Seafloor Reflectivity Anomalies and Their Relationship to Surficial and Shallow Gas Hydrate Occurrence

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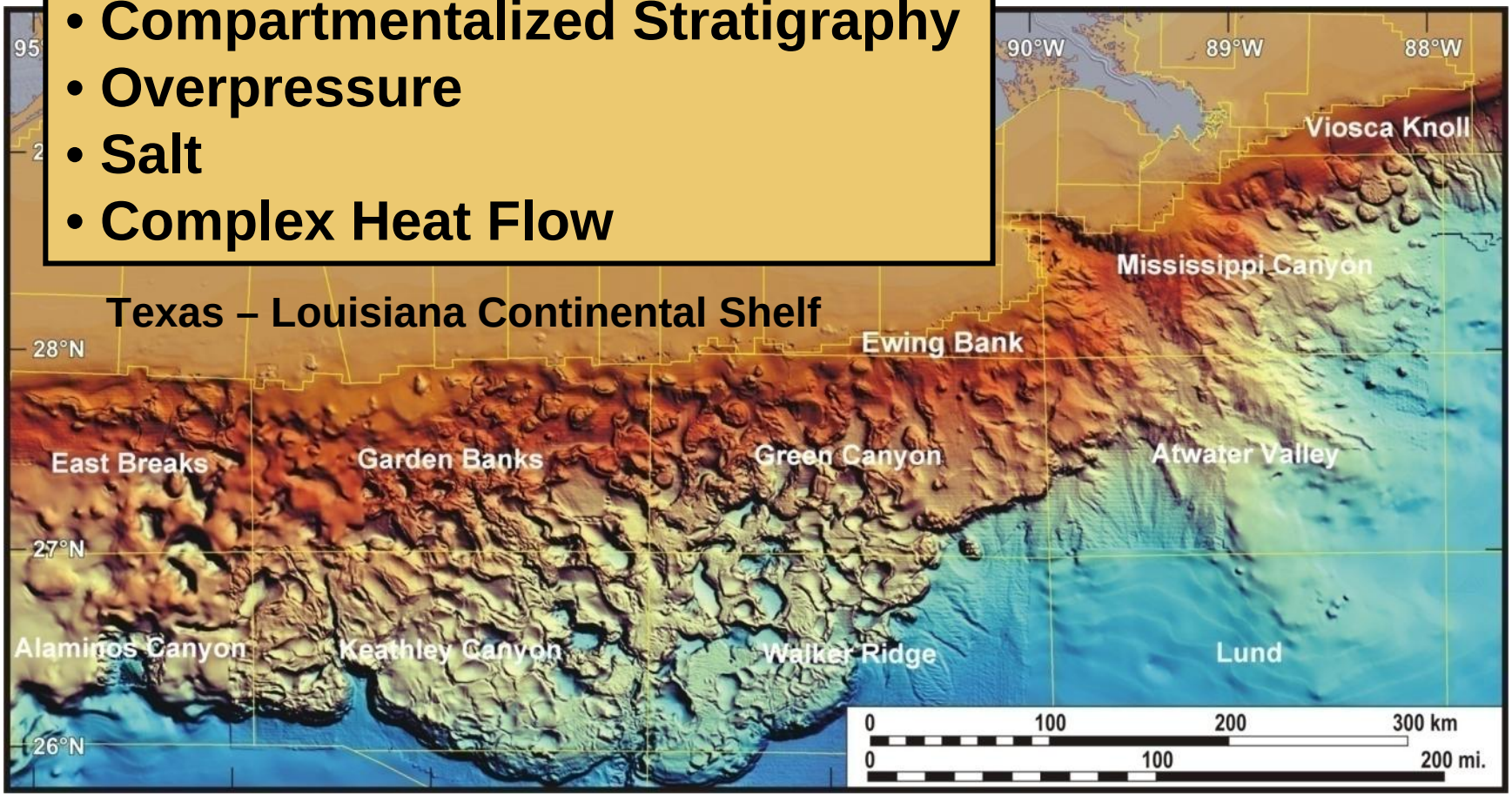
Presentation Points

- **Complex Geologic Framework that Promotes Fluid-Gas Expulsion**
- **Slope-Wide 3D-Seismic Database**
- **Reasons for Seafloor Reflectivity (Amplitude Anomalies)**
- **Relationships of Reflectivity Anomalies and Gas Hydrates – Examples**

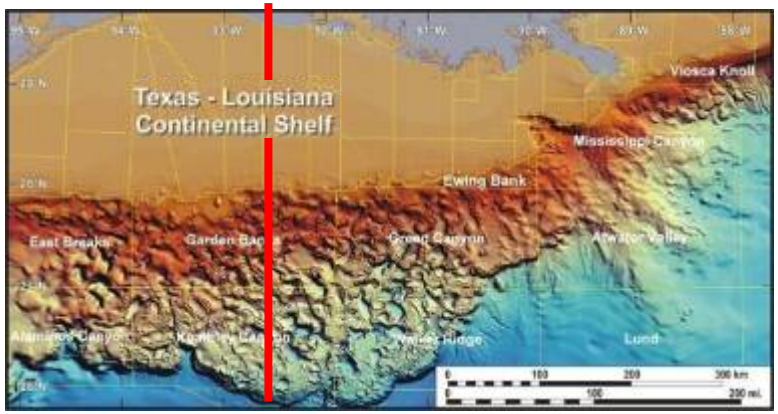
Louisiana Continental Slope

SUBSURFACE GEOLOGY

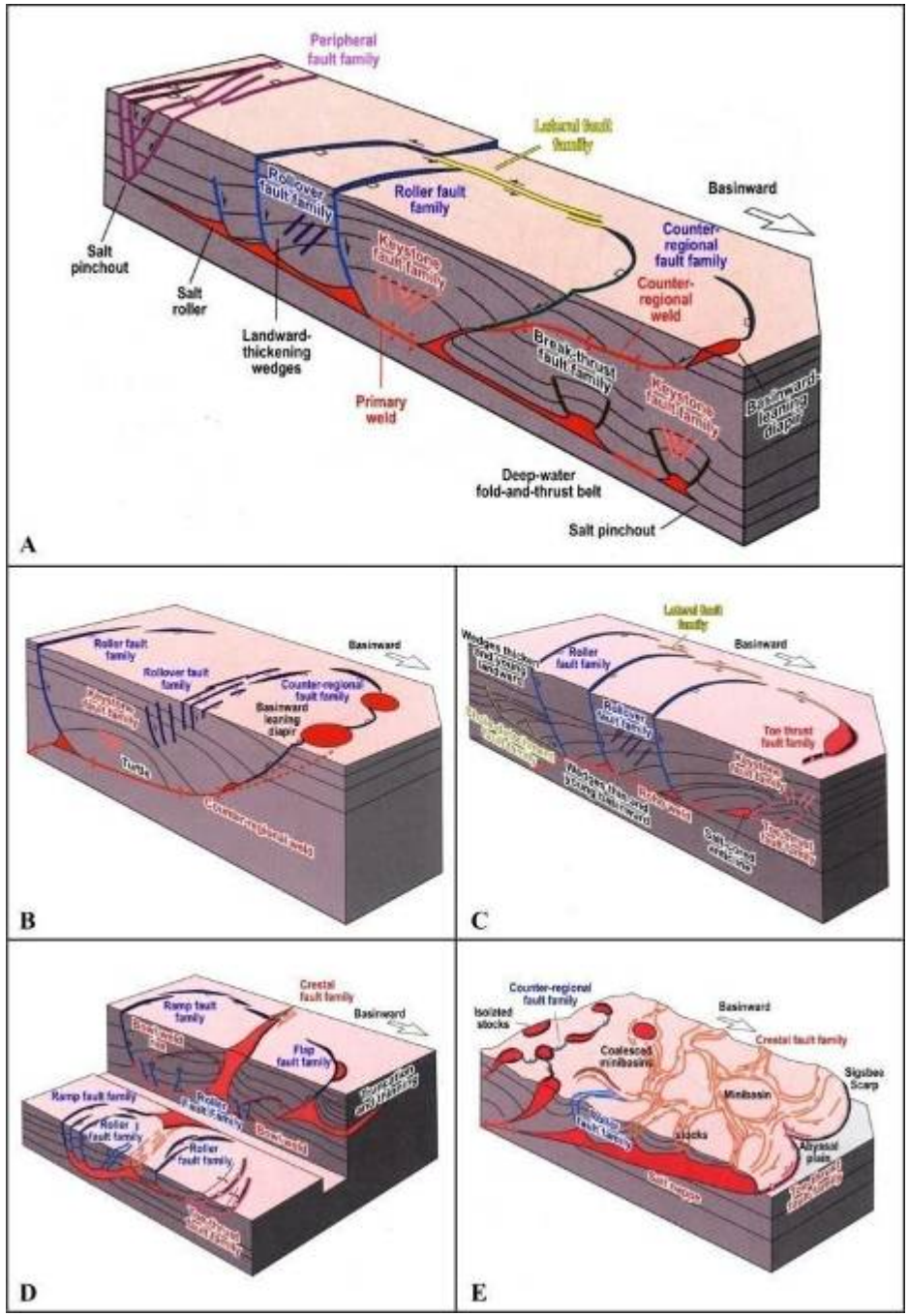
- Numerous Faults
- Compartmentalized Stratigraphy
- Overpressure
- Salt
- Complex Heat Flow



Cross-Continental Margin Structural Styles



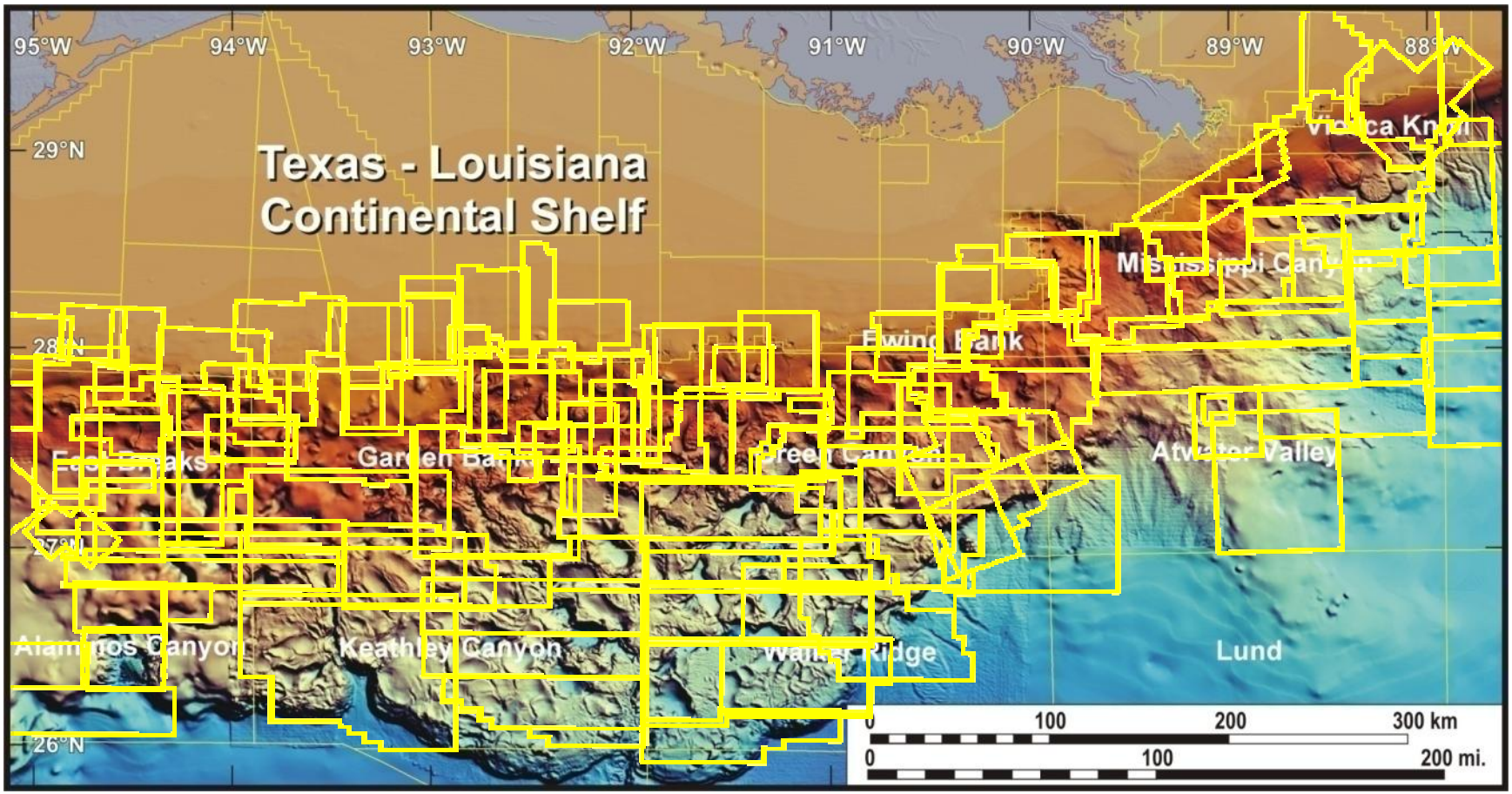
(From Rowan 1999)



