Gas Hydrate Deposits In A Complex Geologic Province (GOM): Linkage To Fluid-Gas Expulsion

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The northern Gulf of Mexico continental slope is now covered with overlapping tracks of high quality 3D-seismic data. Analysis of these data by industry, government (MMS), and academic geoscientists underscores the extreme geologic complexity imposed on this province by the interaction of sediments and salt. In this framework, faults concentrated along intraslope basin margins function as conducts for the migration of fluids and gases to the modern seafloor from deep petroleum-generating horizons. Within the gas hydrate stability zone, this vertical flux produces gas hydrate composed largely of thermogenic gases (structure II). Flux rate is linked to hydrate formation in that rapid fluid systems may transfer heat which eliminates the gas hydrate stability zone. In contrast, moderate-to-slow flux results in massive gas hydrate deposits that fill veins and fractions within faulted zones. These faults frequently extend to the seafloor where gas hydrate mounds occur in a spectrum of sizes. Observable gas seeps and larger gas plumes representing the composite effect of many small seeps occur over areas where hydrates are exposed. Such plumes suggest that fault-supplied gas is consistently bypassing the surface and near-surface gas hydrate deposits and entering the water column. This process provides a constant supply of gas for hydrate formation. Results of field experiments show that slight changes in water temperature can cause surface exposures of hydrate to decompose. A constant fault-related supply of subsurface water and gas causes surficial hydrate deposits to regenerate after a thermal decomposition event.

