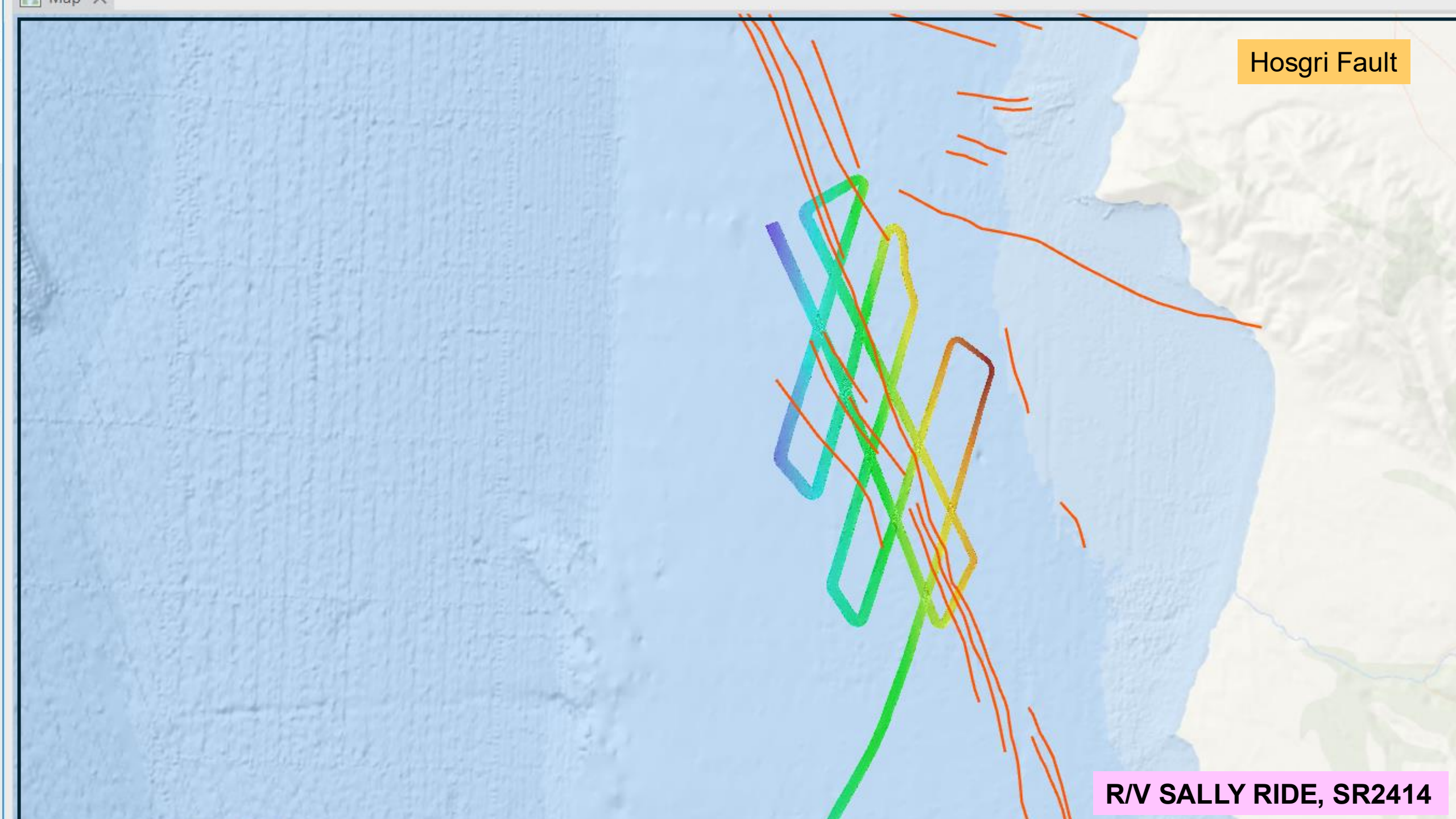
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Bathymetry depth (m)
Bathymetry blues
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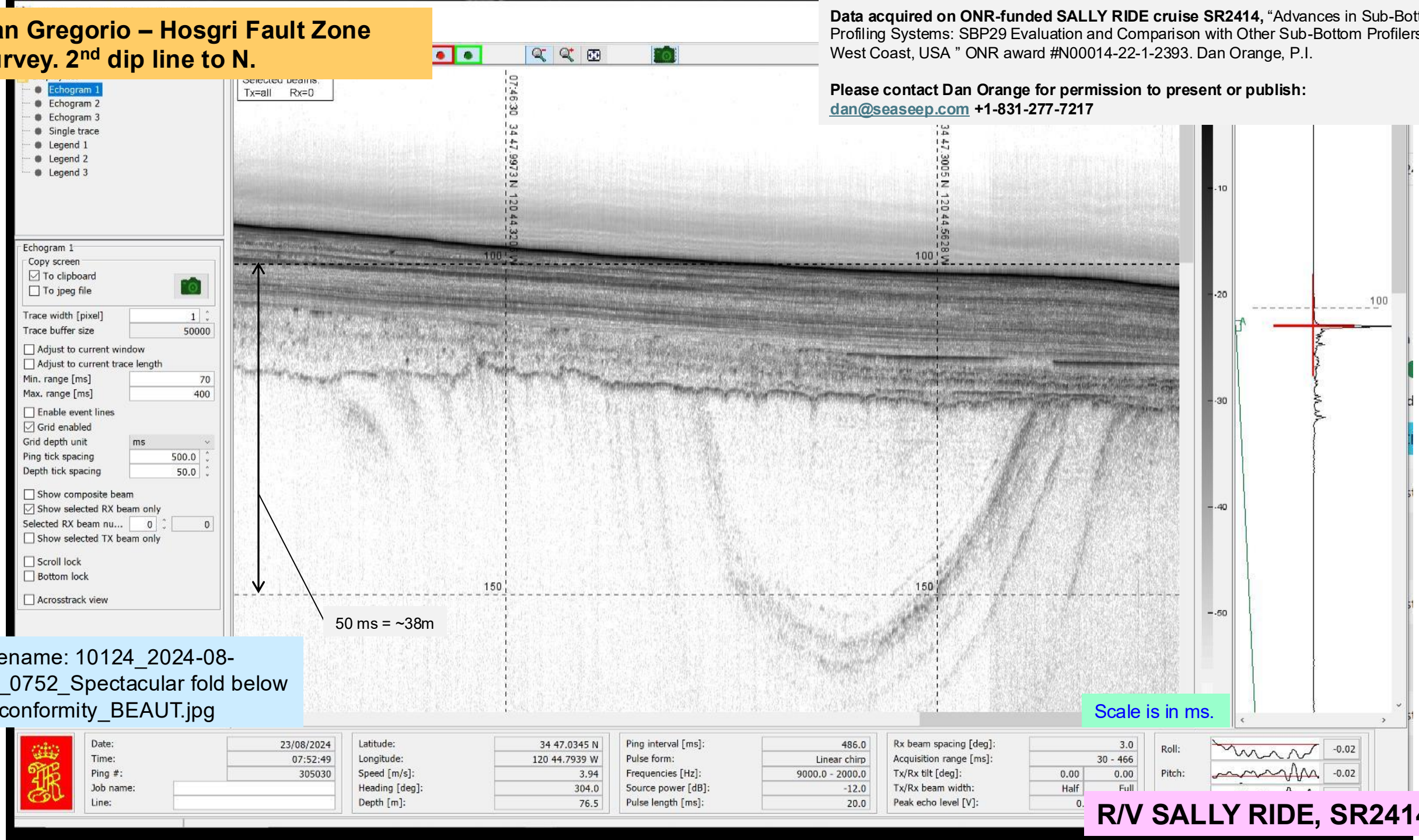

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Data MBARI
Image Landsat / Copernicus
Imagery Date: 12/13/201
R/V SALLY RIDE, SR2414


Hosgri Fault
R/V SALLY RIDE, SR2414

San Gregorio – Hosgri Fault Zone survey. 2nd dip line to N.

Data acquired on ONR-funded SALLY RIDE cruise SR2414, "Advances in Sub-Bottom Profiling Systems: SBP29 Evaluation and Comparison with Other Sub-Bottom Profilers - West Coast, USA " ONR award #N00014-22-1-2393. Dan Orange, P.I.

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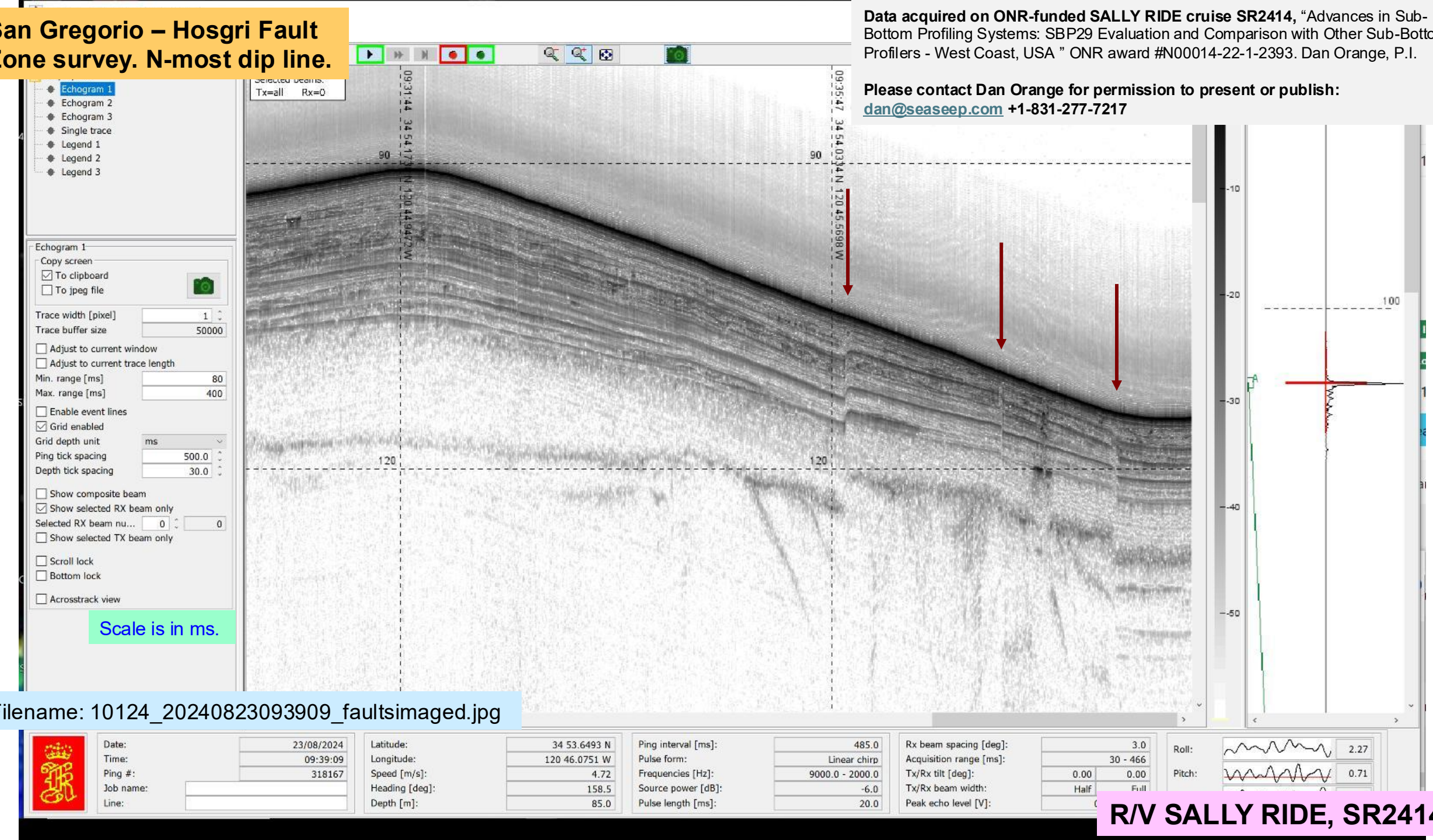
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R/V SALLY RIDE, SR2414

San Gregorio – Hosgri Fault Zone survey. N-most dip line.

Data acquired on ONR-funded SALLY RIDE cruise SR2414, "Advances in Sub-Bottom Profiling Systems: SBP29 Evaluation and Comparison with Other Sub-Bottom Profilers - West Coast, USA " ONR award #N00014-22-1-2393. Dan Orange, P.I.

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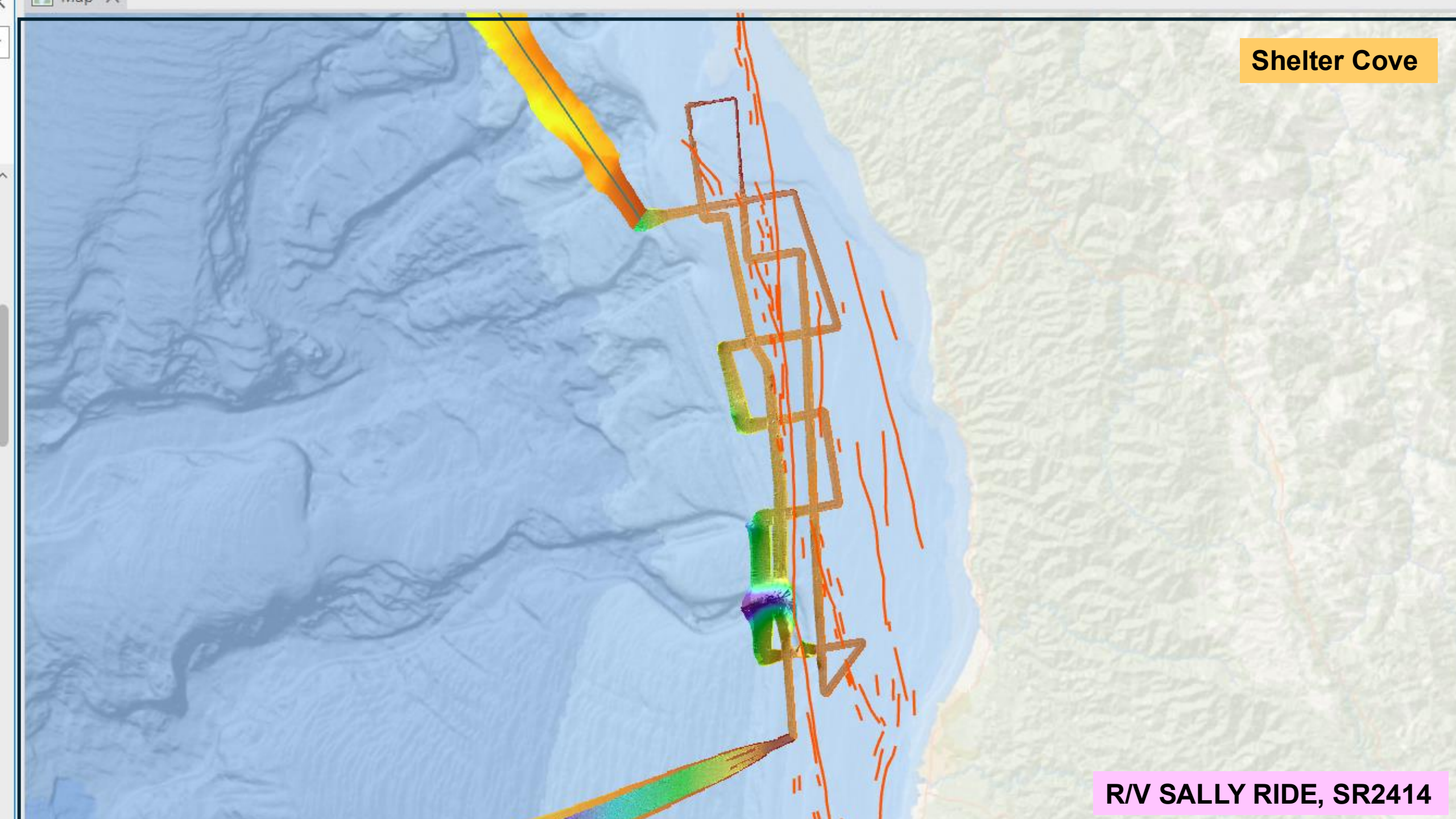


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R/V SALLY RIDE, SR2414

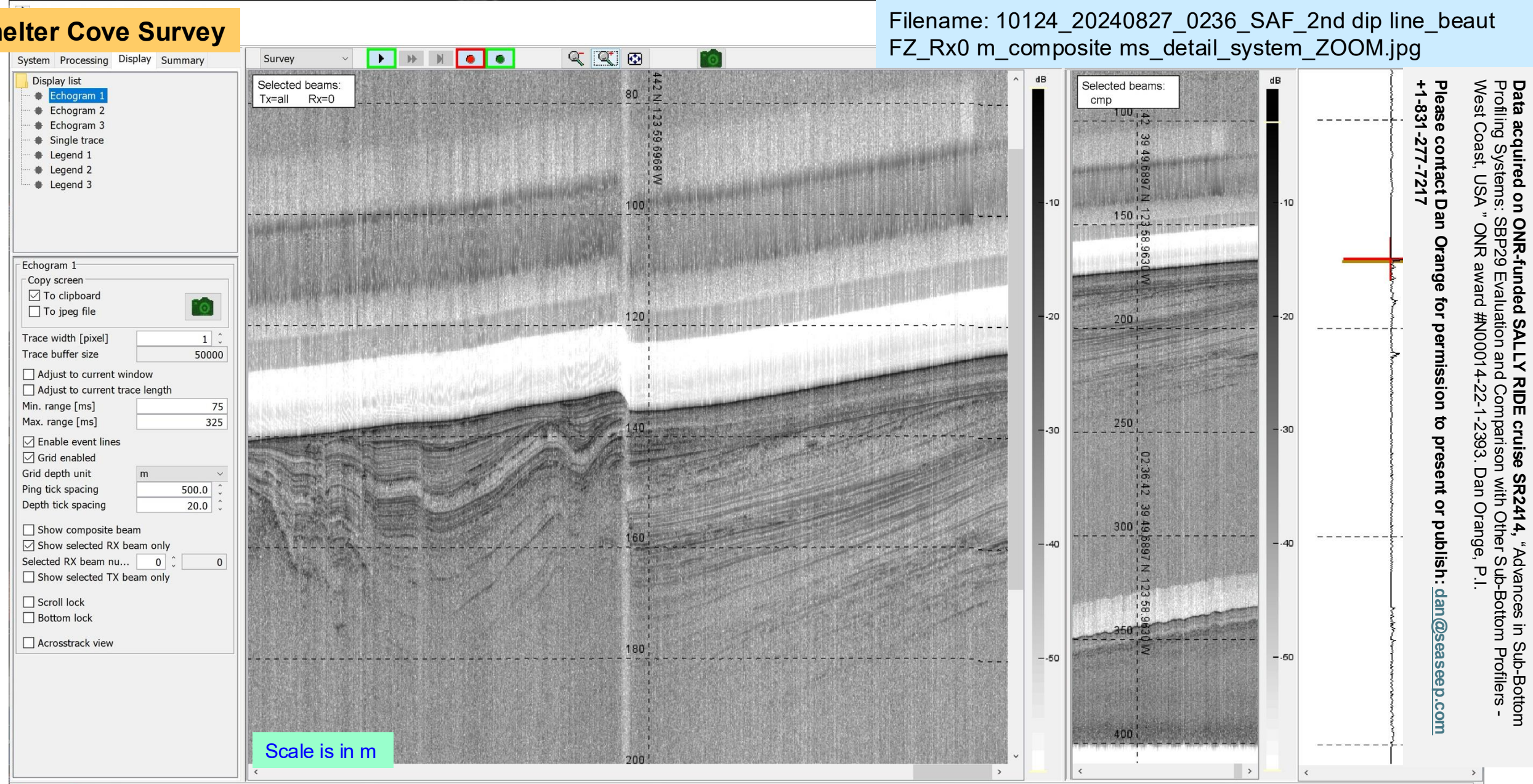

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ODP1015_SantaMonicaLine
PipeLine_sedSBPsurvey
SanPedro_CT_geoline
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Shelter Cove
Shelter Cove: where the 1906 San Francisco Earthquake fault rupture goes offshore.
McKinleyville
Eureka
Trinity Nat'l Forest
Plumas National Forest
Chico
Mendocino National Forest
Fort Bragg
Reno
Fernley
Fallon
Tahoe National Forest
WALKER RIVER RESERVATION
Eldorado National Forest
Sacramento
Santa Rosa
Stanislaus National Forest
Stockton
Yosemite National Park
Mammoth Lakes
San Francisco
Modesto
Sierra National Forest
San Jose
Fresno
Sequoia & Kings Canyon National Parks
Lone Pine
CALIFORNIA
Visalia
Tulare
Porterville
Sequoia National Forest
187 km
Data LDEO-Columbia, NSF, NOAA
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Data MBARI
Image Landsat / Copernicus
R/V SALLY RIDE, SR2414


Shelter Cove
R/V SALLY RIDE, SR2414


Shelter Cove
San Andreas
Fault Scarps
R/V SALLY RIDE, SR2414

Shelter Cove Survey

Filename: 10124_20240827_0236_SAF_2nd dip line_beaut FZ_Rx0 m_composite ms_detail_system_ZOOM.jpg



Data acquired on ONR-funded SALLY RIDE cruise SR2414, "Advances in Sub-Bottom Profiling Systems: SBP29 Evaluation and Comparison with Other Sub-Bottom Profilers - West Coast, USA " ONR award #N00014-22-1-2393. Dan Orange, P.I.

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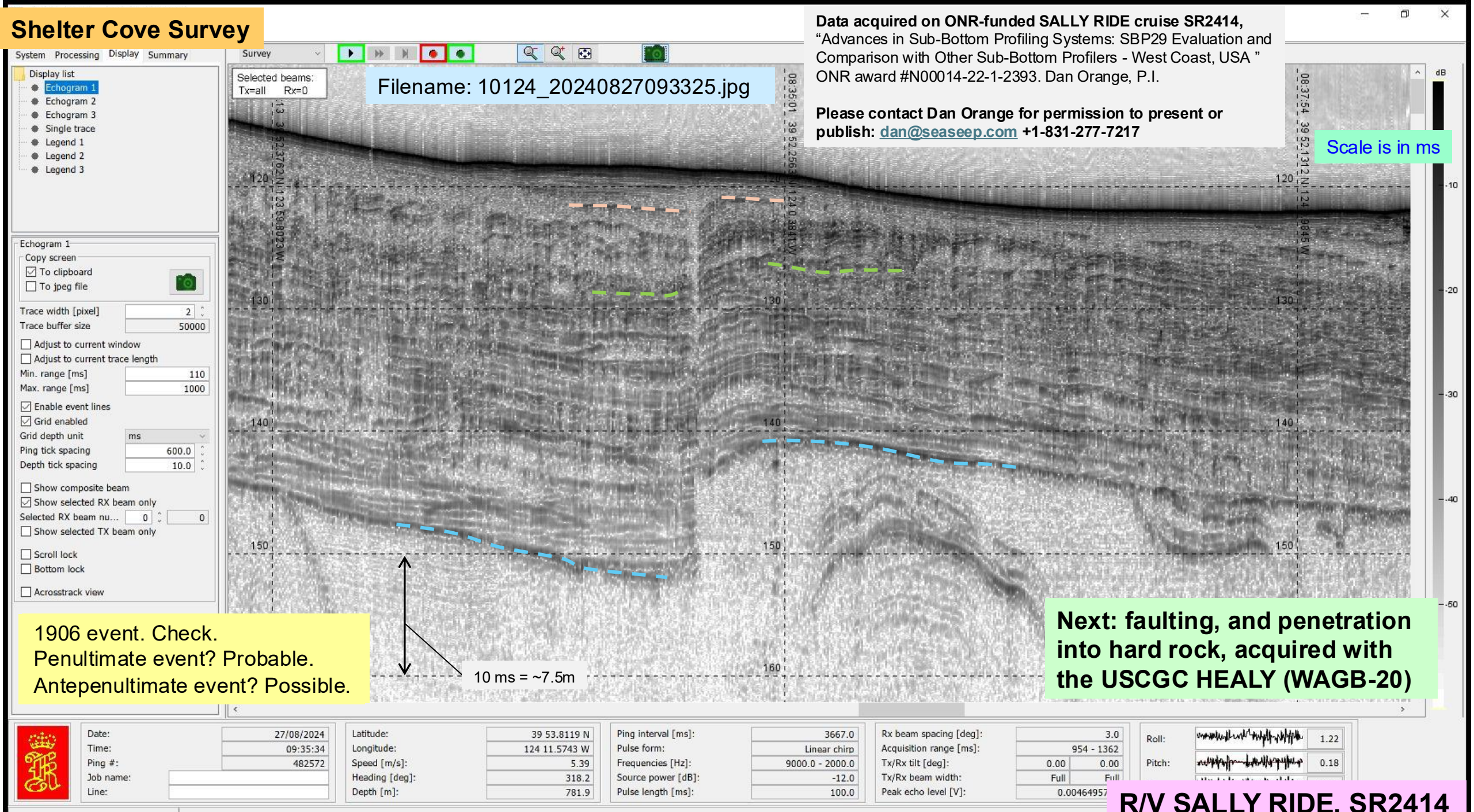
Date:	27/08/2024	Latitude:	39 49.7315 N	Ping interval [ms]:	819.0	Rx beam spacing [deg]:	3.0	Roll:	-1.18
Time:	02:38:23	Longitude:	123 58.5989 W	Pulse form:	Linear chirp	Acquisition range [ms]:	76 - 409	Pitch:	0.01
Ping #:	456089	Speed [m/s]:	5.14	Frequencies [Hz]:	9000.0 - 2000.0	Tx/Rx tilt [deg]:	0.00 0.00		
Job name:		Heading [deg]:	111.7	Source power [dB]:	-12.0	Tx/Rx beam width:			
Line:		Depth [m]:	124.7	Pulse length [ms]:	25.0	Peak echo level [V]:			

R/V SALLY RIDE, SR2414

Shelter Cove Survey

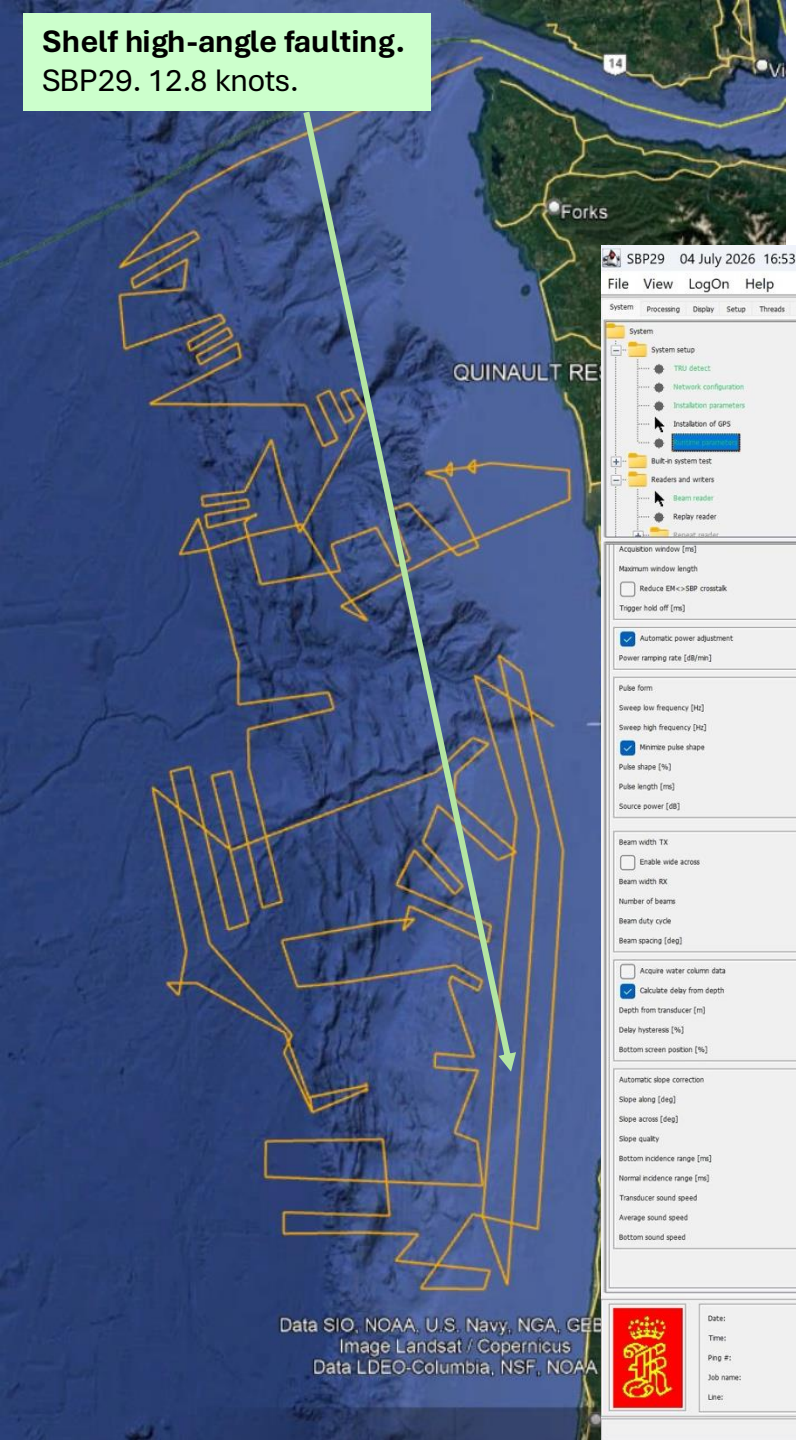
Data acquired on ONR-funded SALLY RIDE cruise SR2414, "Advances in Sub-Bottom Profiling Systems: SBP29 Evaluation and Comparison with Other Sub-Bottom Profilers - West Coast, USA " ONR award #N00014-22-1-2393. Dan Orange, P.I.

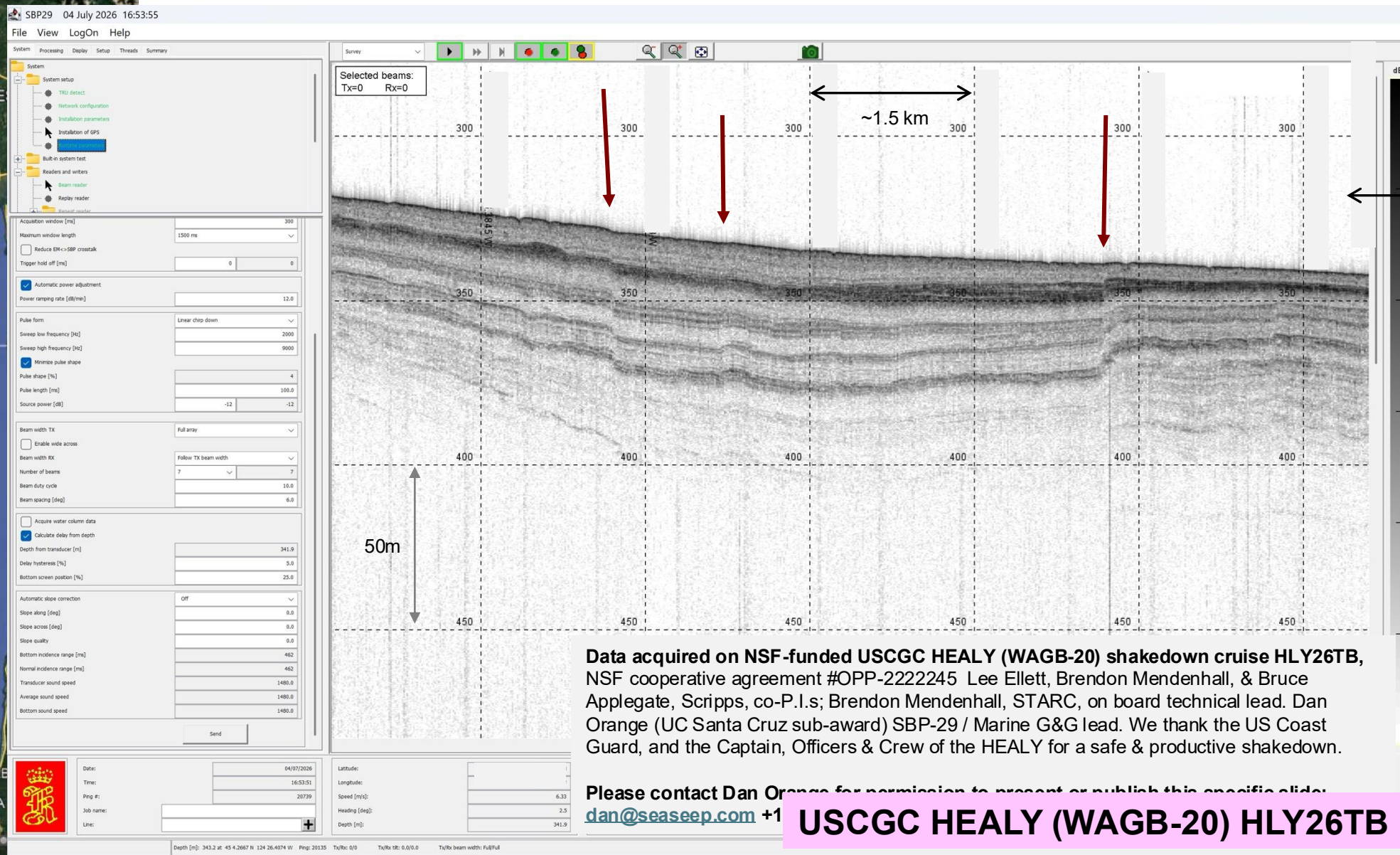
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Shelf high-angle faulting.
SBP29. 12.8 knots.

Vessel acquisition speed 12.6 knots (~6.3 m/s). Note 70m (!!) of penetration with SBP29 3°x6° through 2cm titanium plate!