Slope-Wide Remotely Sensed Data

- **Multibeam Bathymetry**
- **3D-Seismic**

Louisiana Continental Slope
3D-Seismic Coverage



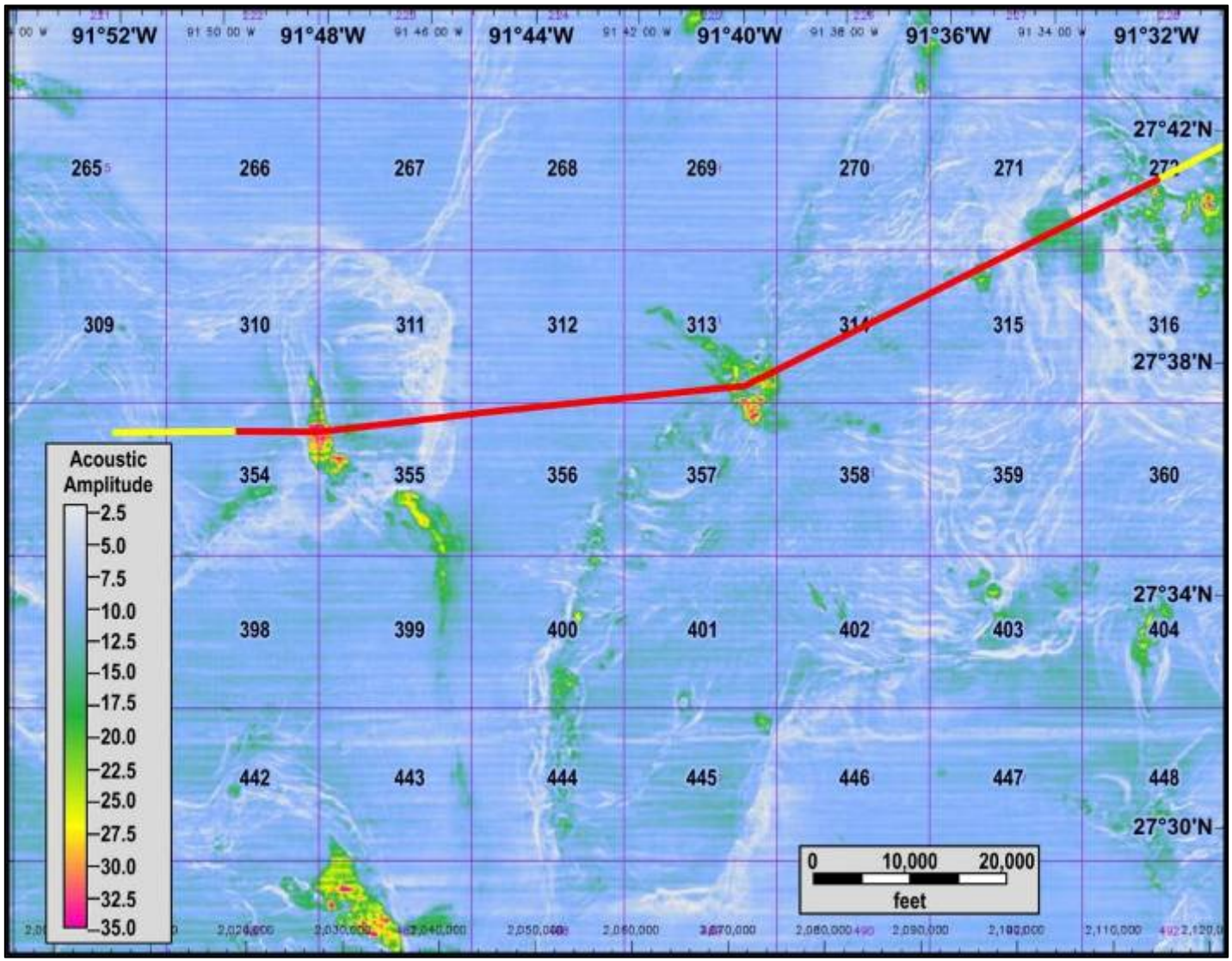
Benefits of 3D-Seismic Data

- **Surface Reflectivity**
- **Phase Relationships**
- **Infinite Subsurface Perspectives**

Data Characteristics and Procedures

1. Used GeoQuest's IESX Interpretation Software
2. Seafloor Identified (Auto- and Hand-Picked) – Generally a Strong Reflector
3. Posted Seafloor Amplitude Extraction for Survey and Selected Sites of Interest
4. High Positives – Hard Bottom Areas
5. Low Positives or Negatives – Gas-Rich Sediments
6. Plan-View Amplitude Patterns – Flows, Cones, etc.
7. Seismic Profiles – Identify Migration Pathways
8. Care Taken to Identify Non-Expulsion Anomalies

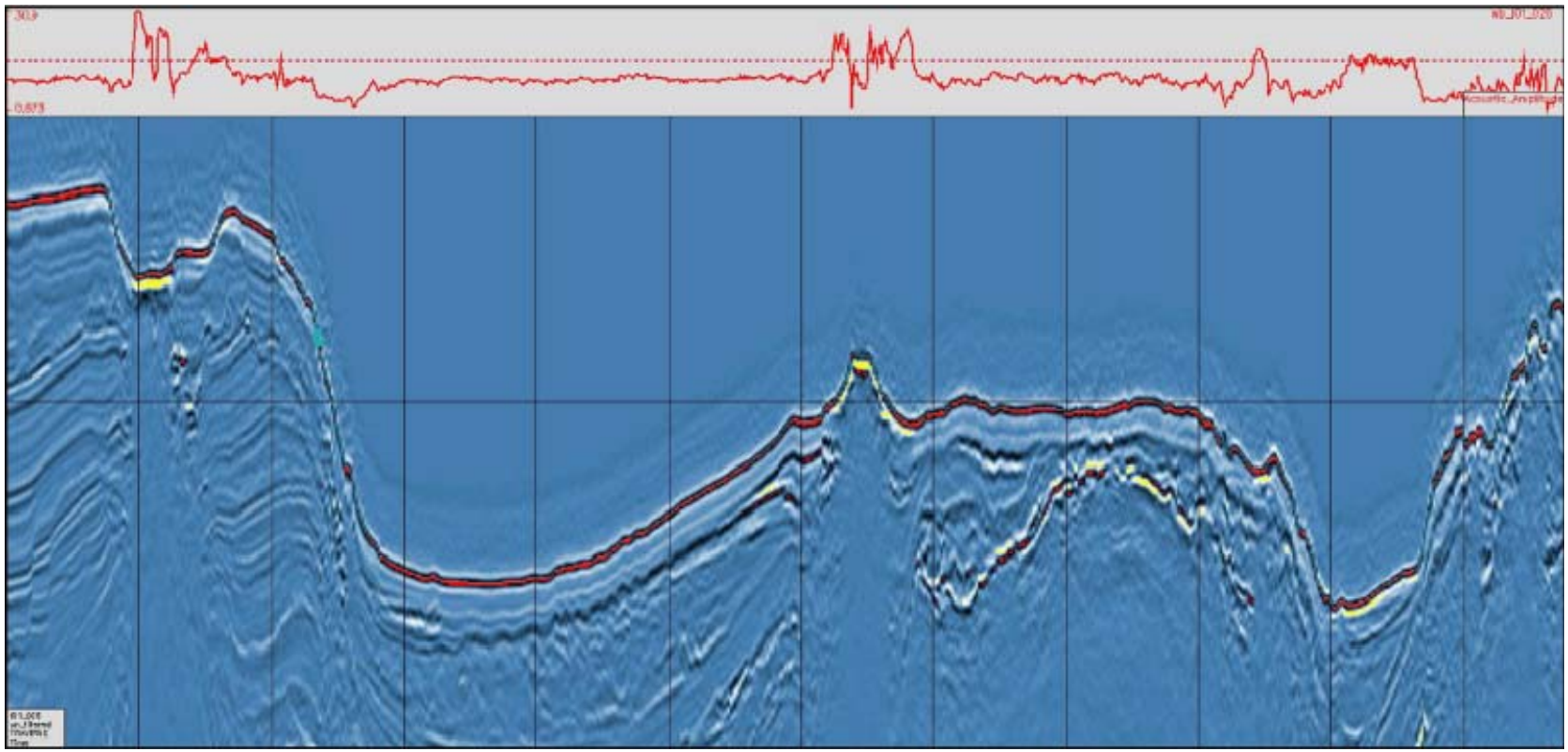
Field of Seafloor Anomalies



What are seafloor reflectivity anomalies as observed with 3D-Seismic data?

- **Positive anomalies – Hard Bottom**
- **Negative anomalies – Soft Bottom**

Along-Profile Amplitude Changes



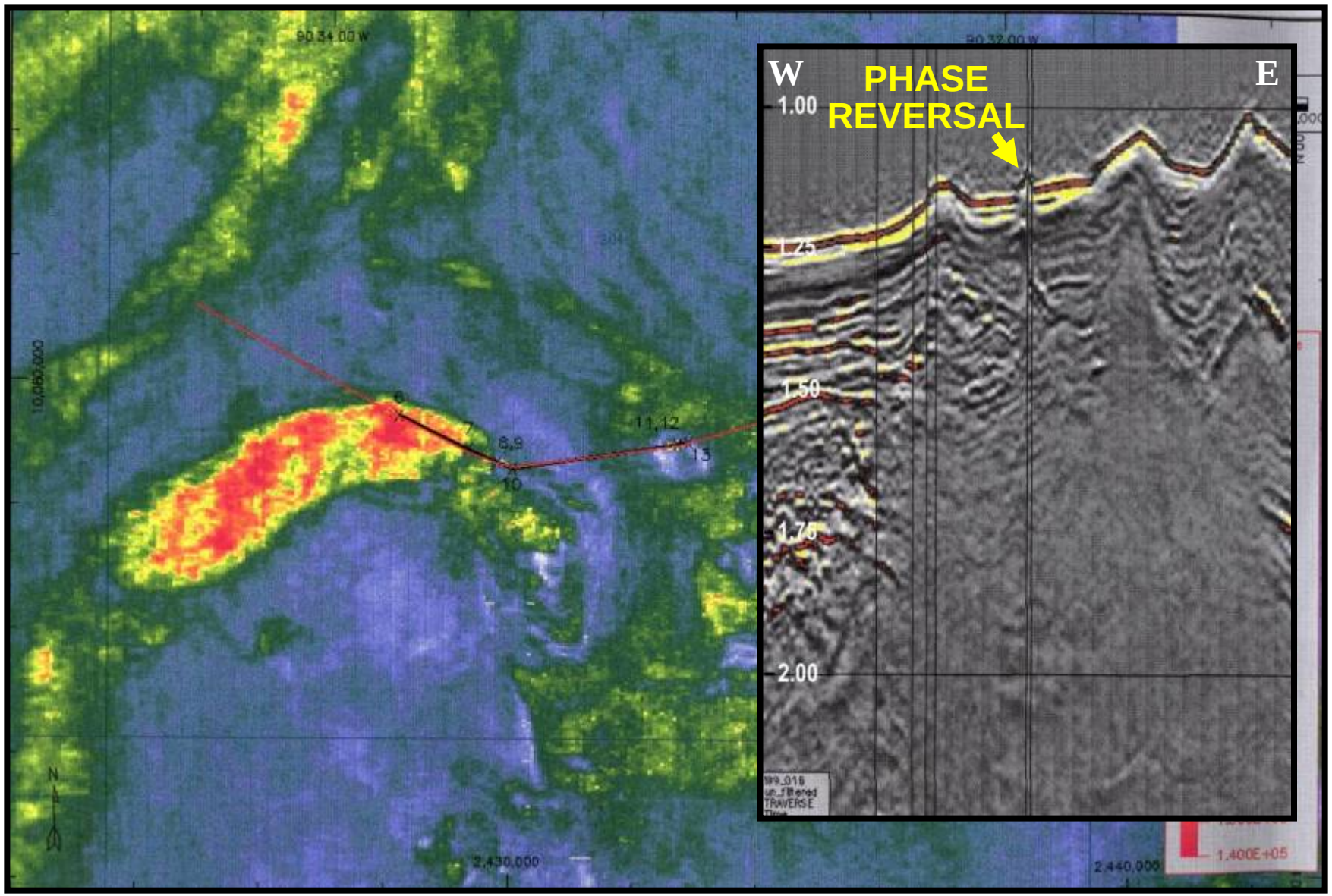
Positive Anomalies

- **Salt (Exposures – Sigsbee Escarpment)**
- **Sand (Basin Floor Fans)**
- **Mineralized Sediments – Barite**
- **Authigenic Carbonates**