Gas Hydrate in a Complex Geologic Province: Linkage to Fluid-Gas Expulsion

BY

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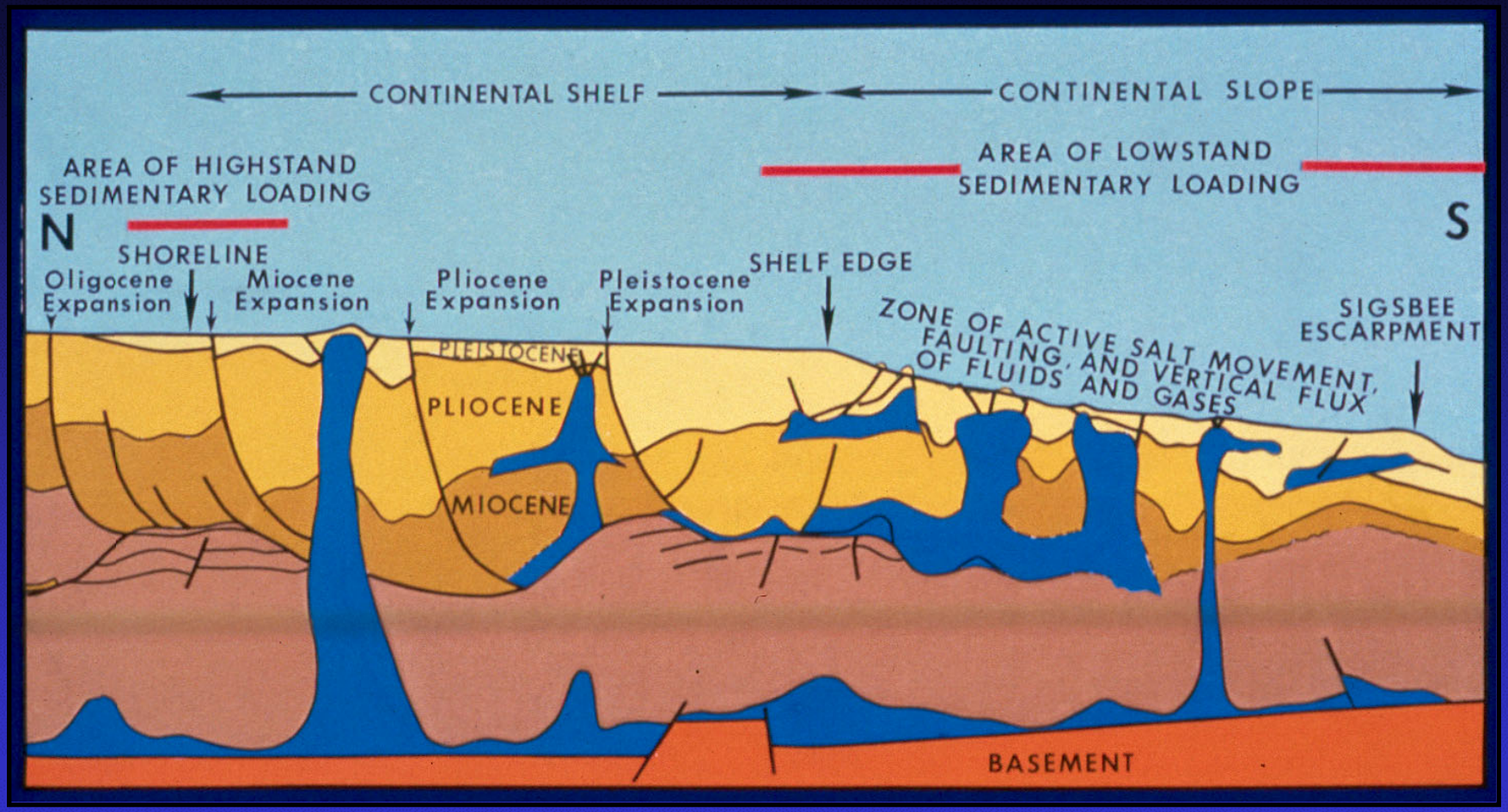
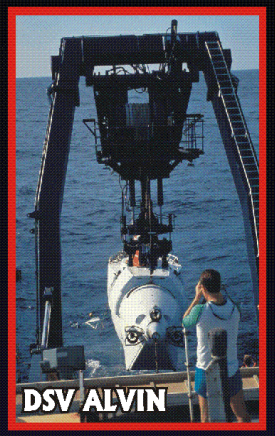
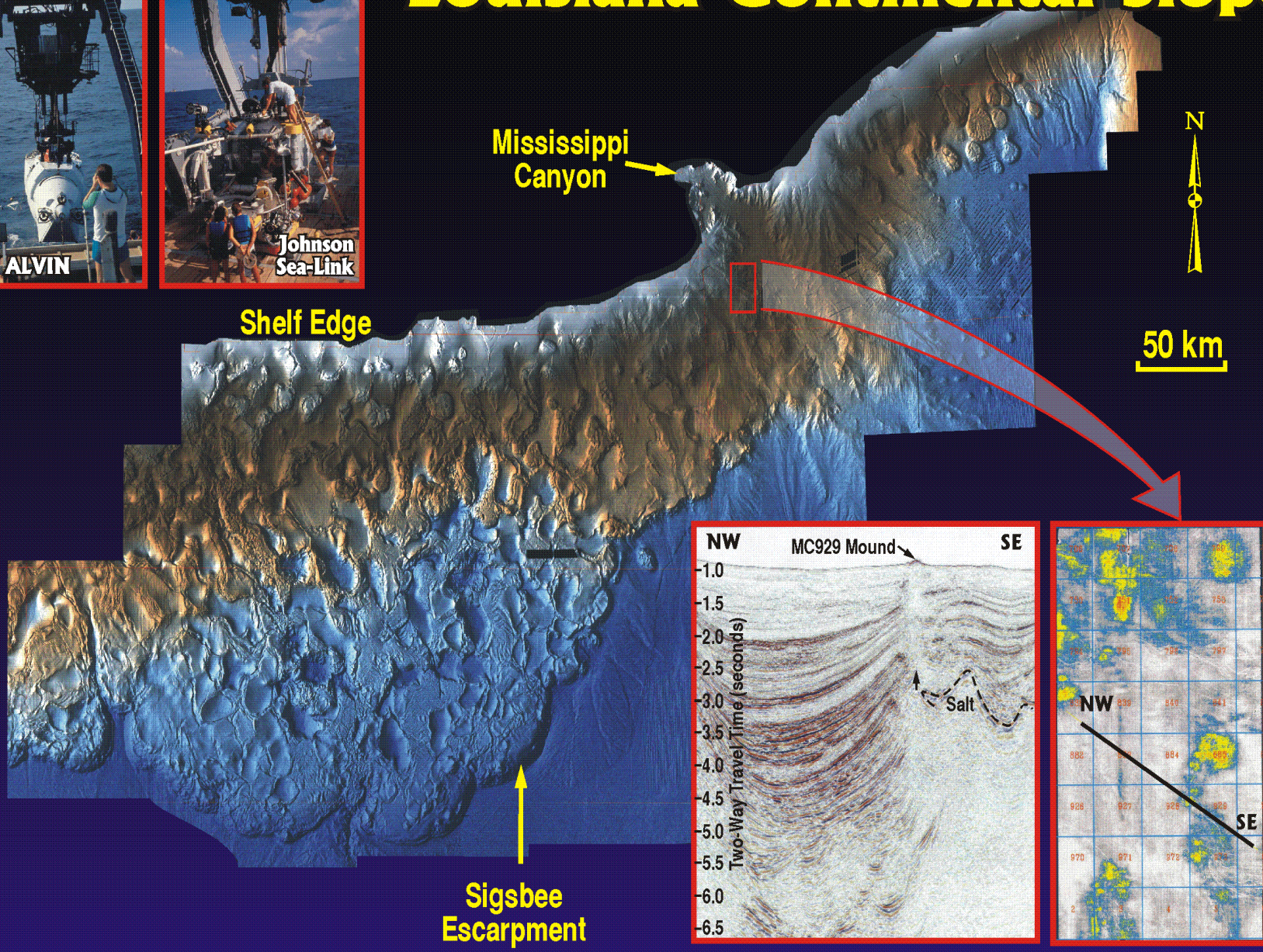
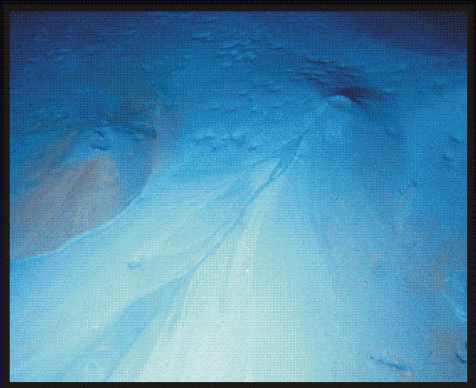
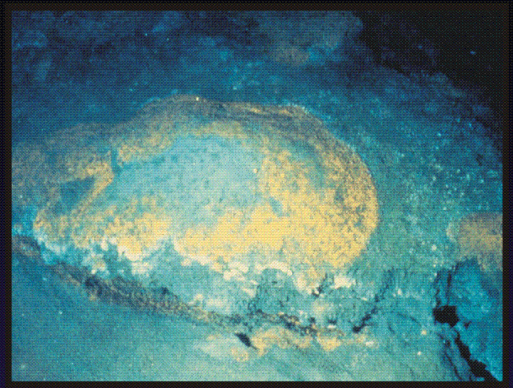
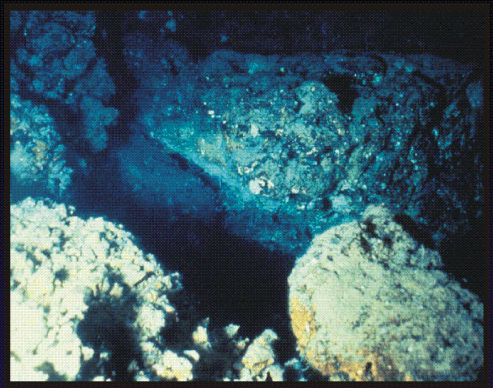
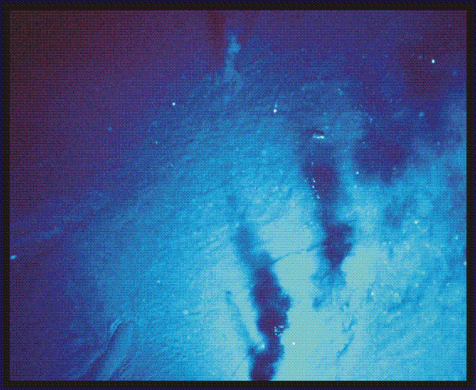
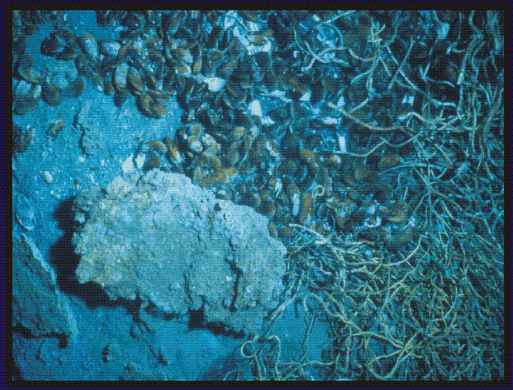
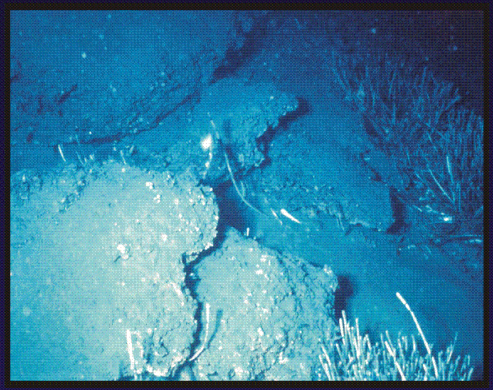

CONTINENTAL SHELF
CONTINENTAL SLOPE
AREA OF HIGHSTAND SEDIMENTARY LOADING
AREA OF LOWSTAND SEDIMENTARY LOADING
N
S
SHORELINE
Oligocene Expansion
Miocene Expansion
Pliocene Expansion
Pleistocene Expansion
SHELF EDGE
SIGSBEE ESCARPMENT
ZONE OF ACTIVE SALT MOVEMENT, FAULTING, AND VERTICAL FLUX OF FLUIDS AND GASES
PLEISTOCENE
PLIOCENE
MIOCENE
BASEMENT

Louisiana Continental Slope





Geological-Biological Responses to Fluid and Gas Expulsion

RAPID FLUX — **MODERATE FLUX** — **SLOW FLUX**

- Mud-Prone Features (Large Mud Volcanoes, Mud Flows, Mud Vents)
- Localized Bacterial Mats, Lucinid Vesycomyid Clays
- Nonbiodegraded - Slightly Biodegraded Hydrocarbons

- Gas Hydrate Mounds, Isolated Authigenic Carbonates, Small Fluid-Gas Expulsion Features
- Dense, Diverse Chemosynthetic Communities (Bacterial Mats, Pogonophoran Tube Worms, Bathymodiolid Mussels, Lucinid Clams)
- Moderately Biodegraded Hydrocarbons