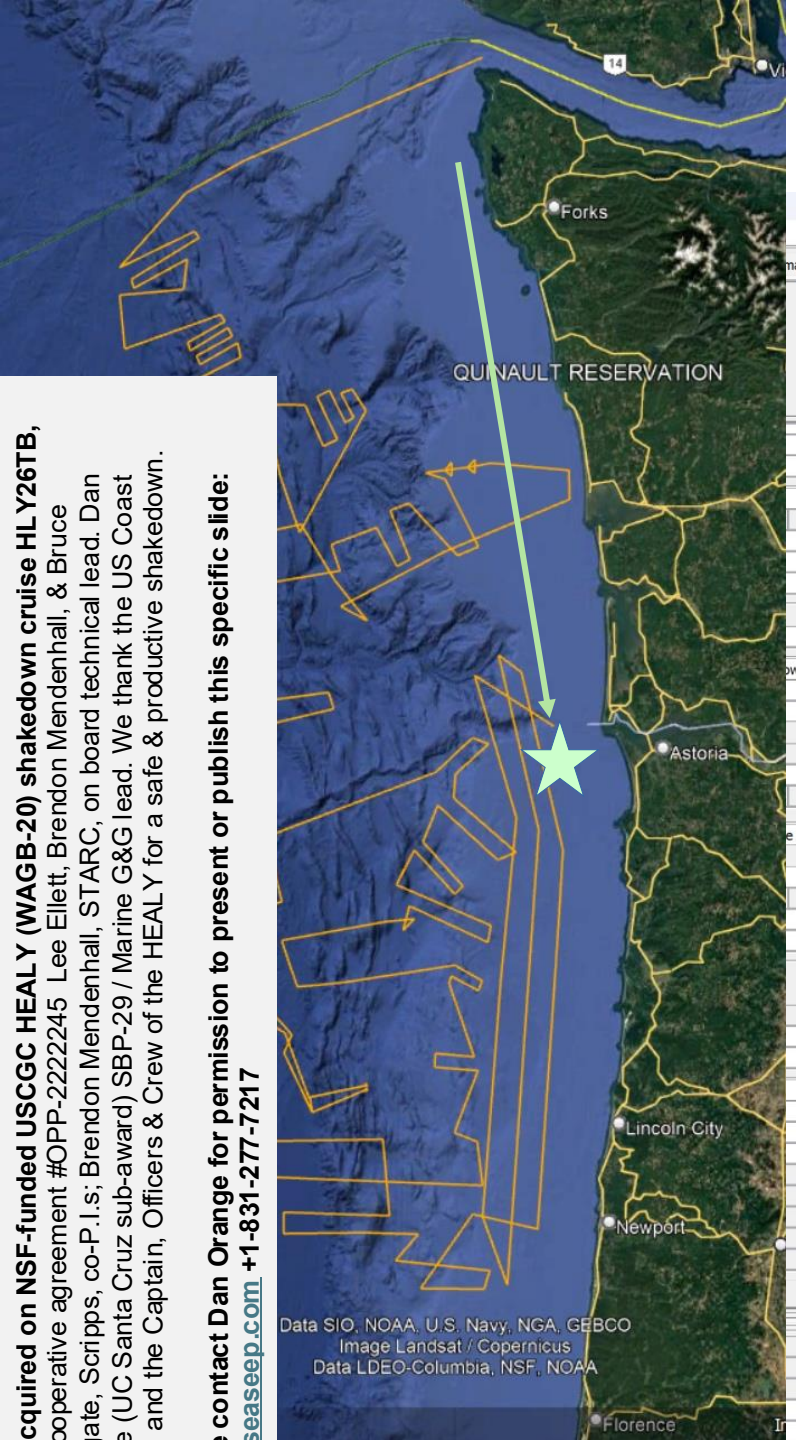


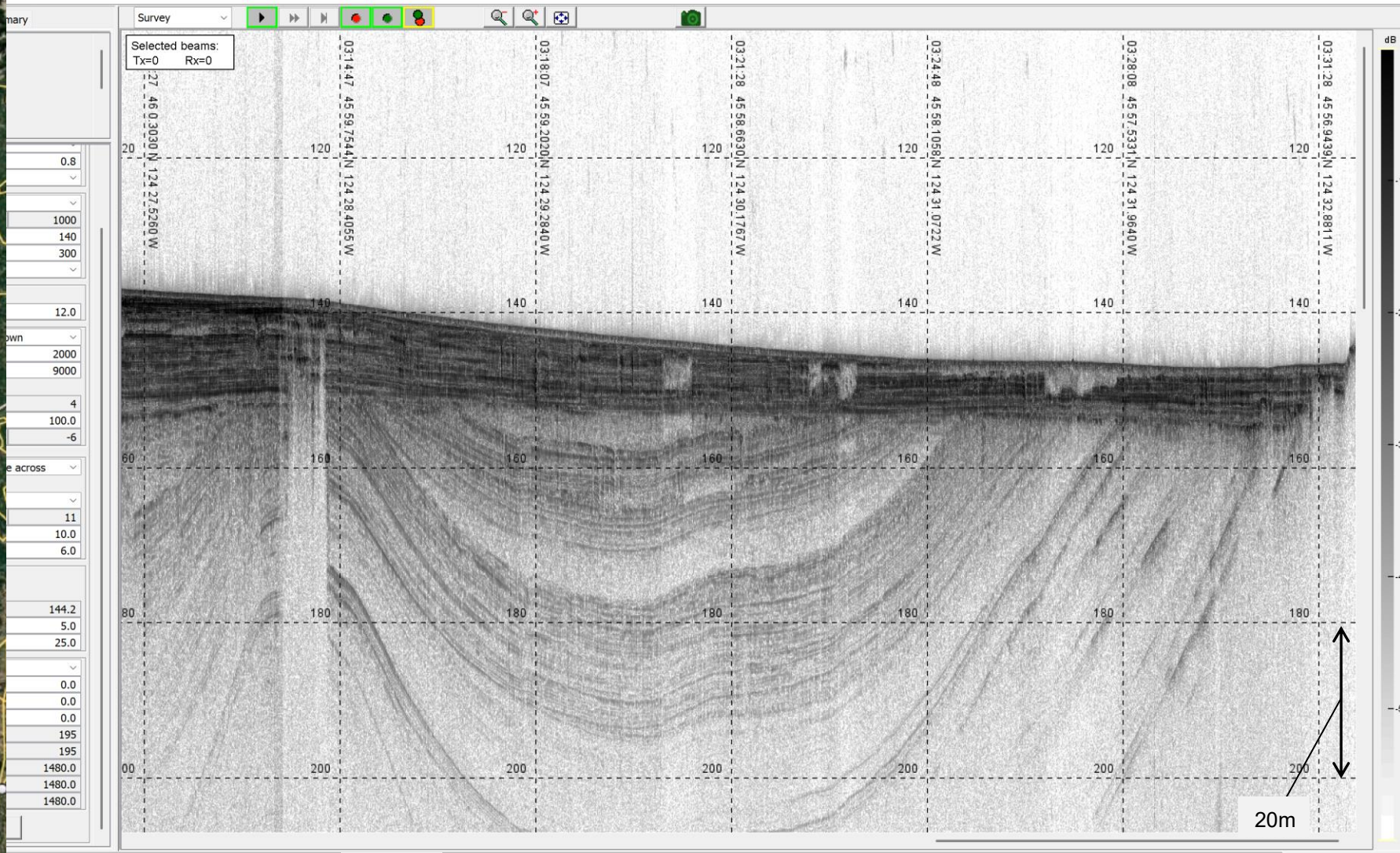
Data acquired on NSF-funded USCGC HEALY (WAGB-20) shakedown cruise HLY26TB, NSF cooperative agreement #OPP-2222245 Lee Ellett, Brendon Mendenhall, & Bruce Applegate, Scripps, co-P.I.s; Brendon Mendenhall, STARC, on board technical lead. Dan Orange (UC Santa Cruz sub-award) SBP-29 / Marine G&G lead. We thank the US Coast Guard, and the Captain, Officers & Crew of the HEALY for a safe & productive shakedown.

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USCGC HEALY (WAGB-20) HLY26TB

Vessel acquisition speed 8 knots (~4 m/s). Note 70m (!!) of penetration with SBP29 3°x6° through 2cm titanium plate!

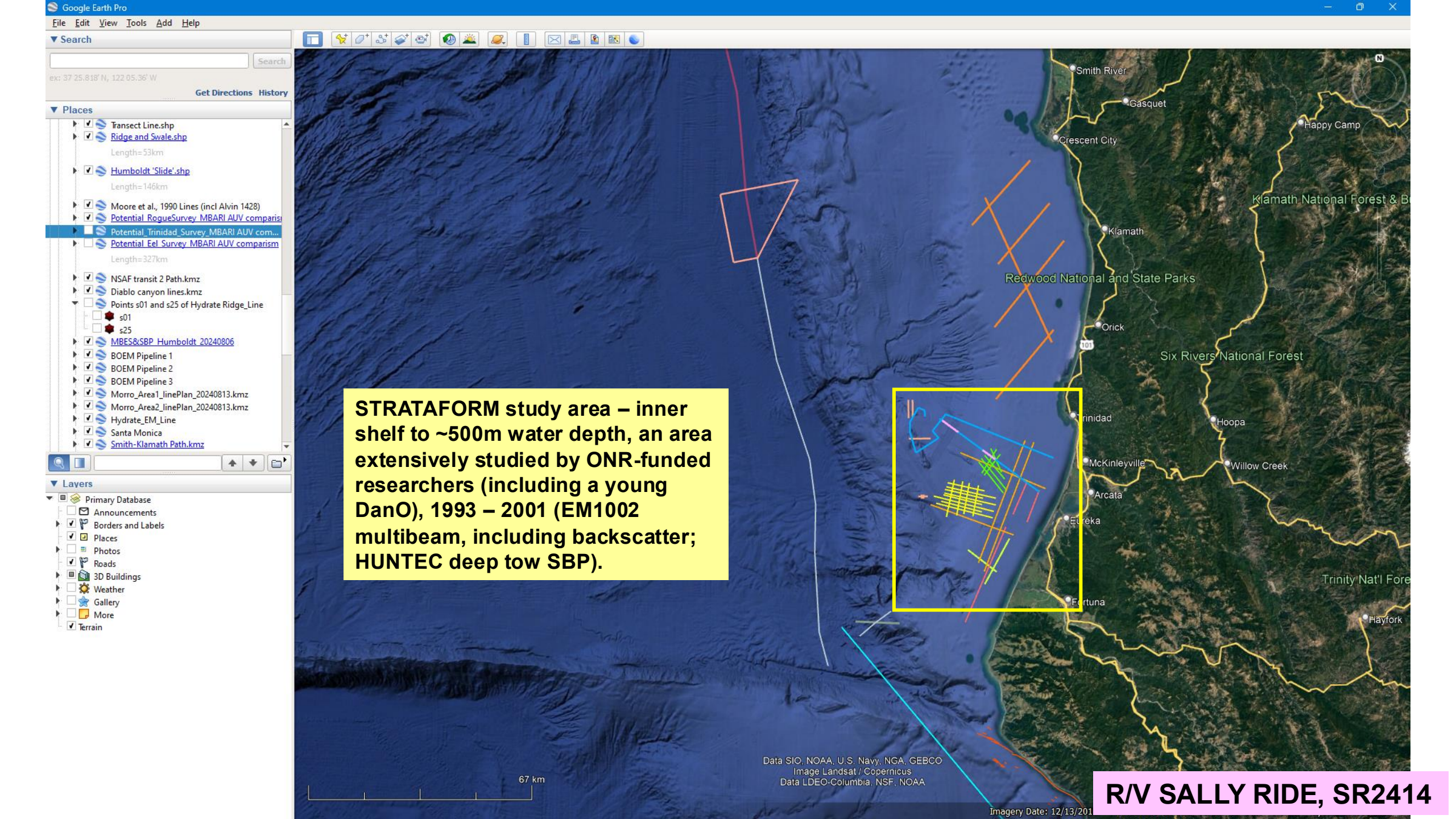




USCGC HEALY (WAGB-20) HLY26TB

cquired on NSF-funded USCGC HEALY (WAGB-20) shakedown cruise HLY26TB,
operative agreement #OPP-2222245 Lee Ellett, Brendon Mendenhall, & Bruce
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and the Captain, Officers & Crew of the HEALY for a safe & productive shakedown.

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STRATAFORM study area – inner shelf to ~500m water depth, an area extensively studied by ONR-funded researchers (including a young DanO), 1993 – 2001 (EM1002 multibeam, including backscatter; HUNTEC deep tow SBP).

R/V SALLY RIDE, SR2414

SR 2414 Cruise Project | Command Search (Alt+Q) | Toluwani - The University of Southern Mississippi TA

Project | Map | Insert | Analysis | View | Edit | Imagery | Share | Help | Group Layer | Linear Referencing

Paste | Cut | Copy | Copy Path — Clipboard
Explore | Bookmarks | Go To XY — Navigate
Basemap | Add Data | Add Graphics Layer — Layer
Select | Select By Attributes | Select By Location | Attributes | Clear | Zoom To — Selection
Measure | Locate | Infographics | Coordinate Conversion — Inquiry
Pause | Lock | View Unplaced | More | Convert — Labeling
Download Map | Sync | Remove — Offline

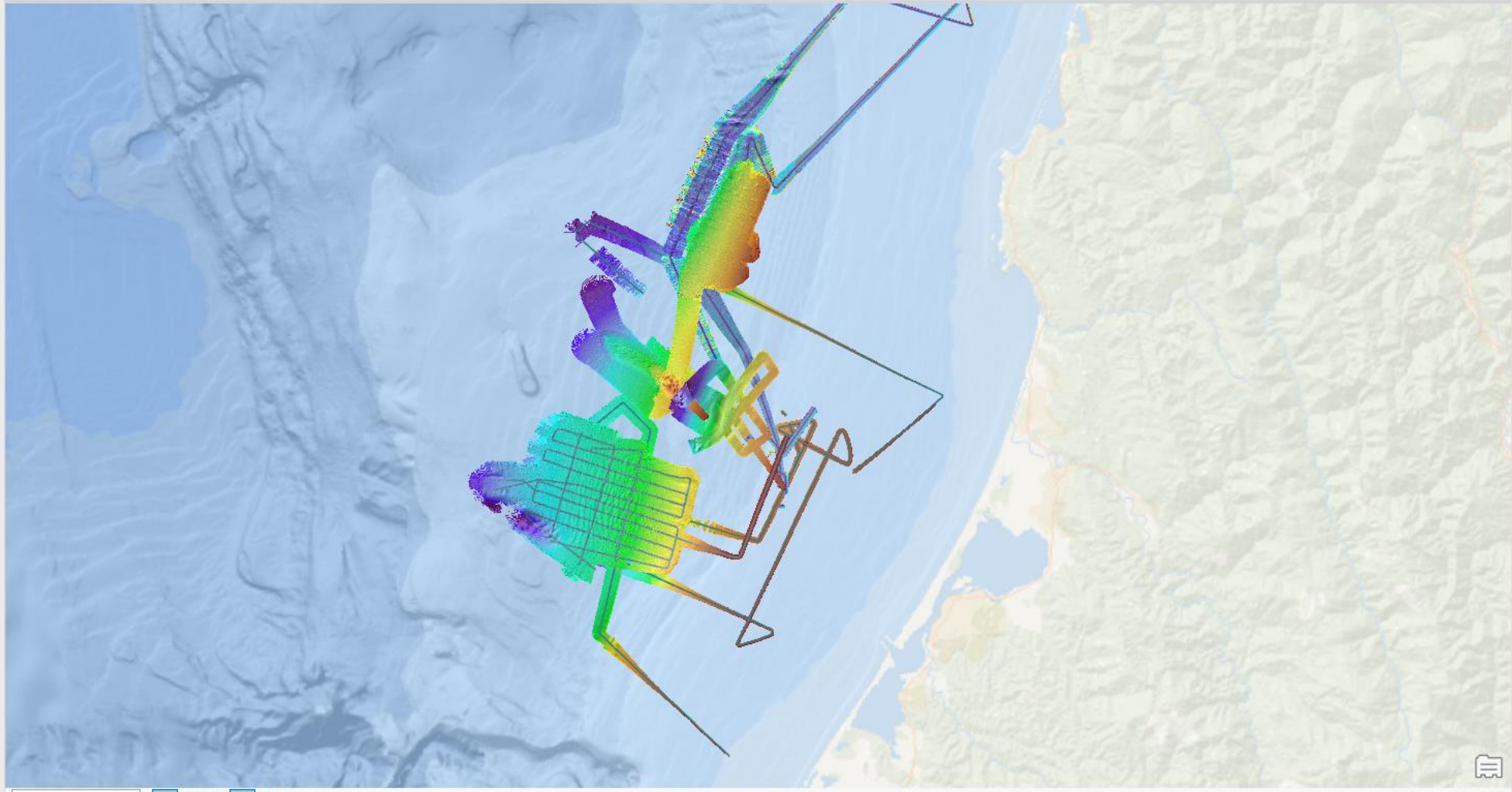
Contents

Search

Drawing Order

- Map
  - Q-Faults California
  - Humboldt Slide
    - Shaded Relief
      - HS_HS_124
        - Value
        - 254
        - 0
      - HS_HS_712
        - Value
        - 254
        - 0
    - NAV
    - EM 712
      - Backscatter
      - Bathymetry
    - EM 124
      - Backscatter
      - Bathymetry
  - Template

Map



1:413,251 | 125.4044080°W 41.2306361°N | Selected Features: 0

Type here to search

R/V SALLY RIDE, SR2414

SR 2414 Cruise Project | Command Search (Alt+Q) | Toluwani - The University of Southern Mississippi TA

Project | Map | Insert | Analysis | View | Edit | Imagery | Share | Help | Group Layer | Linear Referencing

Clipboard: Paste, Cut, Copy, Copy Path
Navigate: Explore, Bookmarks, Go To XY
Layer: Basemap, Add Data, Add Graphics Layer
Selection: Select, Select By Attributes, Select By Location, Attributes, Clear, Zoom To
Inquiry: Measure, Locate, Infographics, Coordinate Conversion
Labeling: Pause, Lock, View Unplaced, More, Convert
Offline: Download Map, Sync, Remove

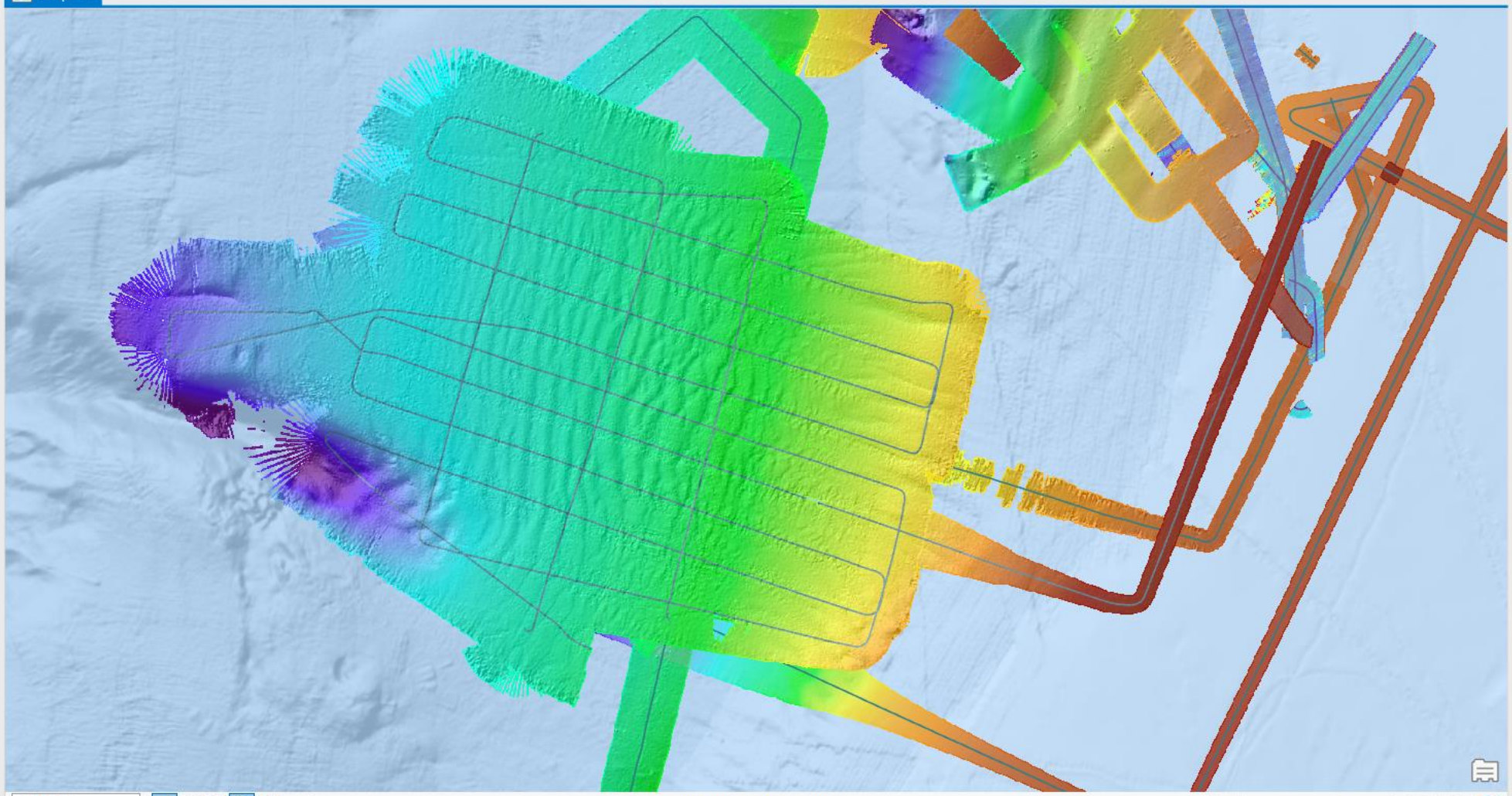
Contents

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- Map
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      - Backscatter
      - Bathymetry
    - EM 124
      - Backscatter
      - Bathymetry
  - Template

Map



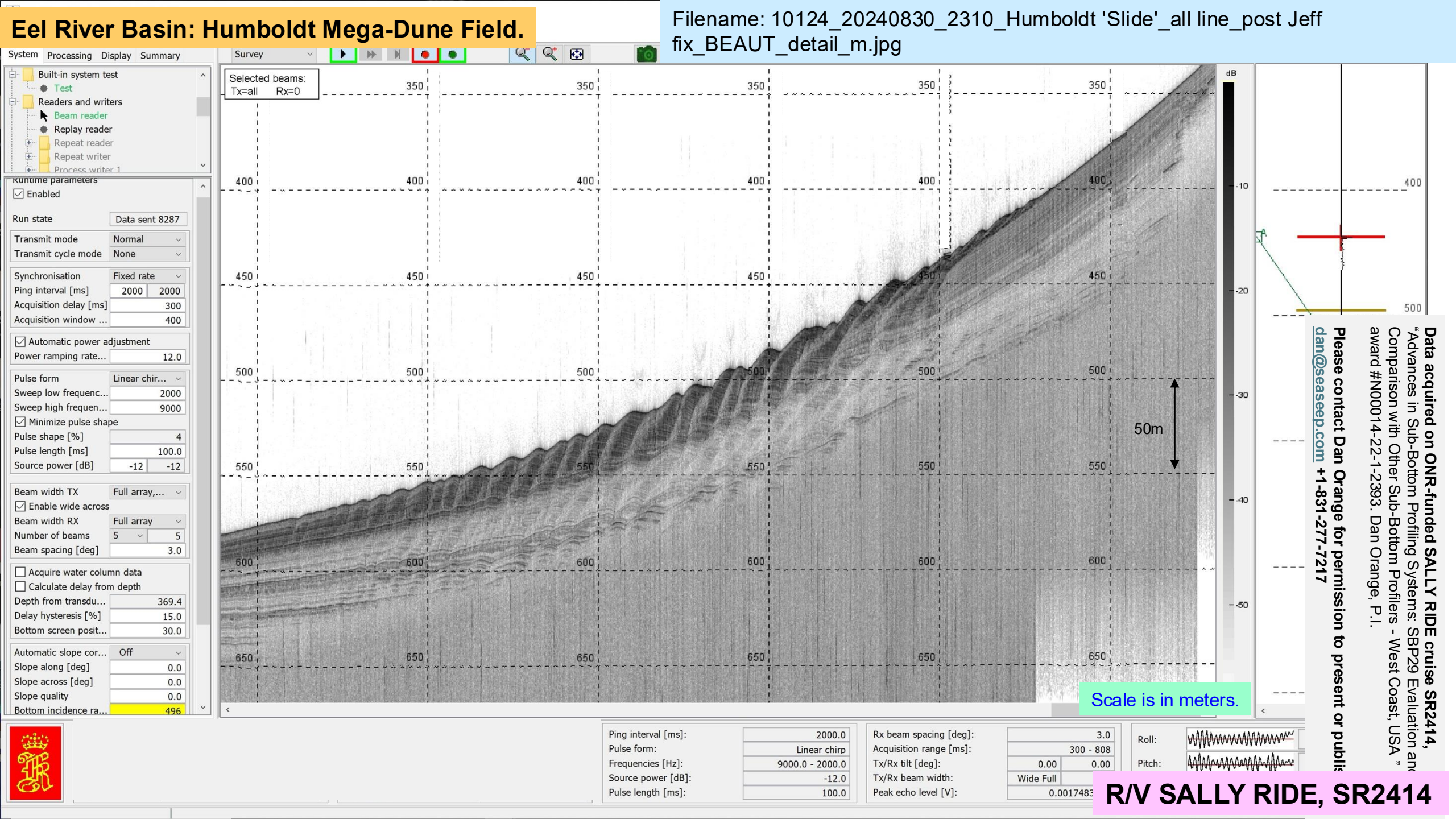
1:108,331 | 124.5162103°W 40.8353983°N | Selected Features: 0

Type here to search

R/V SALLY RIDE, SR2414

Eel River Basin: Humboldt Mega-Dune Field.

Filename: 10124_20240830_2310_Humboldt 'Slide'_all line_post Jeff fix_BEAUT_detail_m.jpg



Data acquired on ONR-funded SALLY RIDE cruise SR2414, "Advances in Sub-Bottom Profiling Systems: SBP29 Evaluation and Comparison with Other Sub-Bottom Profilers - West Coast, USA " award #N00014-22-1-2393. Dan Orange, P.I.

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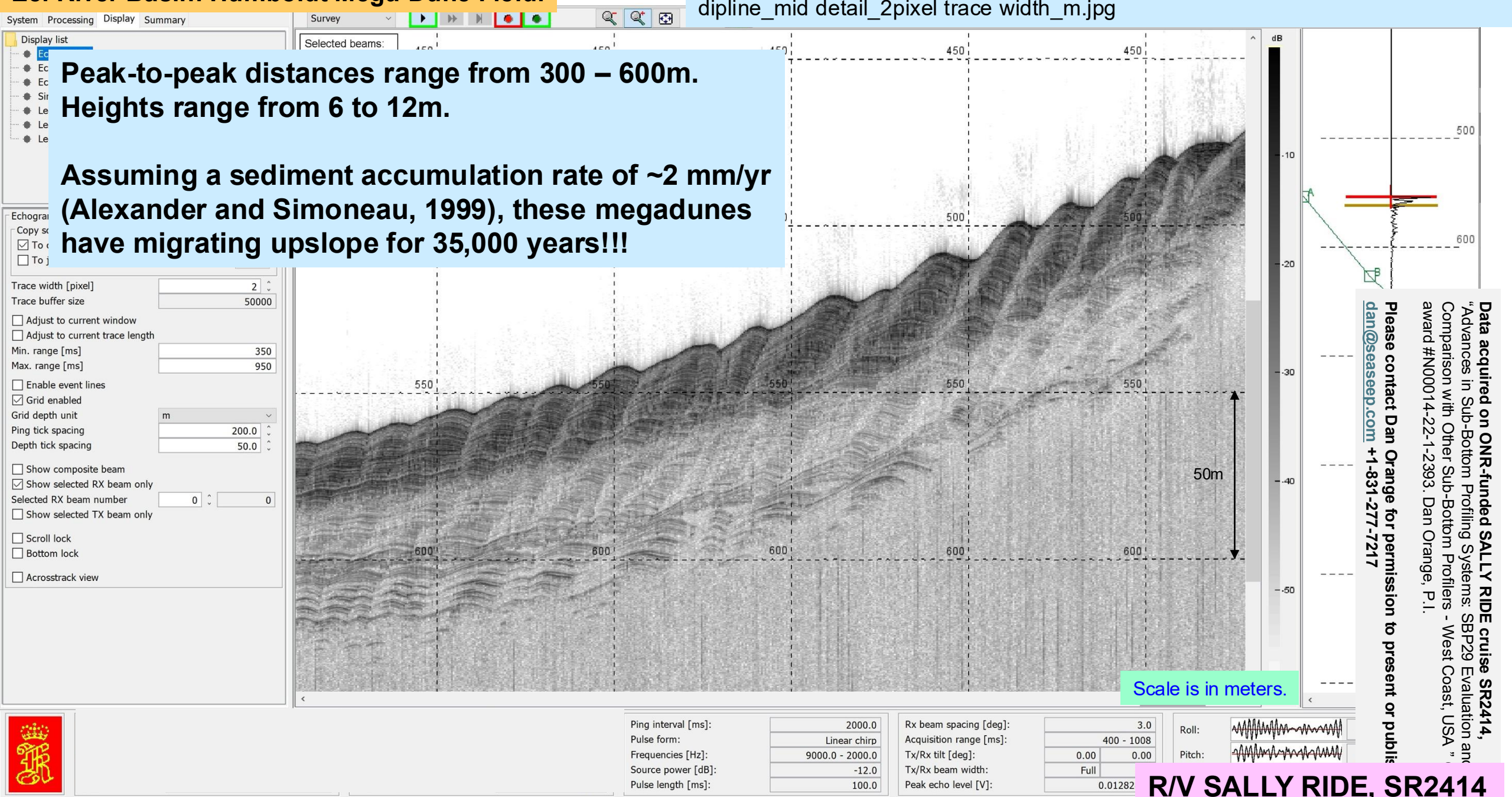
R/V SALLY RIDE, SR2414

Eel River Basin: Humboldt Mega-Dune Field.

Filename: 10124_20240831_0558_Humboldt 'Slide'_4th southernmost dipline_mid detail_2pixel trace width_m.jpg

Peak-to-peak distances range from 300 – 600m.
Heights range from 6 to 12m.

Assuming a sediment accumulation rate of ~2 mm/yr (Alexander and Simoneau, 1999), these megadunes have migrating upslope for 35,000 years!!!



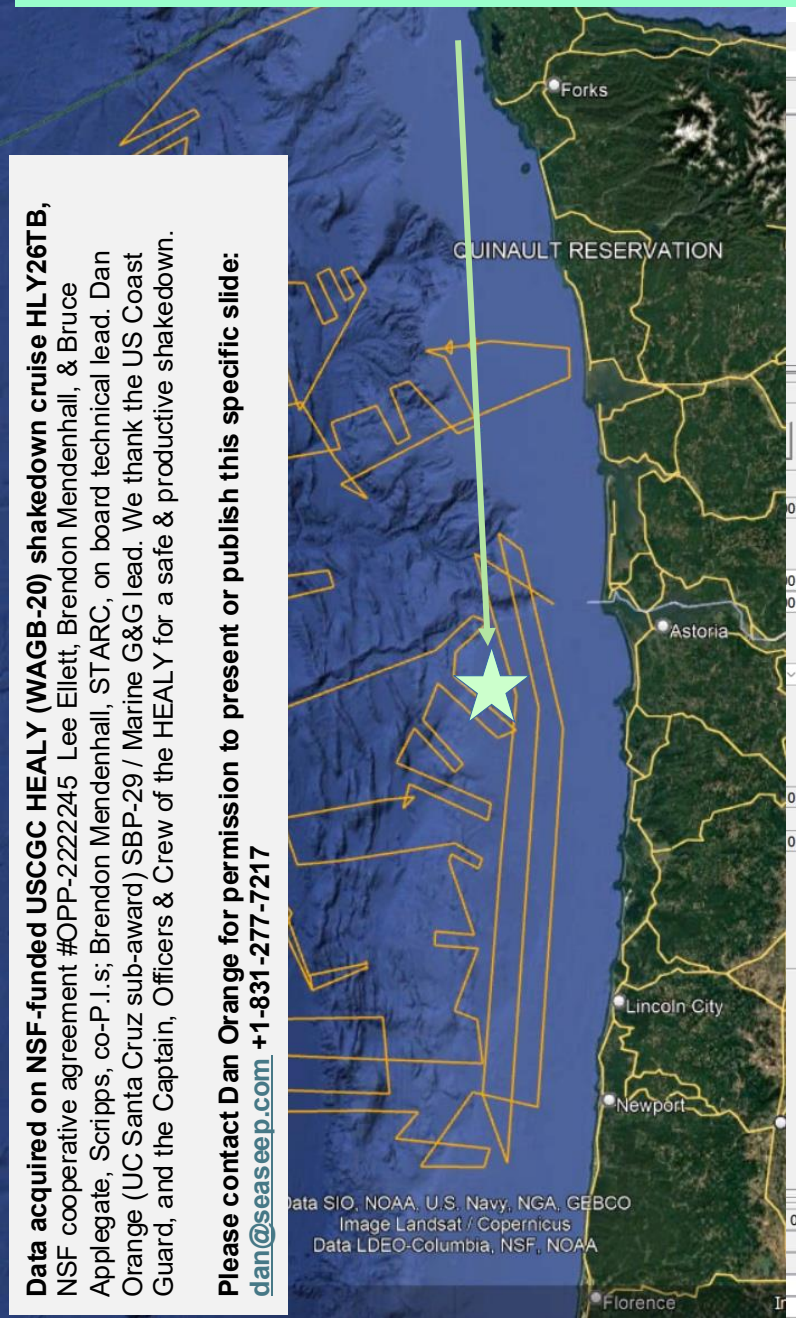
Scale is in meters.

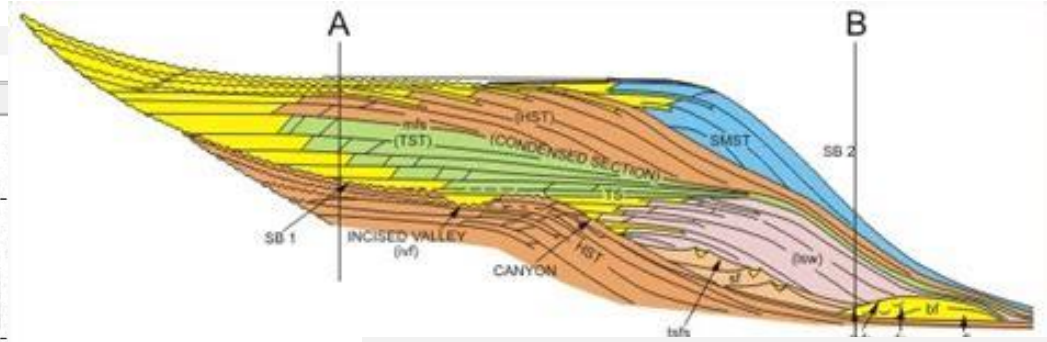
Data acquired on ONR-funded SALLY RIDE cruise SR2414, "Advances in Sub-Bottom Profiling Systems: SBP29 Evaluation and Comparison with Other Sub-Bottom Profilers - West Coast, USA " award #N00014-22-1-2393. Dan Orange, P.I.

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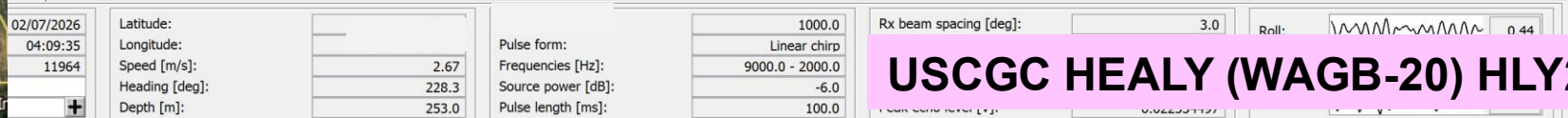
R/V SALLY RIDE, SR2414

“Slug” represents sea level high stand & low stand deposits. Sampling horizons can constrain timing.





Textbook example of a “Slug” showing highstand to lowstand deposits due to fluctuating of sea level.