Negative Anomalies

- **Gas-charged Sediments**
- **Fluidized Muds**

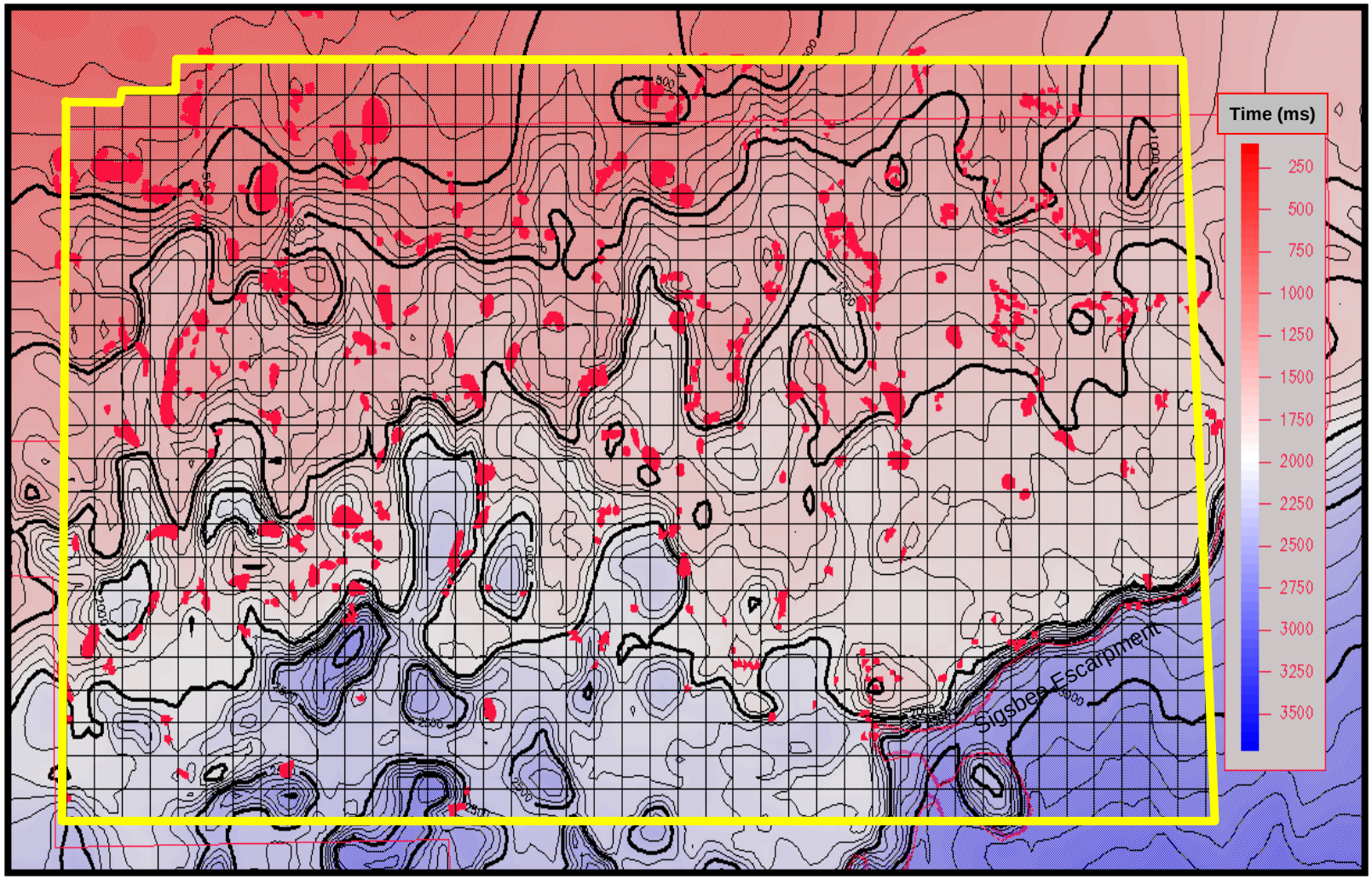
Phase Reversal



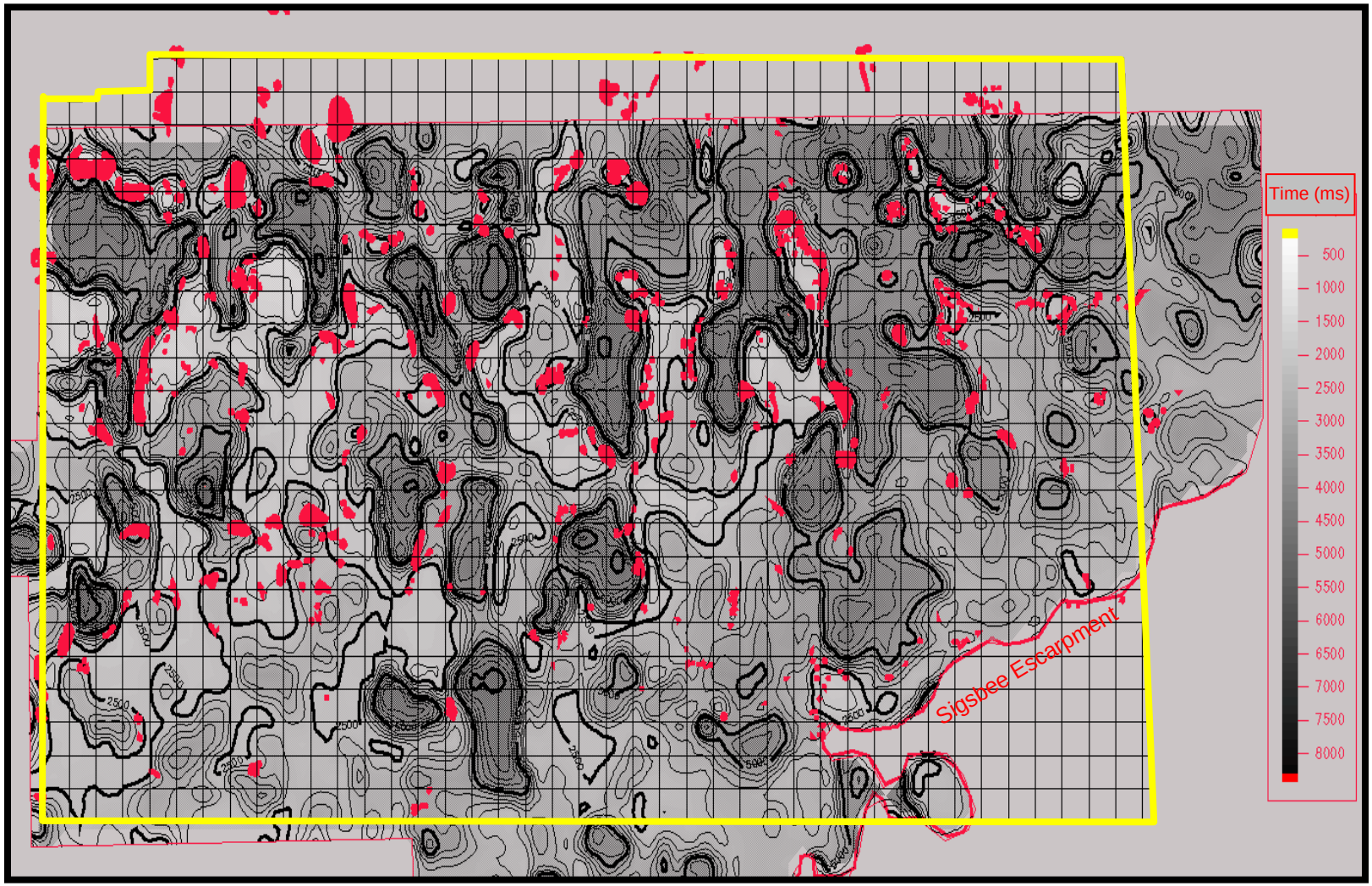
Seafloor Reflectivity Anomalies

- **Where do they occur?**
- **Are there many of them?**
- **What do most of them represent?**
- **Do they correlate to surface/shallow subsurface gas hydrate occurrence?**

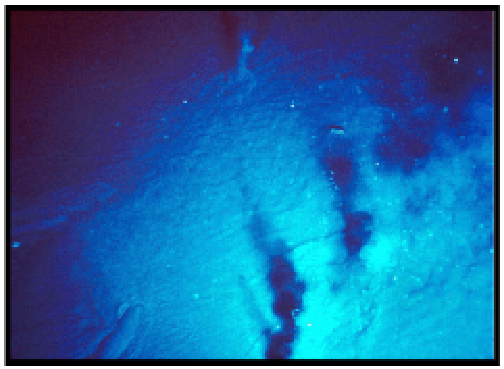
Bathymetry (2-way Travel Time)
Green Canyon Area

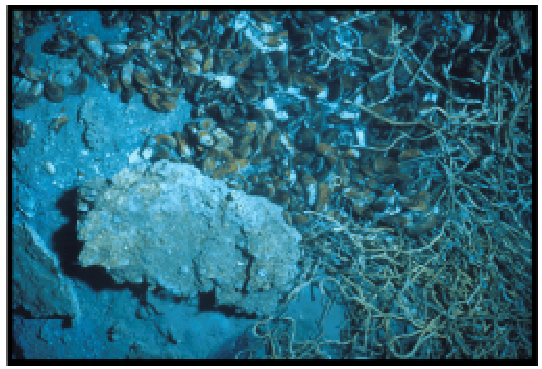


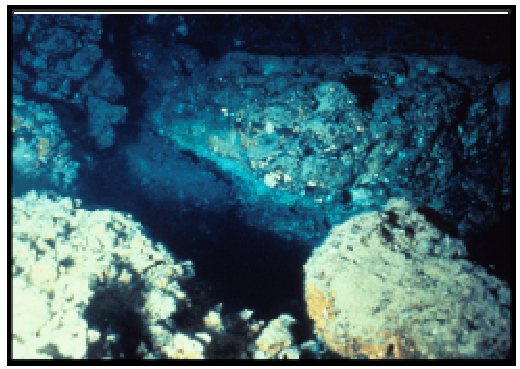
Top of Salt
Green Canyon Area



Seafloor Response to Fluid and Gas Expulsion







RAPID FLUX — MODERATE FLUX — SLOW FLUX

MUD-PRONE — MINERAL-PRONE

Flux Rate of Fluids and Gases to the Seafloor

- **Rapid Flux – negative anomalies (e.g. mud volcanoes)**

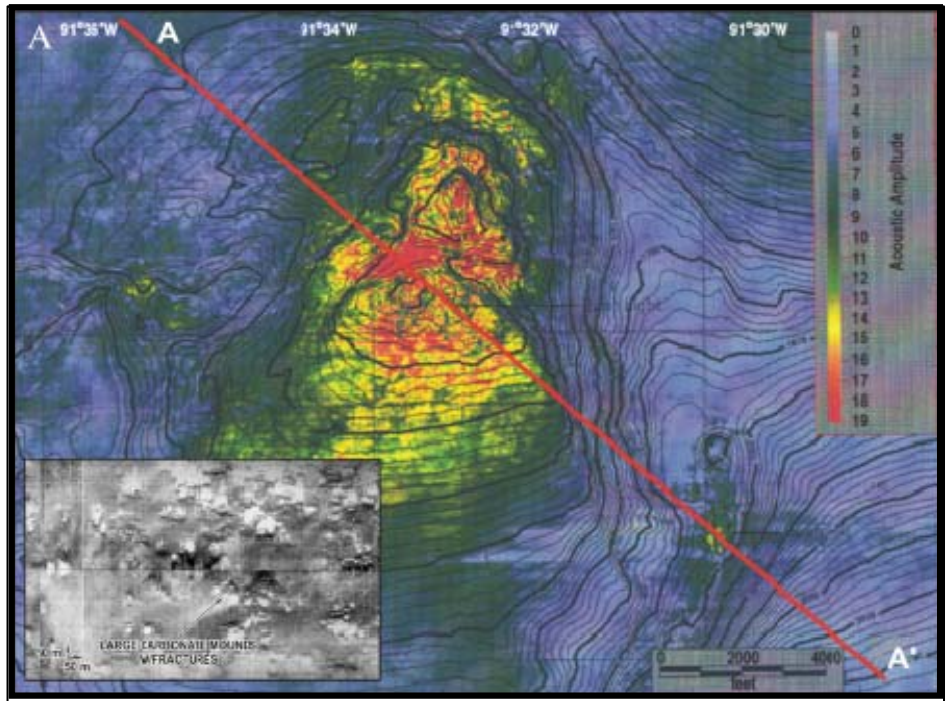
- **Slow Flux – carbonate pavements, blocks, mounds**

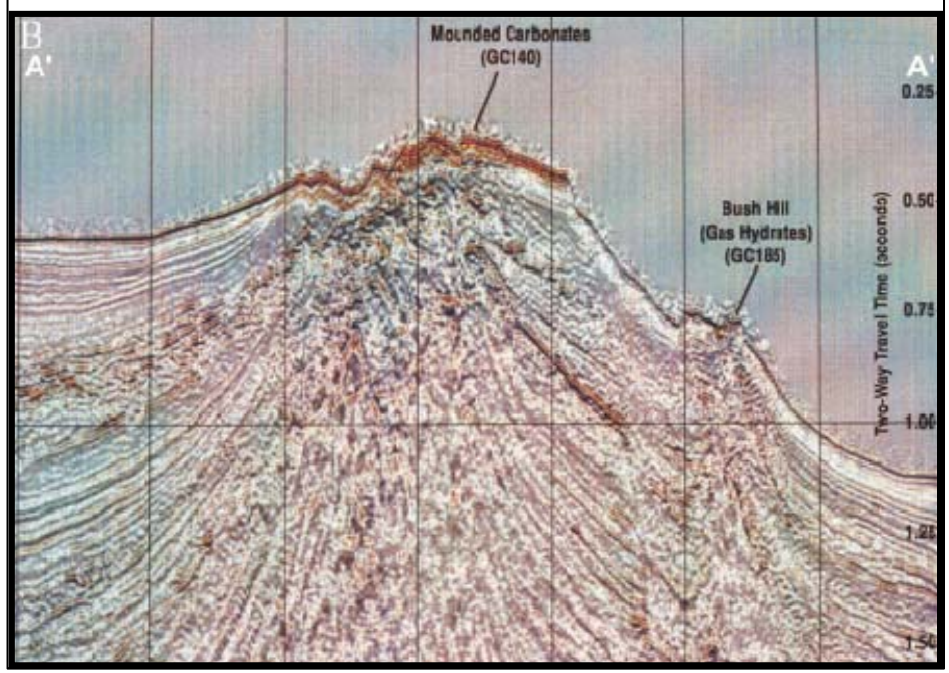
Rapid Flux Expulsion System

Mud Cone and Surface Mudflows

Slow Fluid-Gas Delivery System

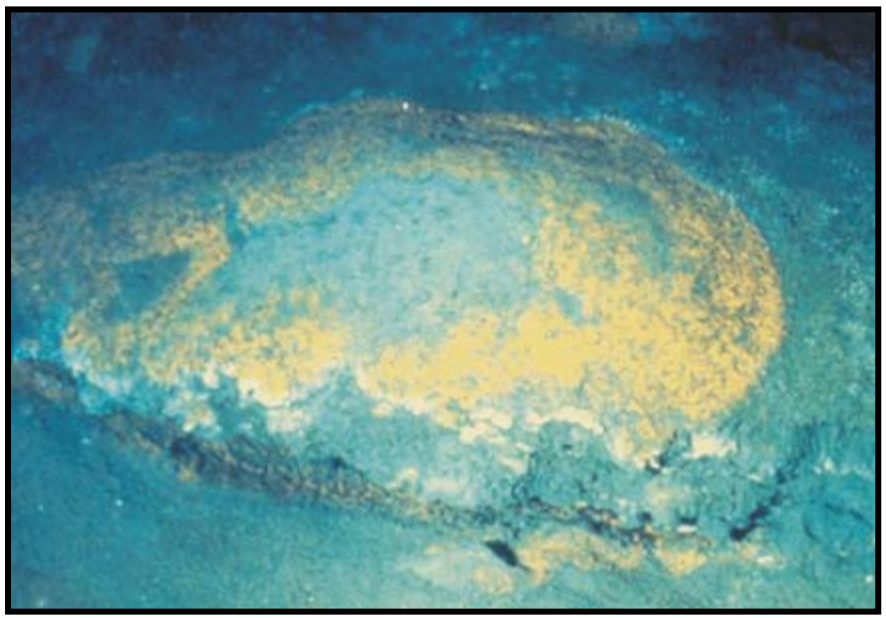
- **Highly Reflective Seafloor**
- **Mounded Carbonates and Hardgrounds**
- **Limited Chemosynthetic Communities**