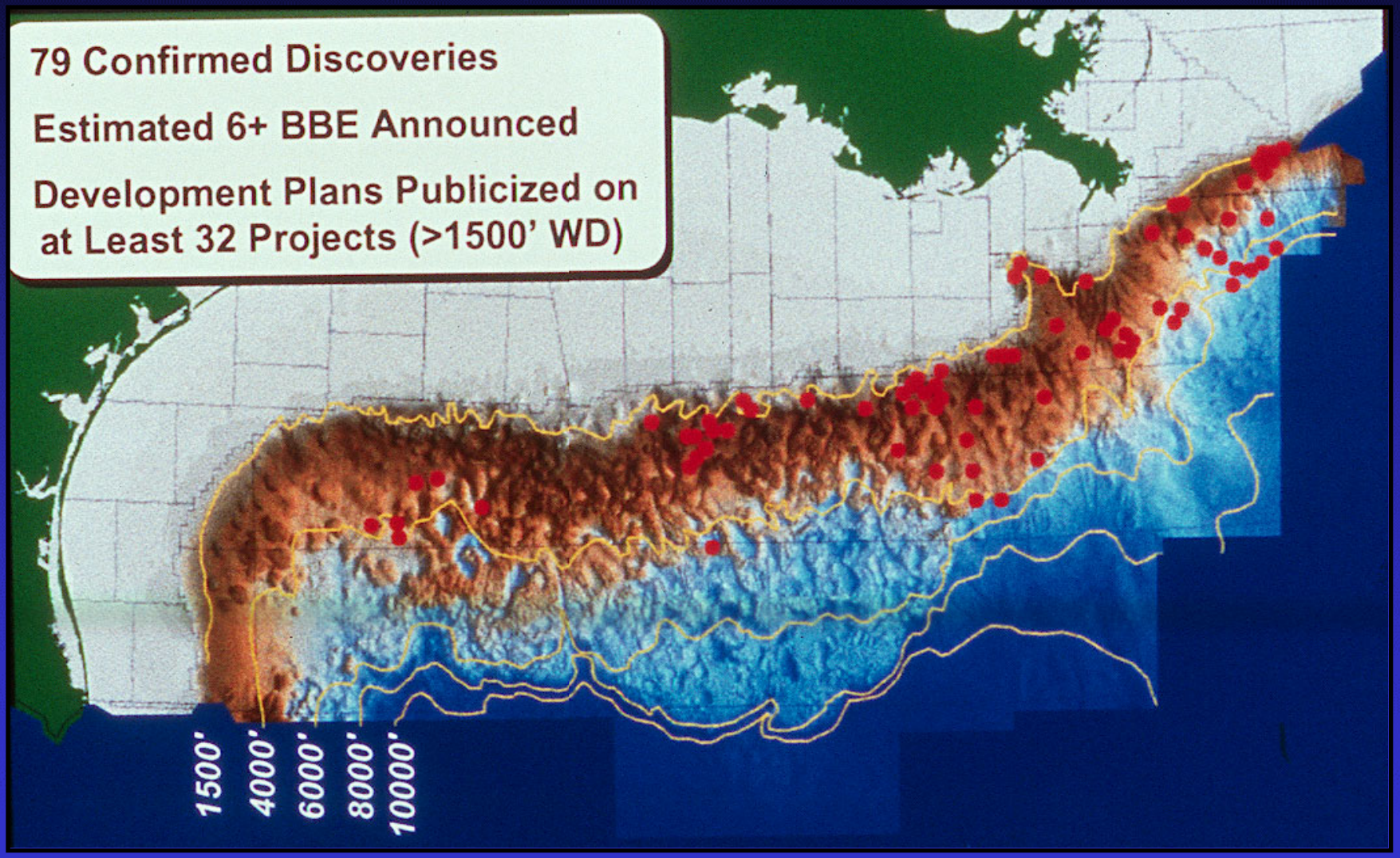
- Mineral-Prone Features (Authigenic Carbonate Mounds - Hardgrounds - Nodules; Mineralized Cones and Chimneys)
- Very Localized and Poorly Developed Chemosynthetic Communities
- Highly Biodegraded Hydrocarbons

MUD-PRONE — **MINERAL-PRONE**

Problem:

Reliable Prediction of Bottom Type from Remotely Sensed Data

Deepwater Discoveries



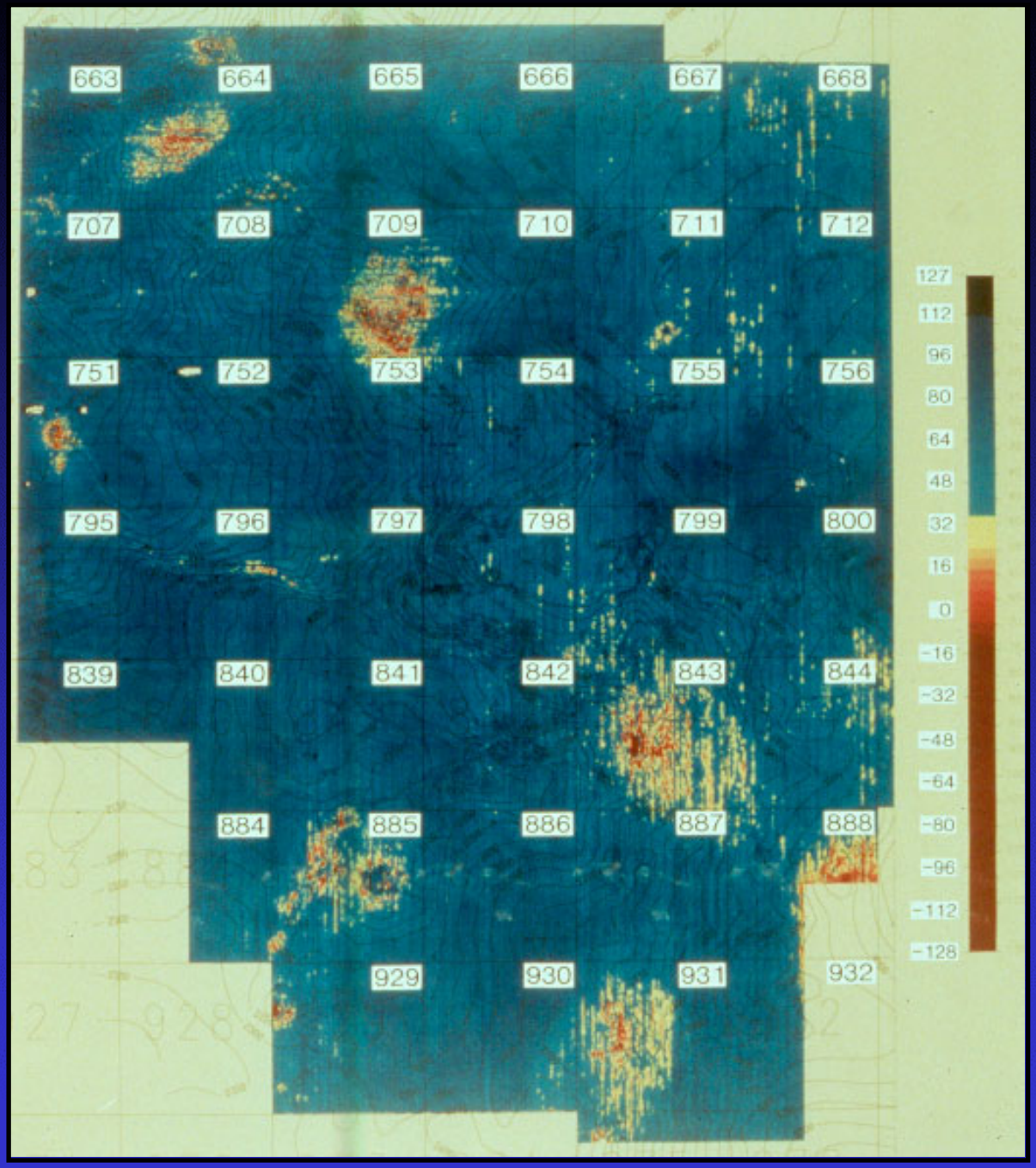
Approach:

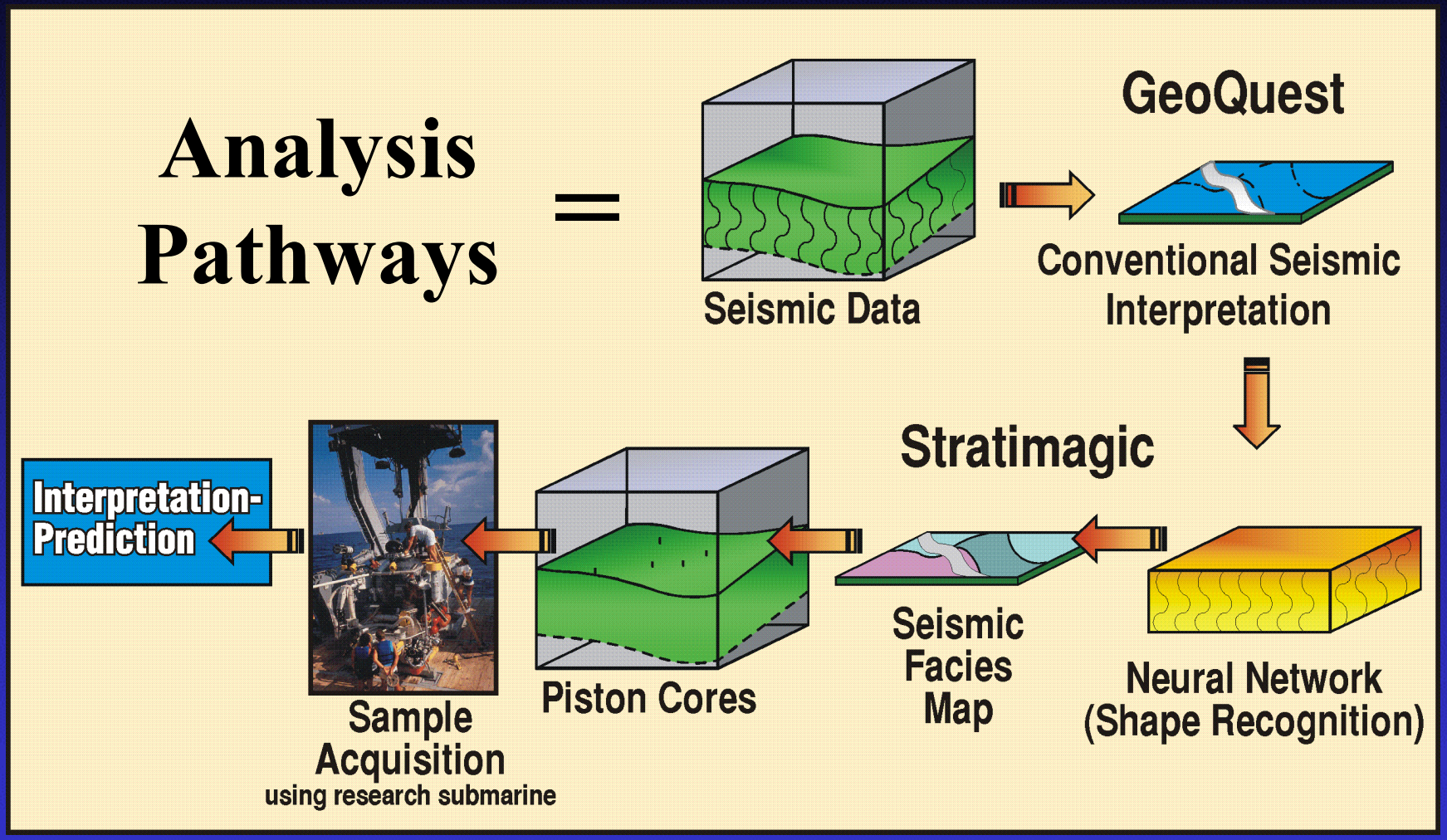
3D-Seismic Surface Attribute Data and Wave-Form Analysis Calibrated to “Ground-Truth”