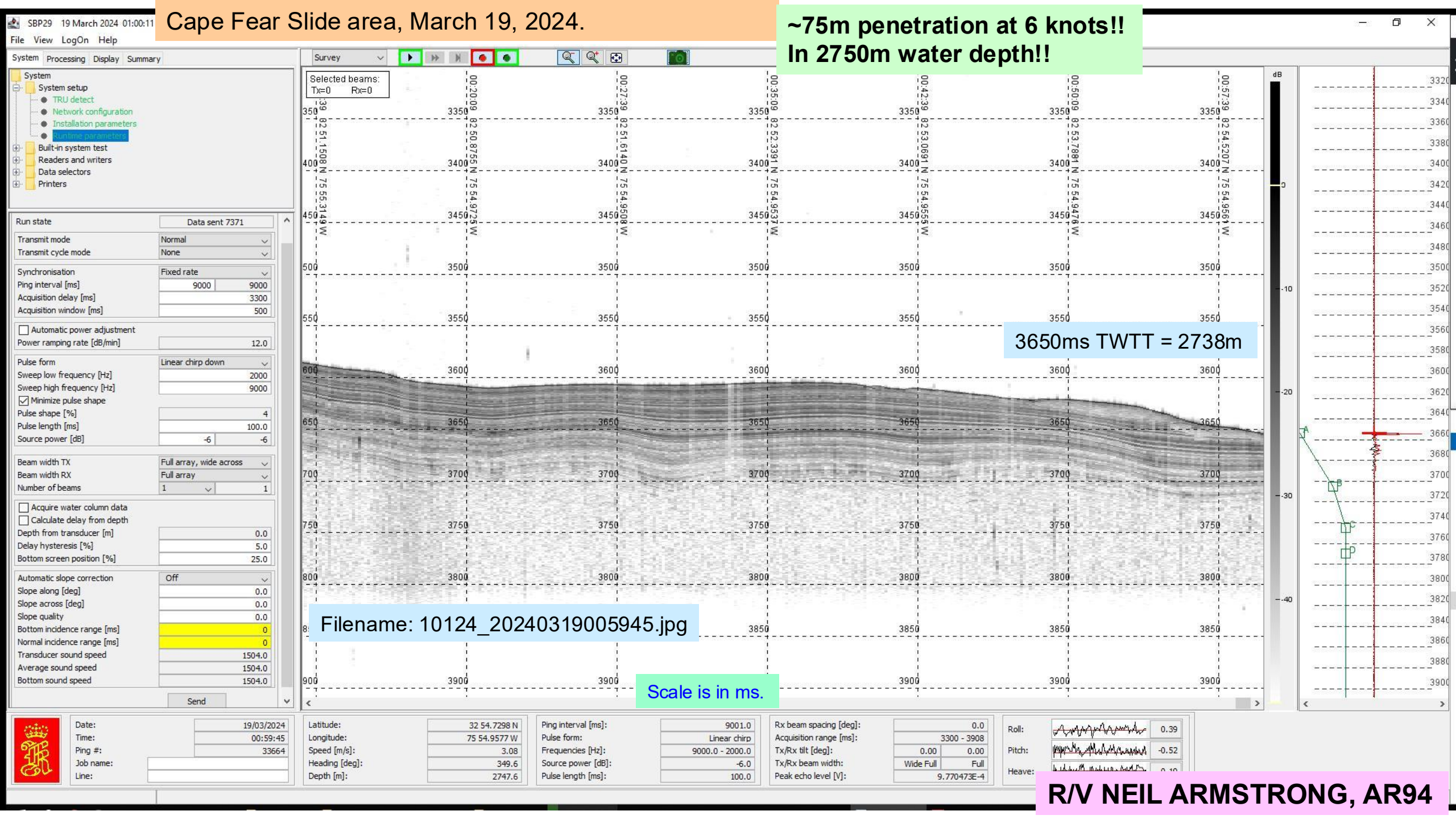
USCGC HEALY (WAGB-20) HLY26TB

Data acquired on NSF-funded USCGC HEALY (WAGB-20) shakedown cruise HLY26TB, NSF cooperative agreement #OPP-2222245 Lee Ellett, Brendon Mendenhall, & Bruce Applegate, Scripps, co-P.I.s; Brendon Mendenhall, STARC, on board technical lead. Dan Orange (UC Santa Cruz sub-award) SBP-29 / Marine G&G lead. We thank the US Coast Guard, and the Captain, Officers & Crew of the HEALY for a safe & productive shakedown.

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Cape Fear Slide area, March 19, 2024.

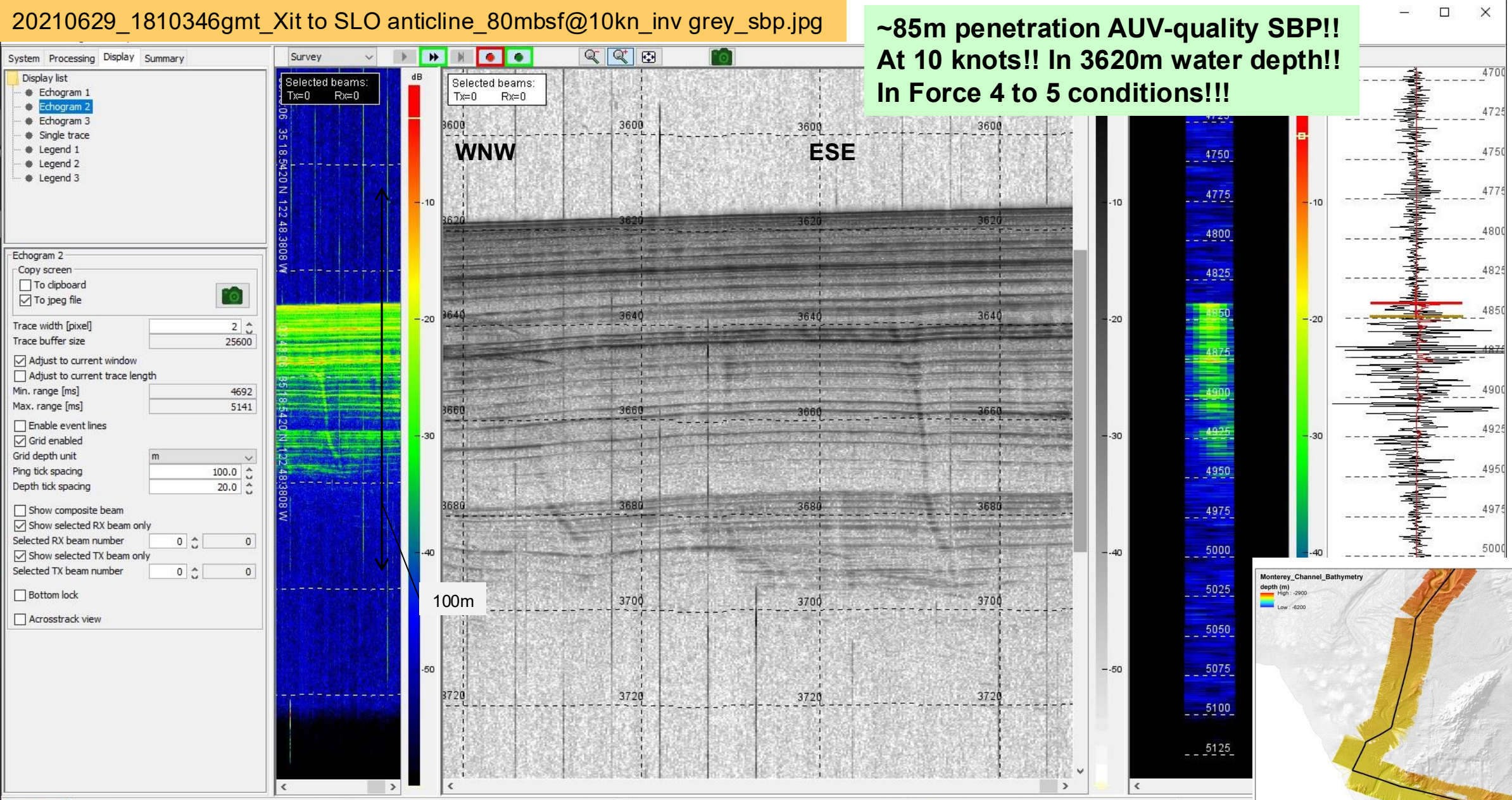
~75m penetration at 6 knots!!
In 2750m water depth!!



R/V NEIL ARMSTRONG, AR94

20210629_1810346gmt_Xit to SLO anticline_80mbsf@10kn_inv grey_sbp.jpg

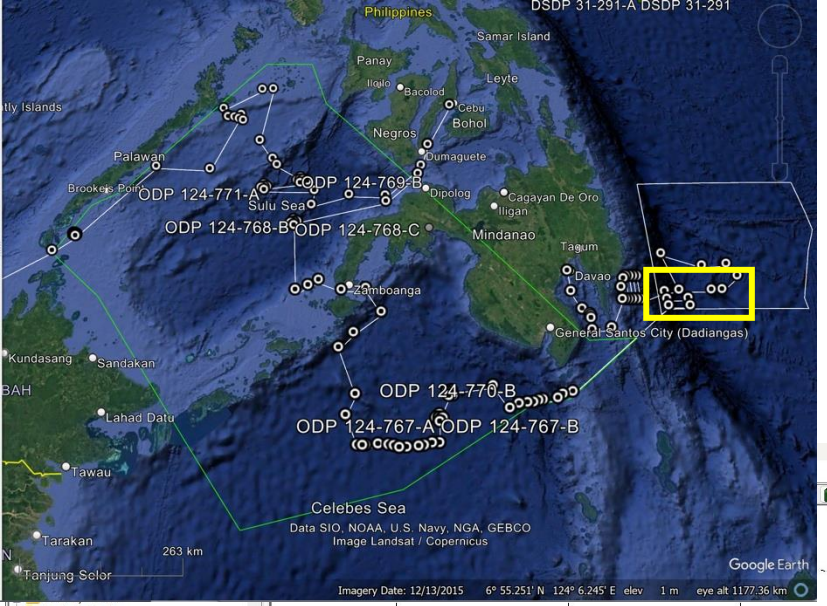
~85m penetration AUV-quality SBP!!
At 10 knots!! In 3620m water depth!!
In Force 4 to 5 conditions!!!



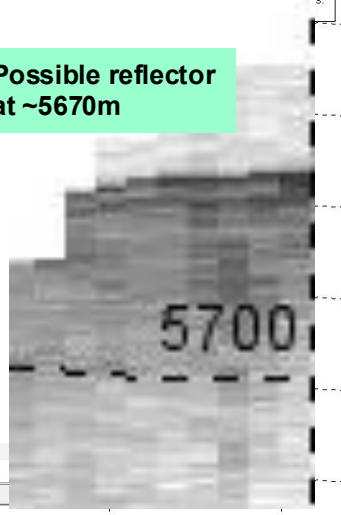
Date:	30/06/2021	Latitude:	35 18.4564 N	Ping interval [ms]:	751.0	Rx beam spacing [deg]:	3.0
Time:	03:44:52	Longitude:	122 48.0293 W	Pulse form:	Linear chirp	Acquisition range [ms]:	4692 - 5140
Ping #:	26740	Speed [m/s]:	5.06	Frequencies [Hz]:	9000.0 - 2000.0	Tx/Rx tilt [deg]:	-0.52 -0.10
Job name:		Heading [deg]:	105.1	Source power [dB]:	-12.0	Tx/Rx beam width:	Full Full
Line:		Depth [m]:	3615.6	Pulse length [ms]:	40.0	Peak echo level [V]:	5.2841846E-4

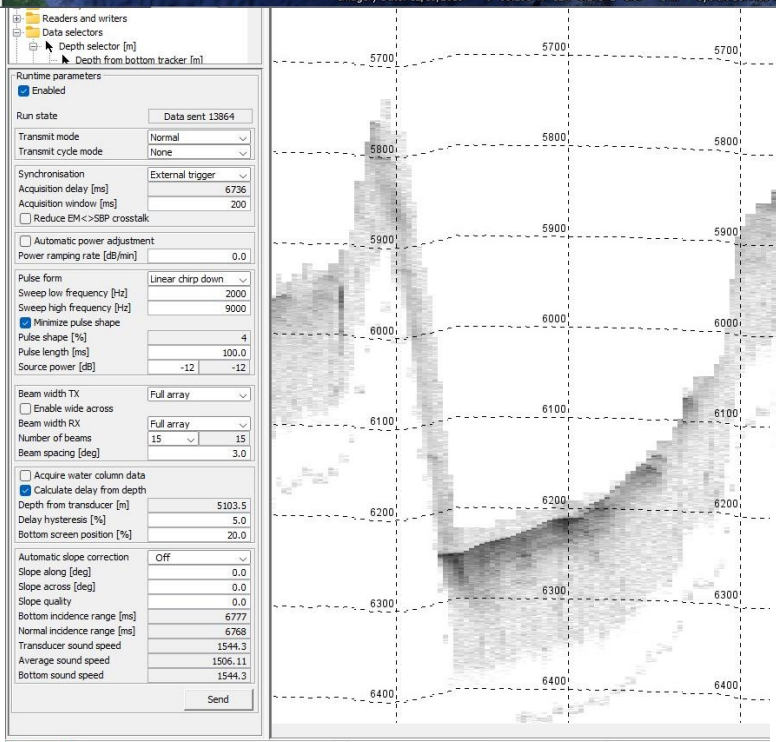
Roll:
Pitch:
Heave:

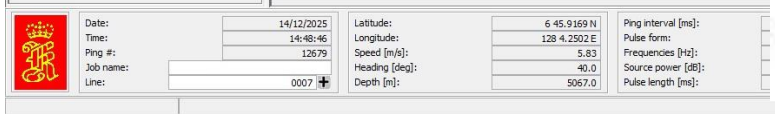
R/V SALLY RIDE, SR104

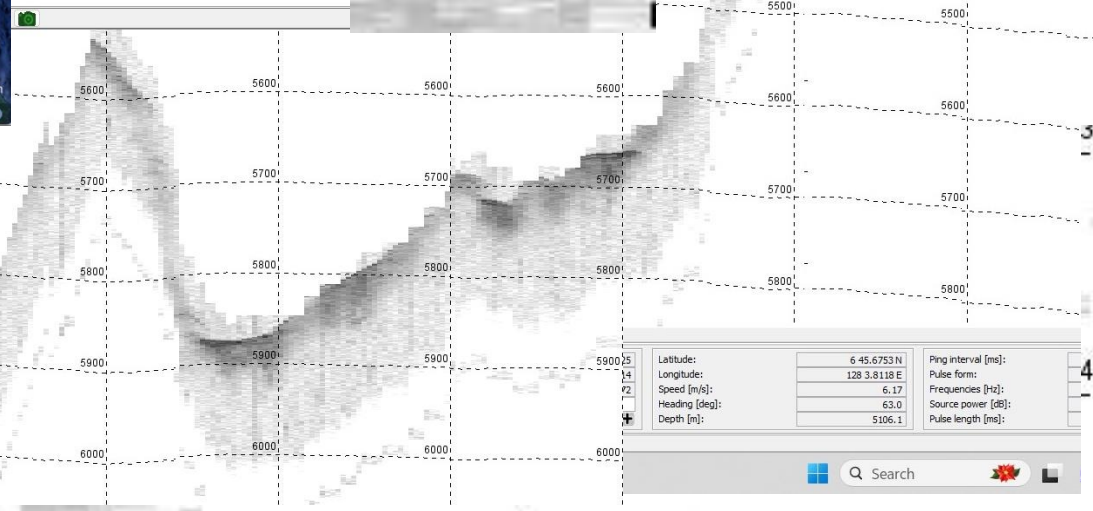


Possible reflector at ~5670m

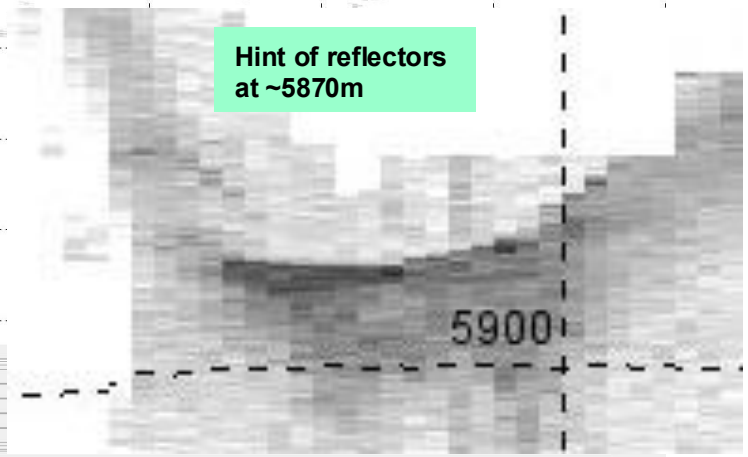






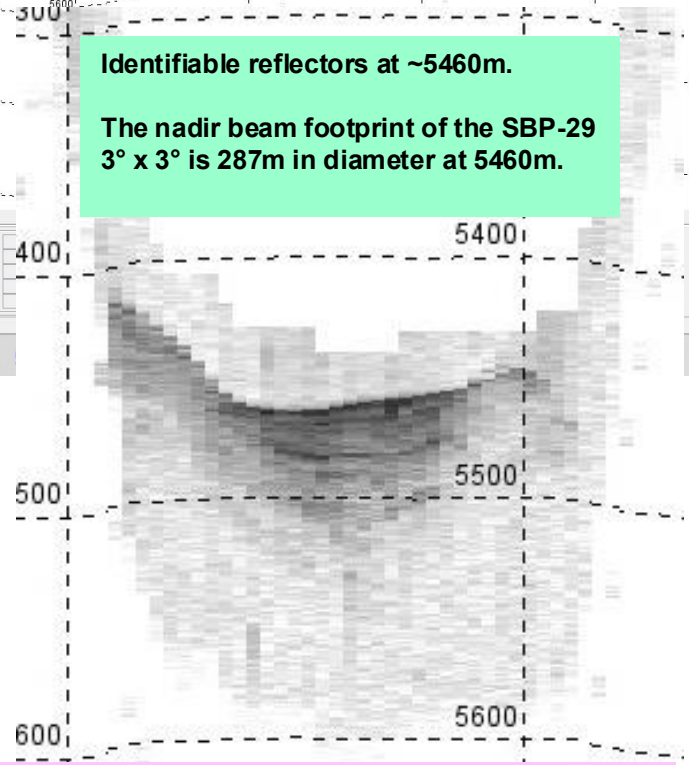


Hint of reflectors at ~5870m



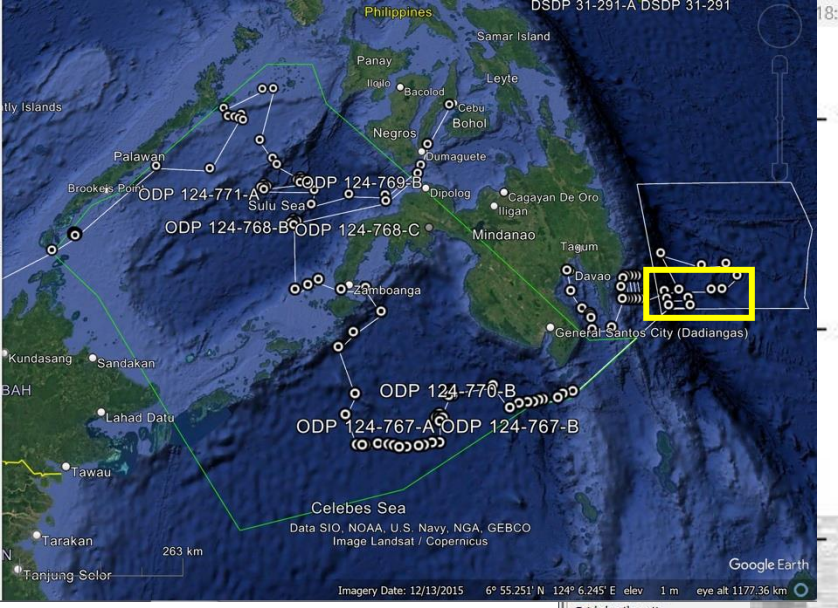
Identifiable reflectors at ~5460m.

The nadir beam footprint of the SBP-29 3° x 3° is 287m in diameter at 5460m.



Scale is in m

R/V THOMAS G. THOMPSON, TN-447



18:54:17

No identifiable reflectors in basins at 8700m, trench axis at 9000m

The nadir beam footprint of the SBP-29 3° x 3° is 473m in diameter at 9000m, with the trench axis 2-4km wide.

8700 8800 8900 9000

Grid depth unit
Ping tick spacing
Depth tick spacing
Show composite beam
Show selected RX beam on
Selected RX beam number
Show selected TX beam on
Selected TX beam number
Scroll lock
Bottom lock
Acrosstrack view

Date:	14/12/2025	Latitude:	7 11.0074 N	Ping interval [ms]:	22382.0	Rx beam spacing [deg]:	2.142857	Roll:	-1.94
Time:	18:54:04	Longitude:	127 31.1269 E	Pulse form:		uisition range [ms]:	9503 - 9812		
Ping #:	13403	Speed [m/s]:	6.36	Frequencies [Hz]:		Rx tilt [deg]:	0.00 0.00	Pitch:	-2.25
Job name:		Heading [deg]:	358.4	Source power [dB]:		Rx beam width:	Full Full	Heave:	0.60
Line:	0007	Depth [m]:	7241.5	Pulse length [ms]:	100.0	Peak echo level [V]:	2.9225223E-4		

Scale is in m

25°C Partly cloudy

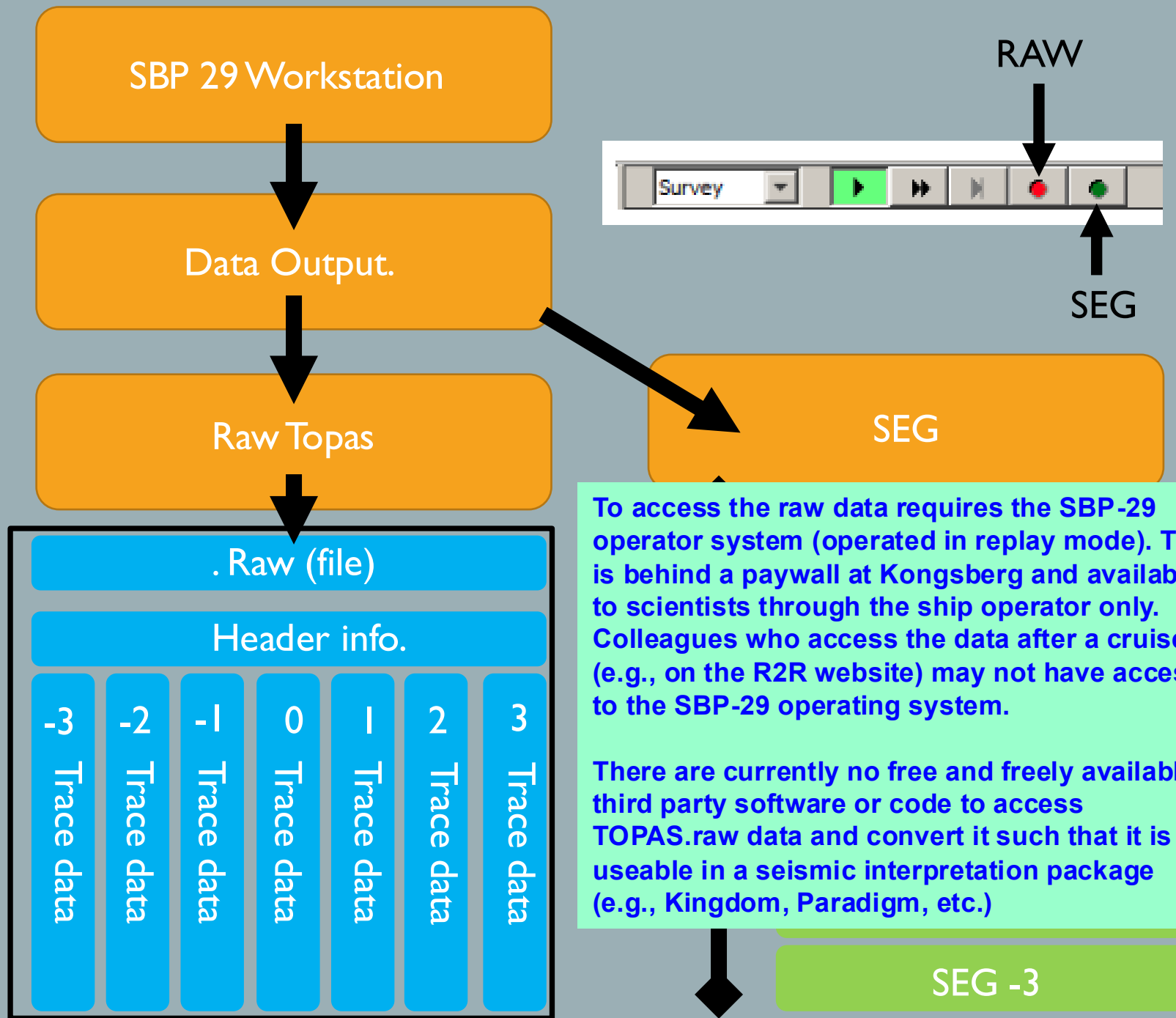
Search

R/V THOMAS G. THOMPSON, TN-447

Current Data Handling Structure:

SBP-29 Workstation
- Acquisition parameters
  - Frequency range
  - Pulse length/shape
  - Recording window
  - Processing workflow
  - Etc. …
- Recorded data type
  - .Raw (topas.raw)
  - .SEG (sgy)

The problem:
Recording both datasets creates redundancy that is costly for archive centers with potential inconsistencies between formats. As SEG files are not raw, it is possible that multiple processing steps have been applied prior to recording SEG format.



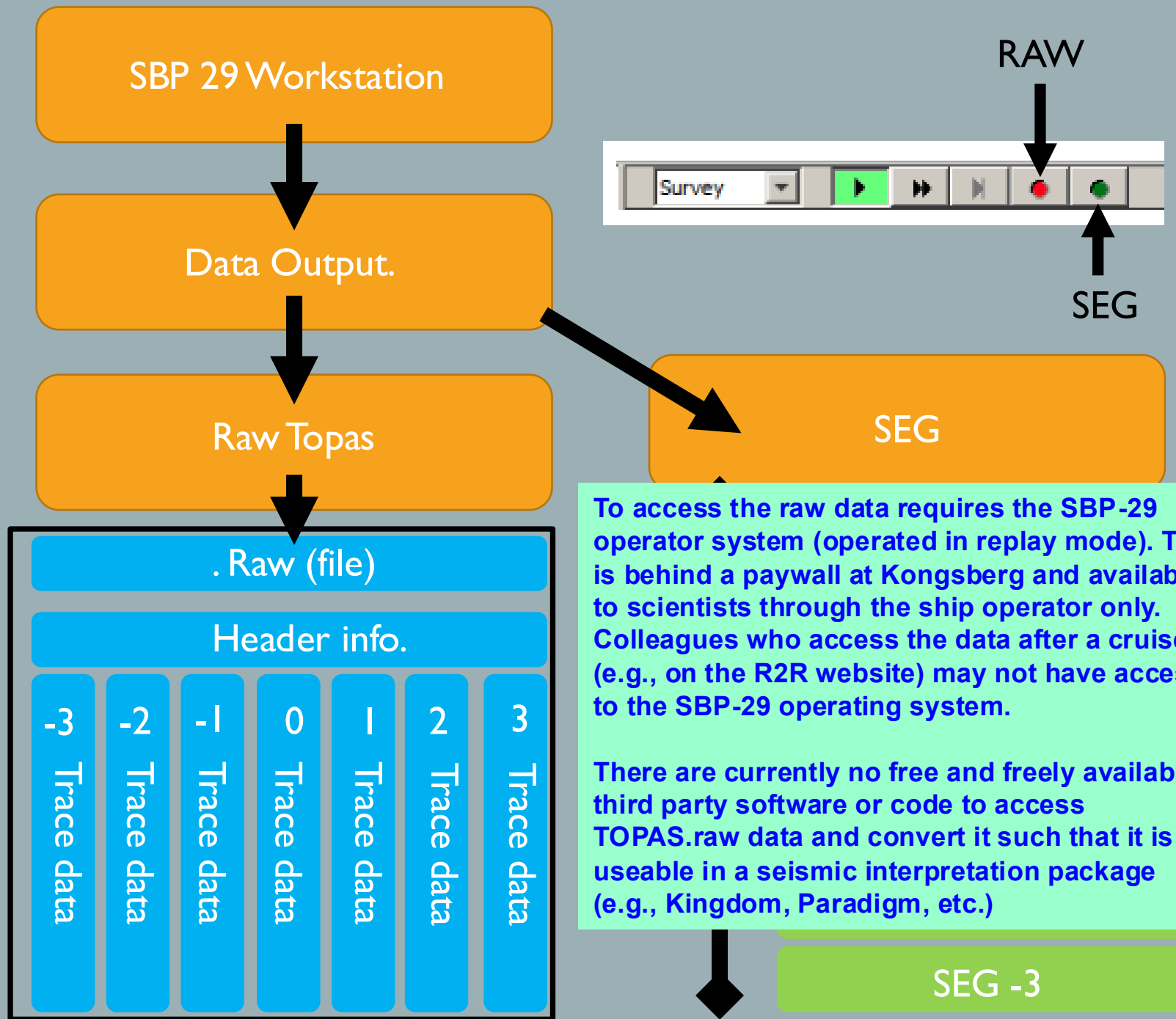
Current Data Handling Structure:

SBP-29 Workstation

- Acquisition parameters
  - Frequency range
  - Pulse length/shape
  - Recording window
  - Processing workflow
  - Etc. …
- Recorded data type
  - .Raw (topas.raw)
  - .SEG (sgy)

Currently, NSF-funded data are not meeting open-access requirements for scientists to access useable raw data.

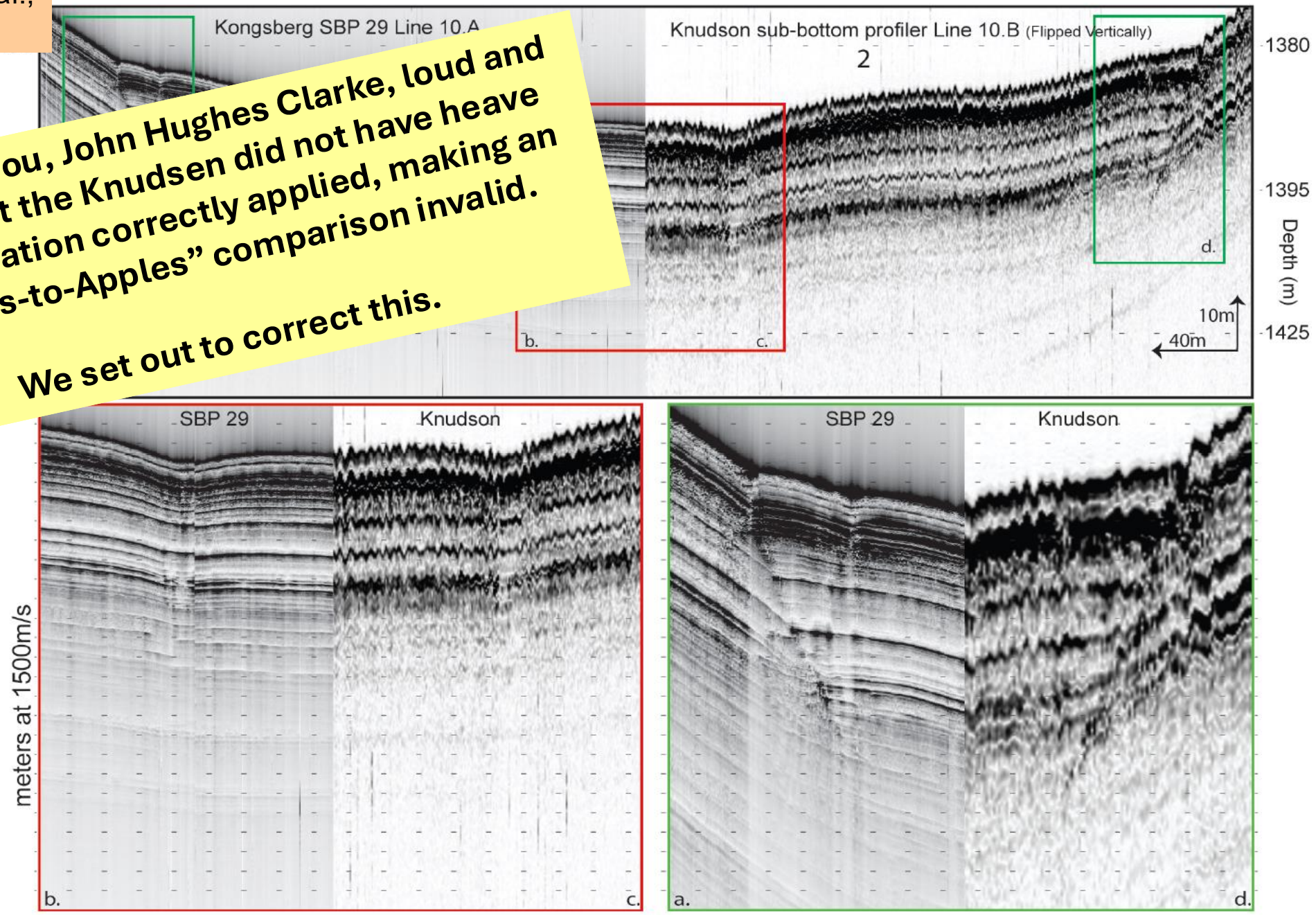
Solution: Have Kongsberg host the software on their existing software access website.



To access the raw data requires the SBP-29 operator system (operated in replay mode). This is behind a paywall at Kongsberg and available to scientists through the ship operator only. Colleagues who access the data after a cruise (e.g., on the R2R website) may not have access to the SBP-29 operating system.

There are currently no free and freely available third party software or code to access TOPAS.raw data and convert it such that it is useable in a seismic interpretation package (e.g., Kingdom, Paradigm, etc.)

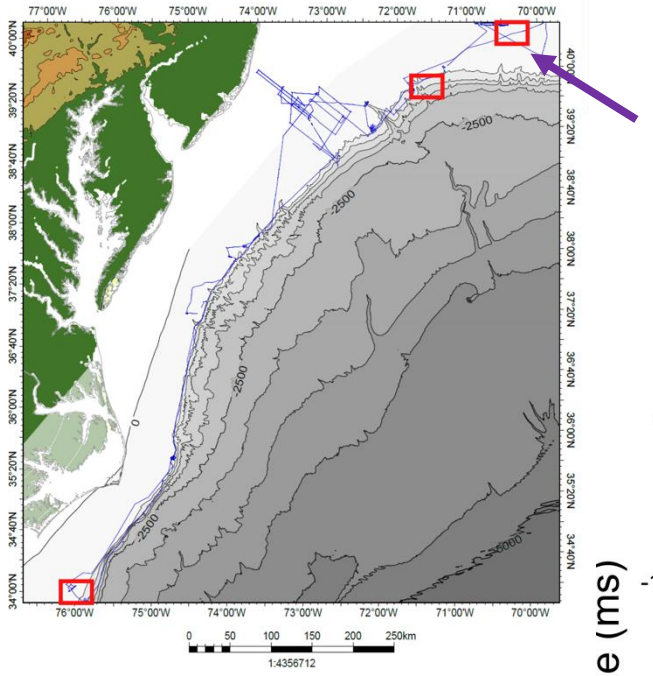
From Orange et al., FEMME 2023.