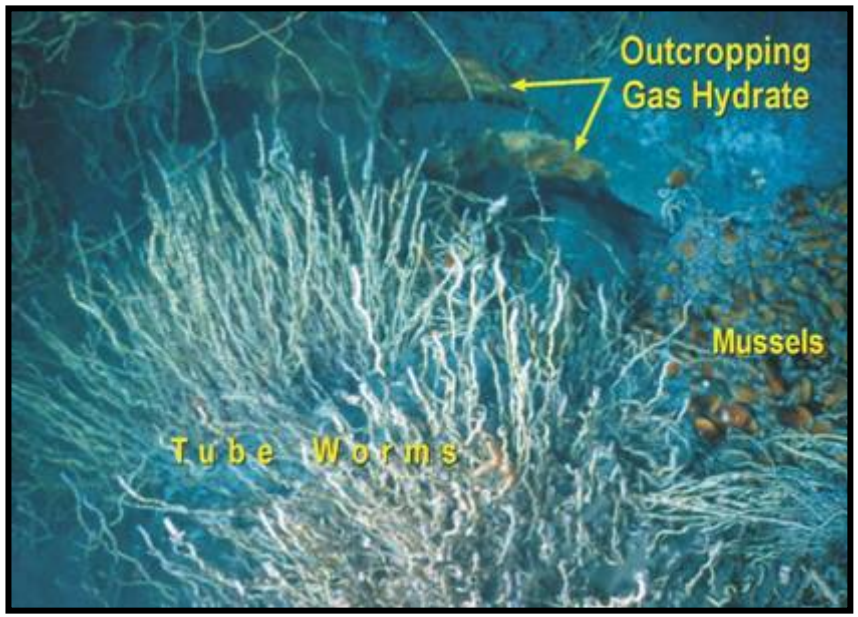


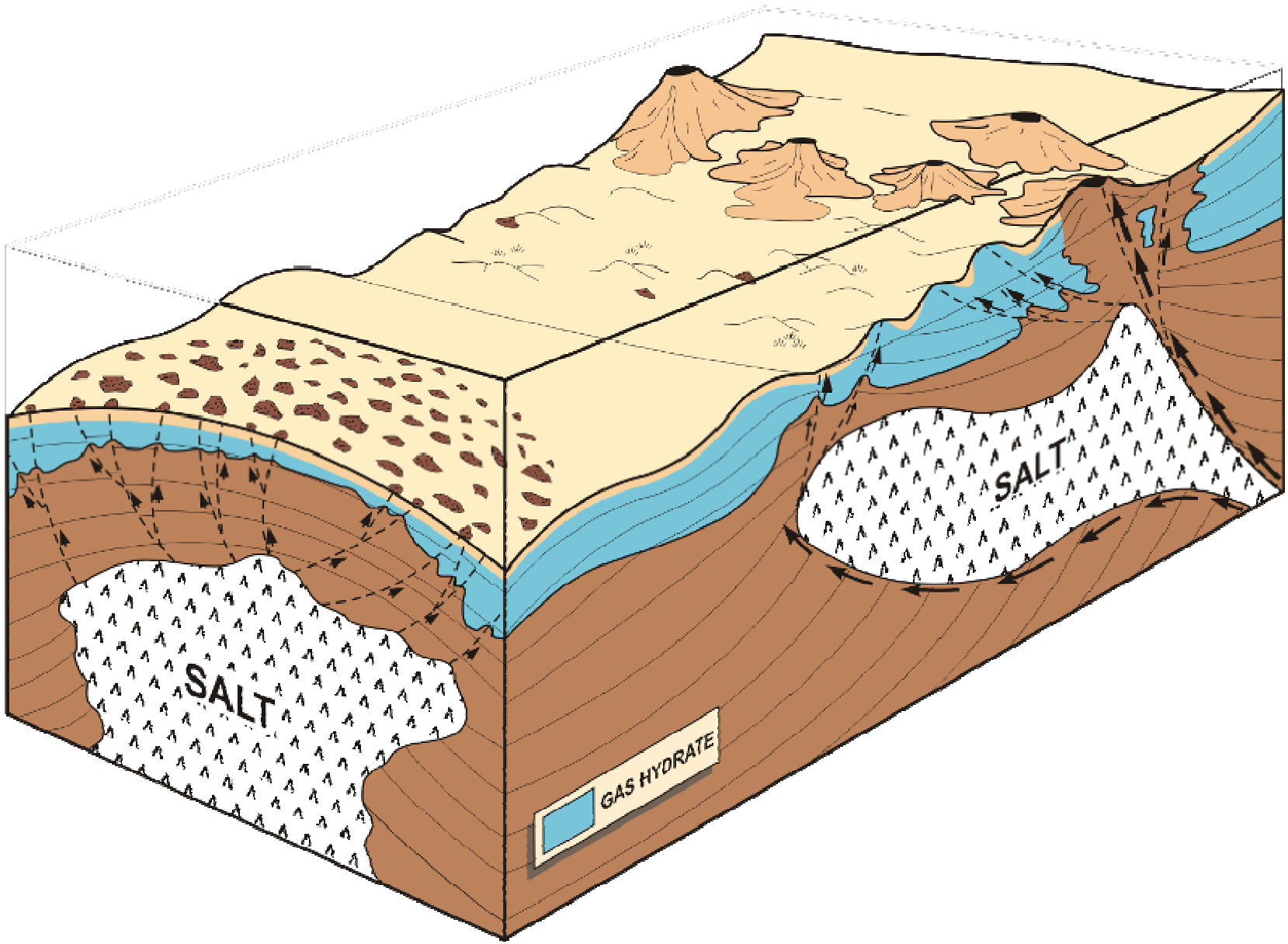


Moderate Flux Expulsion System

Seafloor Exposures of Gas Hydrate





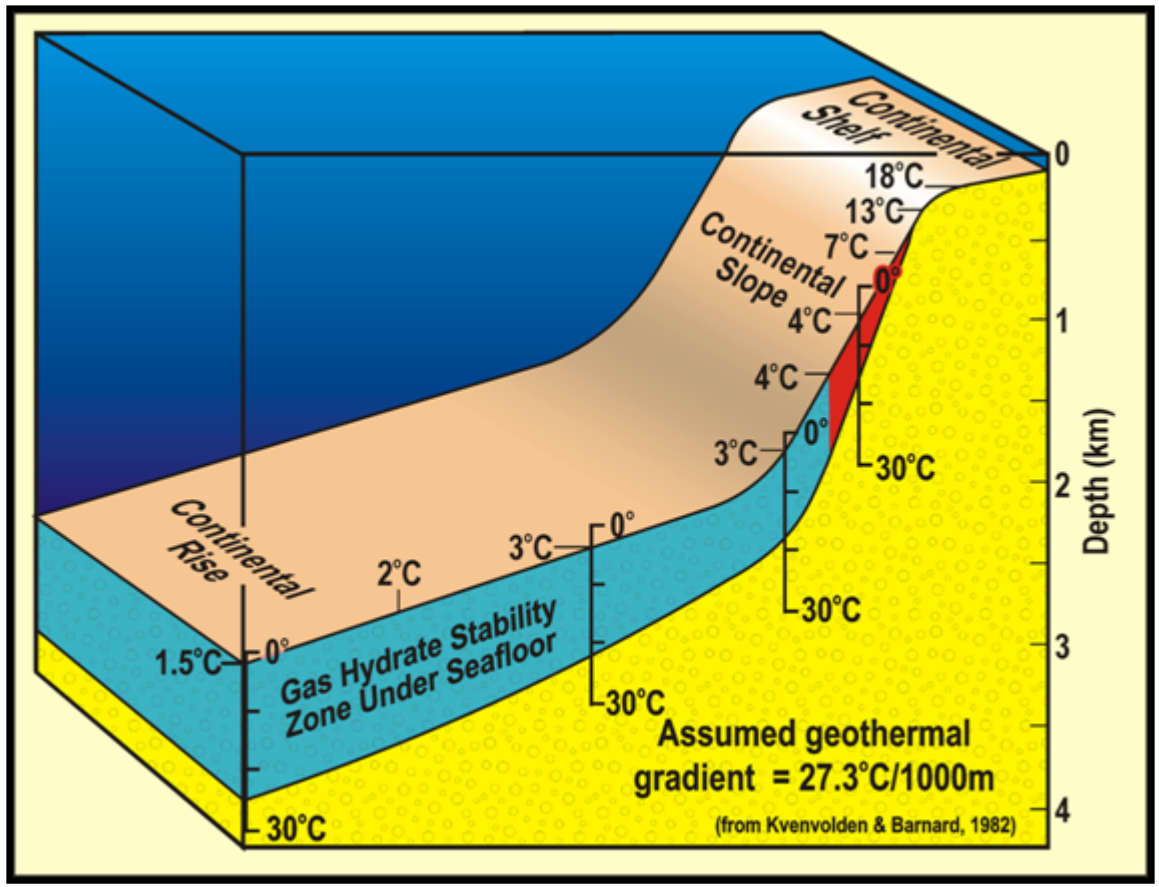

SALT
SALT
GAS HYDRATE

Link Between Seafloor Reflectivity and Gas Hydrate

Authigenic carbonate and chemosynthetic communities are associated with surface and near-surface gas hydrate occurrence (moderate flux settings).