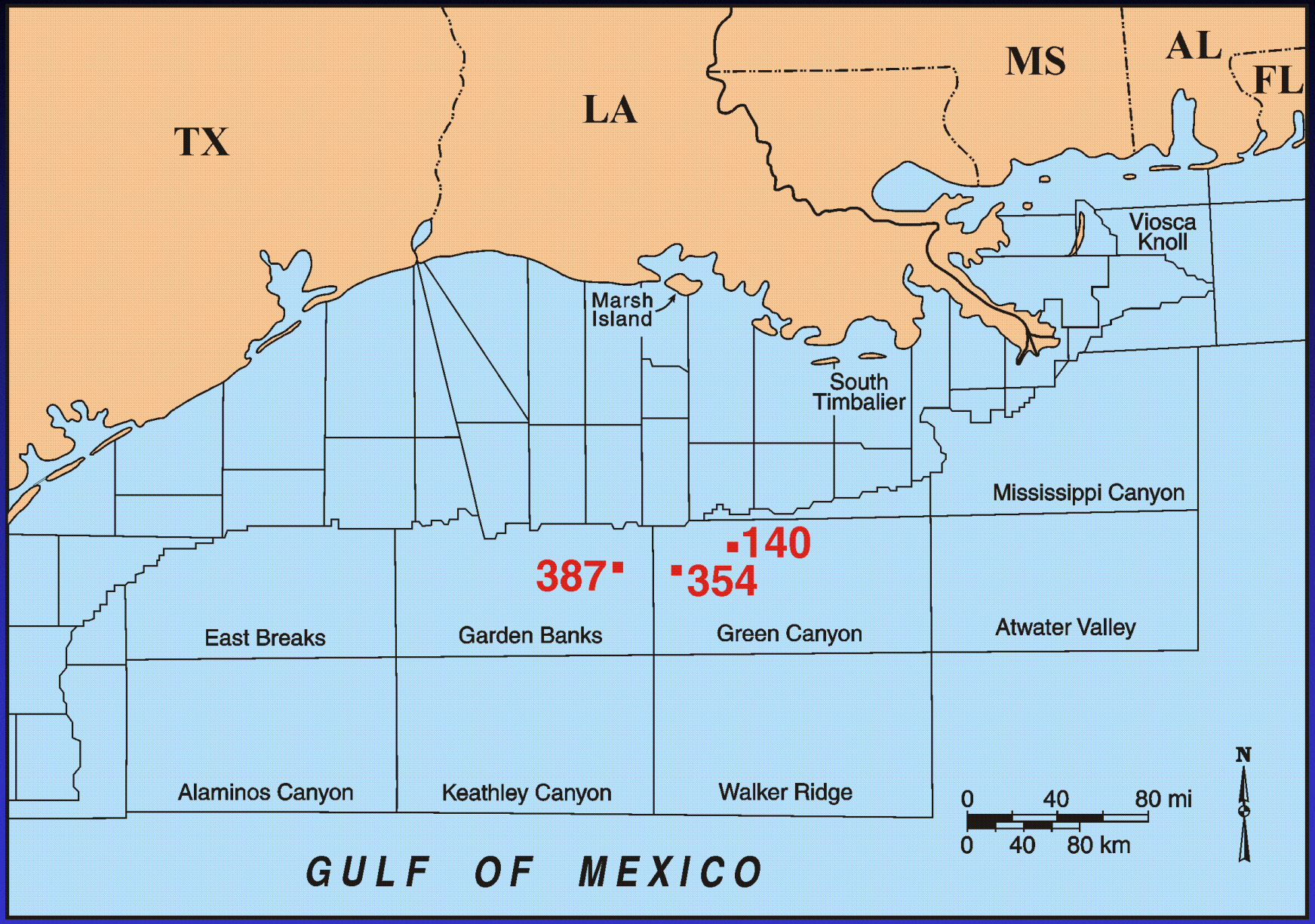
Methods

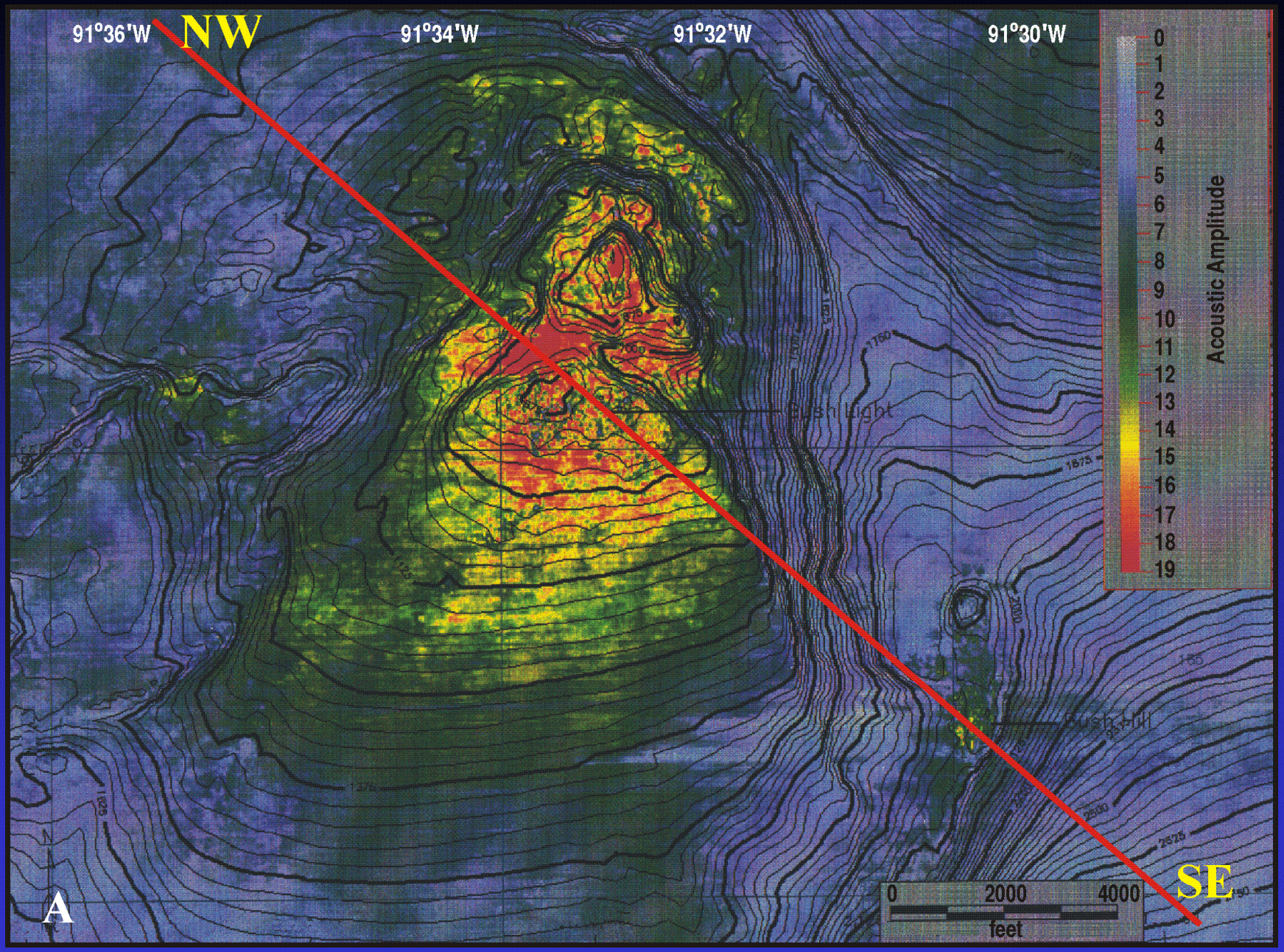
- 3D-Seismic
- Geoquest Software
- Ground Truth
  - **Submersible Observation**
  - **Piston Cores**