We heard you, John Hughes Clarke, loud and clear, that the Knudsen did not have heave compensation correctly applied, making an "Apples-to-Apples" comparison invalid.

We set out to correct this.

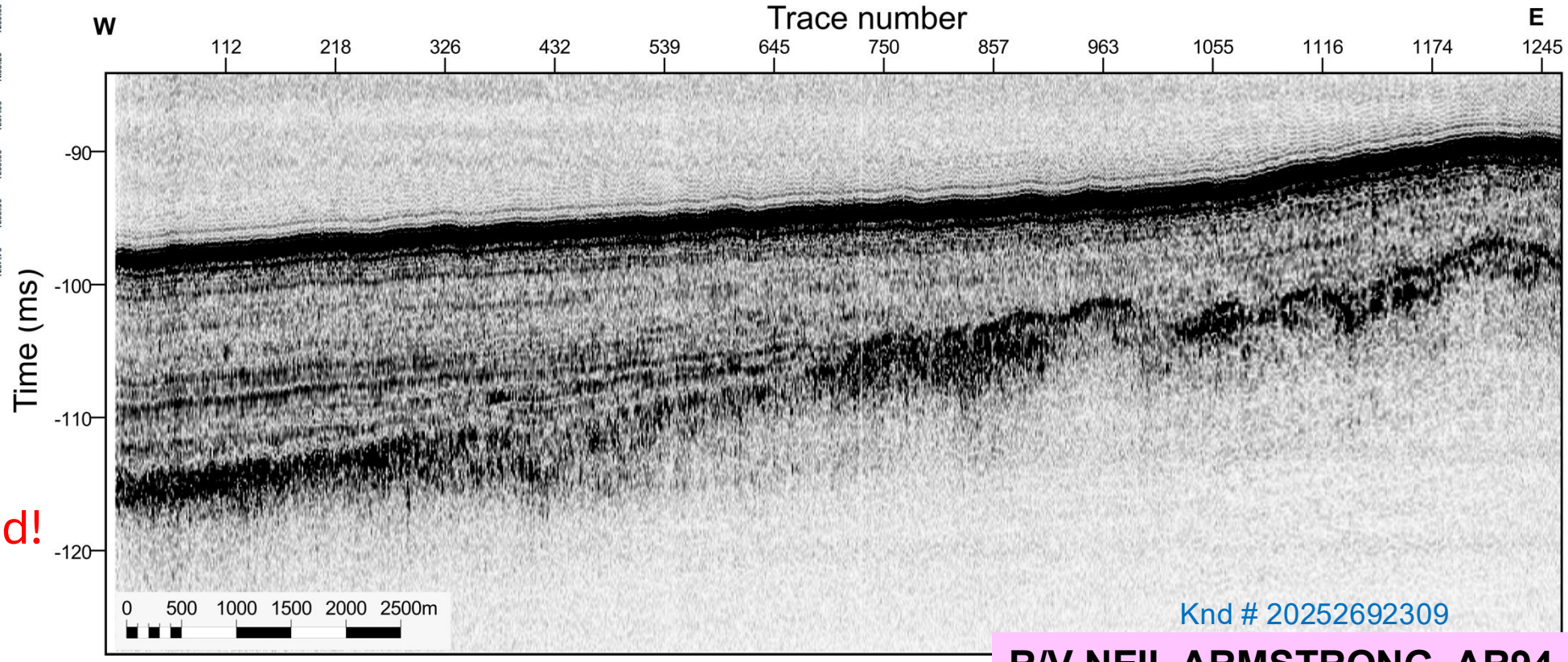
SBP29 vs Knudsen



- Similar resolution

- Heave compensated!

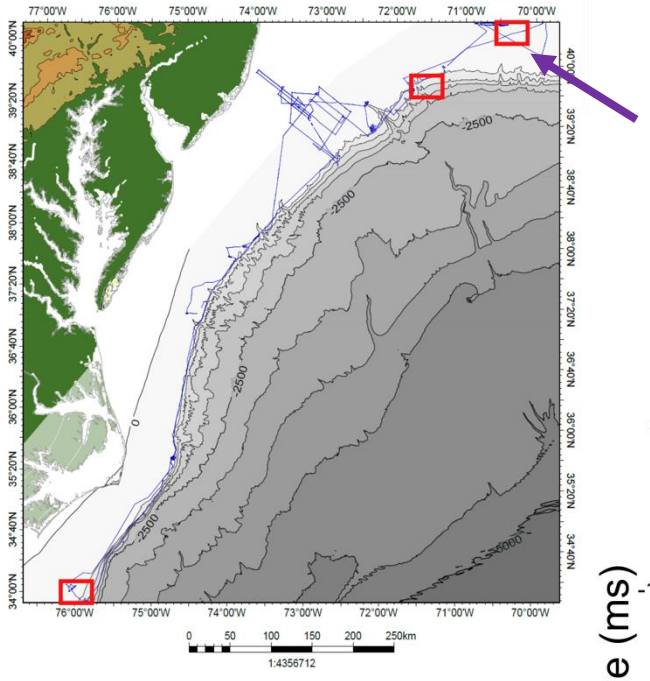
Knudsen



Knd # 20252692309

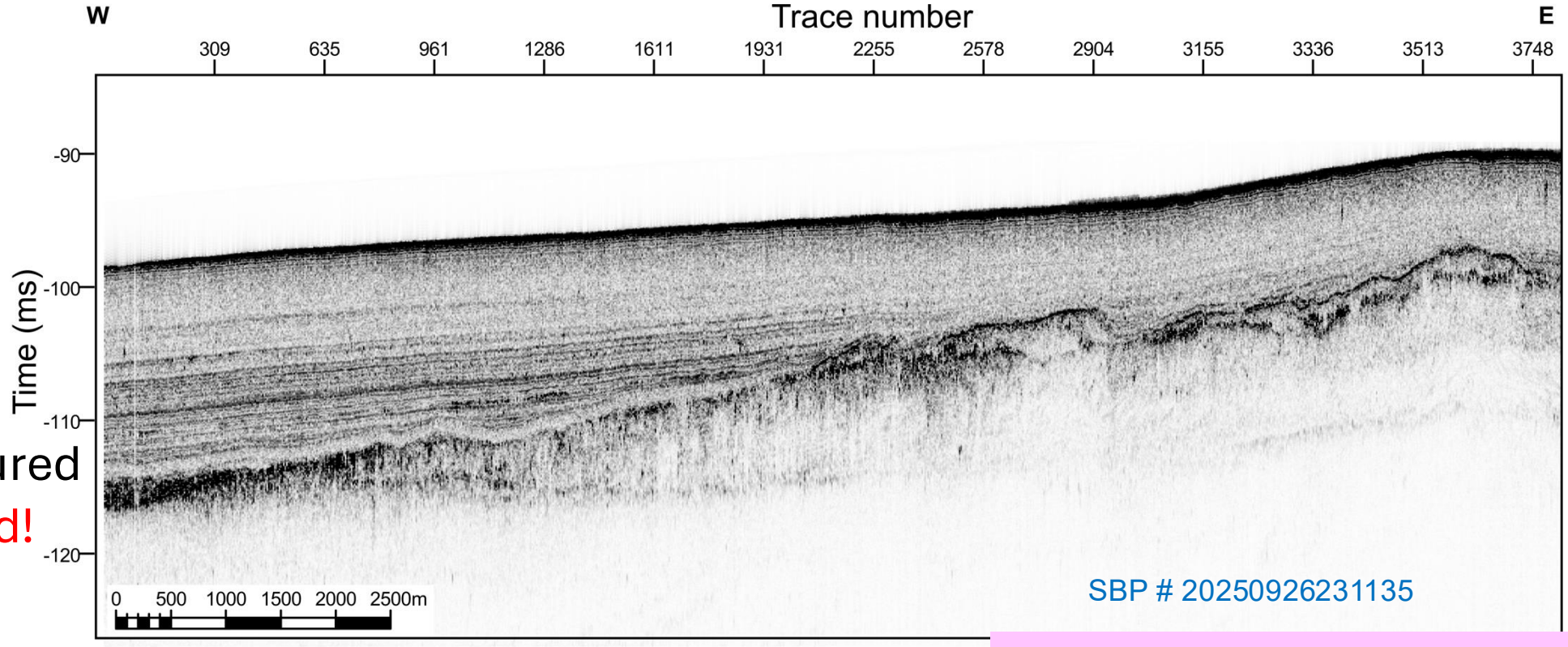
R/V NEIL ARMSTRONG, AR94

SBP29 vs Knudsen



- Similar resolution
- Thinner layers captured
- Heave compensated!

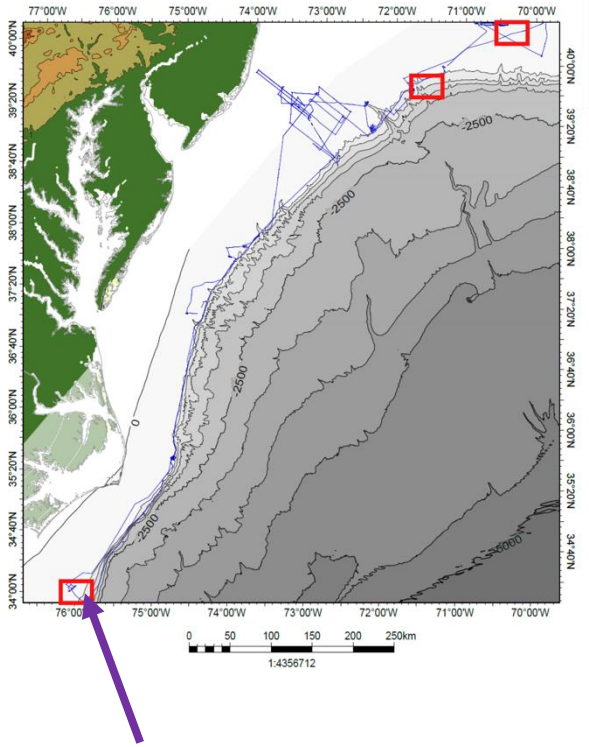
SBP29



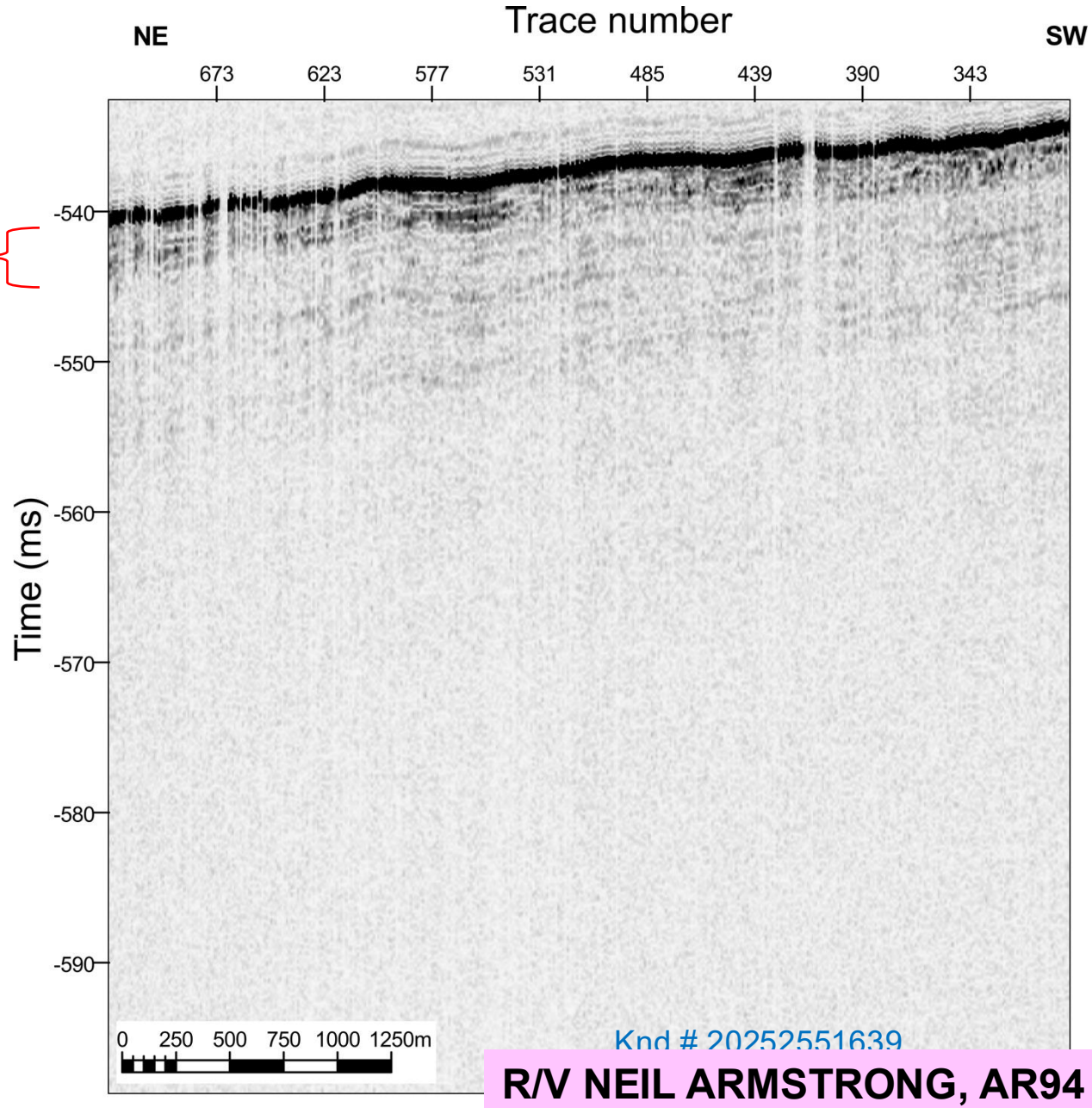
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R/V NEIL ARMSTRONG, AR94

SBP29 vs Knudsen



Limited penetration

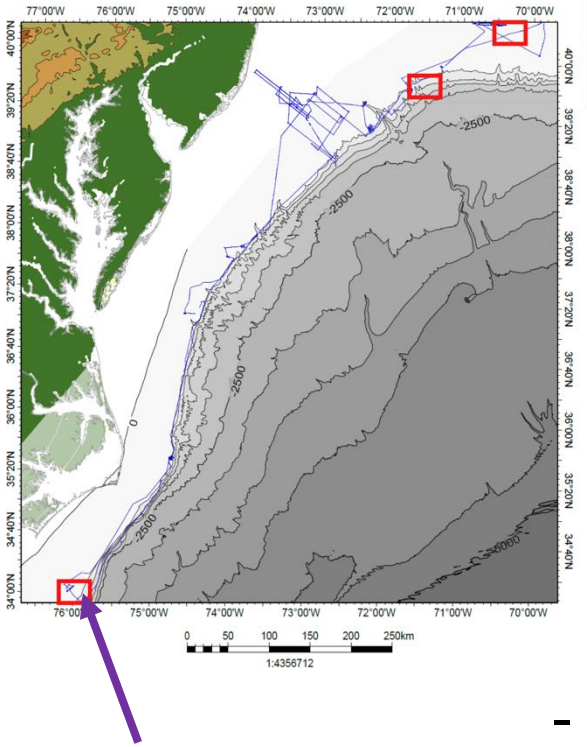


Knudsen

R/V NEIL ARMSTRONG, AR94

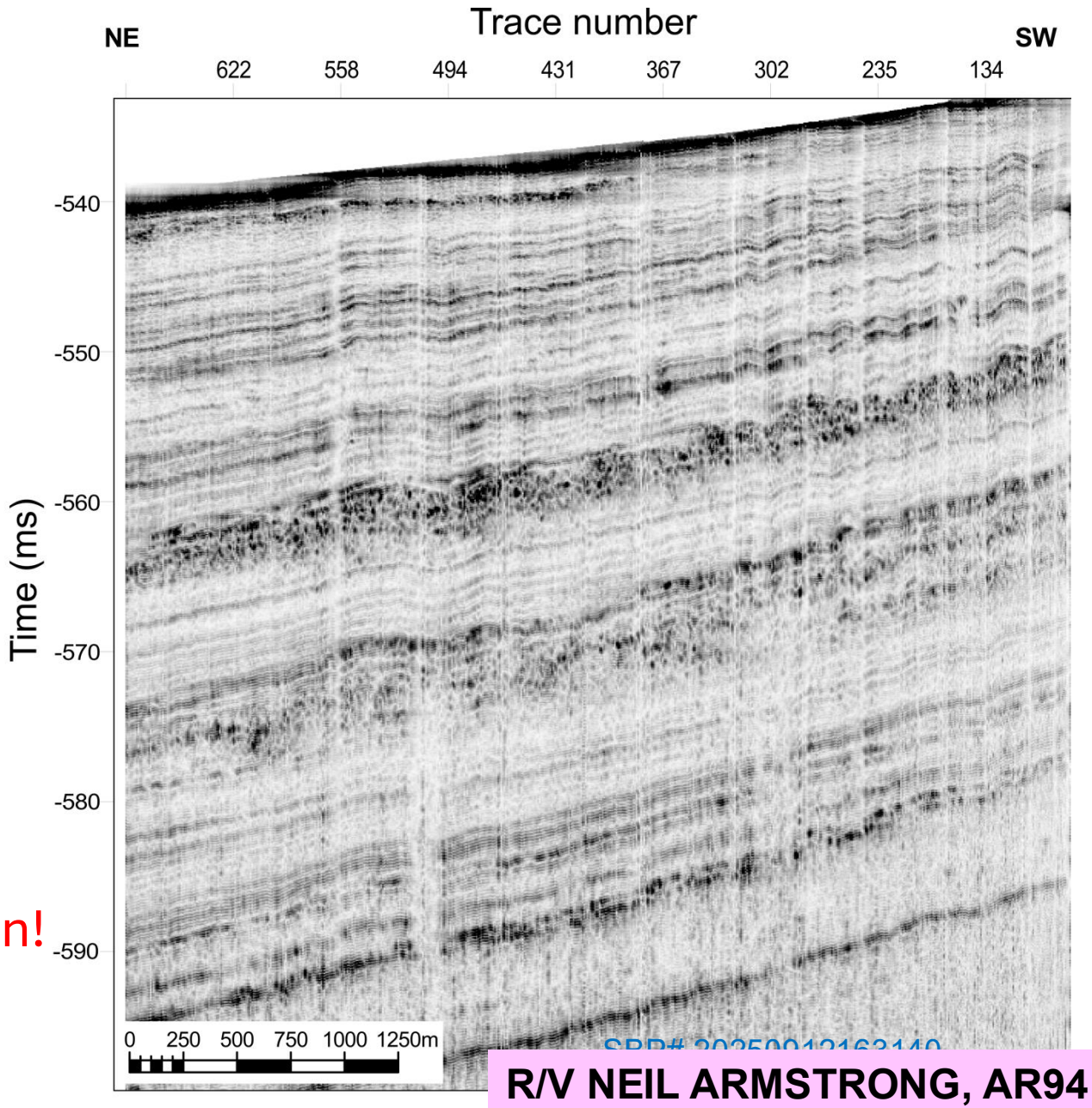
US East Coast. R/V NEIL ARMSTRONG. AR94

SBP29 vs Knudsen



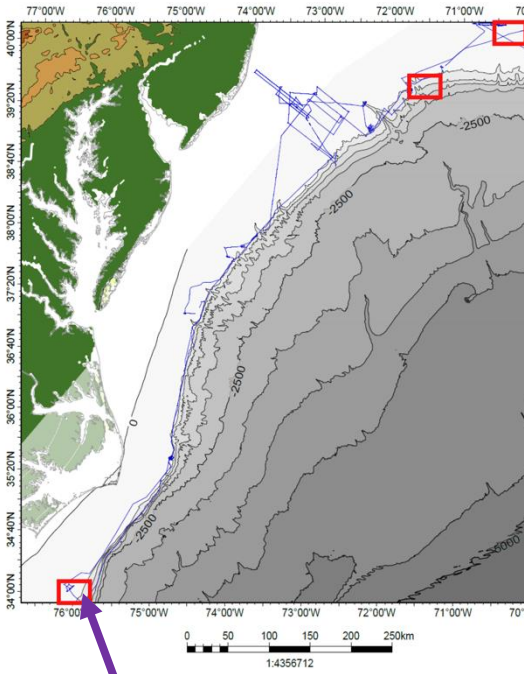
- Finer resolution
- Thinner layers captured
- >10X Deeper penetration!

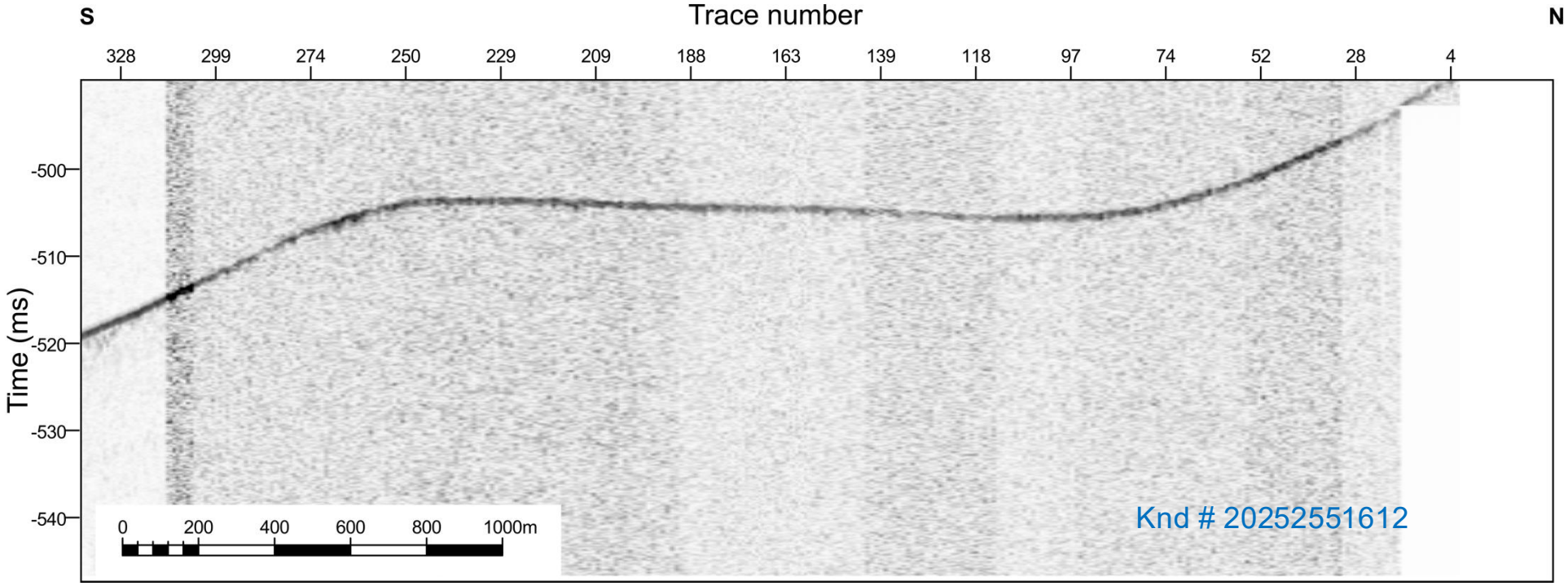
SBP29



R/V NEIL ARMSTRONG, AR94

SBP29 vs Knudsen





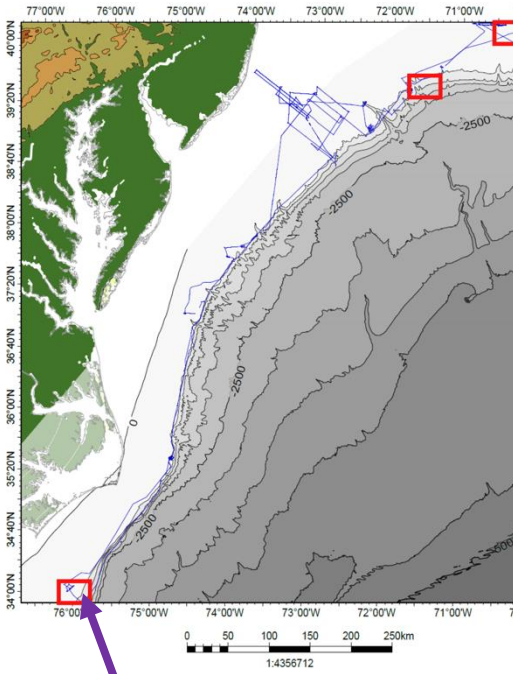
In noisy environment

Knudsen unable to penetrate

Knudsen

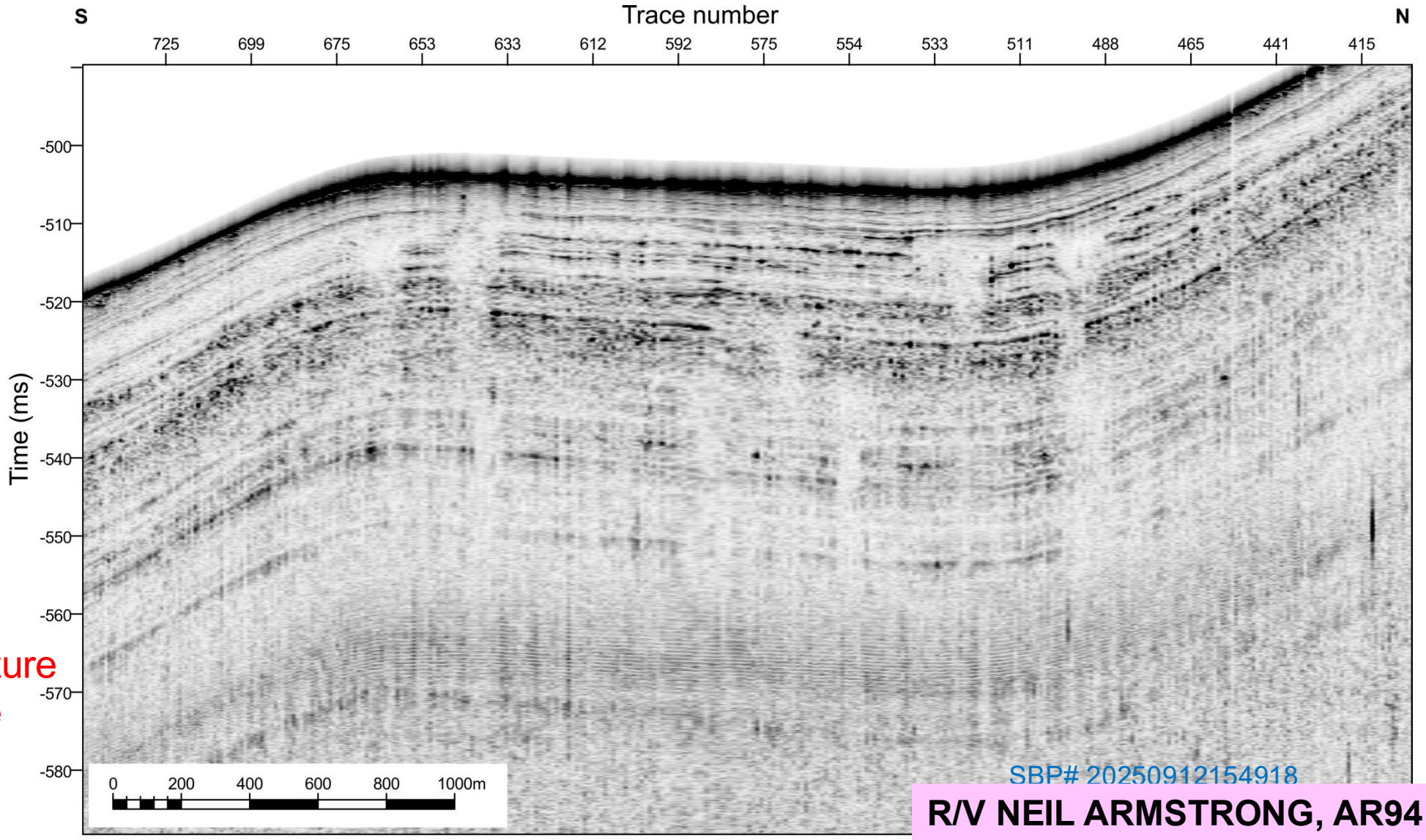
US East Coast. R/V NEIL ARMSTRONG. AR94

SBP29 vs Knudsen



In noisy environment SBP29 still able to capture structure and penetrate deeper

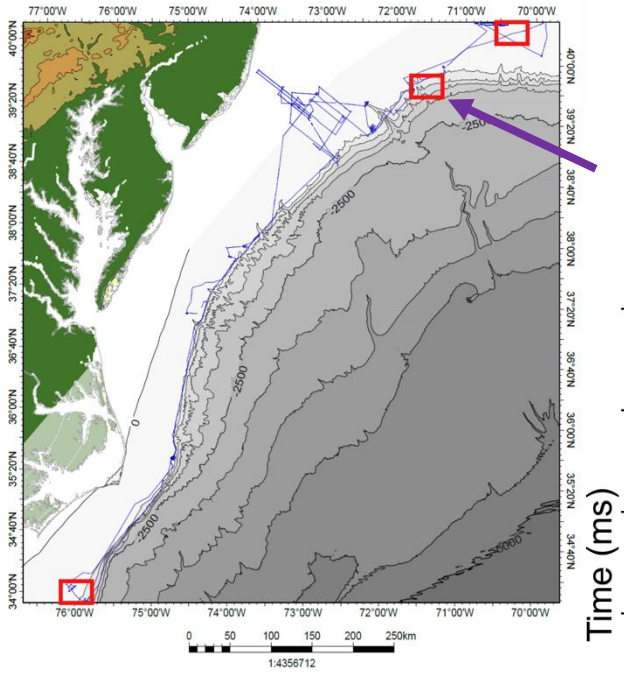
SBP29



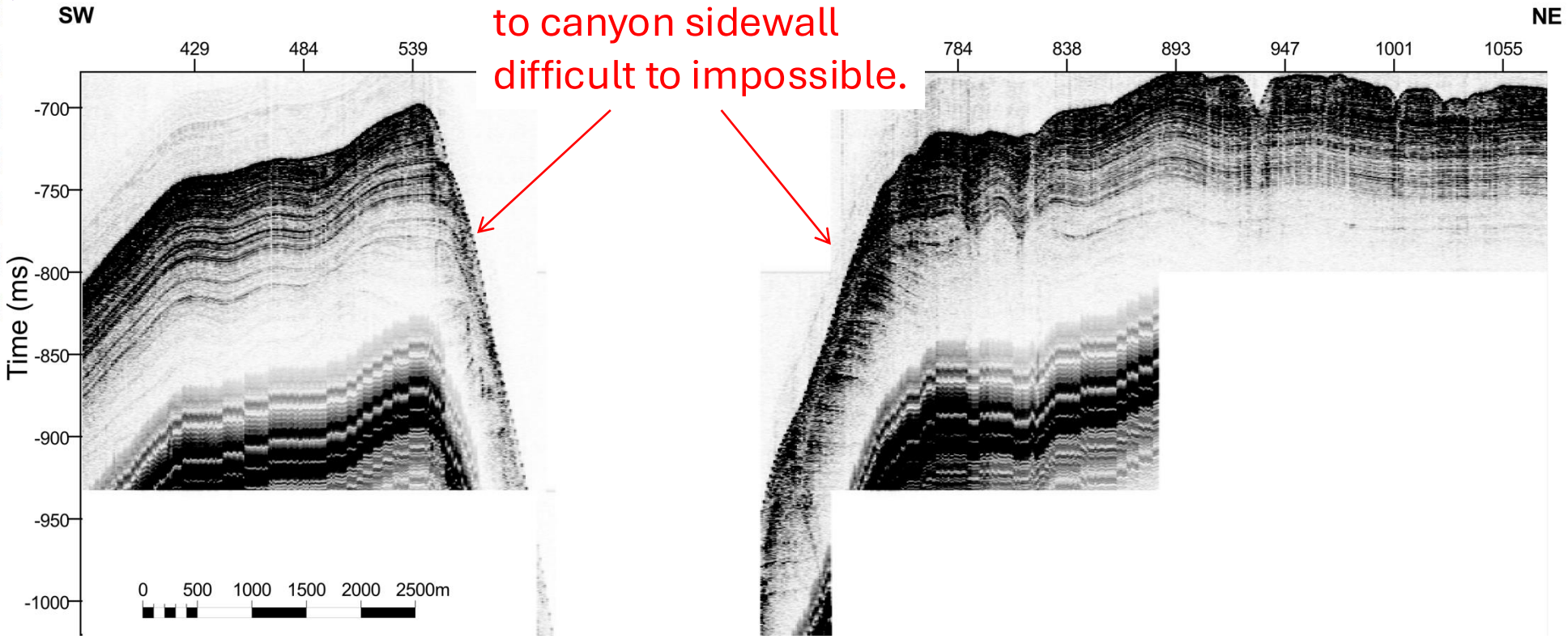
R/V NEIL ARMSTRONG, AR94

In a relatively quiet environment…

SBP29 vs Knudsen



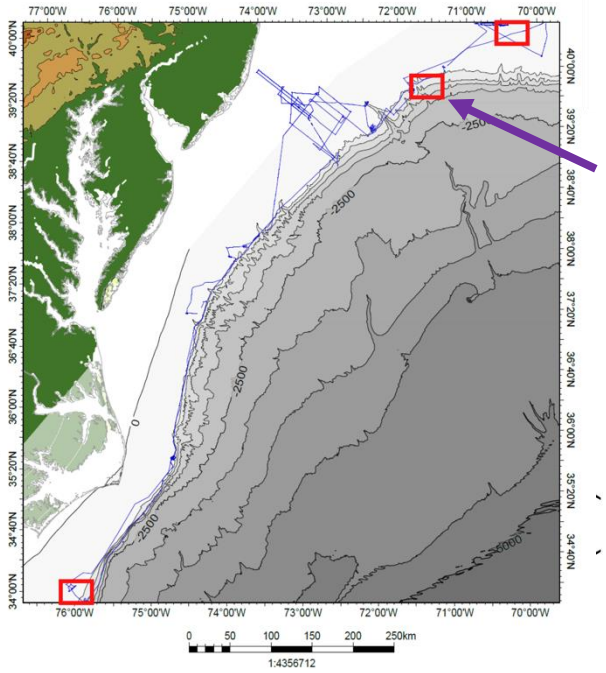
Diffractions make reflector identification to canyon sidewall difficult to impossible.