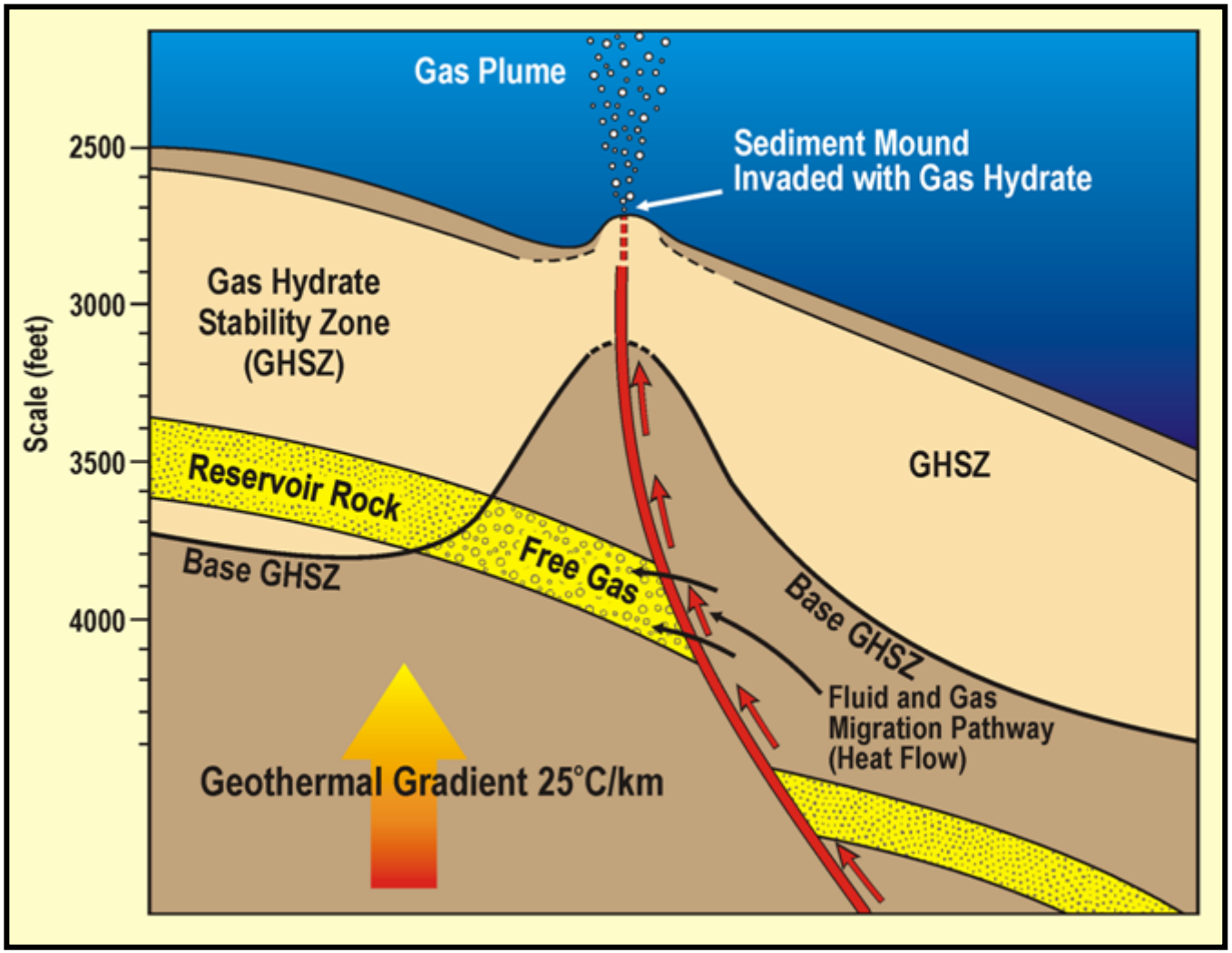
Constraints on Occurrence

Gas Hydrate in a Continental Margin

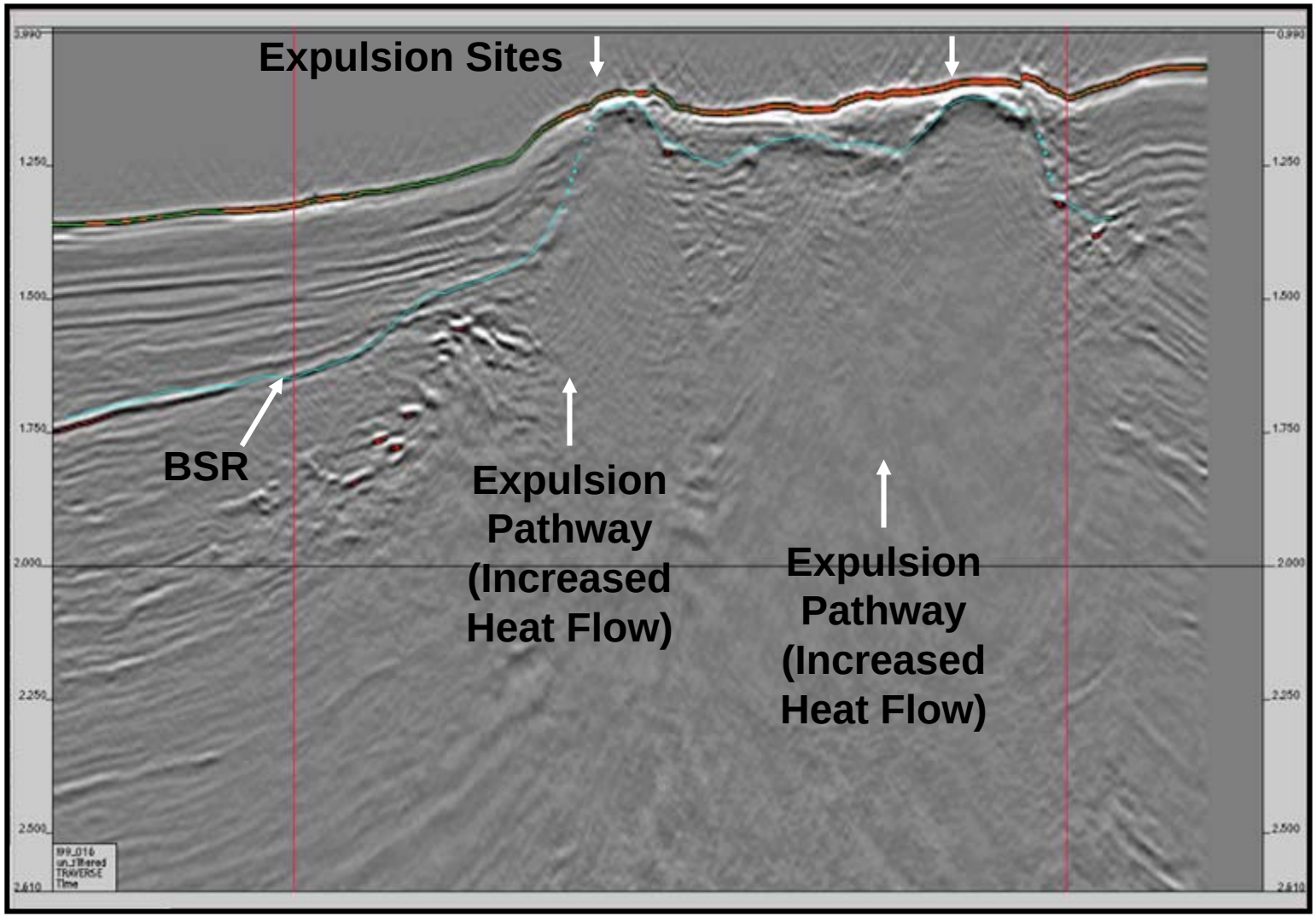


The red area of the upper slope, between 400–1000m, is most affected by hydrate decomposition associated with sea level change.