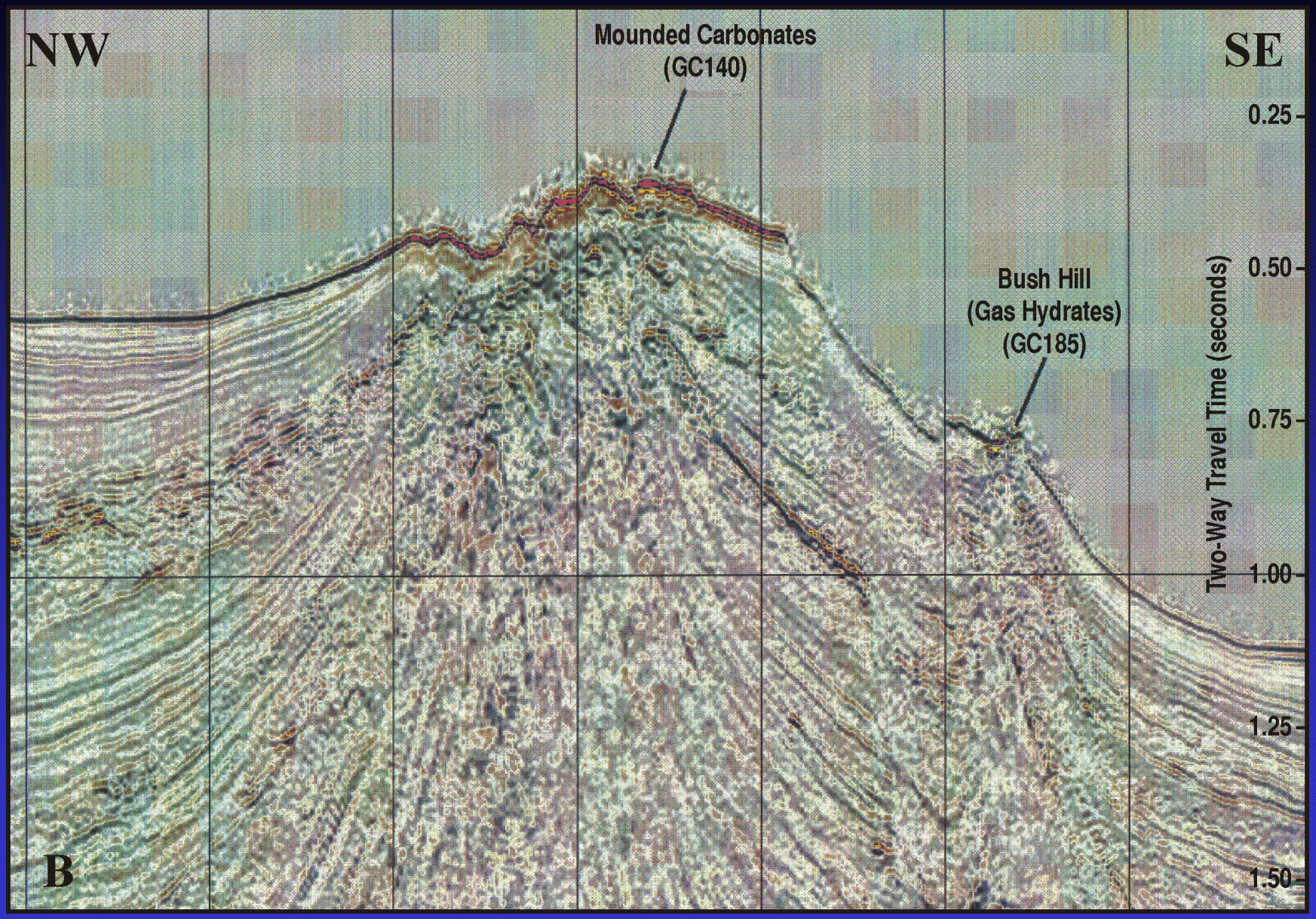
3D-Seismic Surface Amplitudes



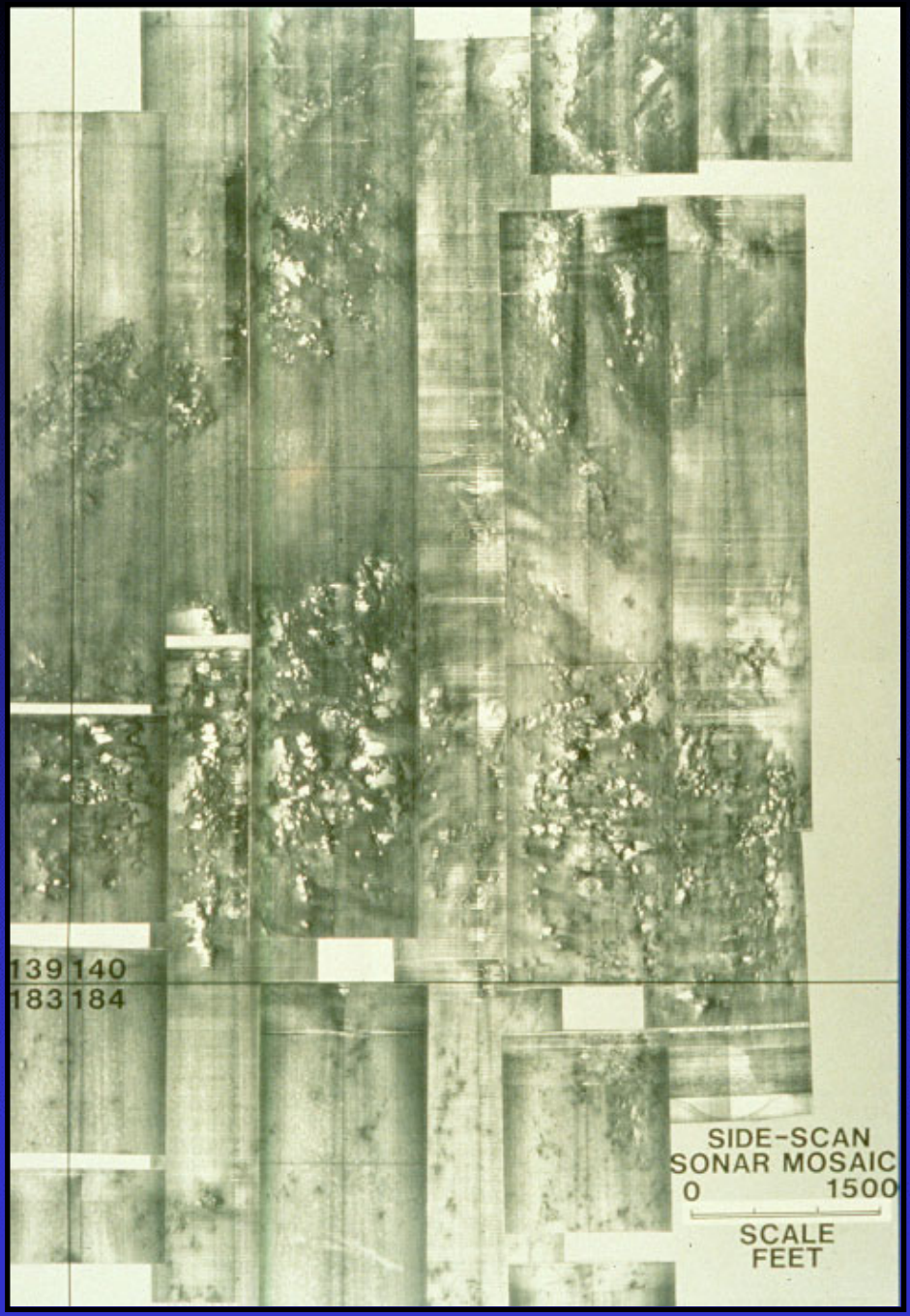

Analysis Pathways
=
Seismic Data
GeoQuest
Conventional Seismic Interpretation
Stratimagic
Neural Network (Shape Recognition)
Seismic Facies Map
Piston Cores
Sample Acquisition
using research submarine
Interpretation-Prediction