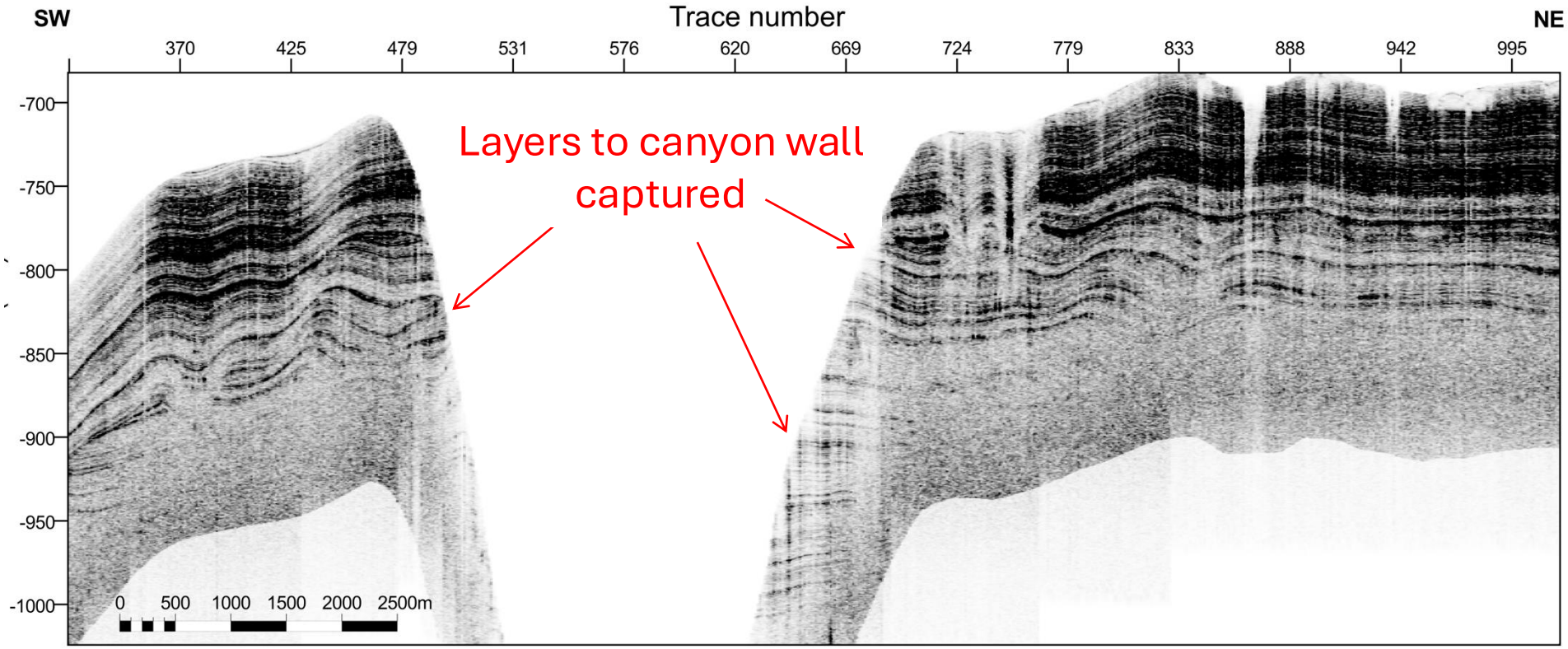


Knudsen

In a relatively quiet environment…

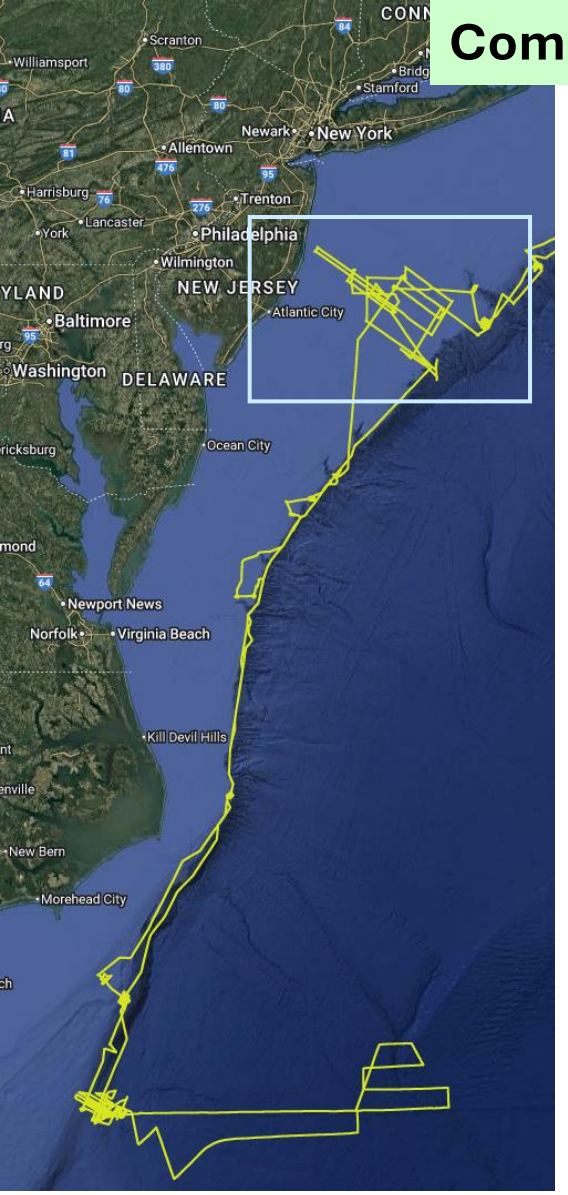
SBP29 vs Knudsen

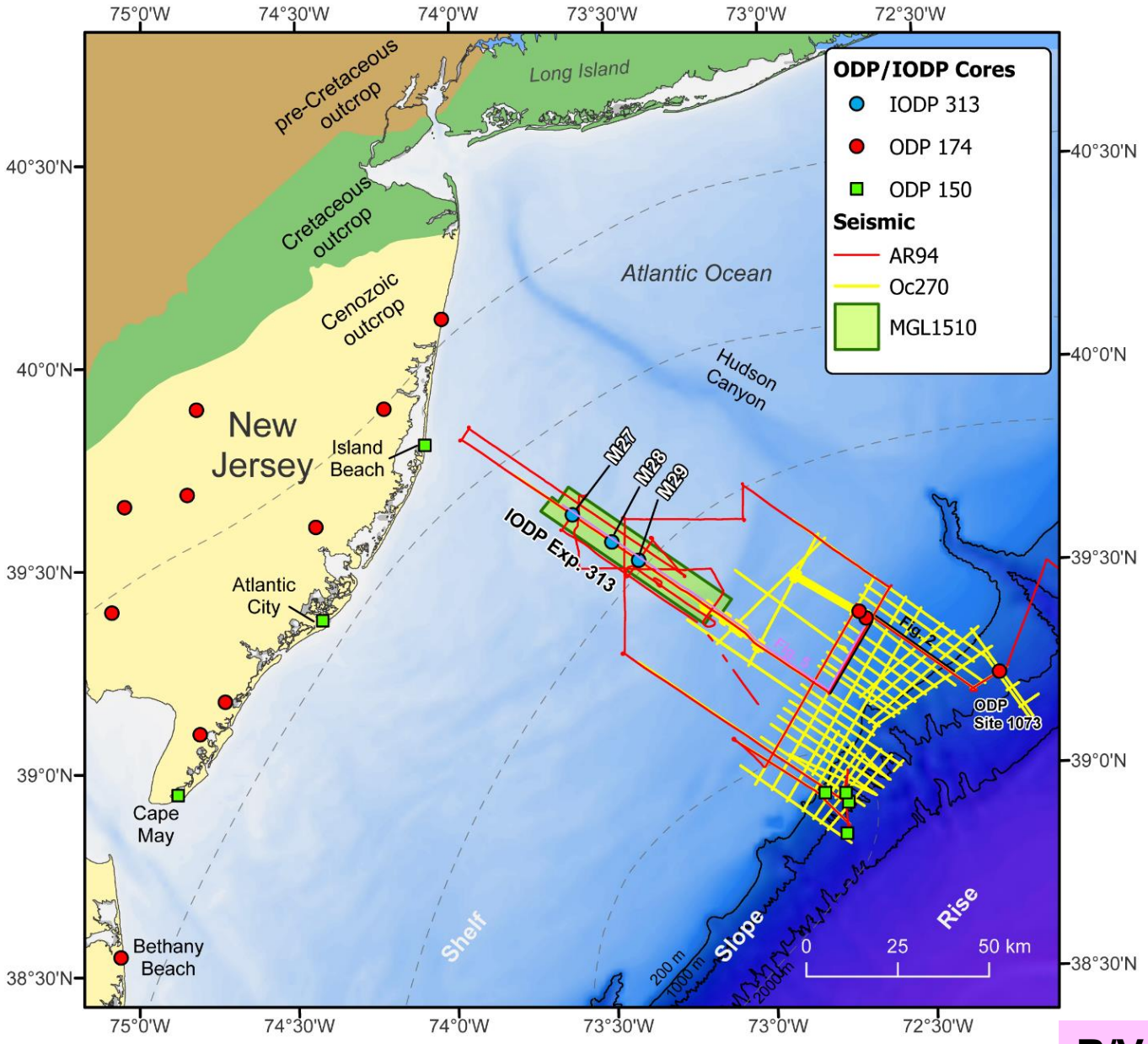




SBP29

Comparing SBP-29 with legacy sub-bottom systems, including Multi-Channel Seismic

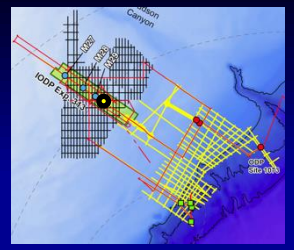




For a variety of reasons, the New Jersey Confinental Shelf (& upper slope) is *incredibly* well studied (Ocean Drilling Program, New York State Energy Research and Development Authority [NYSERDA], US Navy).

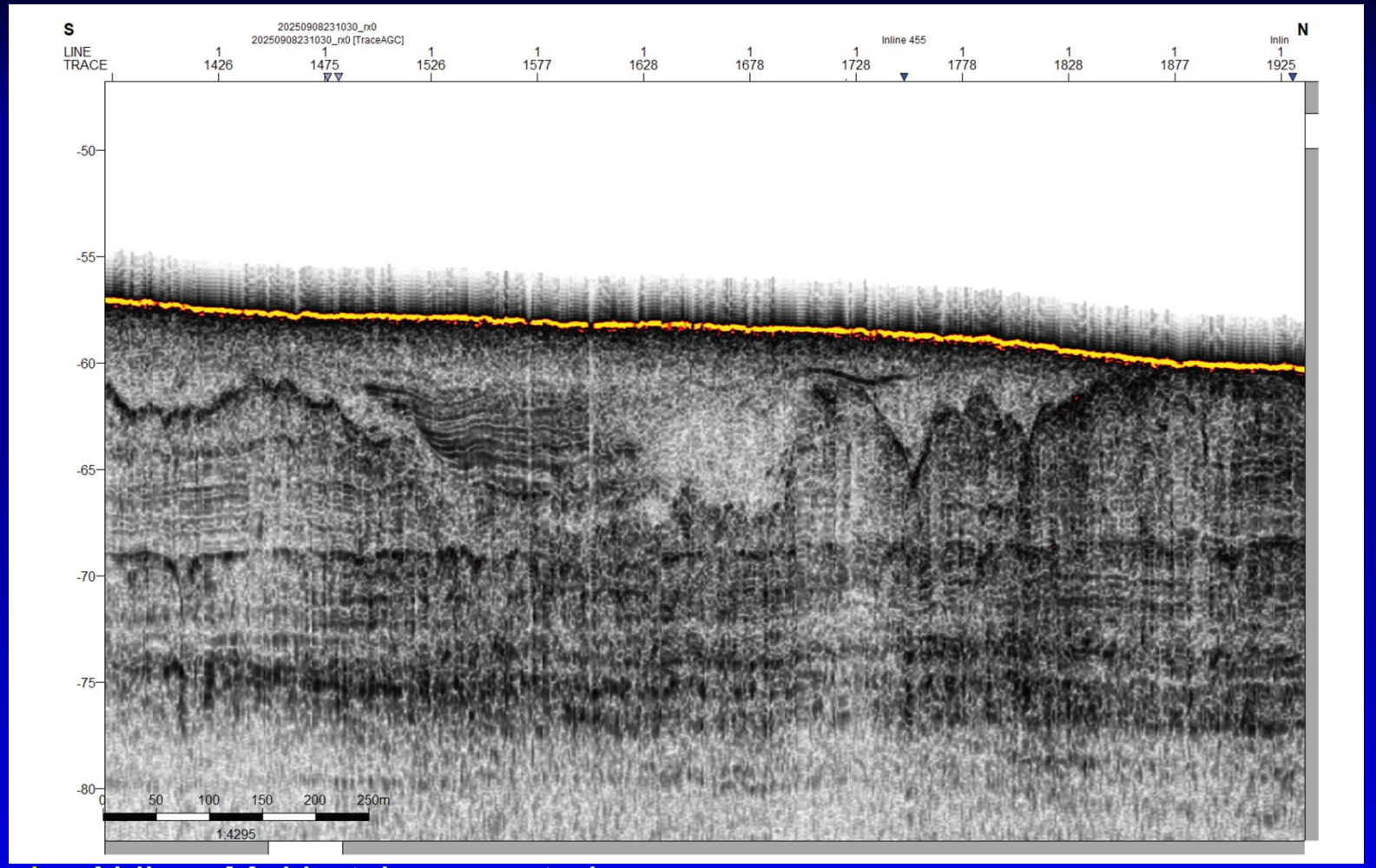
R/V NEIL ARMSTRONG, AR94

Data comparisons - SBP29



AR94 Leg 1
SBP29

Instantaneous amplitudes

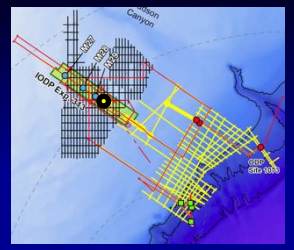


W. John Schmelz, Aldiyar Mukhatzhanov, et al.

FEMME Slides
Sept. 23, 2026

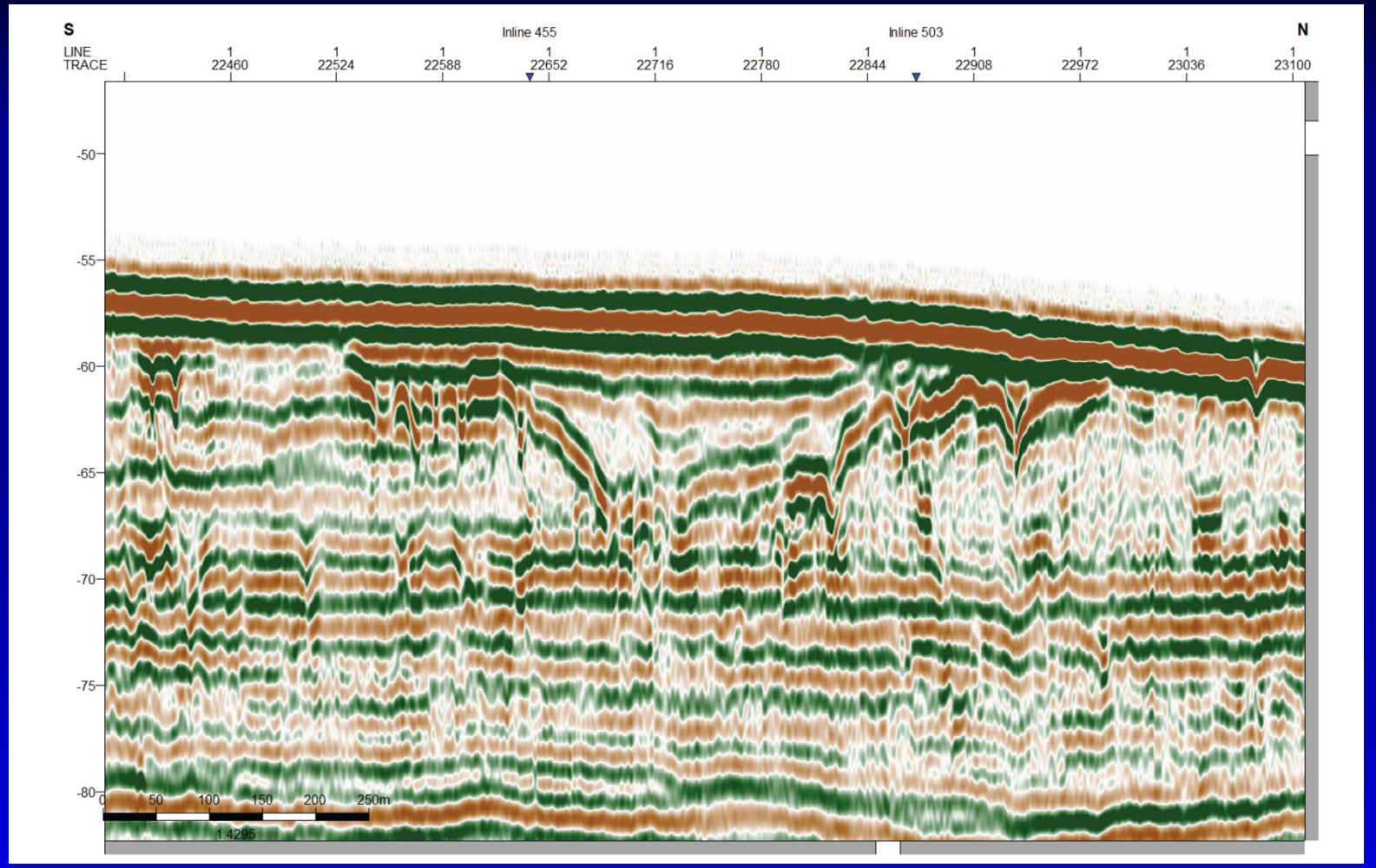
RUTGERS
THE STATE UNIVERSITY OF NEW JERSEY

Data comparisons - NYSERDA Ultra-Hi Res Seismic

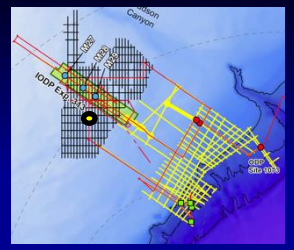


NYSERDA ultra-high resolution seismic data (2021)

~200 to 1200 Hz bandwidth

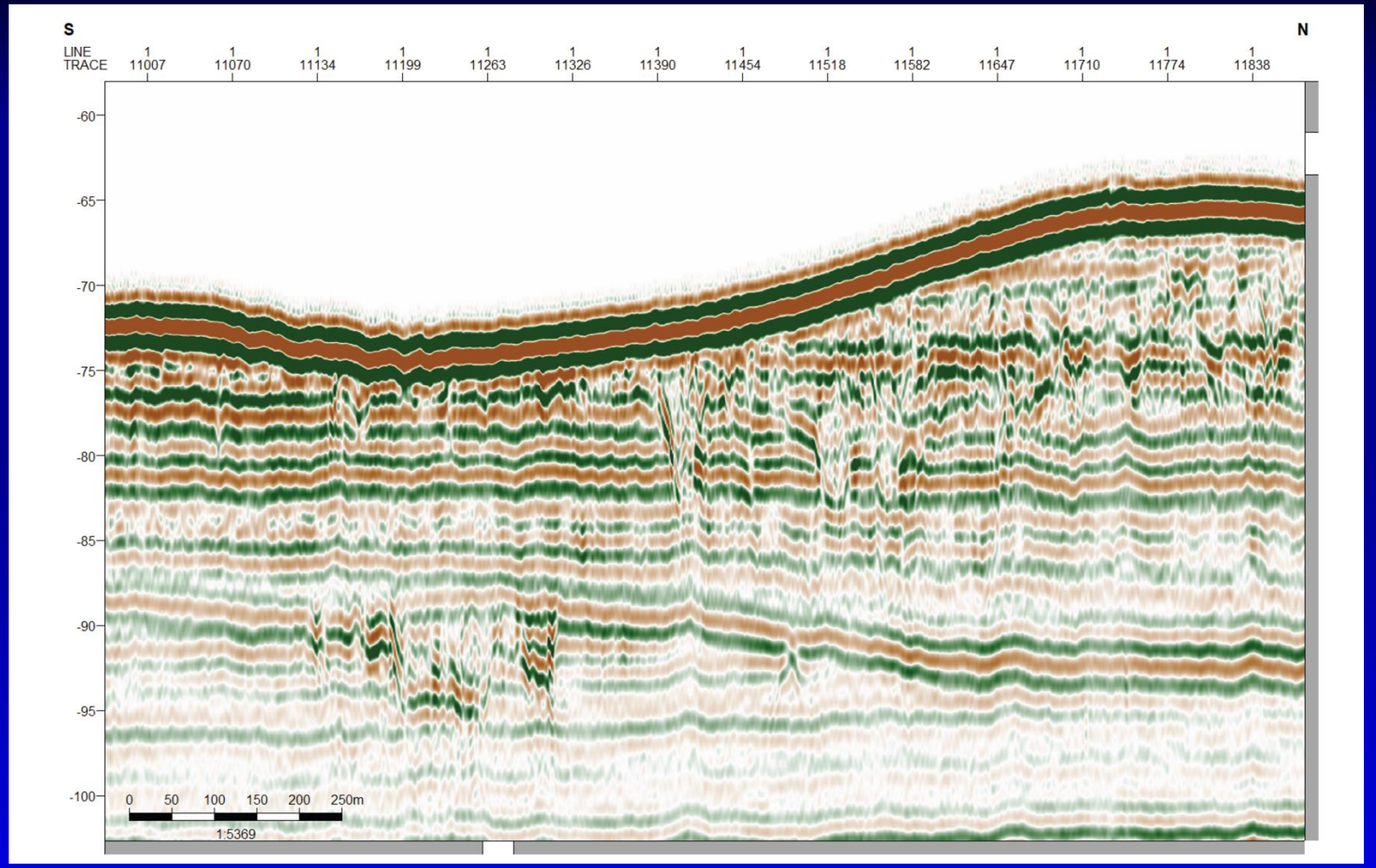


Data comparisons - NYSERDA UHRS

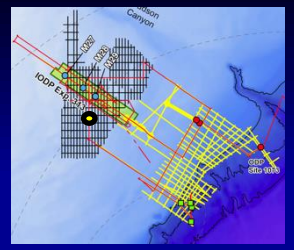


NYSERDA ultra-high resolution seismic data (2021)

~200 to 1200 Hz bandwidth

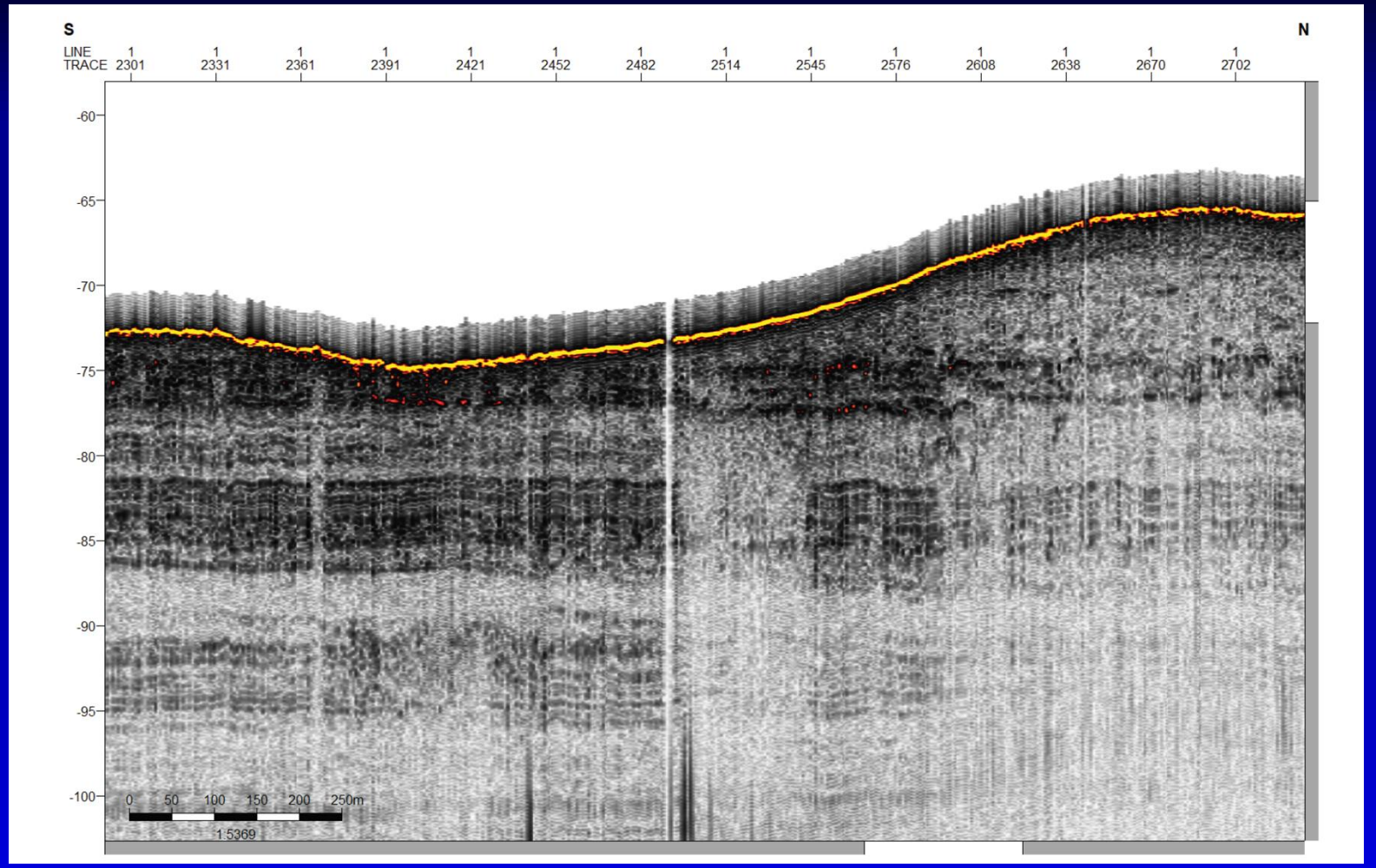


Data comparisons - SBP29

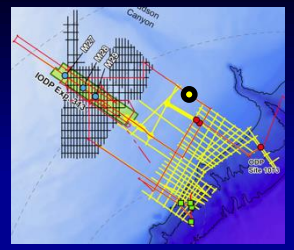


AR94 Leg 1
SBP29

Instantaneous amplitudes



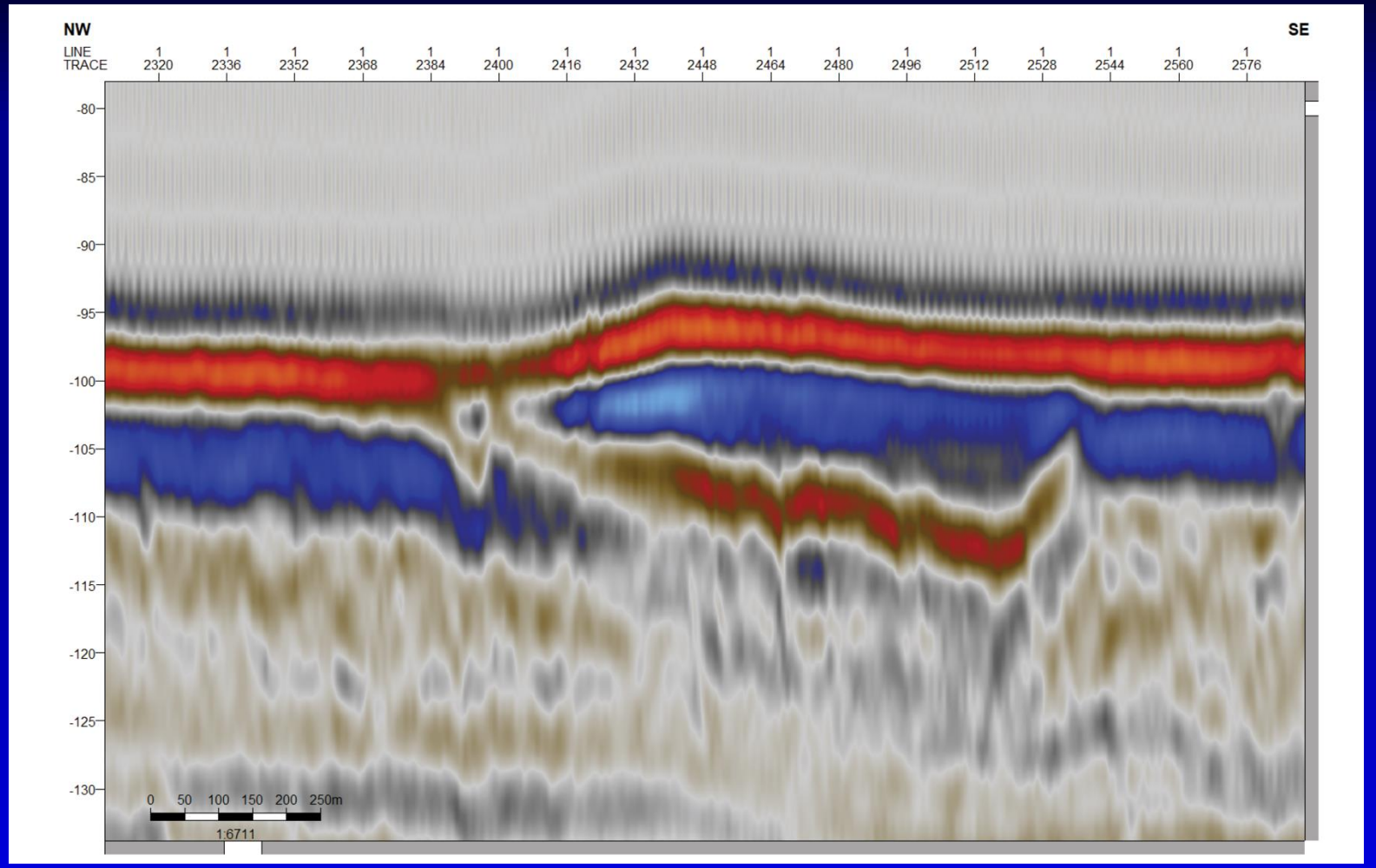
Data comparisons - OC270 Multi-Channel Seismic



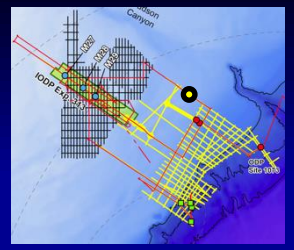
OC270 MCS (1995)

~30 to 500 Hz bandwidth

~5 m vertical resolution

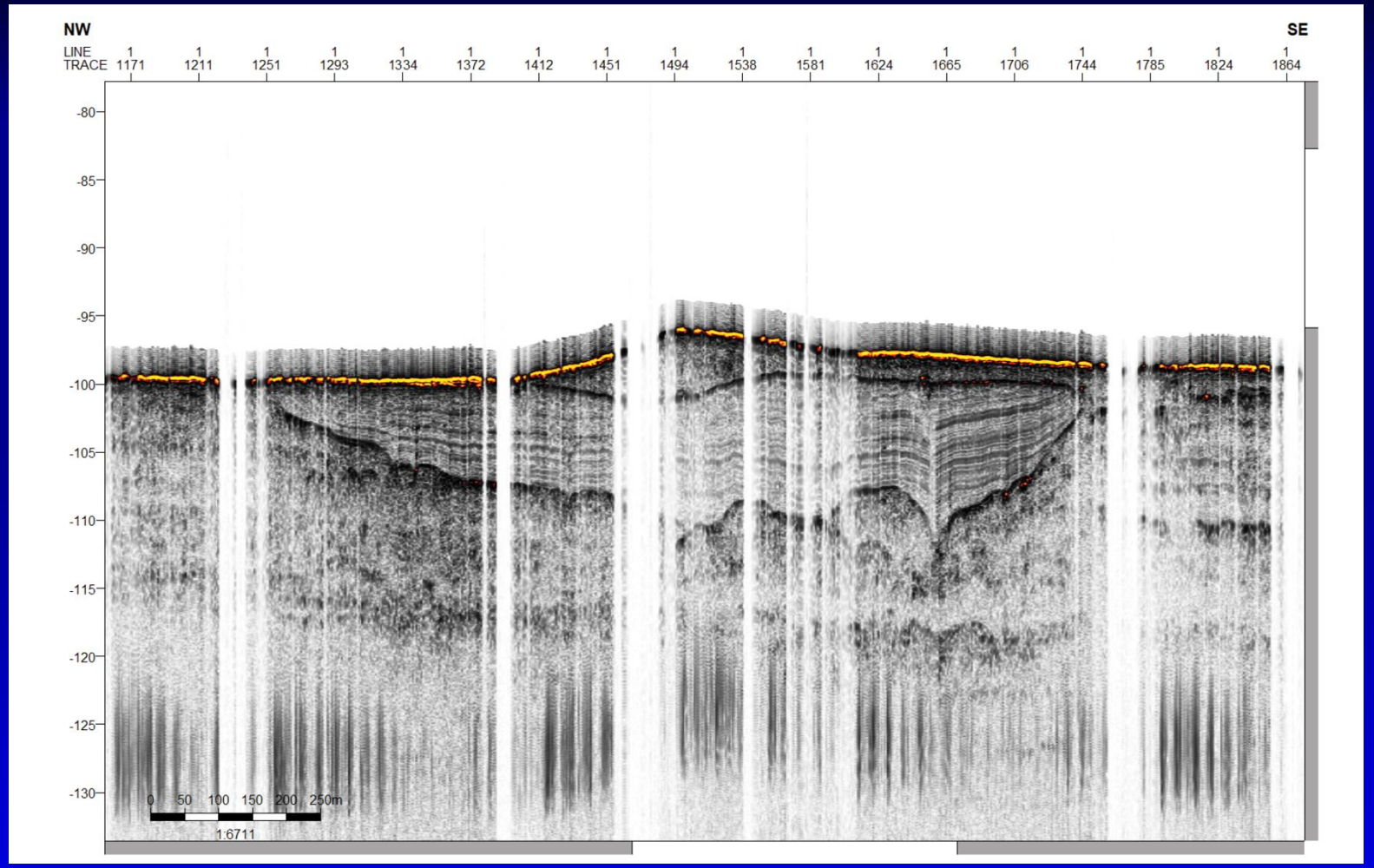


Data comparisons - SBP29

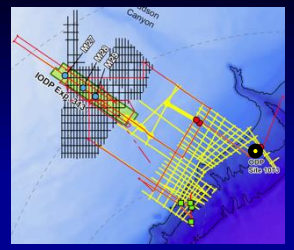


AR94 Leg 1
SBP29

Instantaneous amplitudes



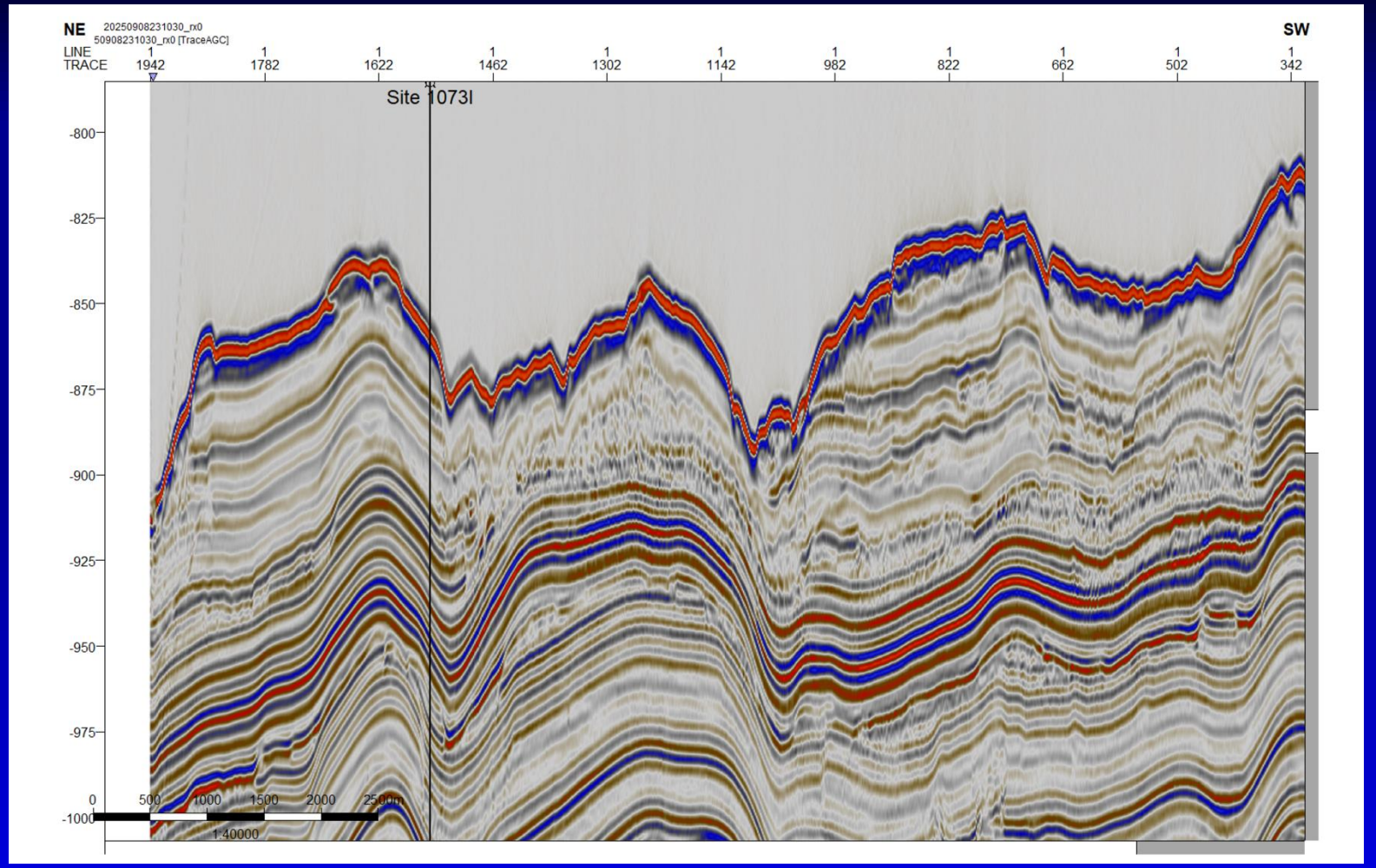
Data comparisons - OC270 Multi-Channel Seismic