Schematic Diagram of Warped BSR



BSR Distorted by Differential Heat Flow



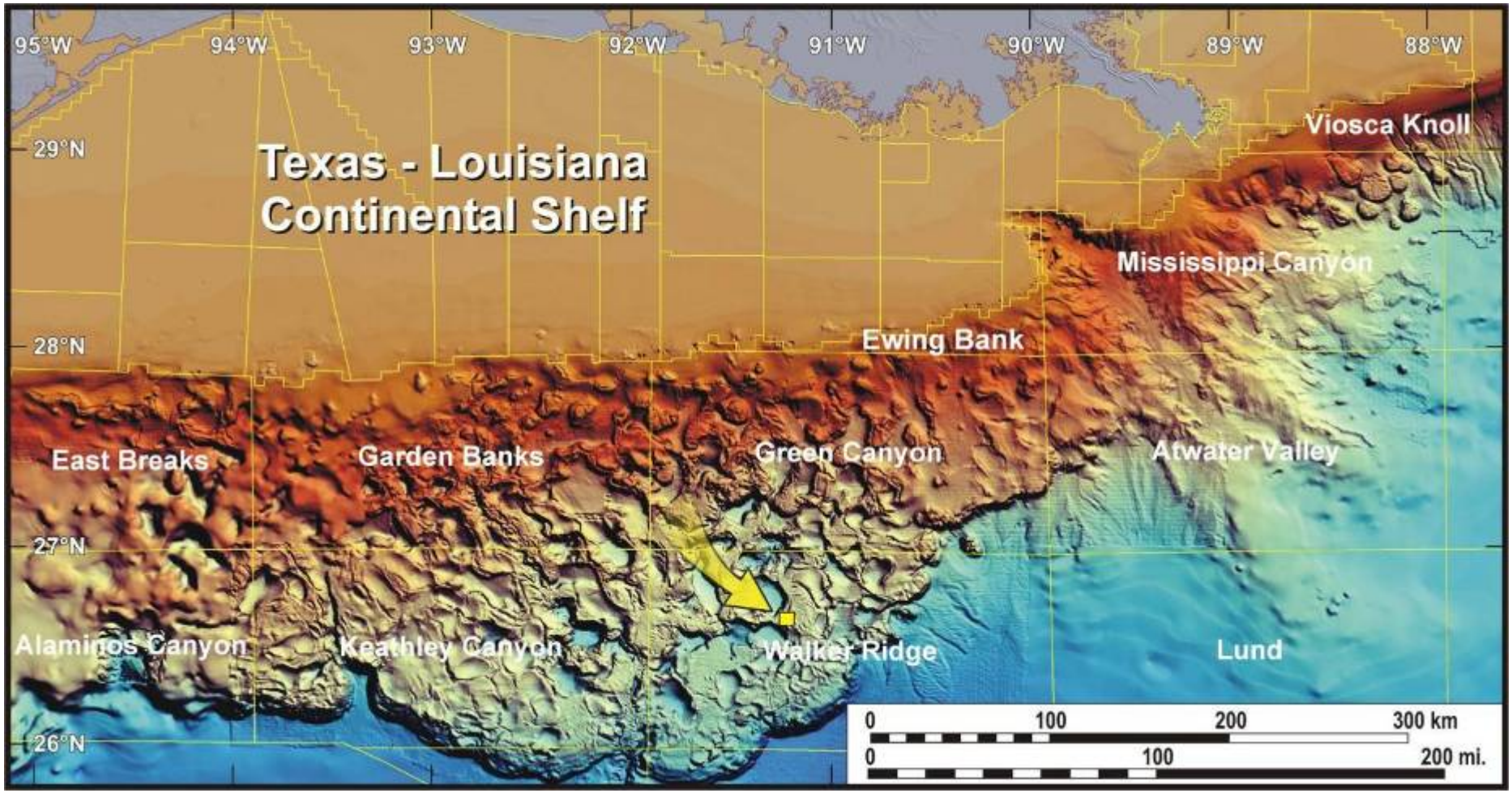
MC 118-7-t2

MC 118-7-t1

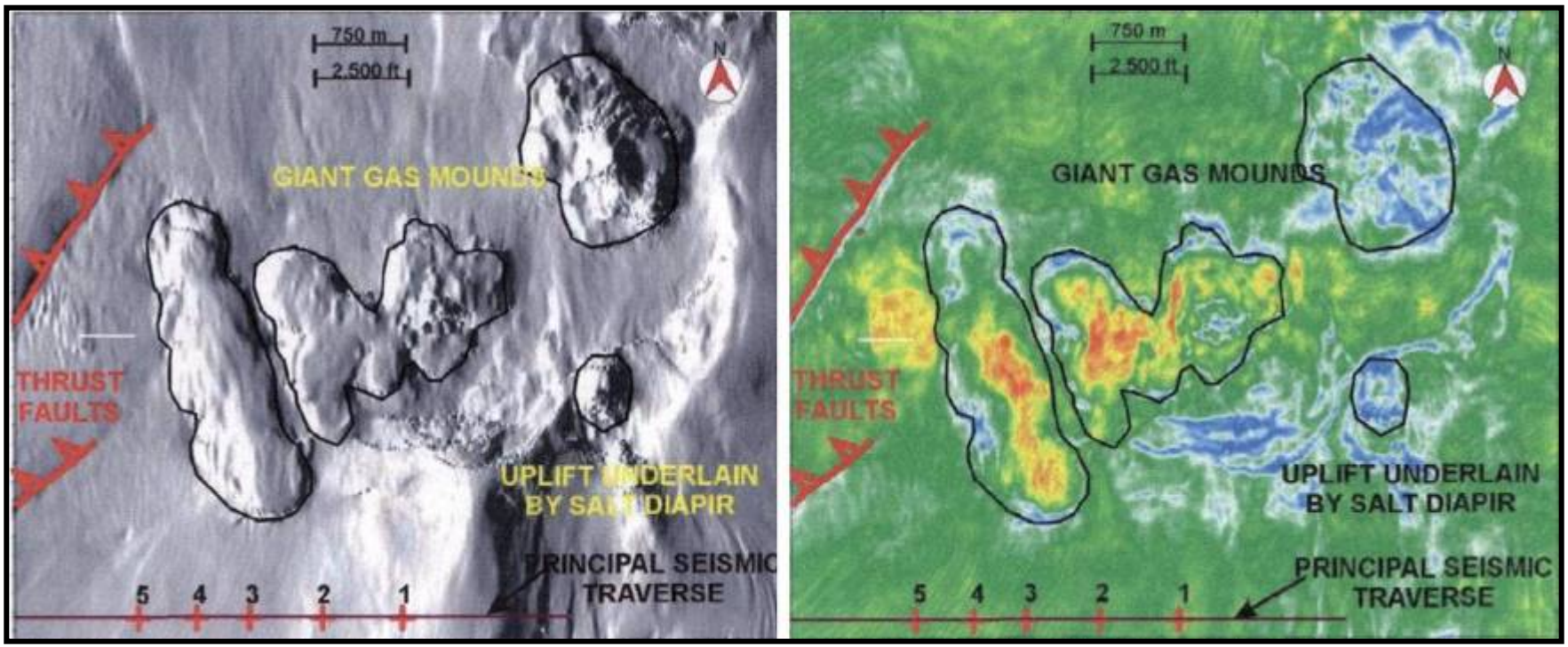
GC 234-t2-5

GC 234-t2-7

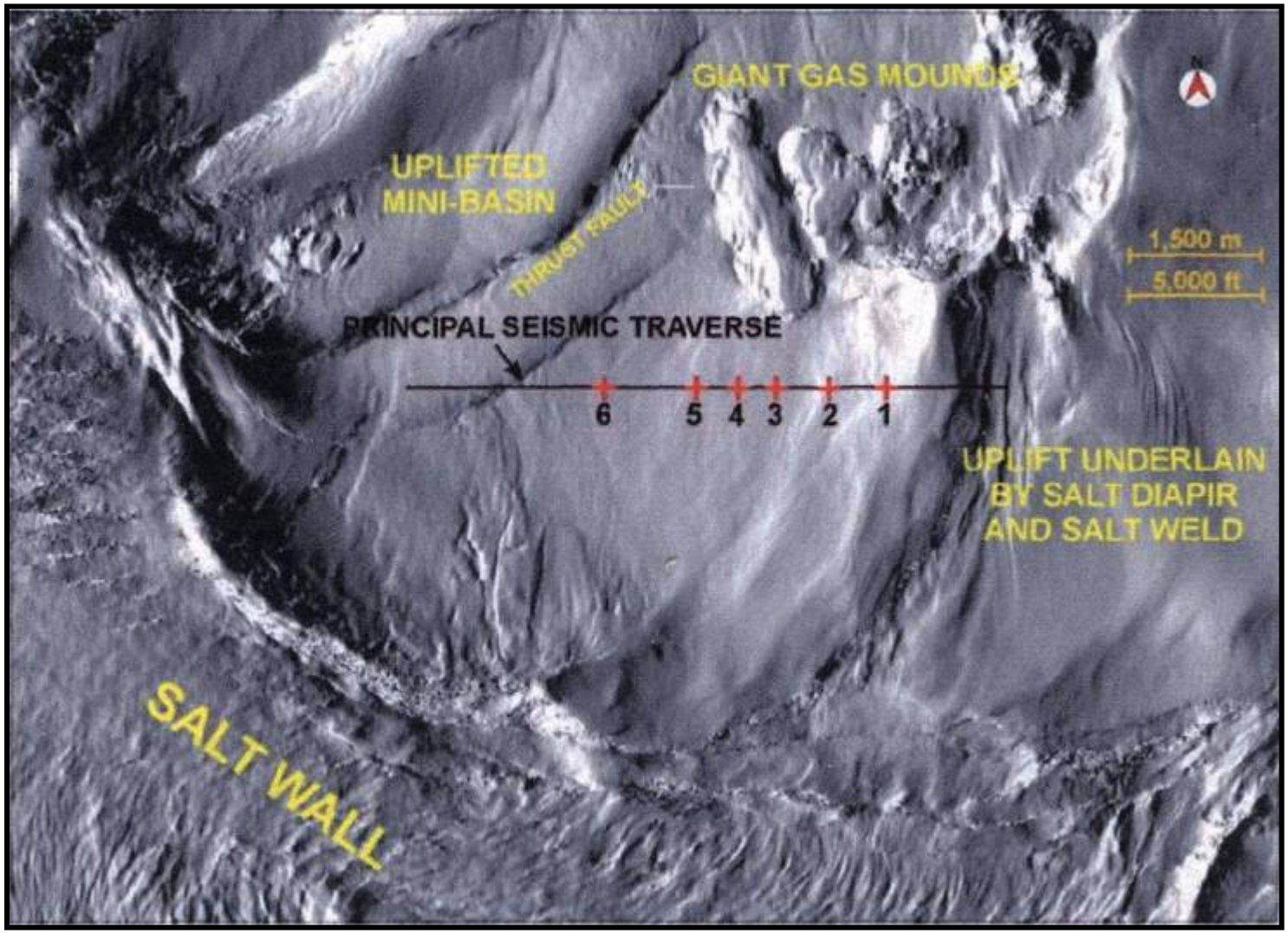
WR 269
Location Map



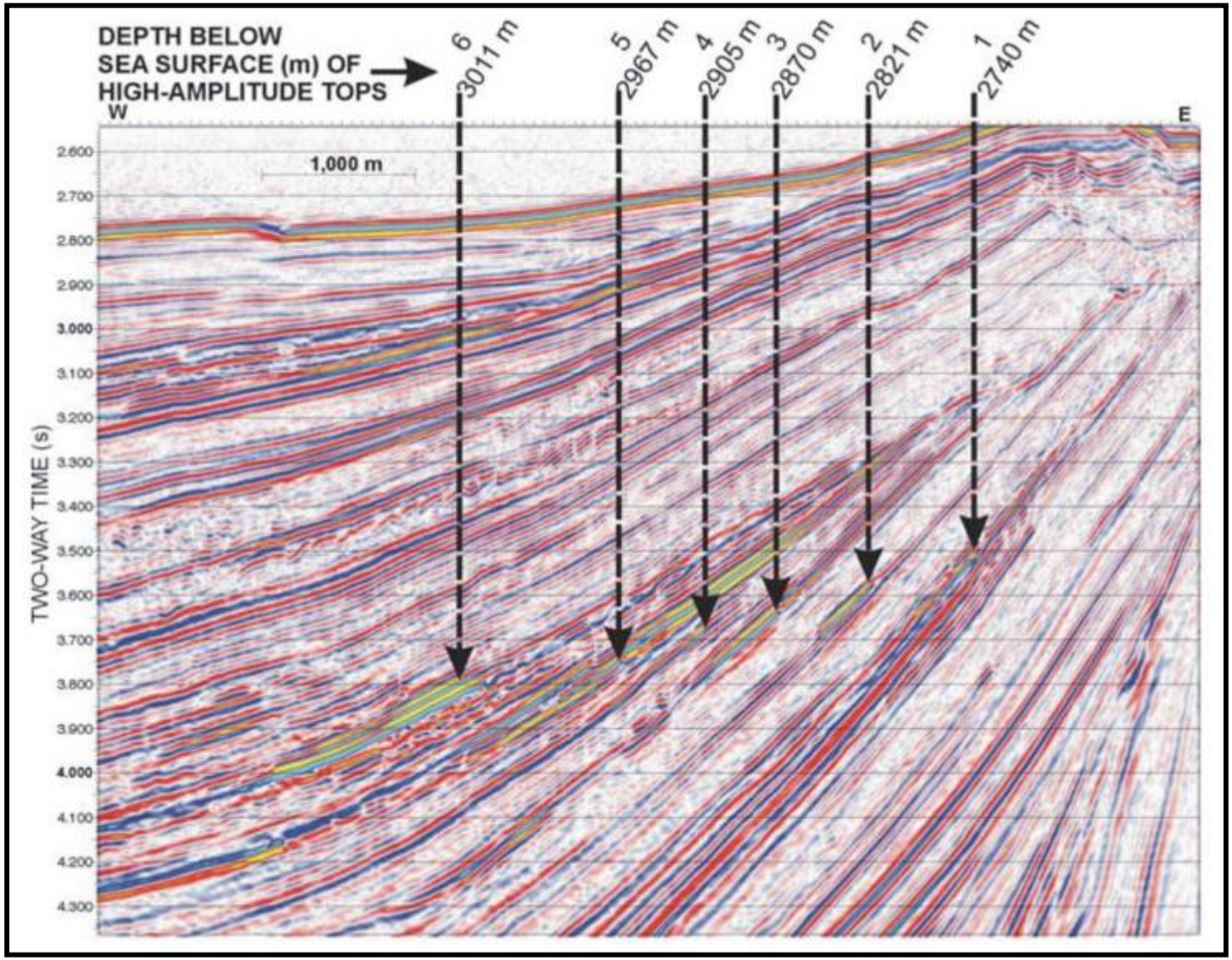
Seafloor Image and Surface Amplitude Map



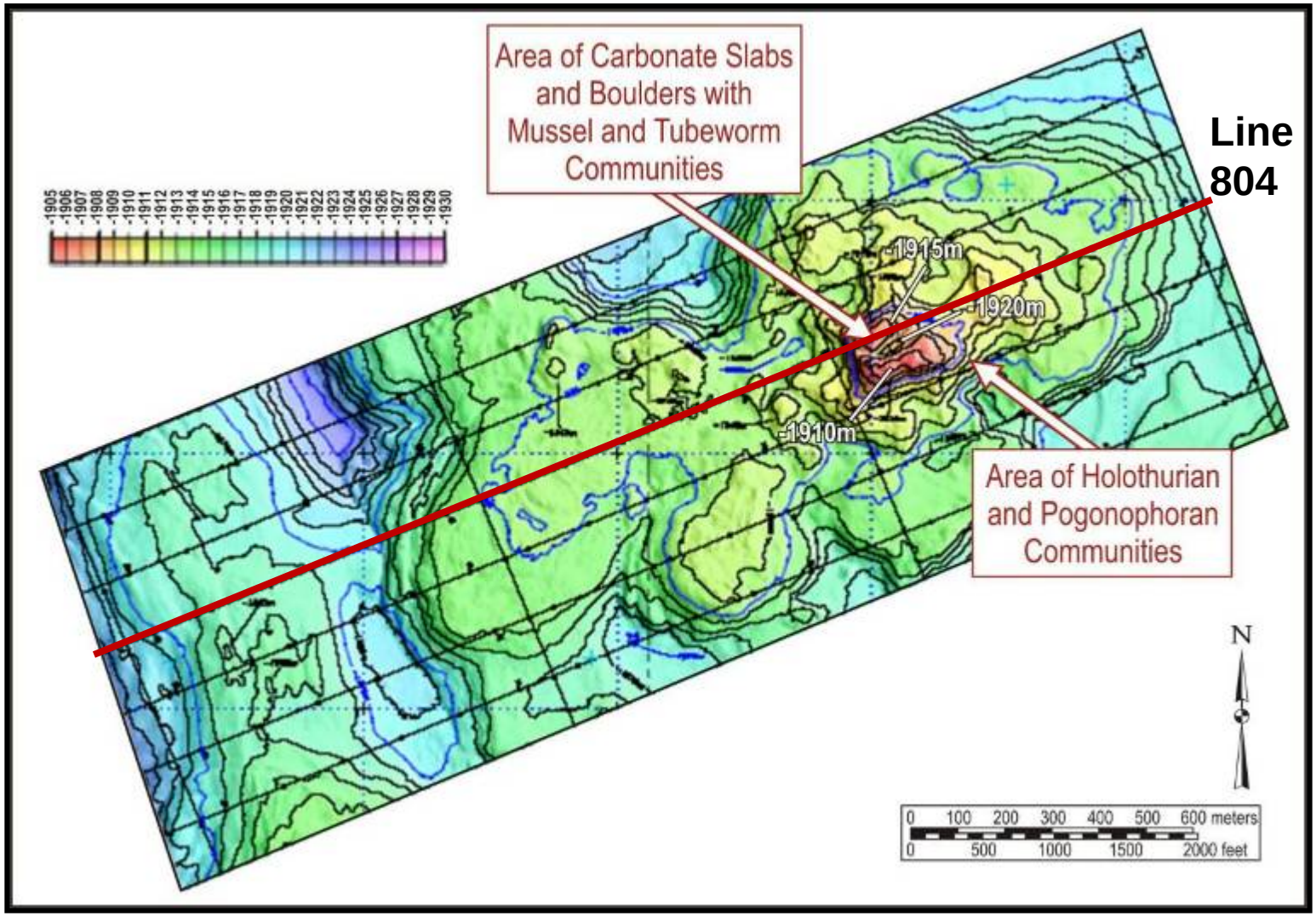
Northwest Walker Ridge



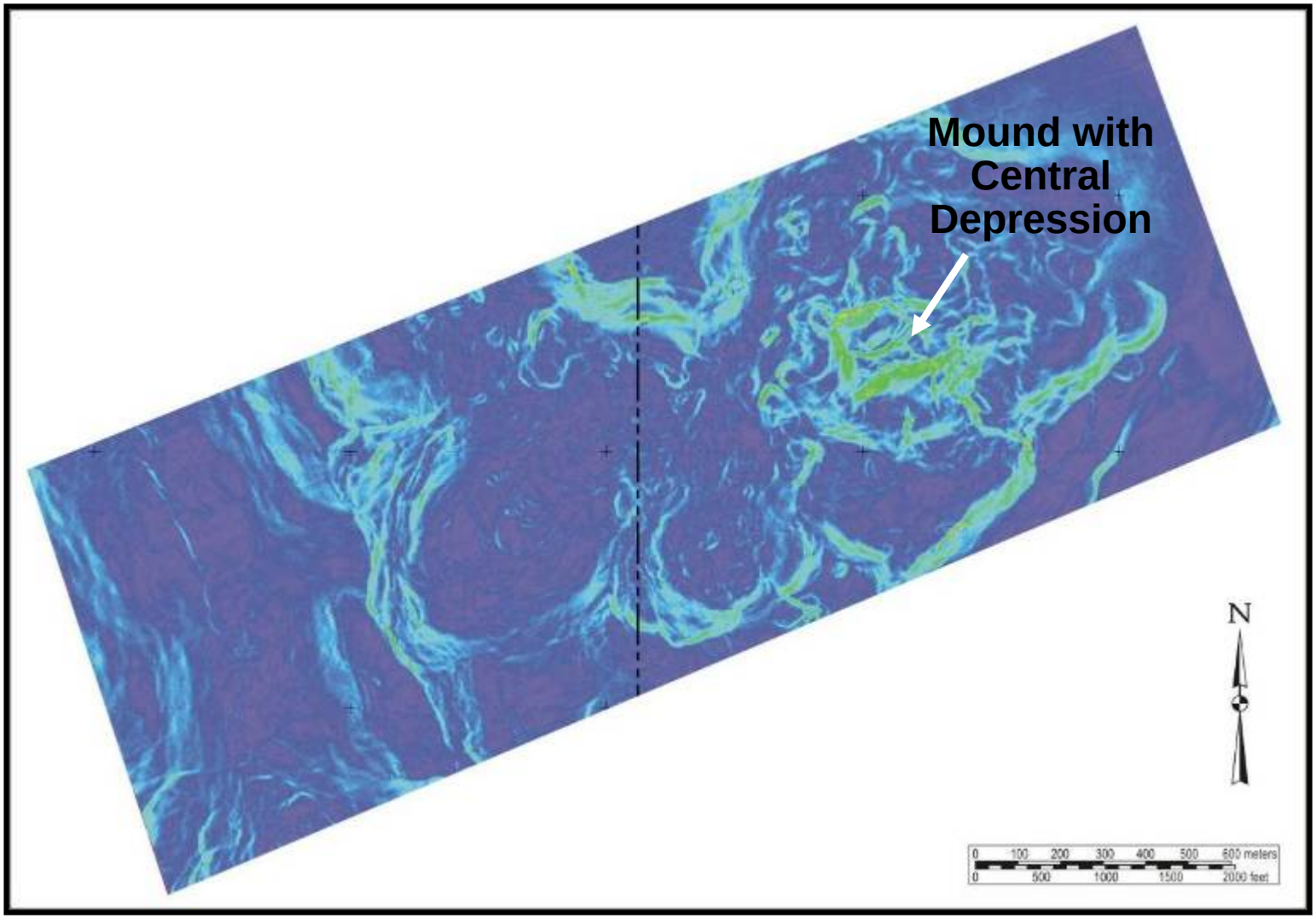
High Amplitude “Dim-Outs”