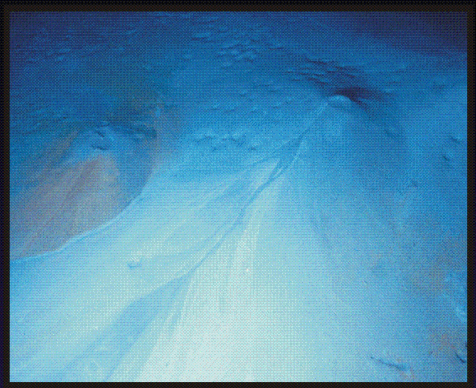
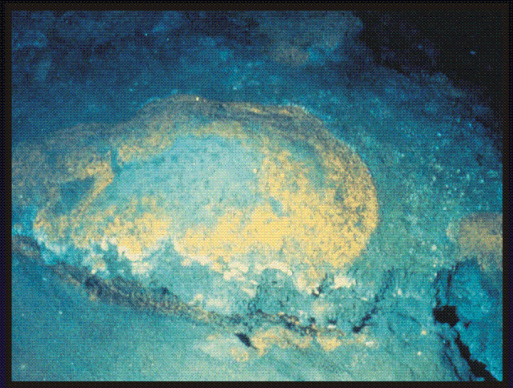
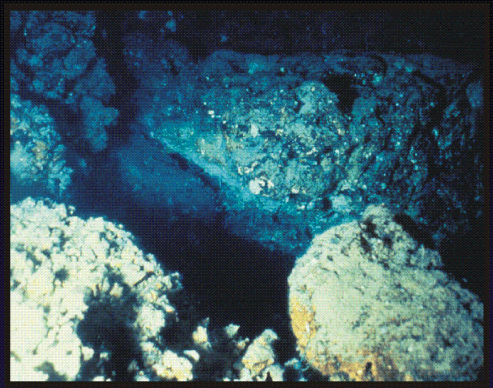
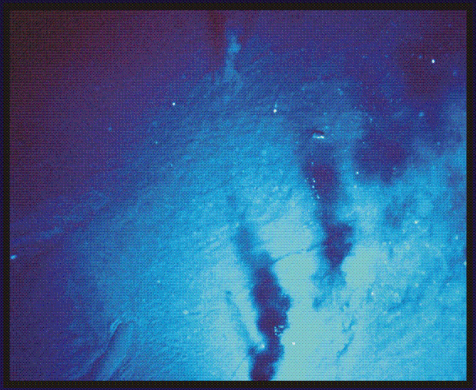
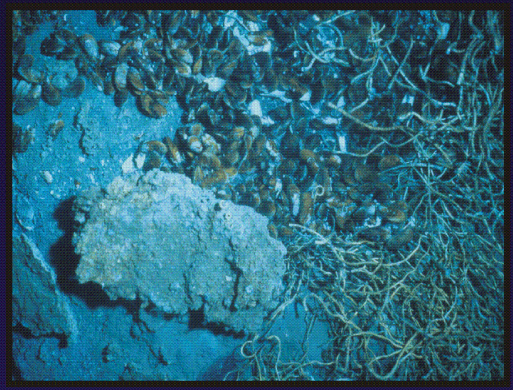
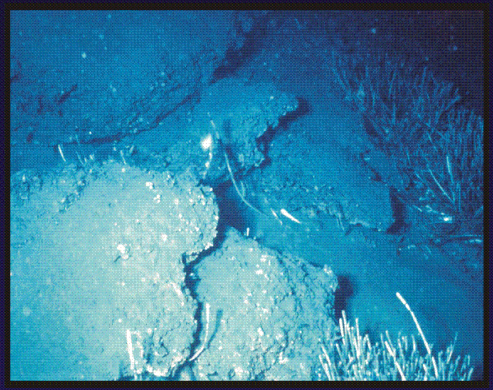

TX
LA
MS
AL
FL
Viosca Knoll
Marsh Island
South Timbalier
Mississippi Canyon
140
387
354
East Breaks
Garden Banks
Green Canyon
Atwater Valley
Alaminos Canyon
Keathley Canyon
Walker Ridge
0 40 80 mi
0 40 80 km
N
GULF OF MEXICO


91°36'W
NW
91°34'W
91°32'W
91°30'W
Acoustic Amplitude
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Flashlight
Crushhull
0
2000
4000
feet
SE
A


NW
SE
Mounded Carbonates
(GC140)
Bush Hill
(Gas Hydrates)
(GC185)
Two-Way Travel Time (seconds)
0.25
0.50
0.75
1.00
1.25
1.50
B

Side-Scan Sonar Mosaic



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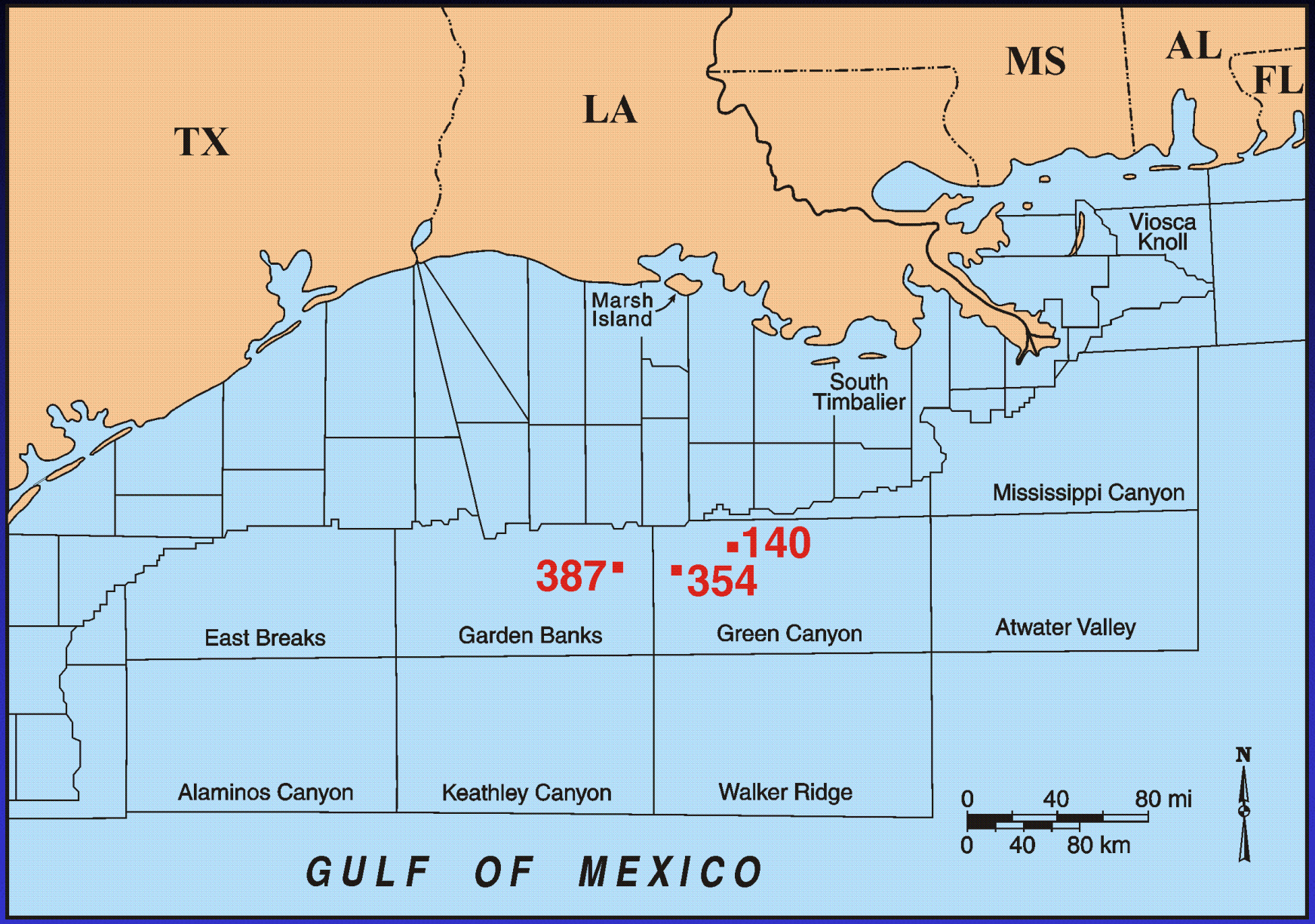
MUD-PRONE — **MINERAL-PRONE**

Garden Banks 387 – 388
(Cooper Prospect)