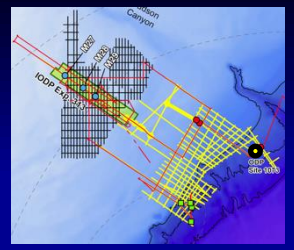
OC270 MCS (1995)

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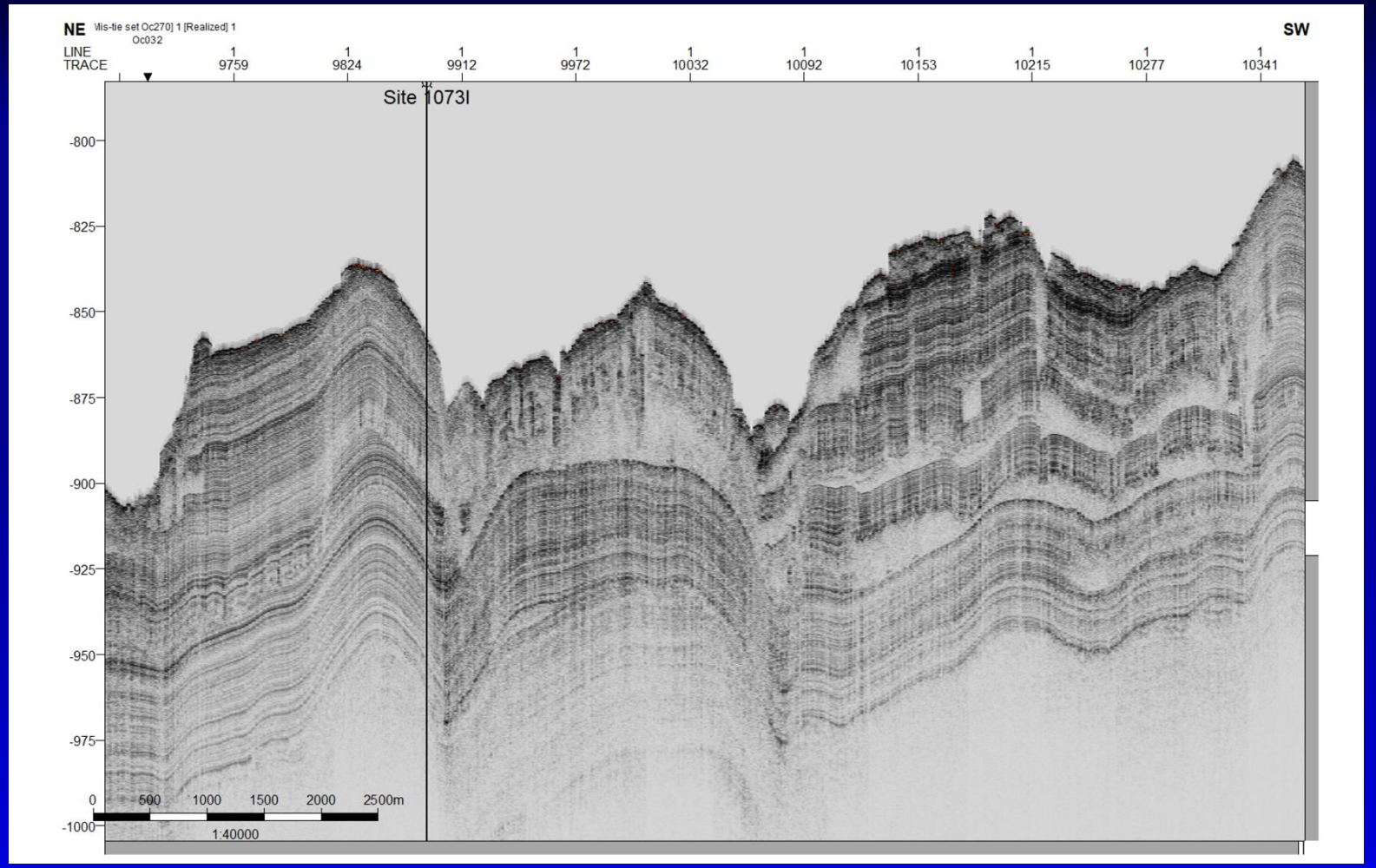


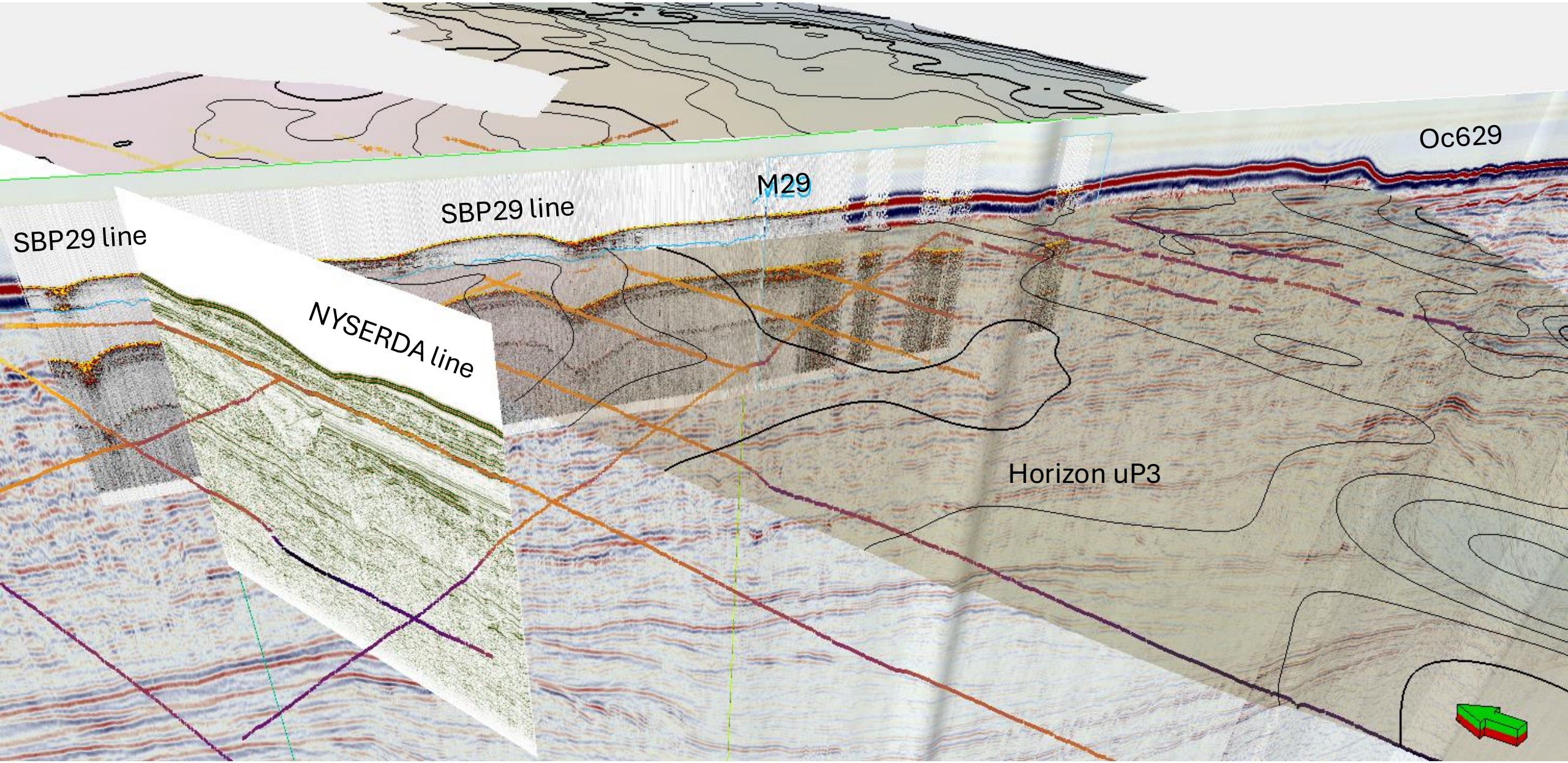
Data comparisons - SBP29



AR94 Leg 1
SBP29

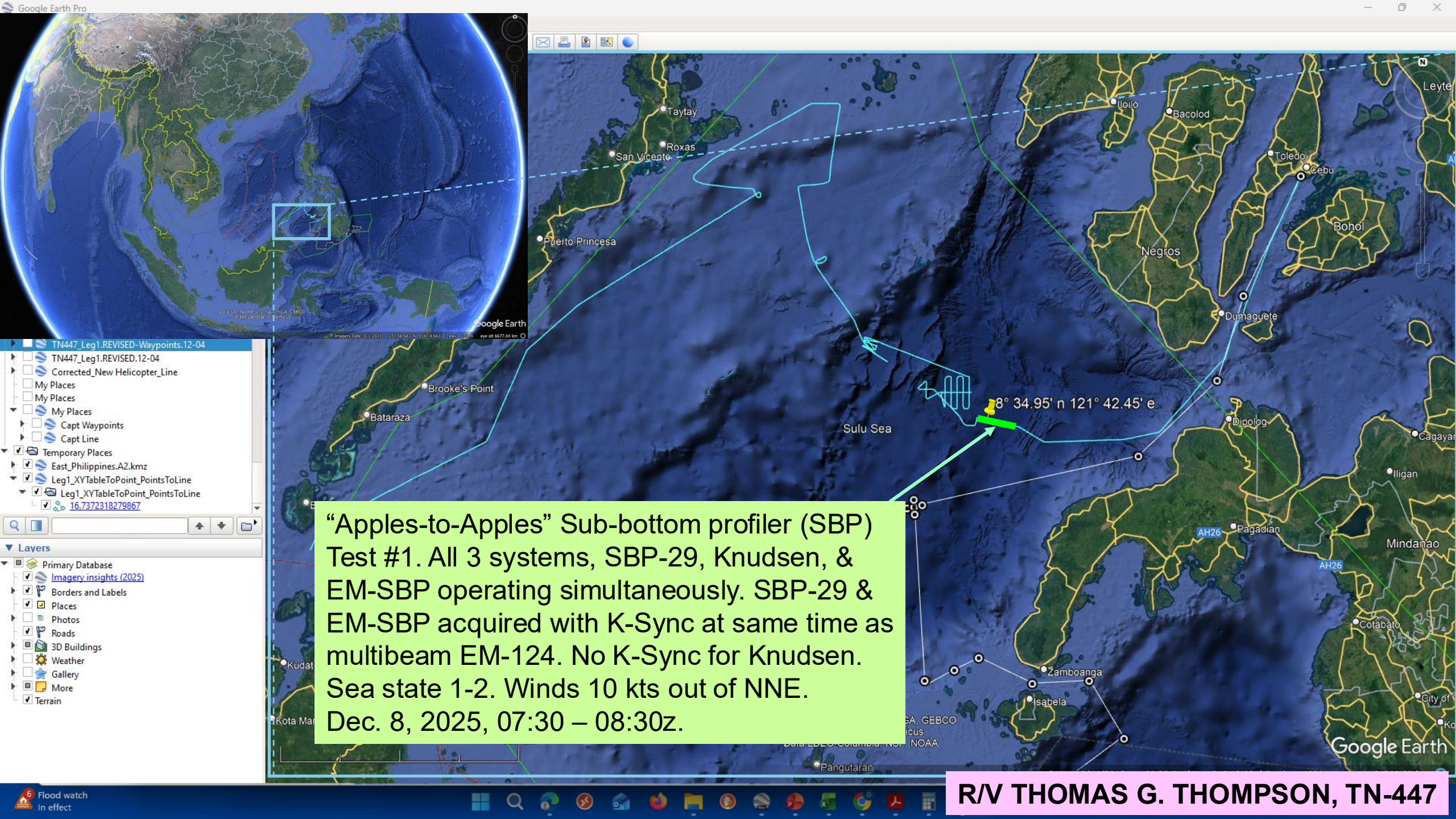
Instantaneous amplitudes





“fence diagram” of various systems that see into the earth below the seafloor.

R/V NEIL ARMSTRONG, AR94

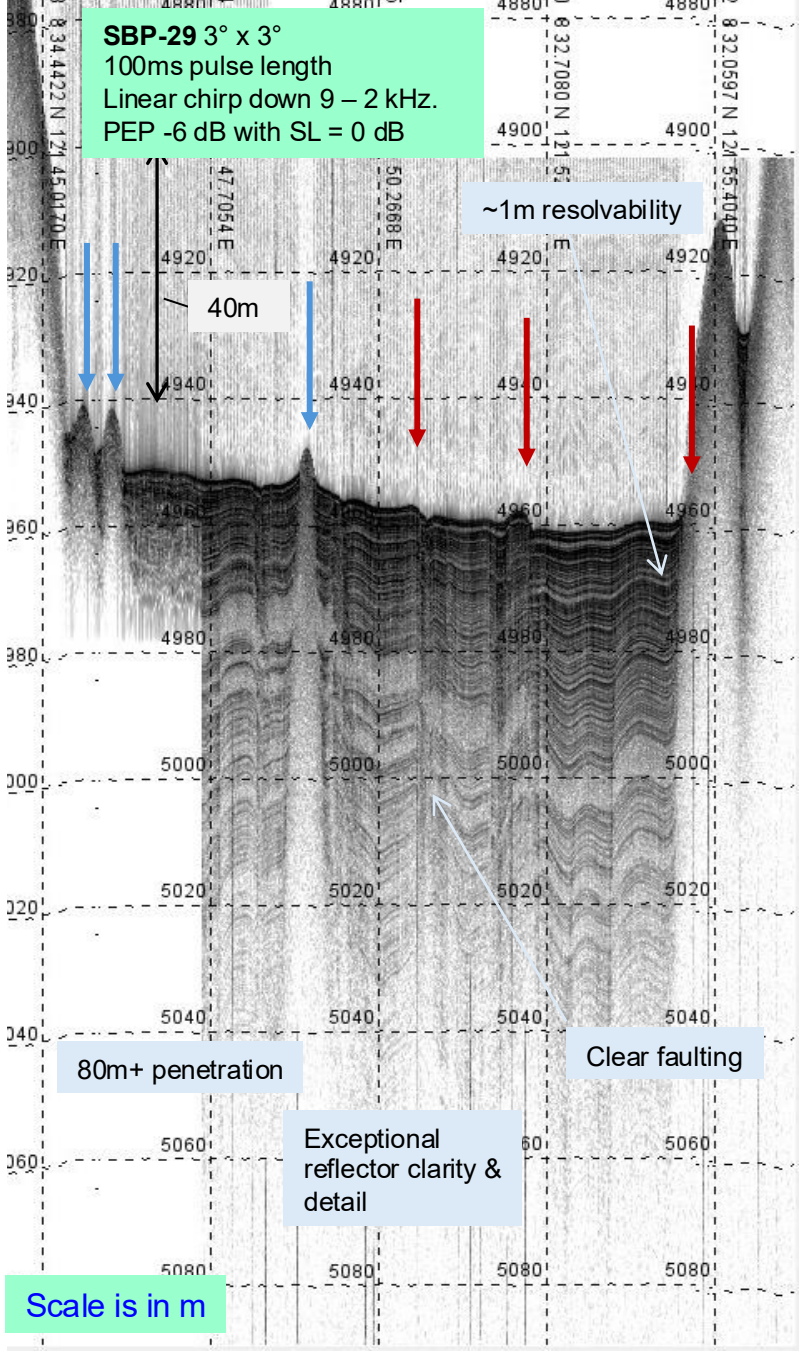


"Apples-to-Apples" Sub-bottom profiler (SBP) Test #1. All 3 systems, SBP-29, Knudsen, & EM-SBP operating simultaneously. SBP-29 & EM-SBP acquired with K-Sync at same time as multibeam EM-124. No K-Sync for Knudsen. Sea state 1-2. Winds 10 kts out of NNE. Dec. 8, 2025, 07:30 – 08:30z.

R/V THOMAS G. THOMPSON, TN-447

SBP comparison. Same scale.

Water depth ~4960m.
Data acquired at 10.2 knots.
Realtime acquisition screen

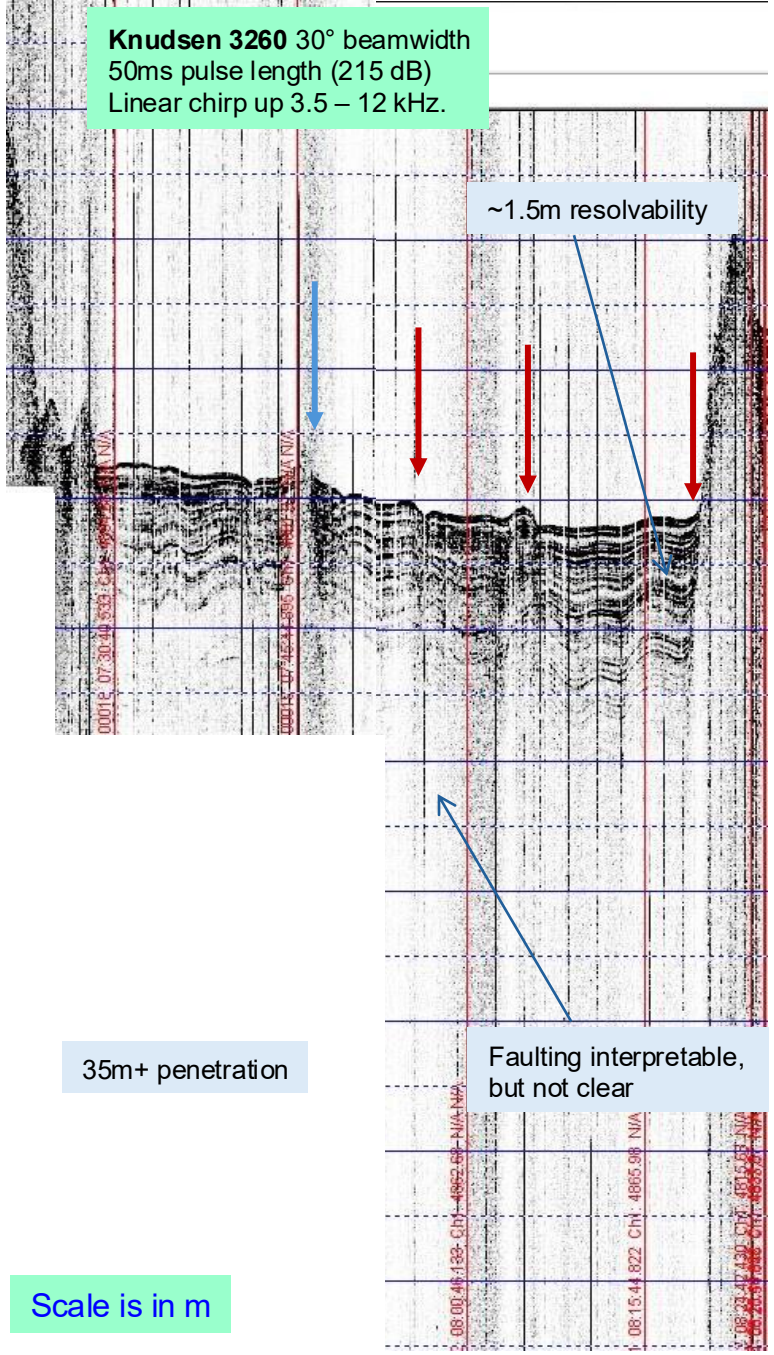


SBP comparison. Same extent for back-and-forth comparison

R/V THOMAS G. THOMPSON, TN-447

SBP comparison. Same scale.

Water depth ~4960m.
Data acquired at 10.2 knots.
Realtime acquisition screen



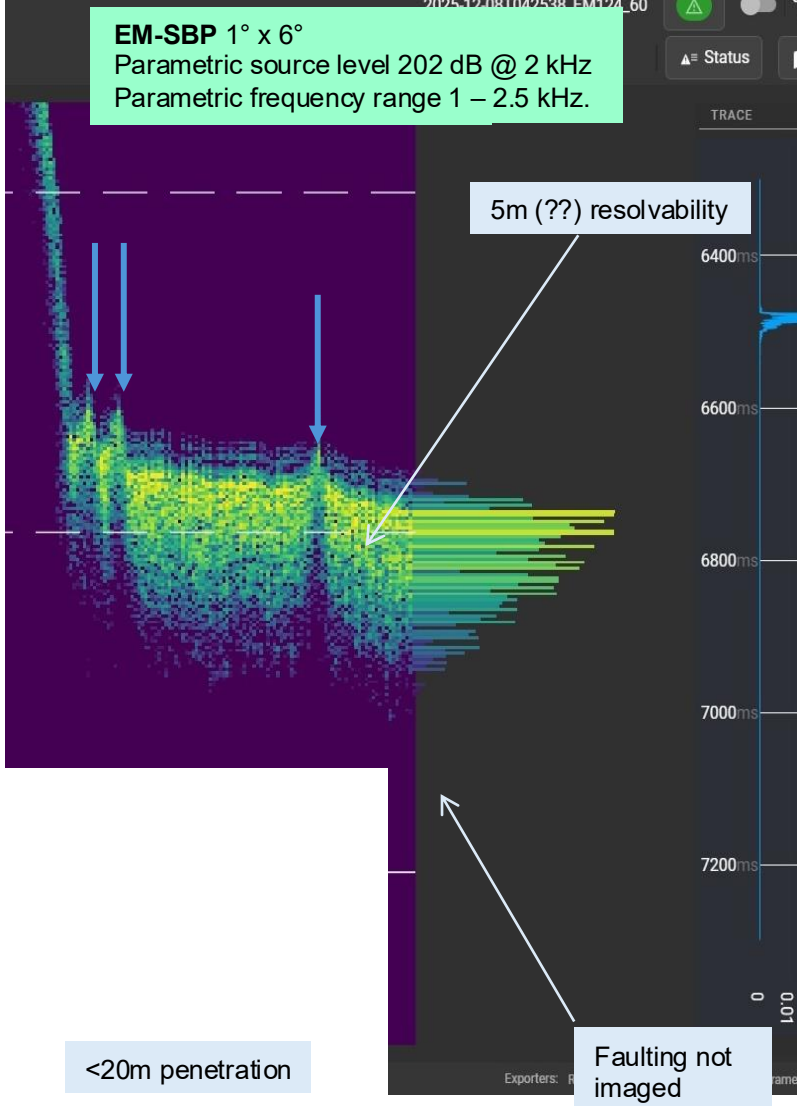
Scale is in m

SBP comparison. Same extent for back-and-forth comparison

R/V THOMAS G. THOMPSON, TN-447

SBP comparison. Same scale.

Water depth ~4960m.
Data acquired at 10.2 knots.
Realtime acquisition screen



SBP comparison. Same extent for back-and-forth comparison

Scale is in ms

R/V THOMAS G. THOMPSON, TN-447

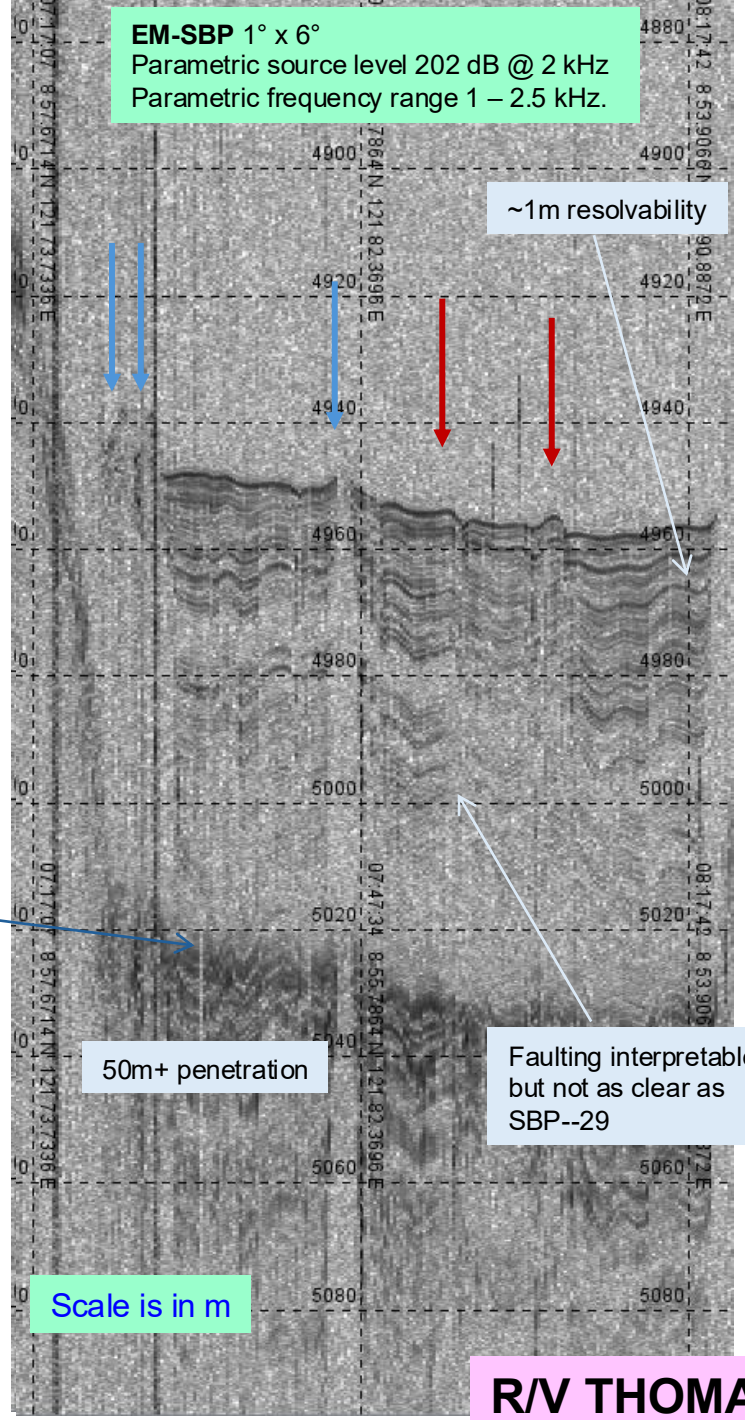
SBP comparison. Same scale.

Water depth ~4960m.
Data acquired at 10.2 knots.
Bjørnar Langli Processed

All 3 SBPs were acquired at the same time on the same line.

Unknown whether the EM-SBP shown is from the EM Tx, SBP-29 Tx or Knudsen Tx.

To do: acquire EM-SBP *without* any other SBP, and then compare to SBP-29 and Knudsen on the same line.

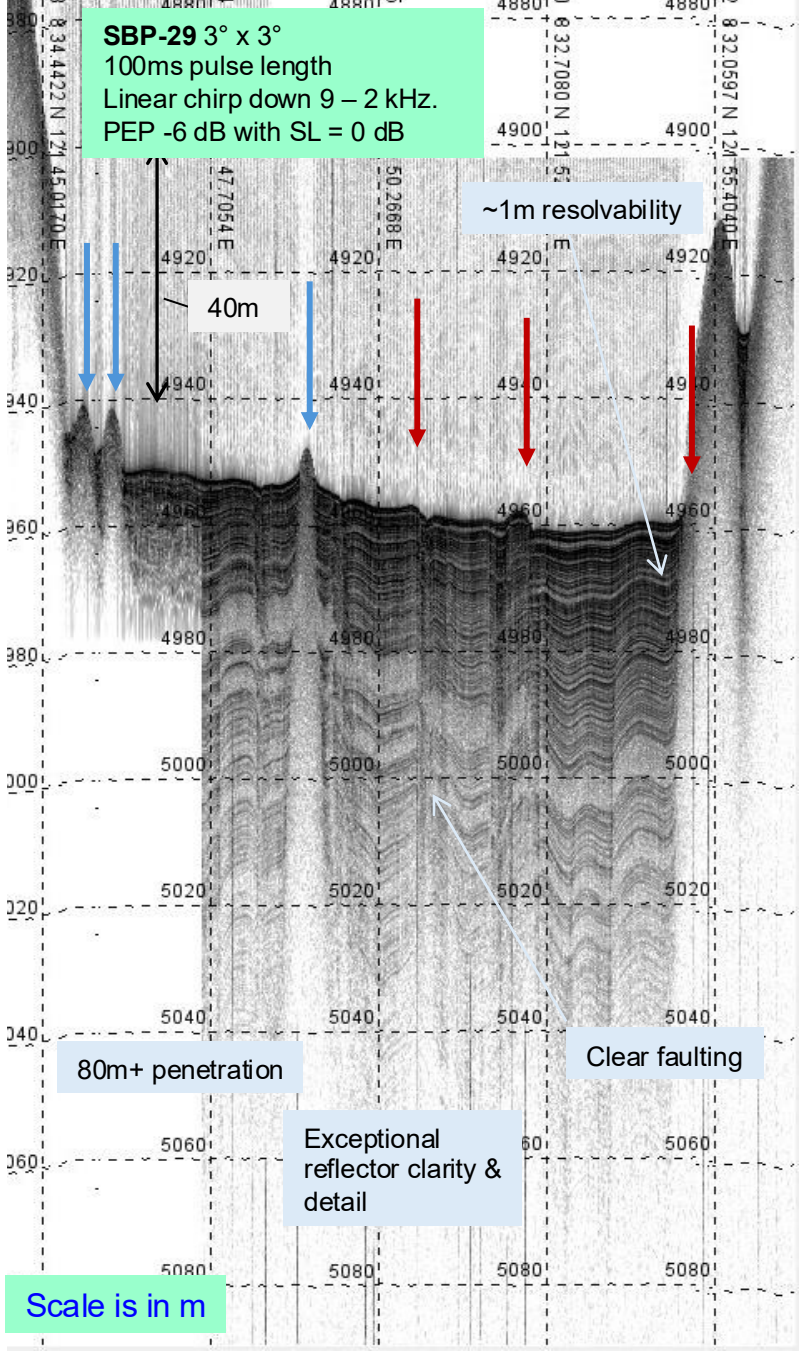


SBP comparison. Same extent for back-and-forth comparison

R/V THOMAS G. THOMPSON, TN-447

SBP comparison. Same scale.

Water depth ~4960m.
Data acquired at 10.2 knots.
Realtime acquisition screen

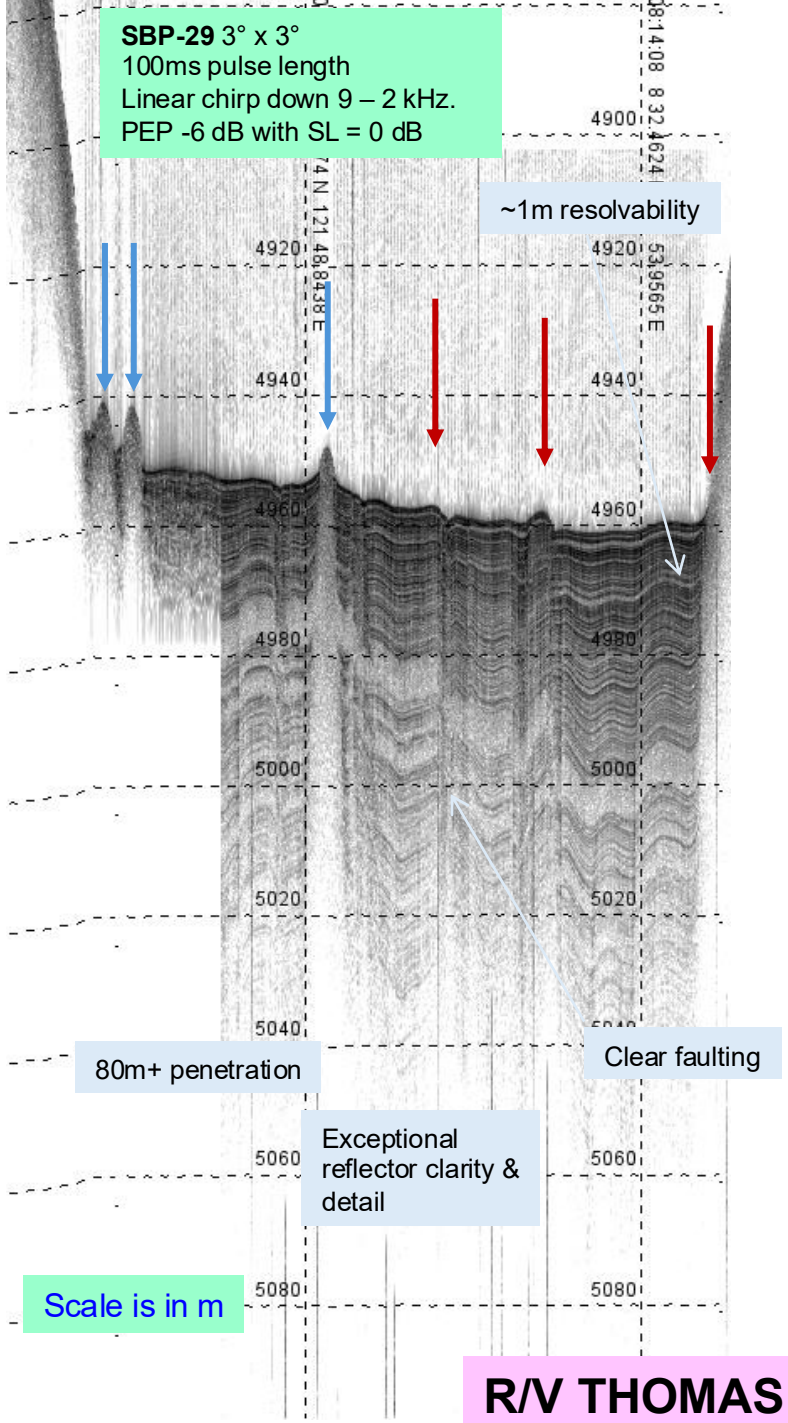


SBP comparison. Same extent for back-and-forth comparison

R/V THOMAS G. THOMPSON, TN-447

SBP comparison. Same scale.