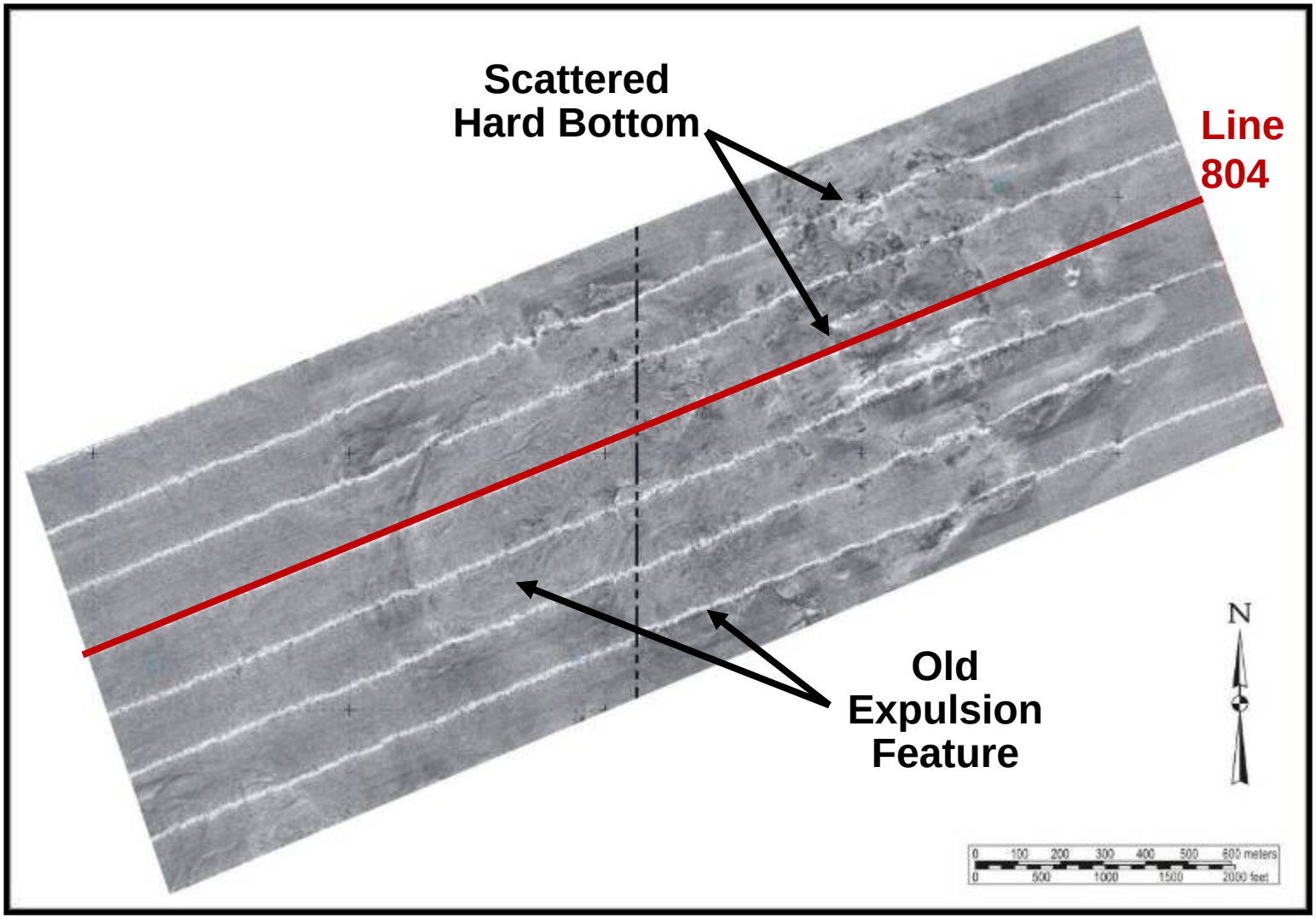
WR269 Multibeam Bathymetry



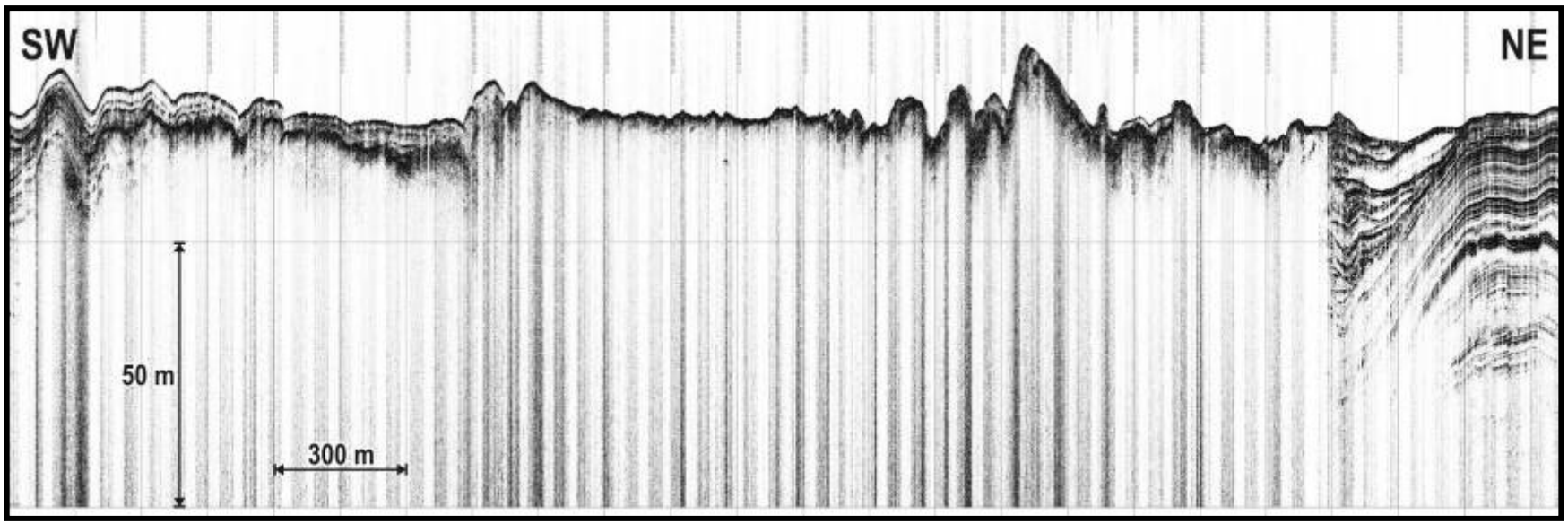
WR269 Gradient



WR269 Backscatter

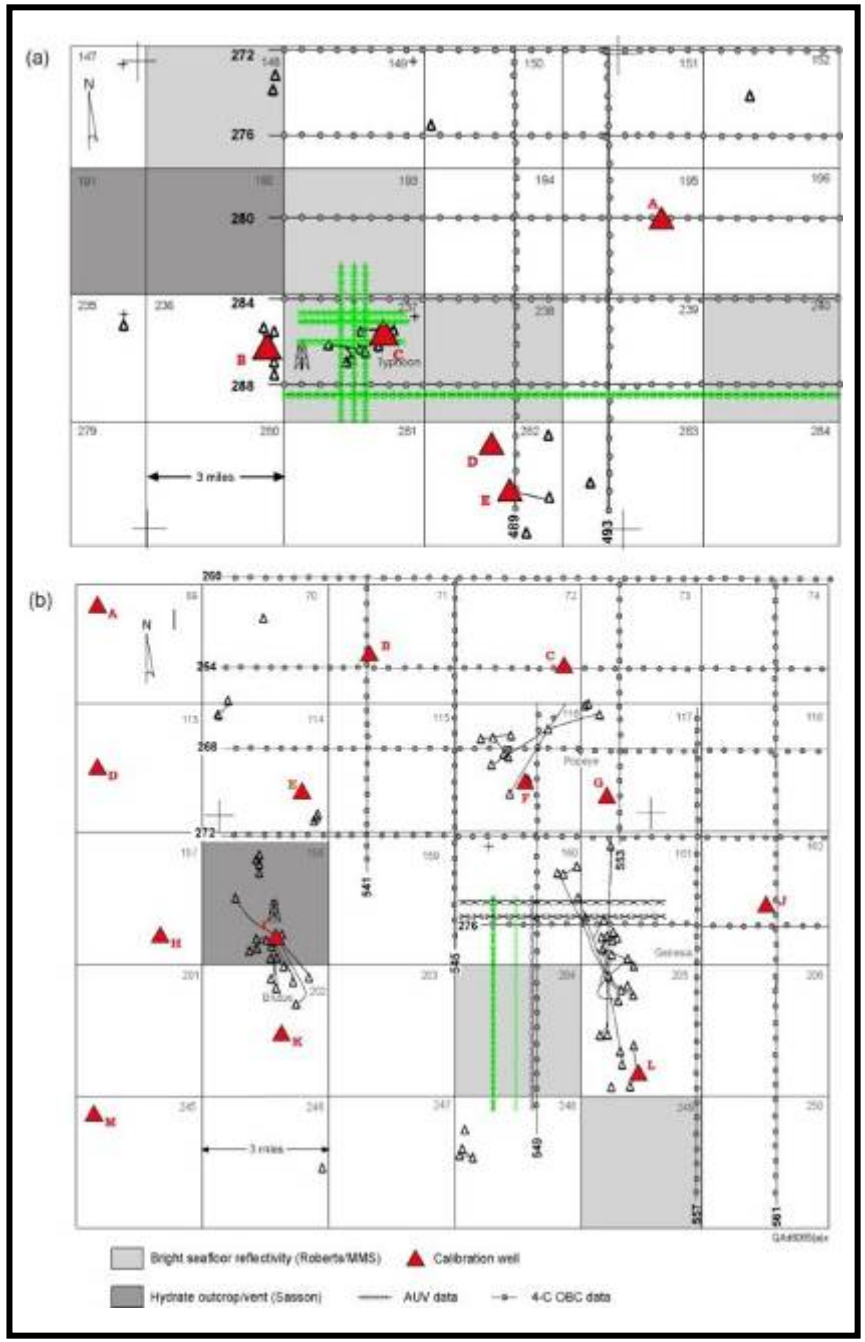


WR269 – Line 804



Acoustically Opaque

Location of OBC and AUV Profiles

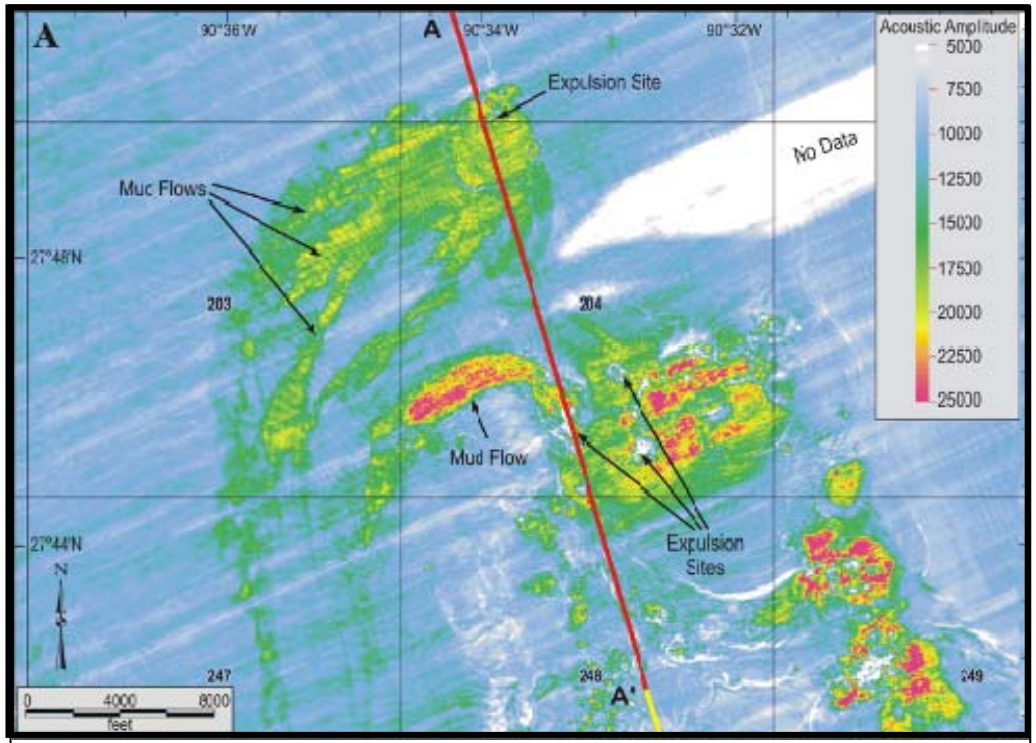


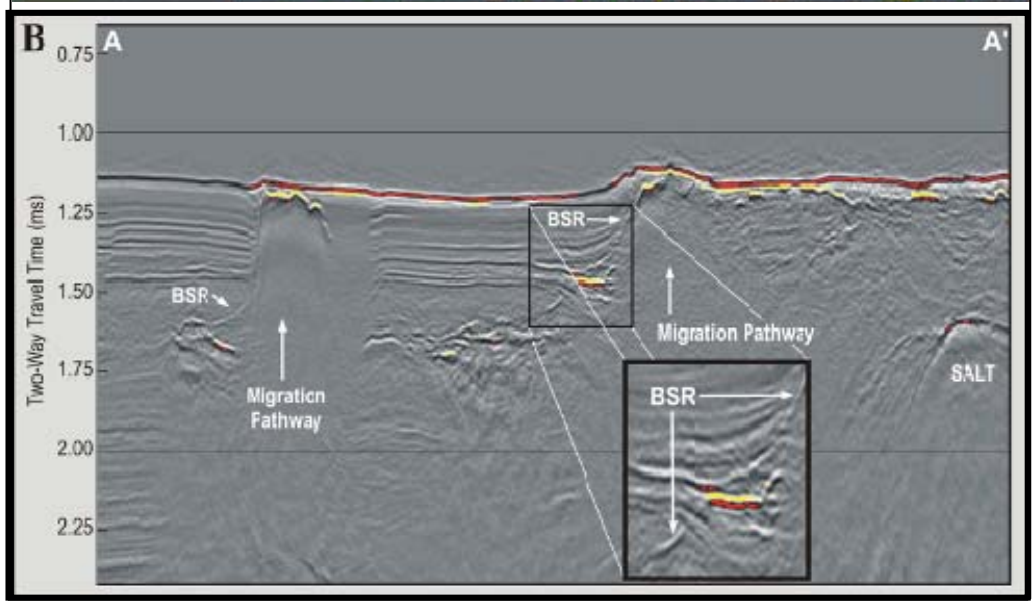
GC 237 New Typhoon Field

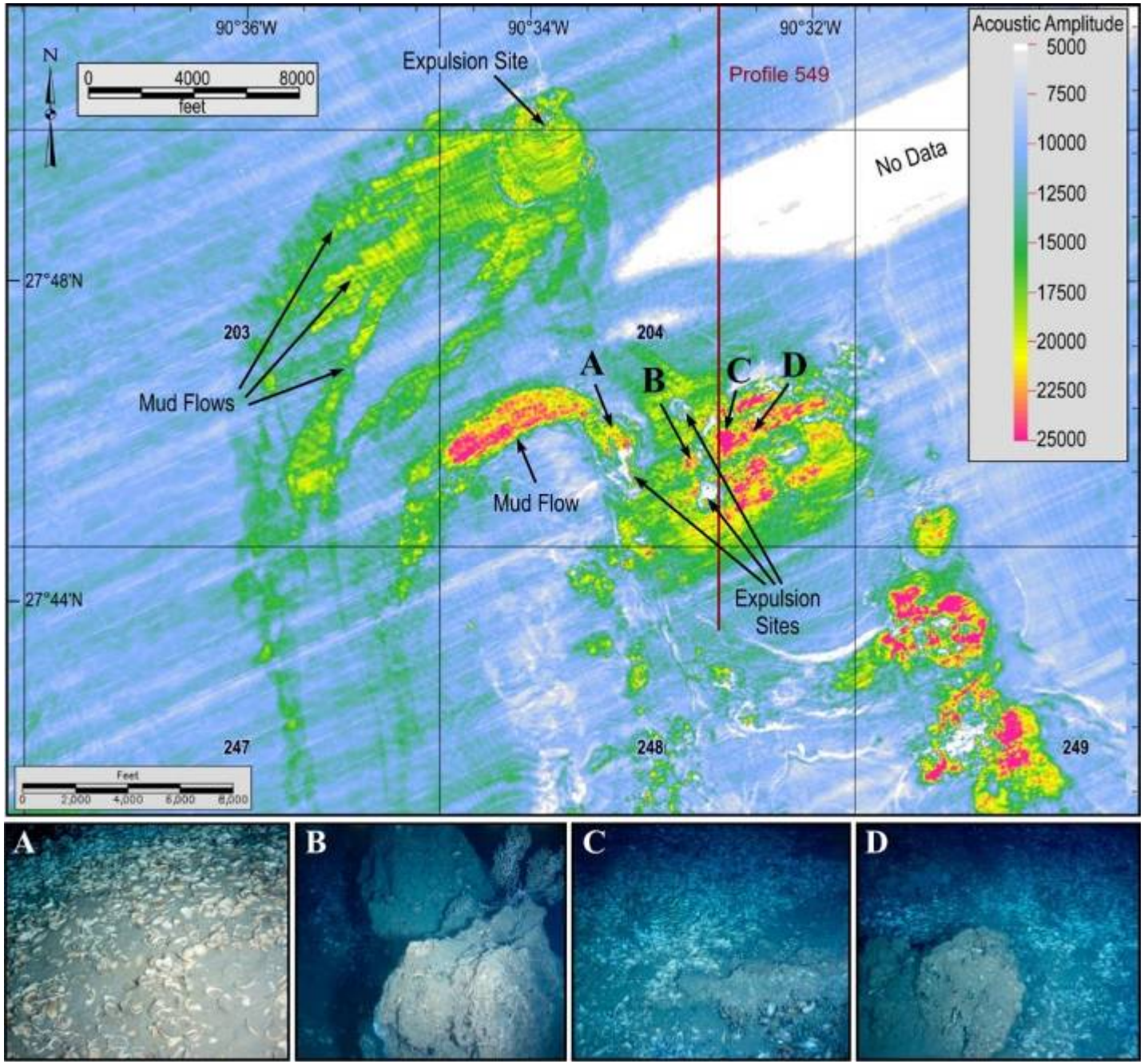
GC 204 New Genesis Field

Rapid Fluid-Gas Delivery System

- Obvious Flow Patterns
- Low Reflectivity Expulsion Centers
- Limited Chemosynthetic Communities

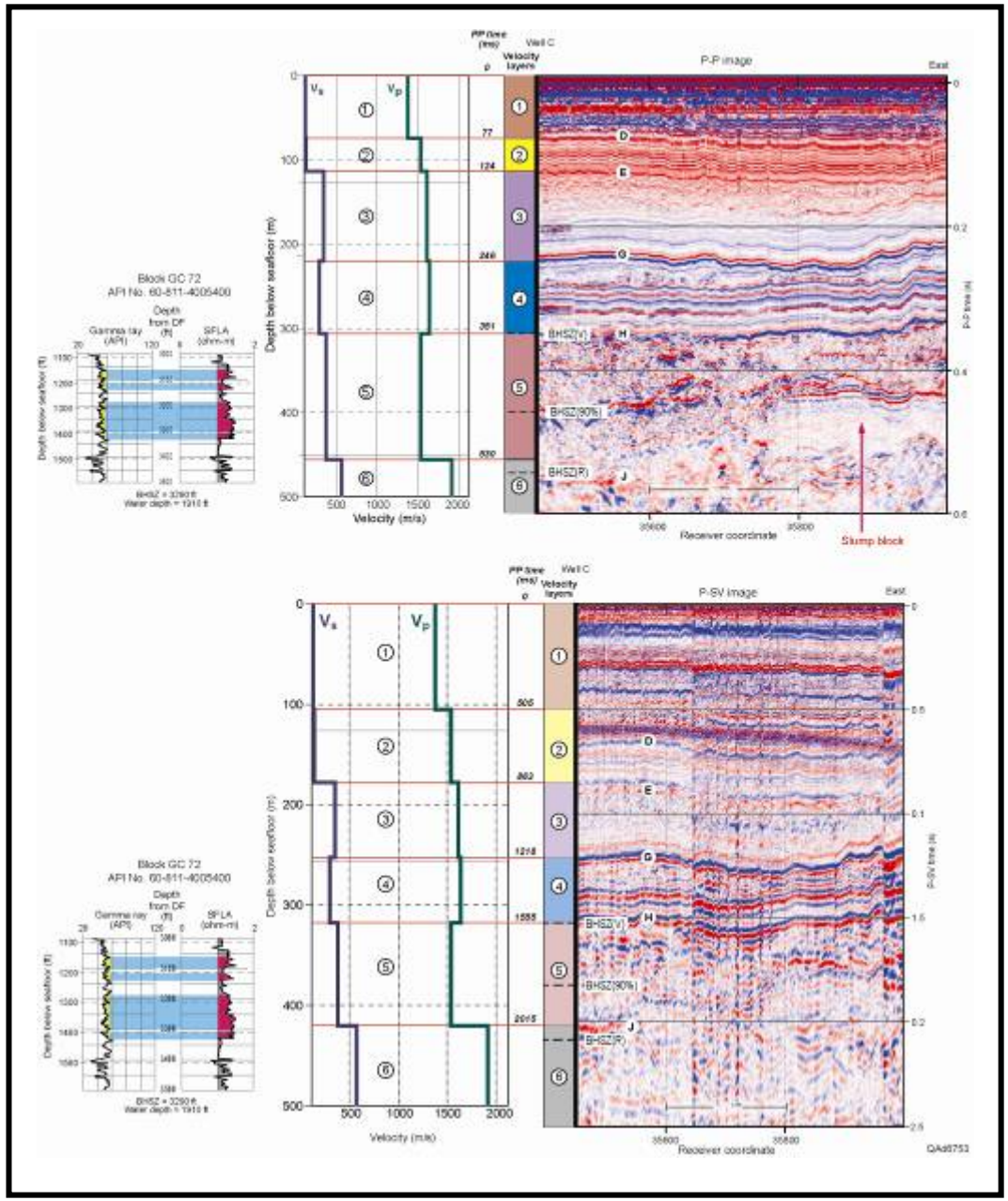


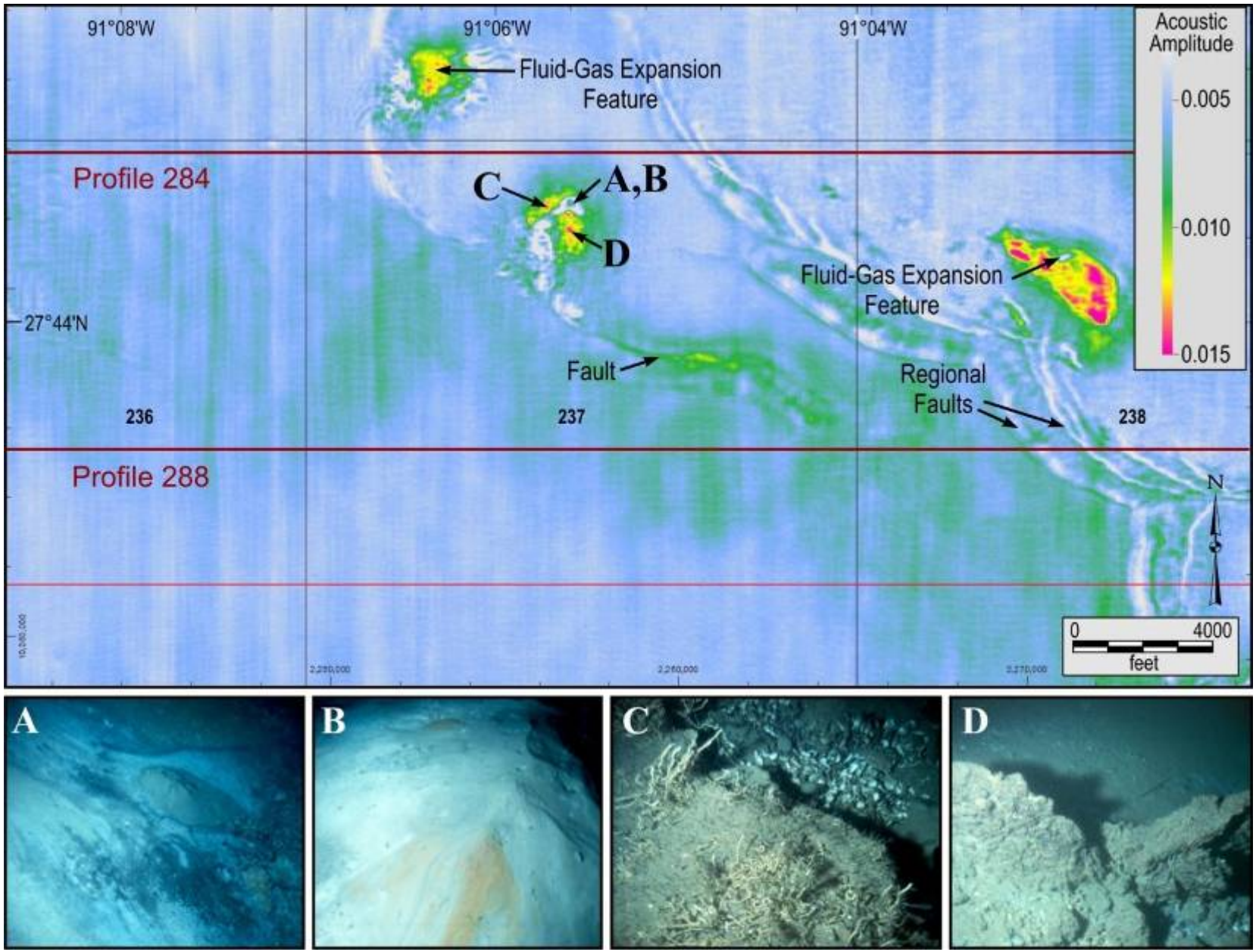



90°36'W
90°34'W
90°32'W
N
0 4000 8000
feet
Expulsion Site
Profile 549
No Data
Acoustic Amplitude
5000
7500
10000
12500
15000
17500
20000
22500
25000
27°48'N
27°44'N
203
204
247
248
249
A
B
C
D
Mud Flows
Mud Flow
Expulsion Sites
Feet
0 2,000 4,000 6,000 8,000
A
B
C
D

Vp and Vs Velocity Analysis of Well C Genesis Field

OBC Profile 264




91°08'W
91°06'W
91°04'W
Fluid-Gas Expansion Feature
Acoustic Amplitude
0.005
0.010
0.015
Profile 284
C
A,B
D
Fluid-Gas Expansion Feature
27°44'N
Fault
Regional Faults
236
237
238
Profile 288
N
0
4000
feet
A
B
C
D

Seafloor Reflectivity and Gas-Hydrate Domain

GAS-HYDRATE DOMAIN	SEAFLOOR REFLECTIVITY	REFLECTIVITY PATTERN	SEAFLOOR FEATURES	GAS-HYDRATE OCURRENCE