Water depth ~4960m.
Data acquired at 10.2 knots.
Bjørnar Langli Processed



SBP comparison. Same extent for back-and-forth comparison

R/V THOMAS G. THOMPSON, TN-447

SBP comparison. Same scale.

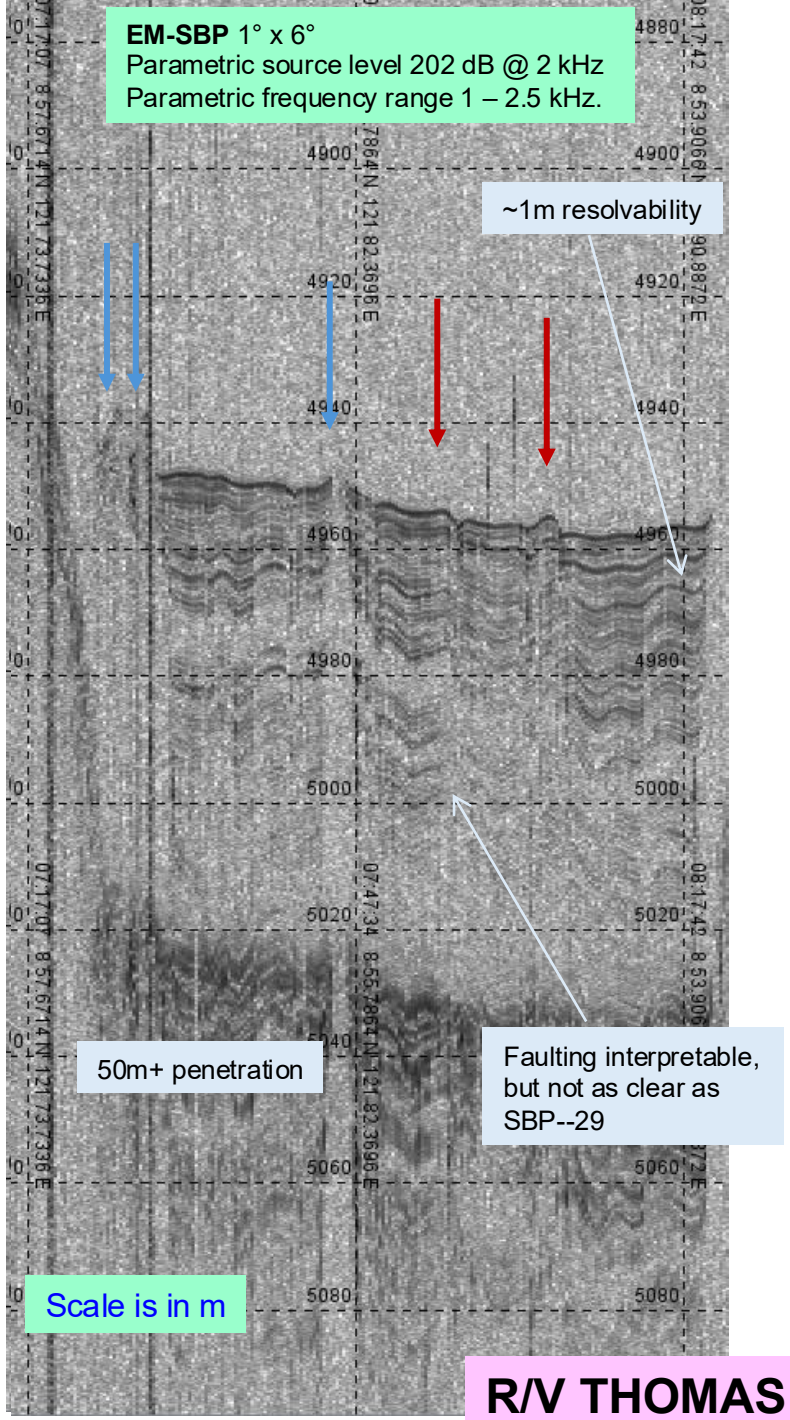
Water depth ~4960m.
Data acquired at 10.2 knots.
Bjørnar Langli Processed

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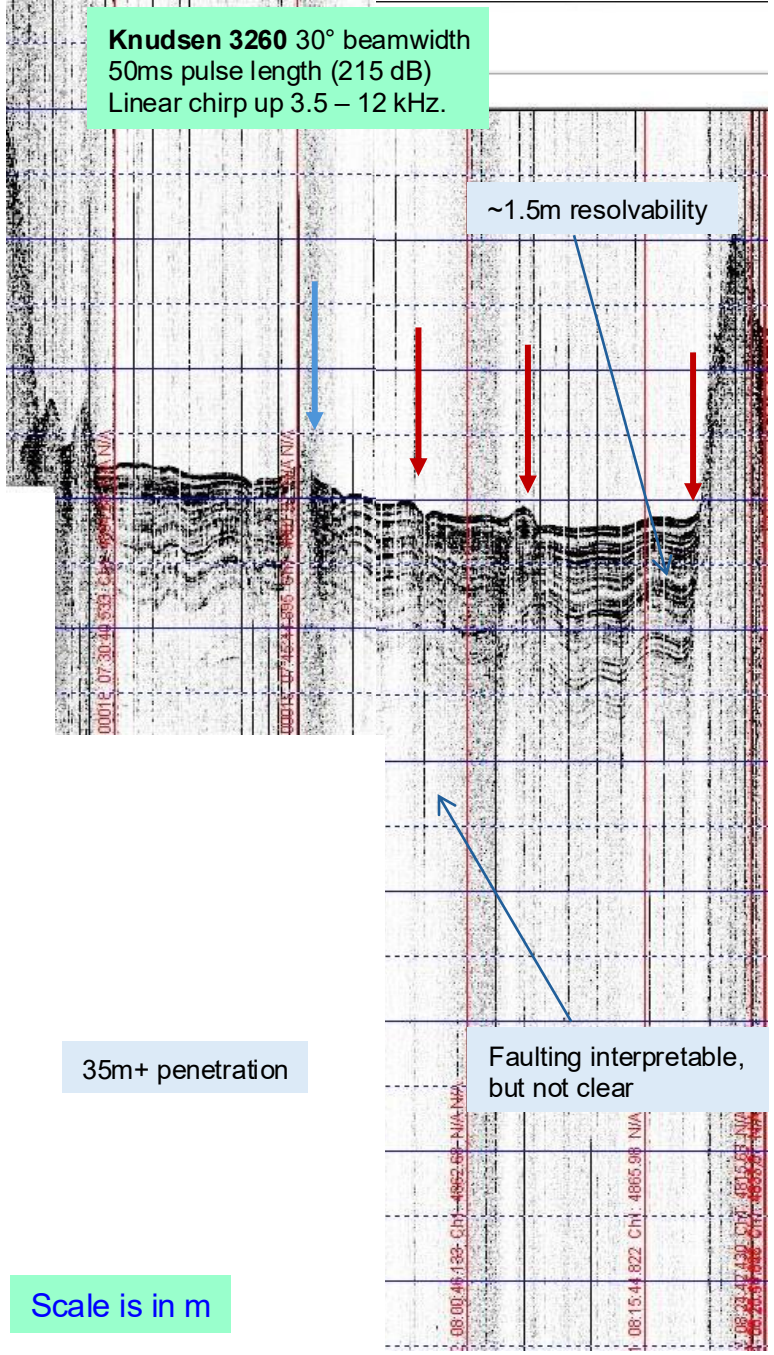
SBP comparison. Same extent for back-and-forth comparison



R/V THOMAS G. THOMPSON, TN-447

SBP comparison. Same scale.

Water depth ~4960m.
Data acquired at 10.2 knots.
Realtime acquisition screen

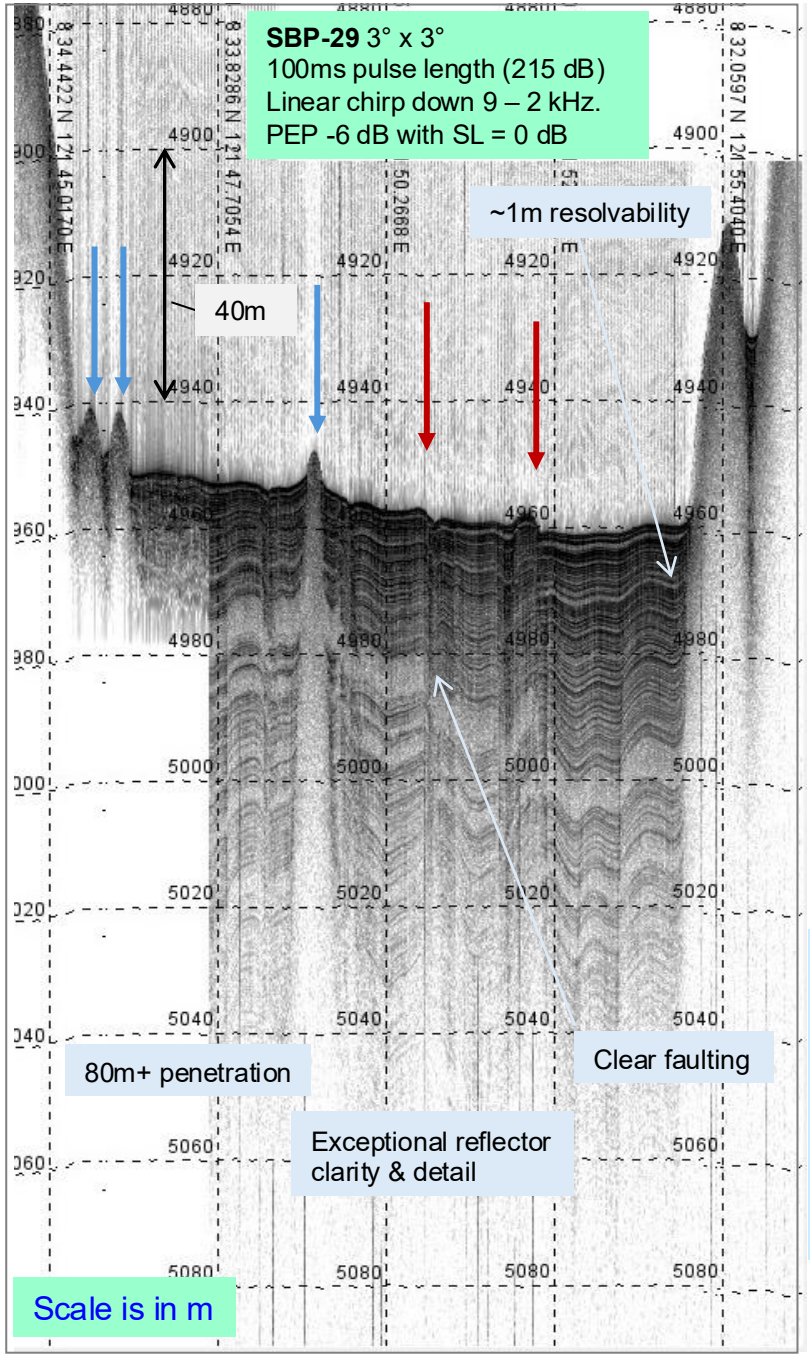


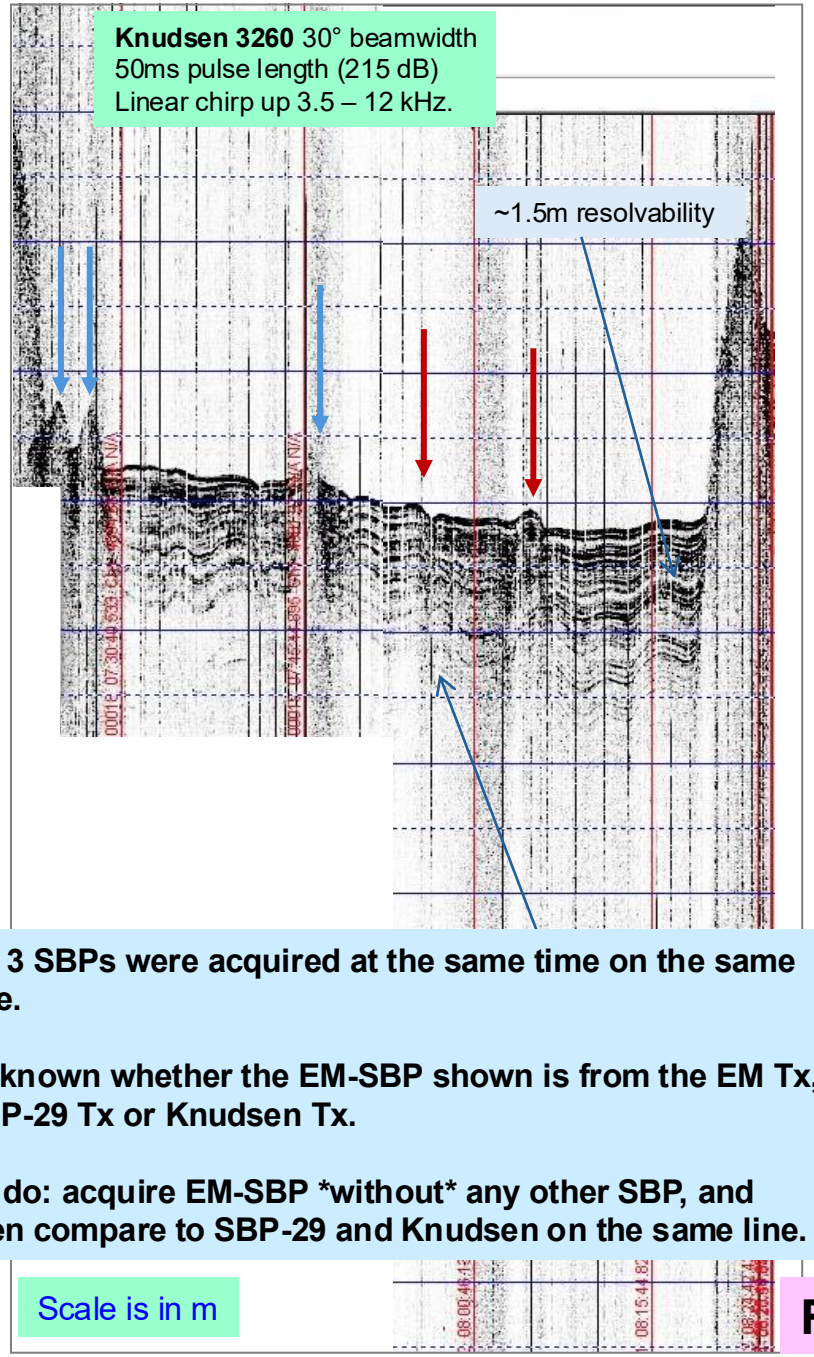
Scale is in m

SBP comparison. Same extent for back-and-forth comparison

R/V THOMAS G. THOMPSON, TN-447

Water depth ~4960m. | R/V THOMAS G. THOMPSON | **SBP comparison. Same scale.** | Data acquired at 10.2 knots.

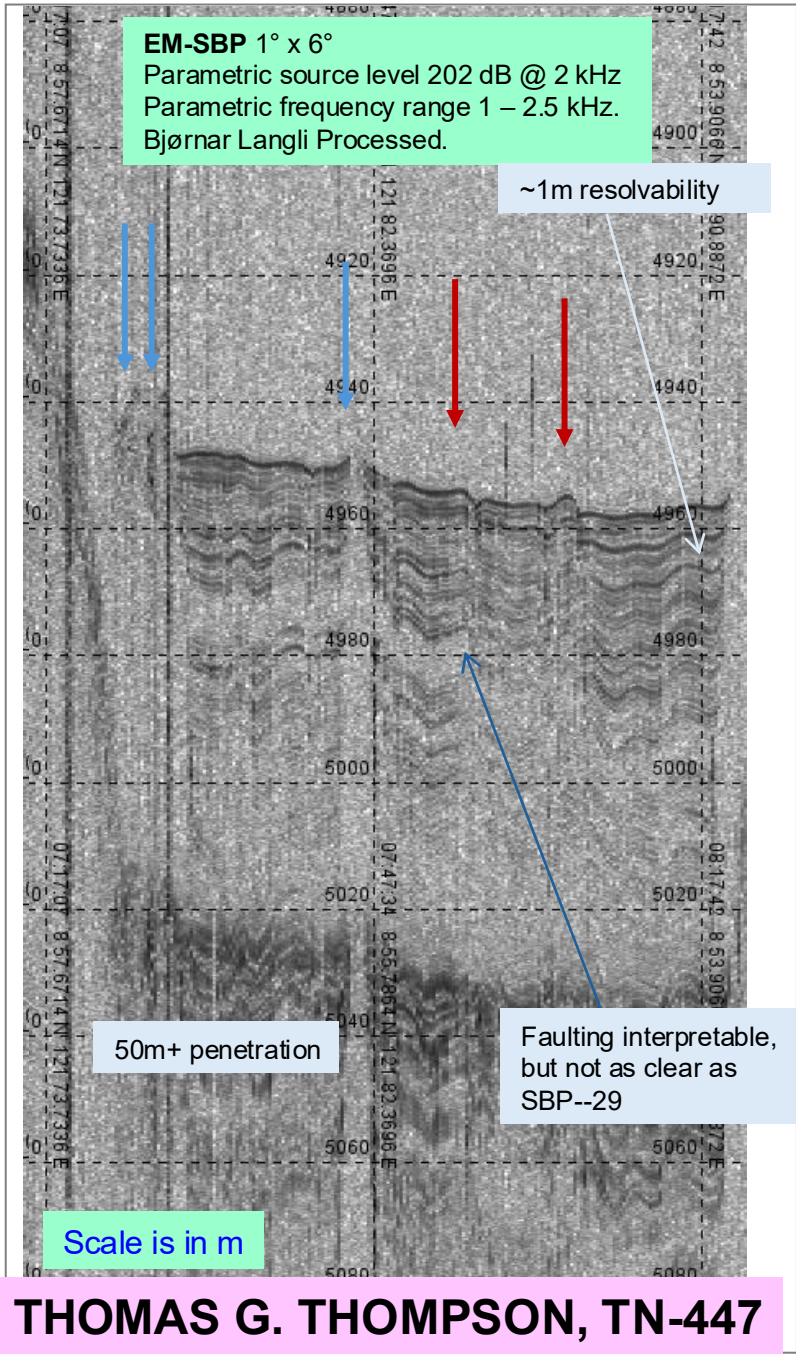




All 3 SBPs were acquired at the same time on the same line.

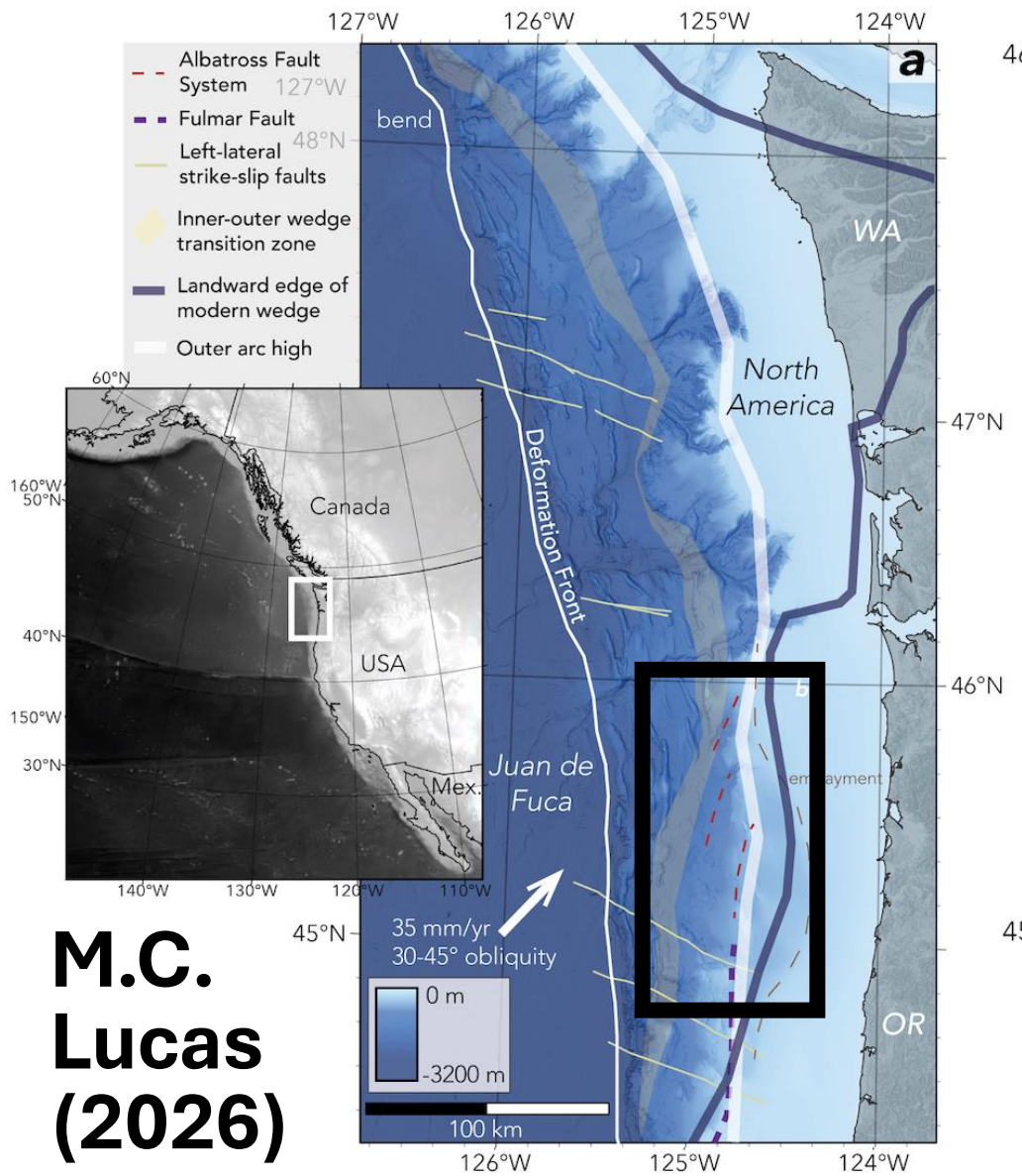
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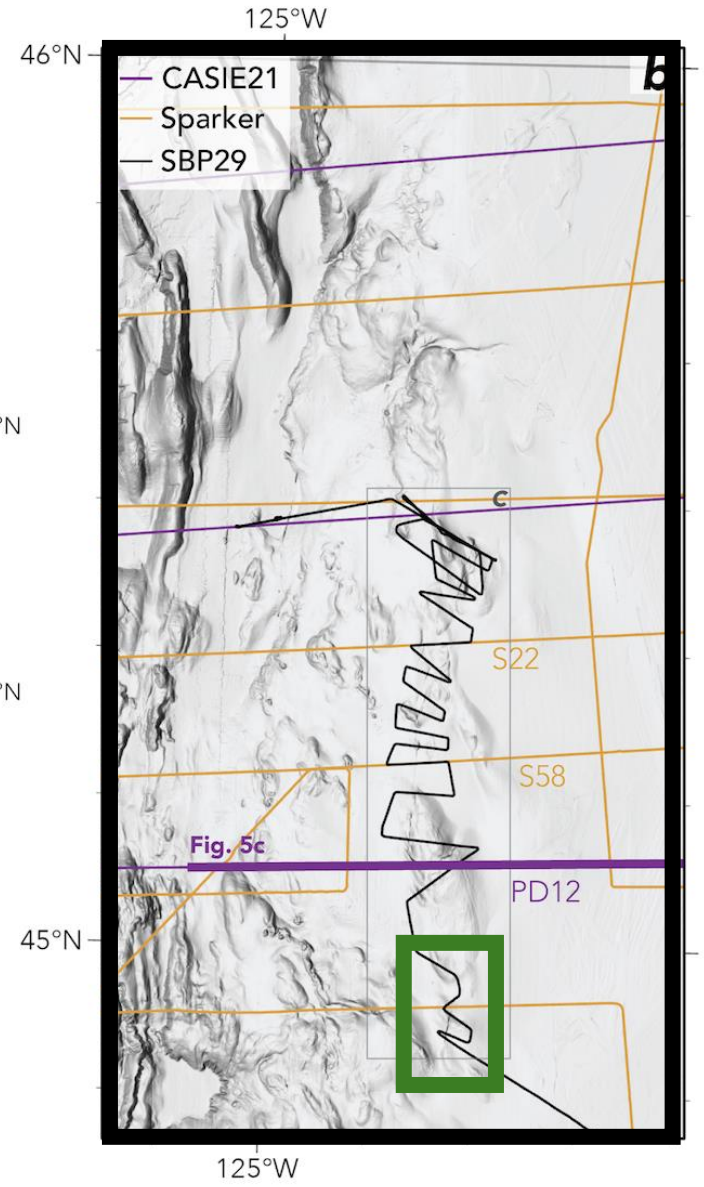
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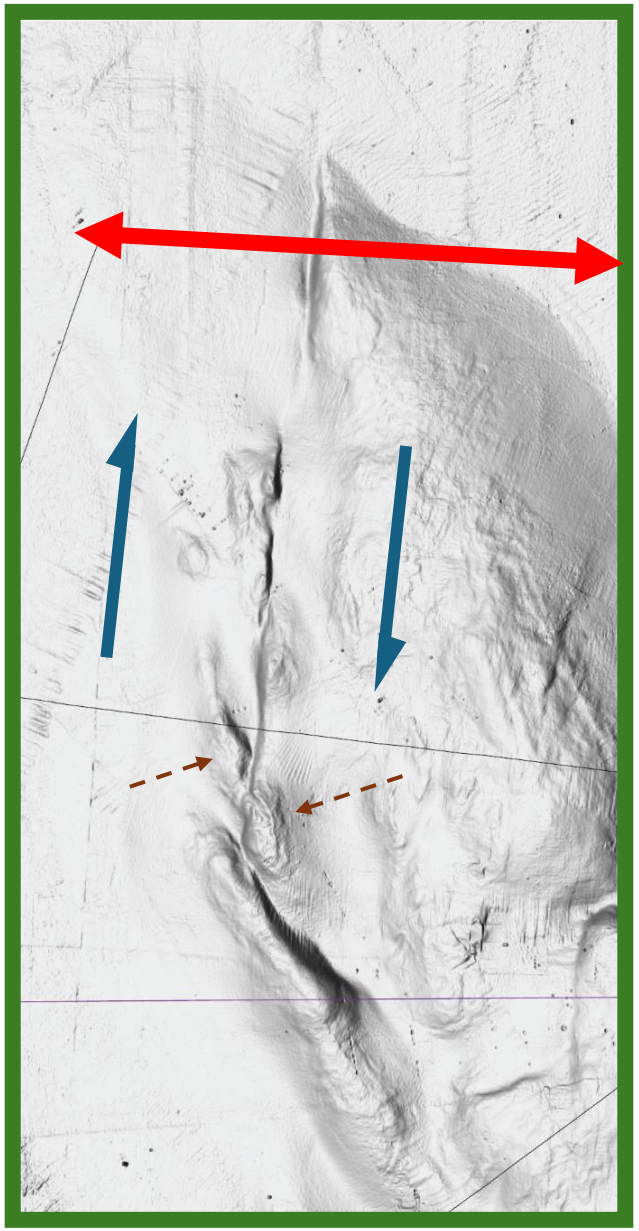


R/V THOMAS G. THOMPSON, TN-447

SR2414 & HLY26TB SBP29 surveys image active right-lateral strike-slip fault system offshore Oregon



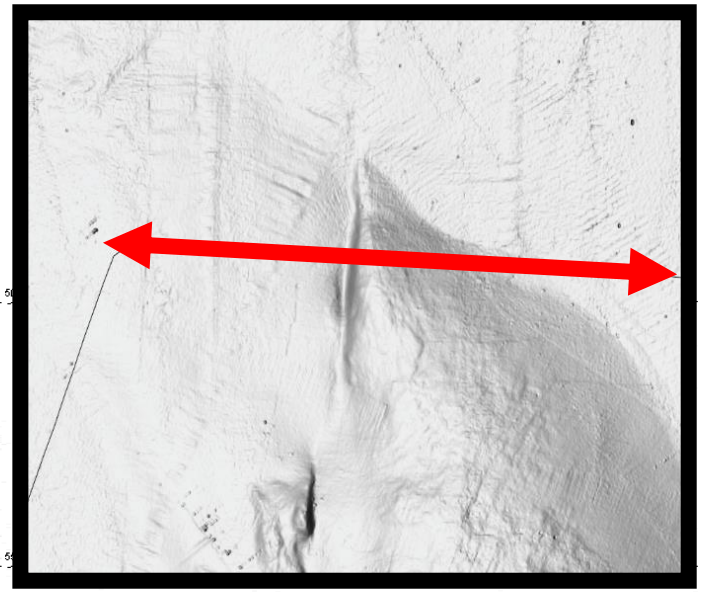




M.C. Lucas (2026)

SR2414 (R/V SALLY RIDE)

Both surveys resolve similar stratigraphy and fault structure at this location.



~60m fault scarp

~200 m

Acquisition speed = 10.7 kts (5.33 m/s)

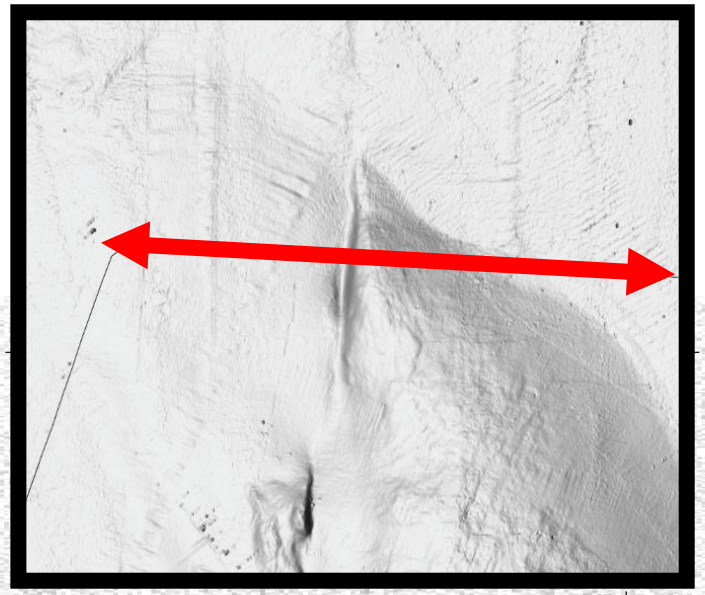
M. C. Lucas (2026)

HLY26TB (USCGC HEALY [WAGB-20])

Both surveys resolve similar stratigraphy and fault structure at this location.

HEALY has more noise than SALLY RIDE, potentially due to slightly higher acquisition speeds, weather sensitivity of the hull, or interference by 2cm titanium plate.
HEALY exhibits packet loss during this part of survey (vertical white lines).

Overall, HEALY SBP29 shows quality imaging of fault structure at high acquisition speeds.



~60m fault scarp

~200 m

Acquisition speed = 12.2 kts (6.19 m/s)

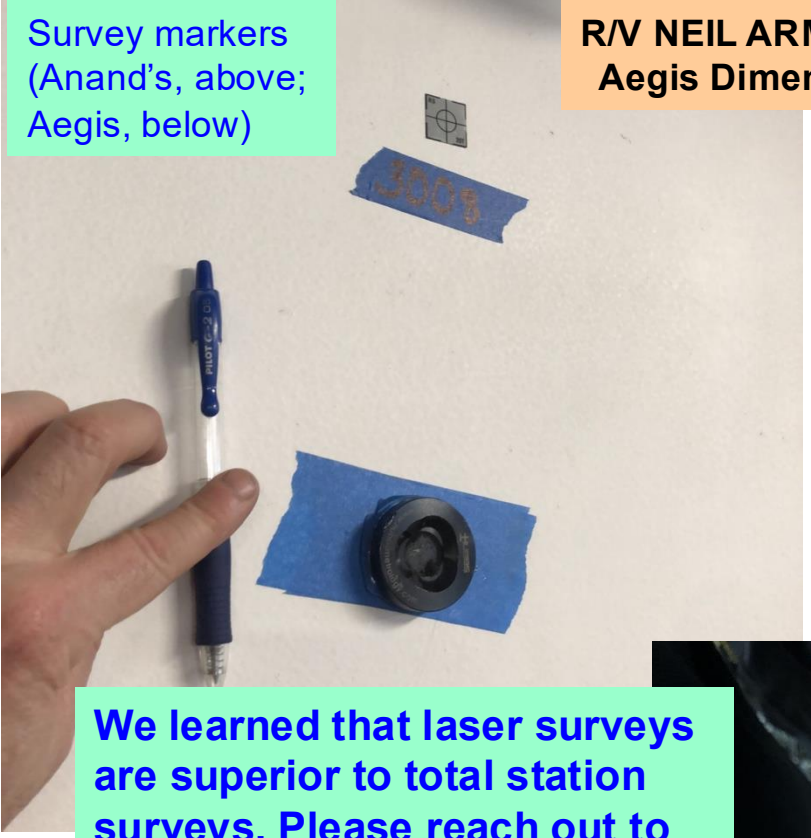
M. C. Lucas (2026)

SBP 29: Concluding Thoughts

- Successful installation and SATs of SBP29 on R/Vs SALLY RIDE, NEIL ARMSTRONG, THOMAS G. THOMPSON, and USCGC HEALY (WAGB-20). All 3°x6° except THOMPSON, 3°X3°.
- SBP29 provides AUV quality SBP sufficient to image geology allowing for testable hypotheses of timing and process (slope failure / slumps, faulting, anti-dune sedimentation, etc.).
- SBP29 quality degrades with depth. We have acquired outstanding data at 3600m, useable data at 5460m, but no identifiable reflectors 6000m or deeper. Wider basins with consistent reflectors may yield better SBP at greater depths.
- In “Apples-to-Apples” acquisition, SBP-29 acquires higher resolution and more penetration than Knudsen, and adds spectacular detail to the upper sections of Ultra-High Resolution Multi-Channel Seismic and long streamer Multi-Channel Seismic.
- In “Apples-to-Apples” acquisition in ~3200m, EM-SBP, when acquired at the same time as SBP-29 and Knudsen, can achieve resolvable horizons with penetration up to 65m. In this comparison, SBP-29 images more / finer reflectors, and resolvable horizons to 80m.
- NSF-funded data are not meeting open-access requirements for scientists to access useable raw SBP-29 data (TOPAS.raw), hindering uptake. A solution would be for Kongsberg to host the SBP-29 software on their existing software access website.