Rapid fluid-gas delivery	Expulsion centers have low positive reflectivity with common phase reversals Linear flows can be highly reflective	Circular expulsion center Linear flows radiating from expulsion centers	Gas-charged and/or gas-emitting expulsion centers Clam beds and nodular carbonates on flow deposits	None in active expulsion centers Subsurface flanks of expulsion centers
Moderate fluid-gas delivery	High spatial variability Phase reversals	Highly variable, frequently fault-aligned	Dense chemosynthetic communities, localized authigenic carbonates	Surface exposures, shallow subsurface
Slow fluid-gas delivery	Highly reflective surface No phase reversals	Broad areas of high reflectivity	Authigenic carbonate mounds and hardgrounds	Subsurface

Conclusions

- **Fluid-Gas Expulsion Sites: Variable Seismic Signatures**
- **Ground Truth Calibrations to 3D-Seismic Surface Reflectivity Accomplished**
  - **Cores and Geochemistry**
  - **Manned Submersible Observations and Sampling**
- **Surface Reflectivity Strengths and Patterns Correlate to Qualitative Rates of Fluid-Gas Expulsion**
- **Surface Exposures of Gas Hydrate linked to Intermediate Flux Expulsion Systems**

Reference

Rowan, M.G., M.P.A. Jackson, and B.D. Trudgill. 1999. Salt-related families and fault welds in the northern Gulf of Mexico. American Association of Petroleum Geologists Bulletin 83: 1454–1484.