R/V NEIL ARMSTRONG 2024
Aegis Dimensional Survey

Survey markers (Anand's, above; Aegis, below)





Laser total station

Granite Block (ship's origin)

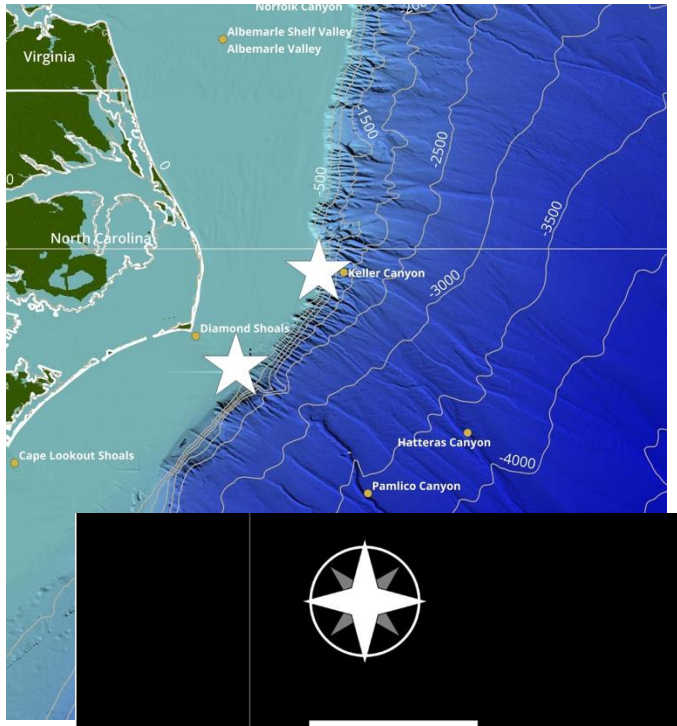
We learned that laser surveys are superior to total station surveys. Please reach out to DanO and/or Anand Hiroji for more detailed discussion on this, including how to revise contract specifications for Dimensional Surveys.

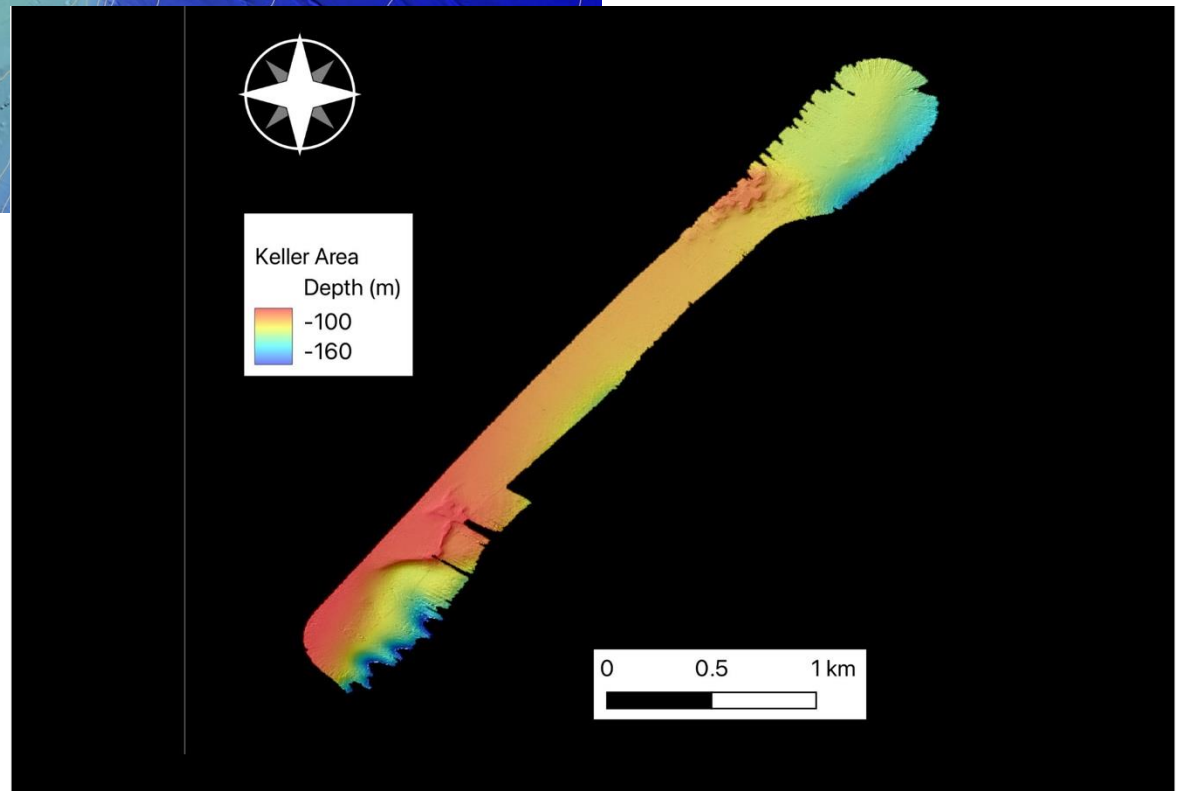


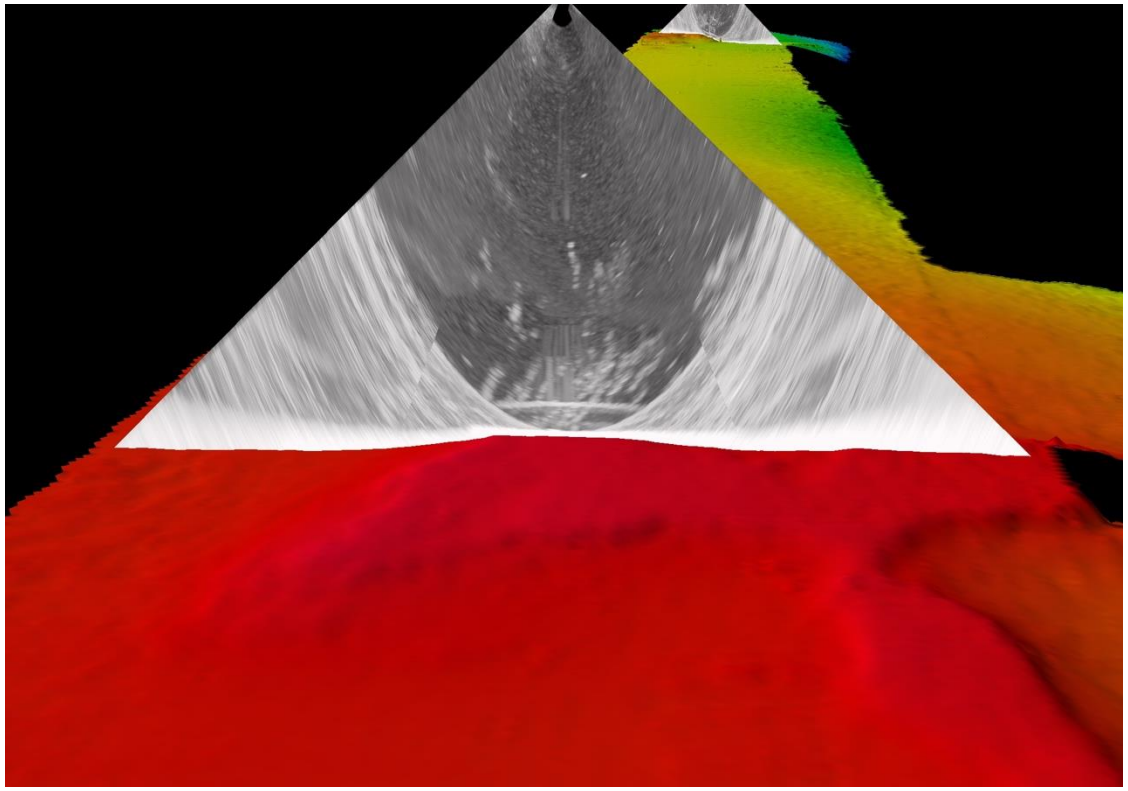
Aegis survey target

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Results: EM712
Keller Mound Seeps

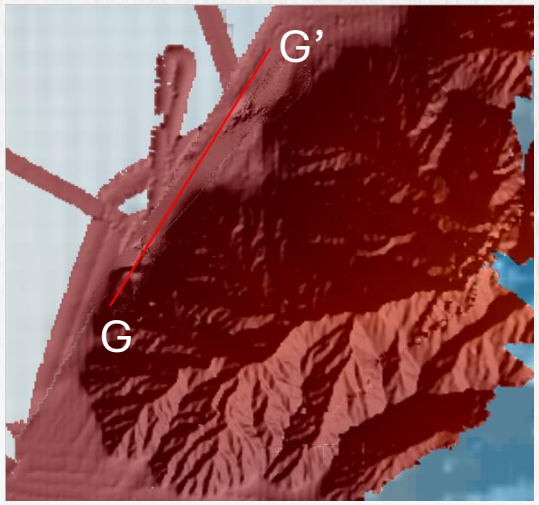






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North Carolina shelf. Keller Mound Seeps. Legacy SBP.



1 km

25 m

USGS 2017-002-FA Edgetech 512i
Asynchronous with Reson 7160 MBES
Shot at ~ 5 kts, 1900 traces.

Ship track missed
Northern mounds

Bubble plumes

Gas wipeout with vertical chimneys

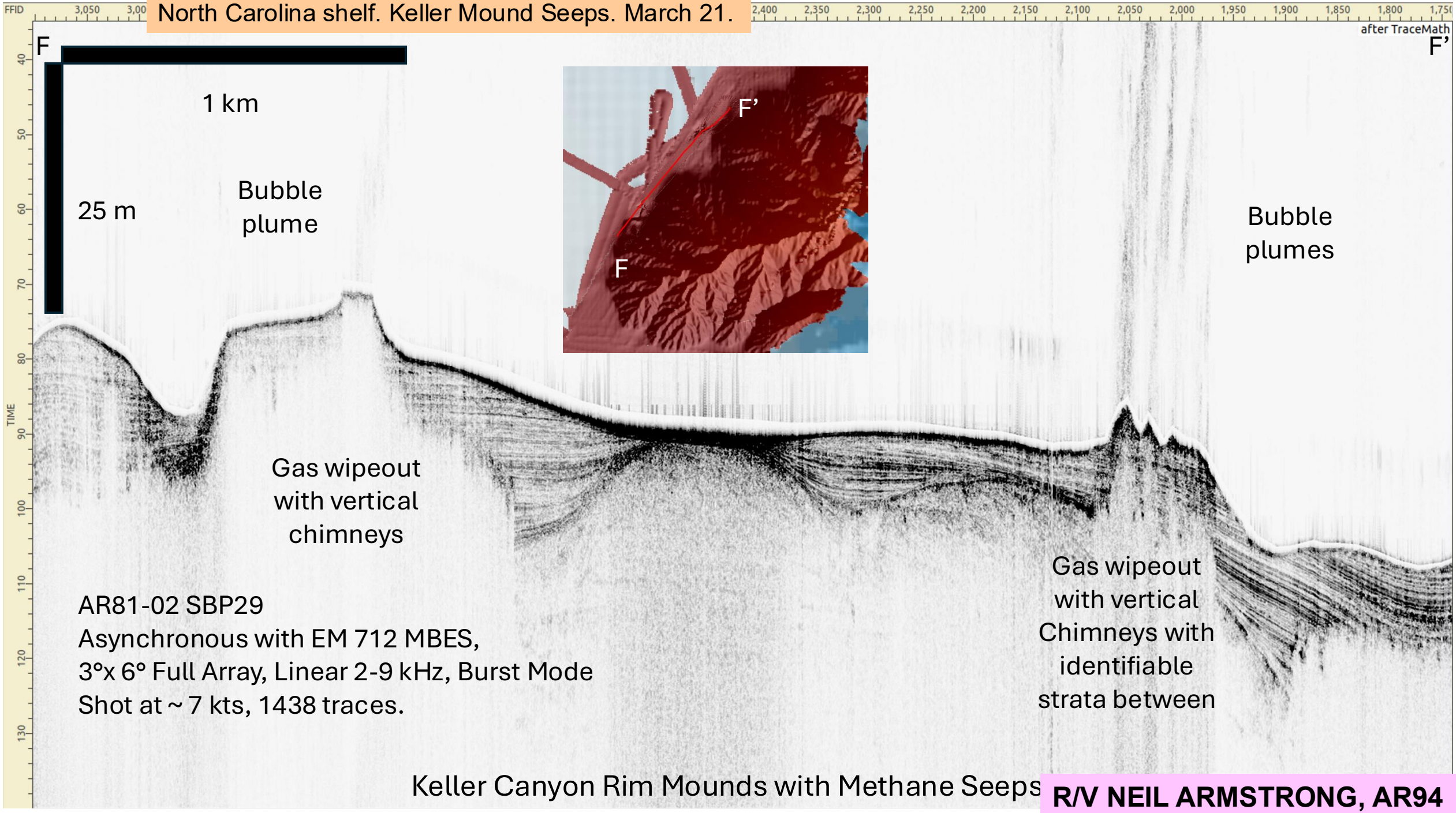
Ghost Reflection

Gas wipeout

Keller Canyon Rim Mounds with Methane Seeps

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North Carolina shelf. Keller Mound Seeps. March 21.



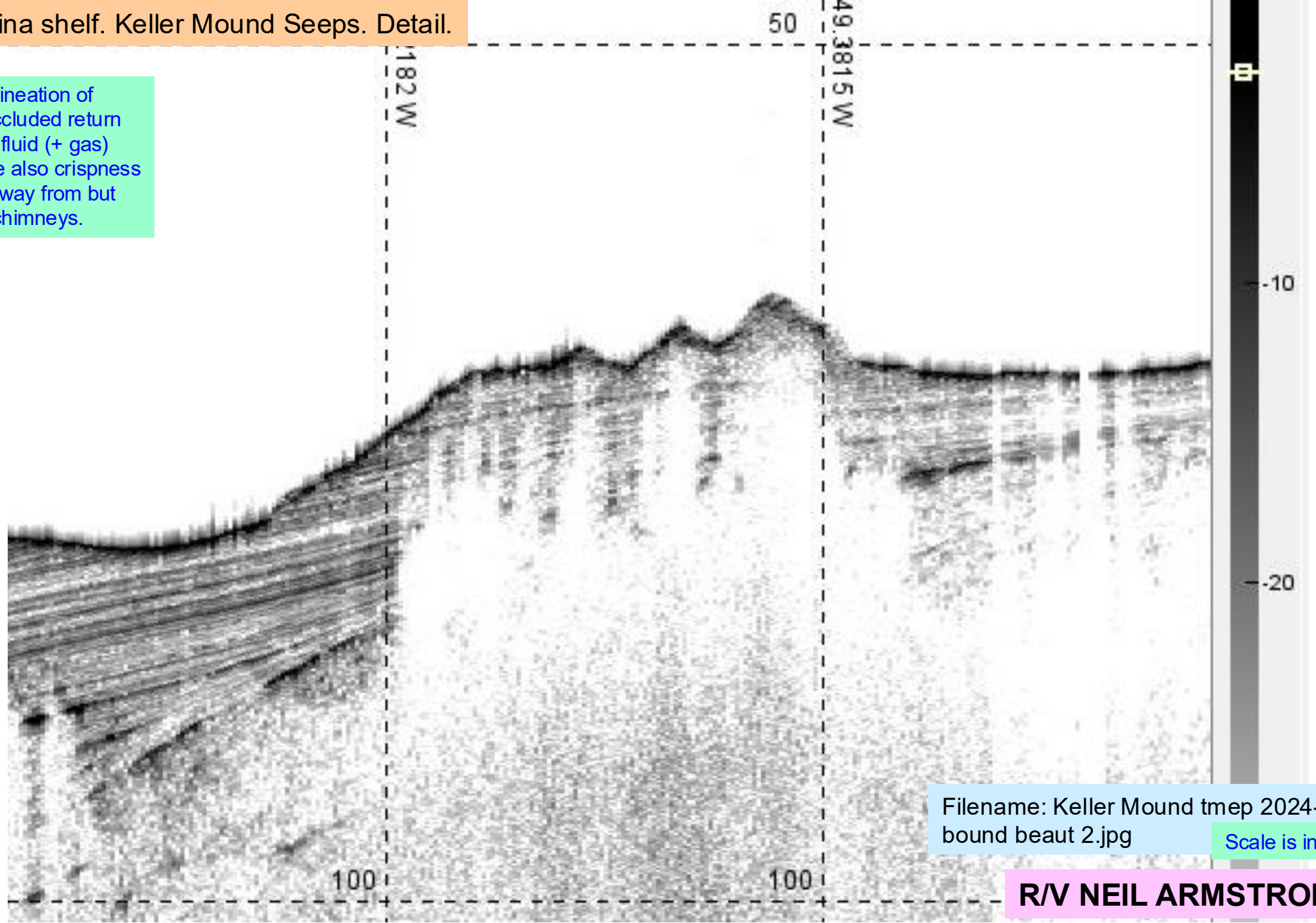
AR81-02 SBP29
Asynchronous with EM 712 MBES,
3°x 6° Full Array, Linear 2-9 kHz, Burst Mode
Shot at ~ 7 kts, 1438 traces.

Keller Canyon Rim Mounds with Methane Seeps

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North Carolina shelf. Keller Mound Seeps. Detail.

Note crisp delineation of subsurface occluded return suggestive of fluid (+ gas) conduits. Note also crispness of reflectors away from but abutting gas chimneys.

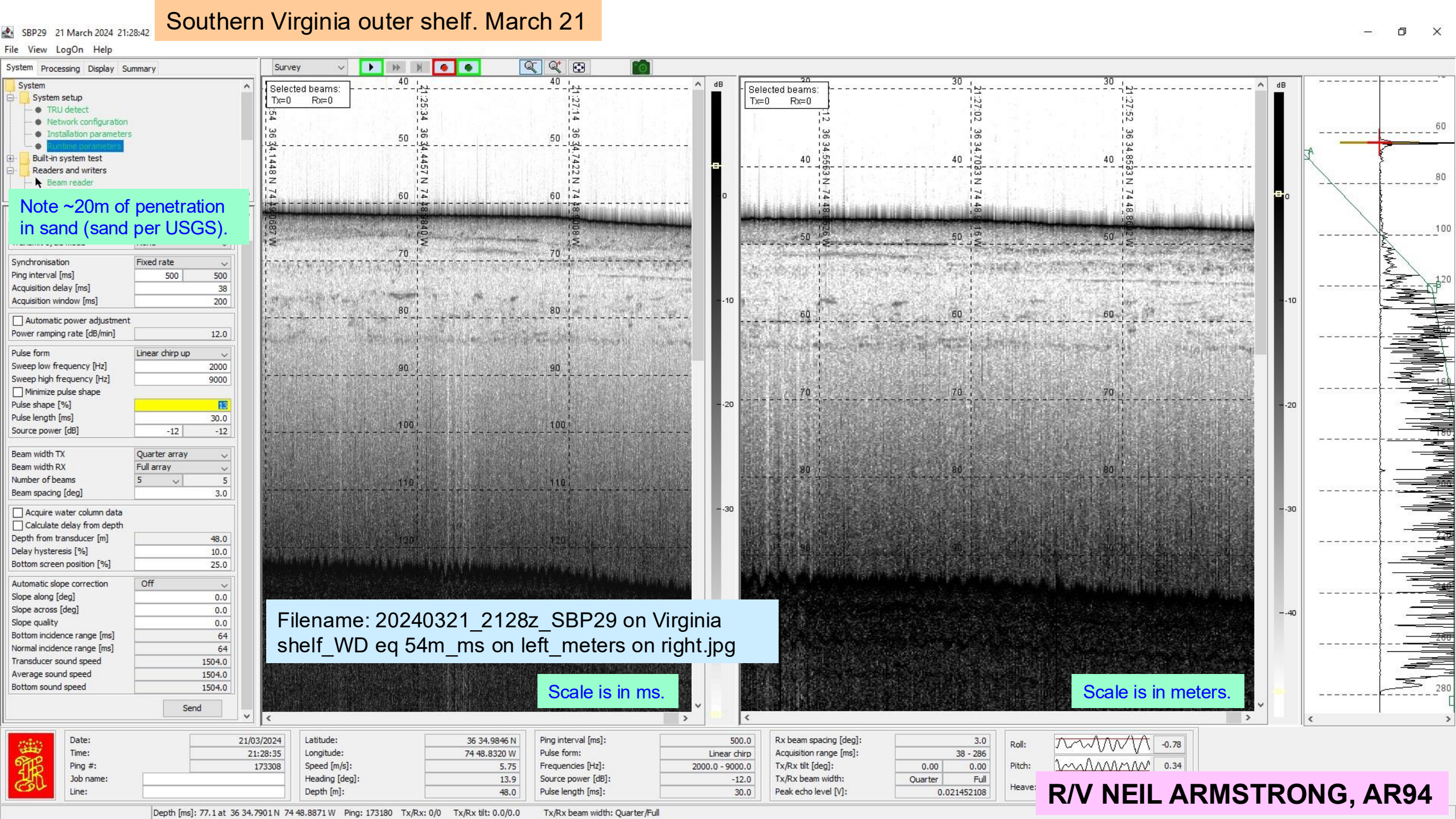


Filename: Keller Mound tmep 2024-03-21_SW bound beaut 2.jpg

Scale is in meters.

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Southern Virginia outer shelf. March 21



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Reflection Coefficient $\mathcal{R}$
[or Bottom Loss]

Charles Holland

Background

Objective: use the SBP29 to obtain the geoacoustic properties of the seabed

Key geoacoustic properties:

- Compressional wave speed as a function of depth
- Bulk density (porosity) as a function of depth
- Compressional wave attenuation as a function of depth

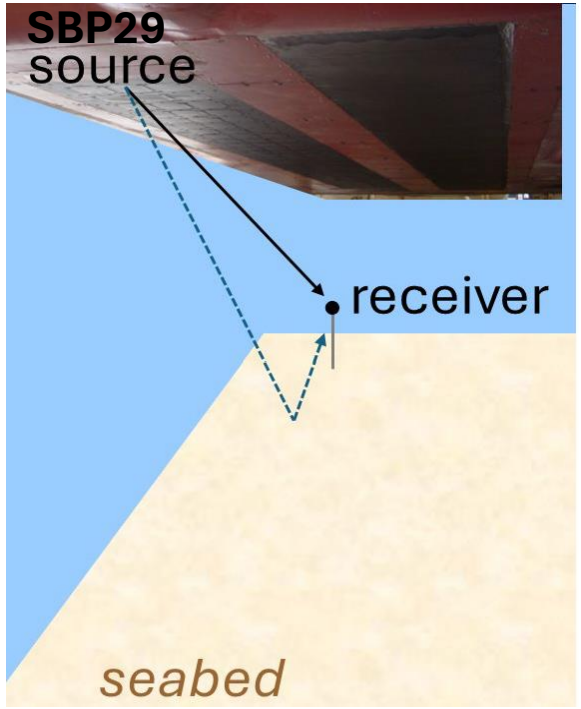
An observable with high geoacoustic information content: **frequency-domain, wide angle reflection coefficient $\mathcal{R}$** [or Bottom Loss]

Enabling tech: SBP29 single element transmit mode (broad alongship beamwidth)

Source: SB29 (2-9 kHz)

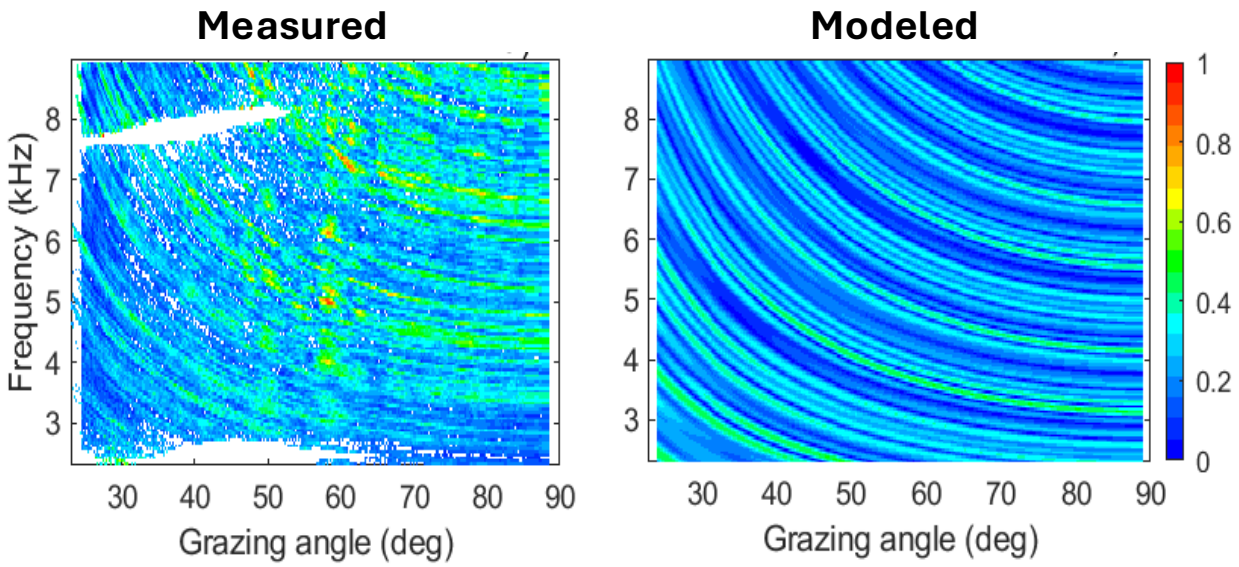
Receiver: offboard single hydrophone, fixed on bottom mooring or drifting

$\mathcal{R}$ is the scaled ratio of the seabed reflected path and the direct path



Holland C.W., Henderson C.R., Sonnemann T., Langli B., and Orange, D.L., Seabed wide-angle reflection coefficient and source radiation pattern measurements from a low frequency multibeam sonar, *IEEE J. Oceanic Eng.*, 51(3), 2298-2313, 2026

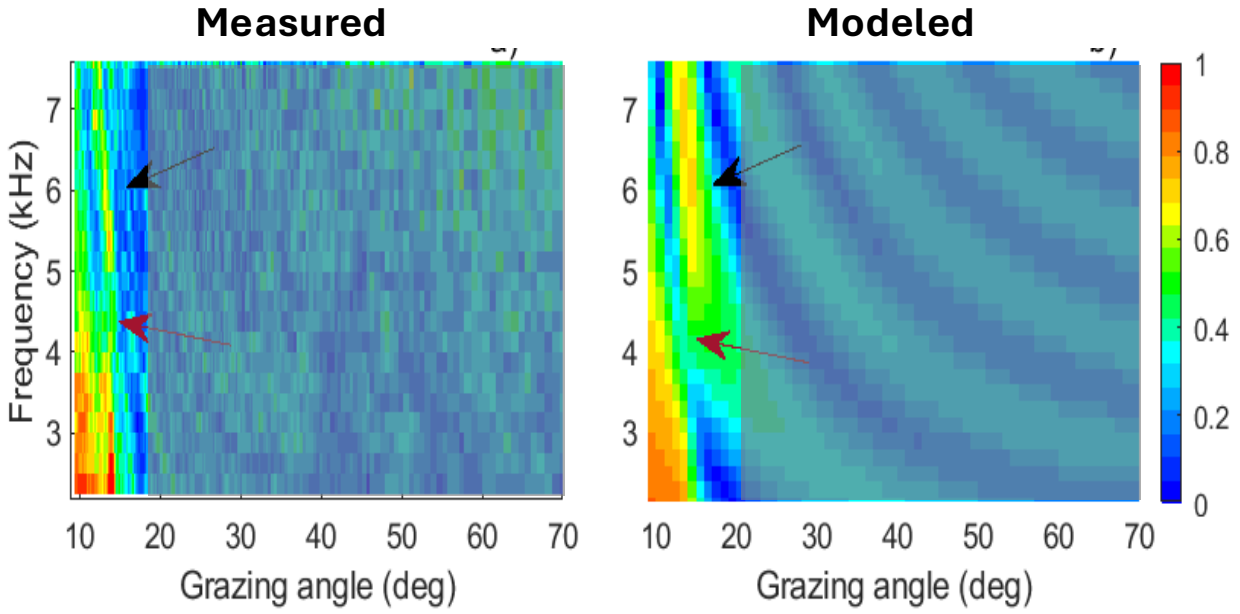
Measurements & modeling



Santa Barbara Basin, So. California, 576 m water depth

Thickness (m)	Sound speed (m/s)	Attenuation (dB/m/kHz)	Density (kg/m^3)	
water	*1486*	*0*	*1000*	
0.9	1455	0.02	1300	Biogenic, summer
2.8	1500	0.1	1700	Terrigenous, winter
1.5	1445	0.03	1400	Biogenic, summer
0.6	1514	0.1	1900	Terrigenous, winter
basement	1464	0.05	1700	

quasi-periodic structure explains much of the data



Eel River shelf, Nor. California, 97 m water depth

Thickness (m)	Sound speed (m/s)	Attenuation (dB/m/kHz)	Density (kg/m^3)
water	1487	0	1000
0.6	1495	0.1	1600
basement	1535	0.1	1800

- Critical angle at 14° yields basement sound speed
- ridge-gap (2 arrows) due to constructive /destructive interference. Their positions & amplitudes yield sediment layer properties & some basement properties
- Scattering from interface roughness(es) and/or volume heterogeneities obscures the interference pattern >20°

Summary

- demonstrated the ability to measure 2-9 kHz wide-angle seafloor reflection coefficient (Bottom Loss) data using a single element of the SBP29 and 1 off-board hydrophone

- showed that the sediment sound speed, density, and attenuation structure as a function of depth can be inferred from those data

SBP 29: Concluding Thoughts

- Successful installation and SATs of SBP29 on R/Vs SALLY RIDE, NEIL ARMSTRONG, THOMAS G. THOMPSON, and USCGC HEALY (WAGB-20). All 3°x6° except THOMPSON, 3°X3°.
- SBP29 provides AUV quality SBP sufficient to image geology allowing for testable hypotheses of timing and process (slope failure / slumps, faulting, anti-dune sedimentation, etc.).
- SBP29 quality degrades with depth. We have acquired outstanding data at 3600m, useable data at 5460m, but no identifiable reflectors 6000m or deeper. Wider basins with consistent reflectors may yield better SBP at greater depths.
- In “Apples-to-Apples” acquisition, SBP-29 acquires higher resolution and more penetration than Knudsen, and adds spectacular detail to the upper sections of Ultra-High Resolution Multi-Channel Seismic and long streamer Multi-Channel Seismic.
- In “Apples-to-Apples” acquisition in ~3200m, EM-SBP, when acquired at the same time as SBP-29 and Knudsen, can achieve resolvable horizons with penetration up to 65m. In this comparison, SBP-29 images more / finer reflectors, and resolvable horizons to 80m.
- NSF-funded data are not meeting open-access requirements for scientists to access useable raw SBP-29 data (TOPAS.raw), hindering uptake. A solution would be for Kongsberg to host the SBP-29 software on their existing software access website.

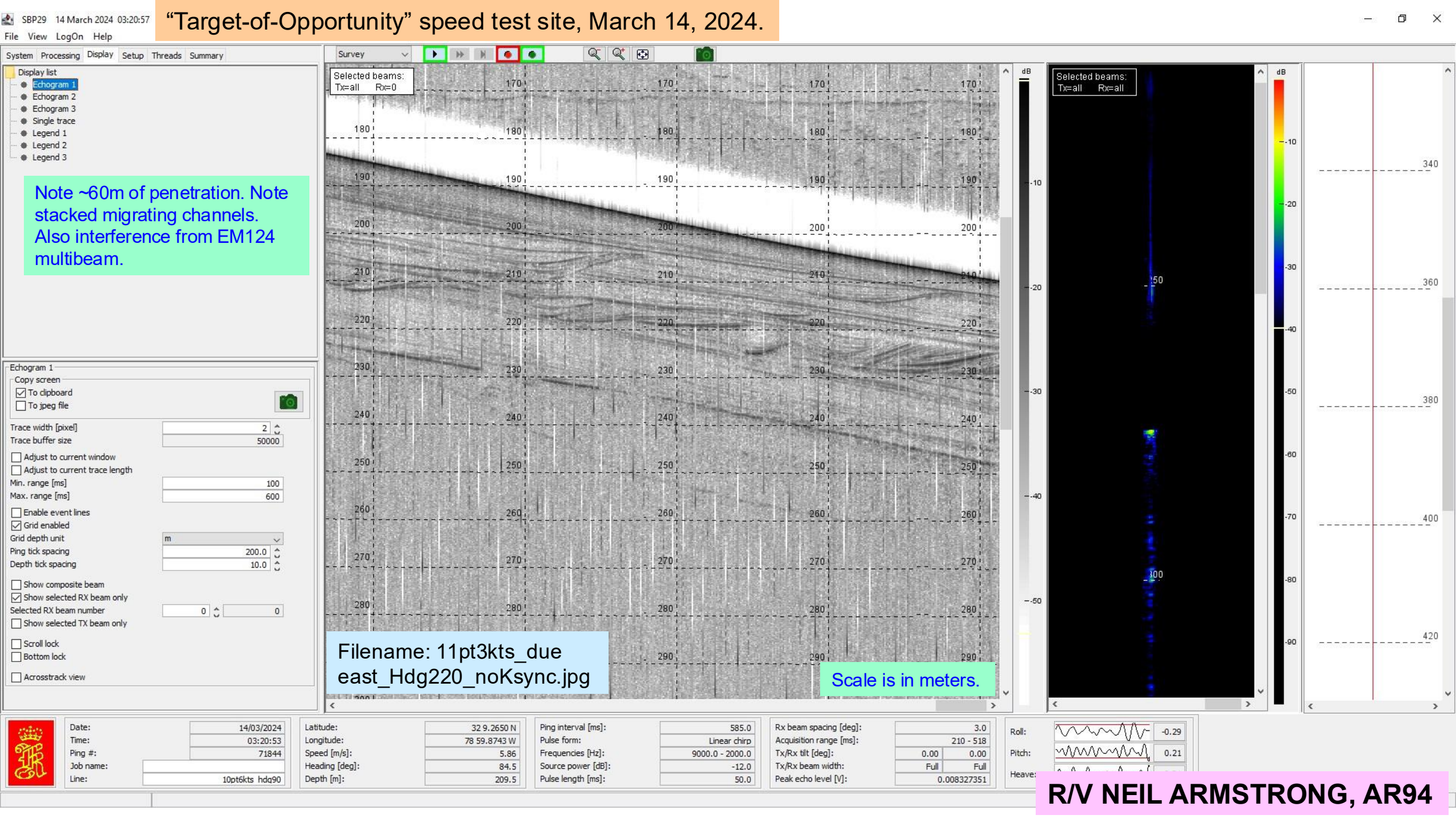


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Detyen's Shipyard, Charleston



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“Target-of-Opportunity” speed test site, March 14, 2024.



R/V NEIL ARMSTRONG, AR94