TX
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N
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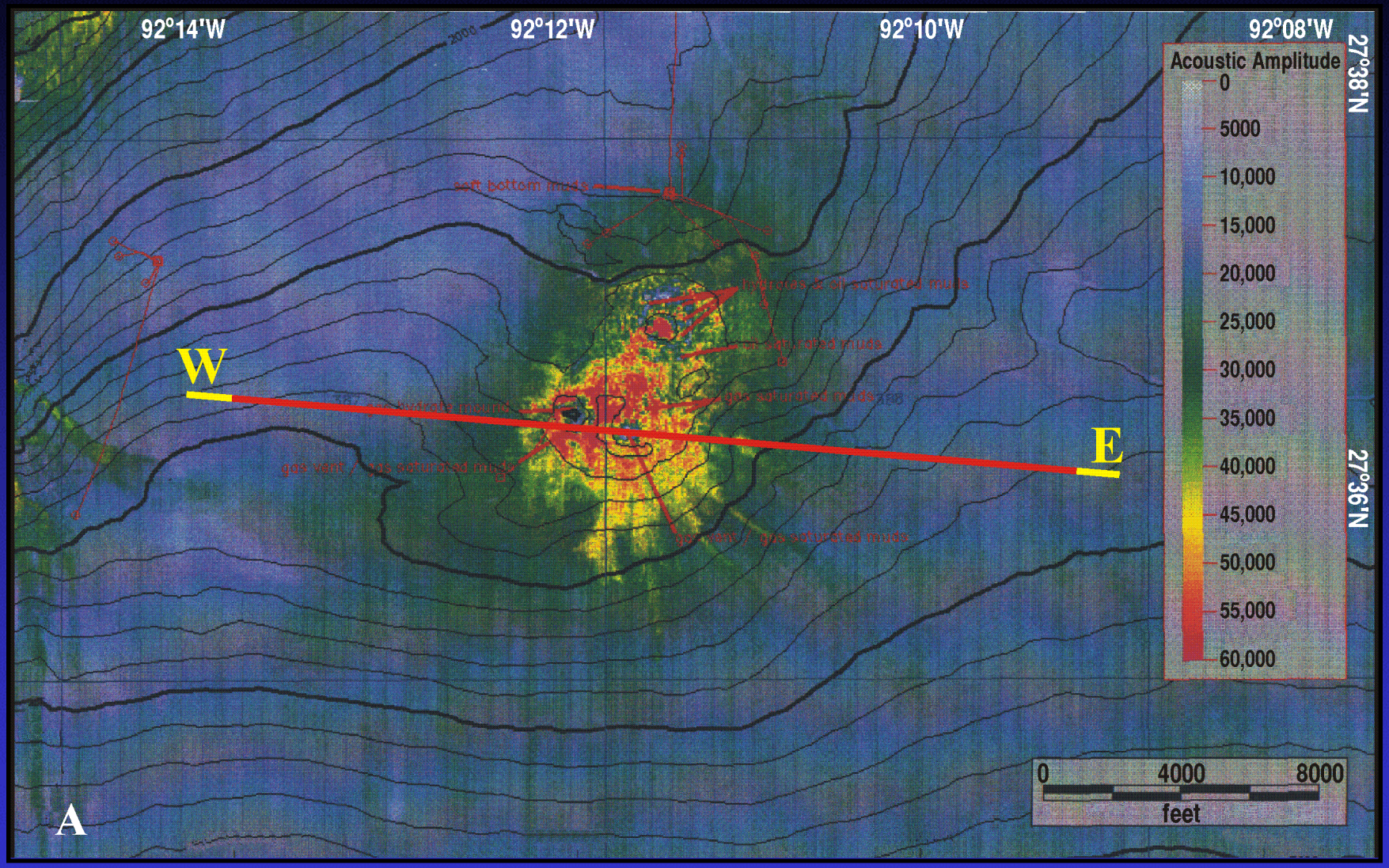
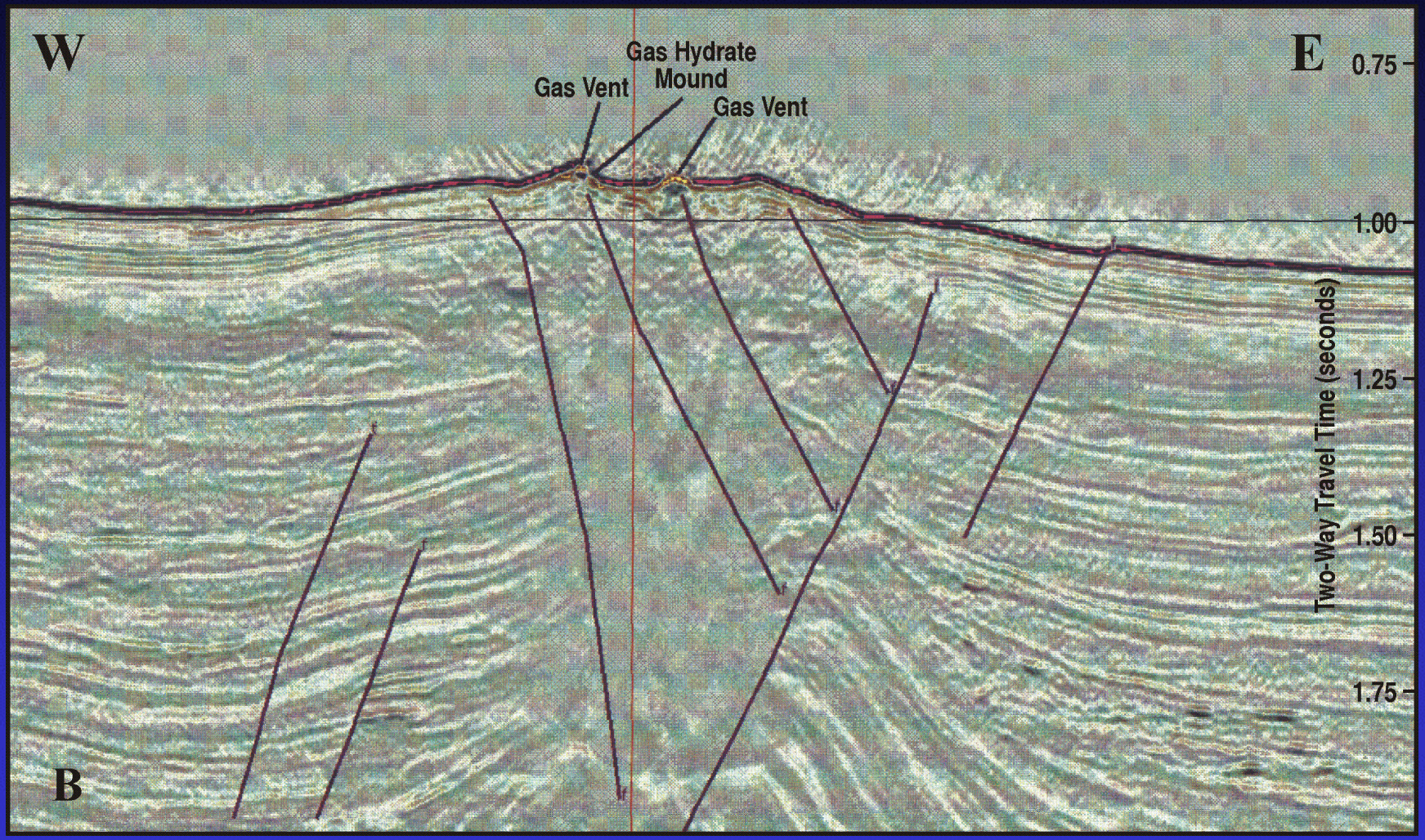
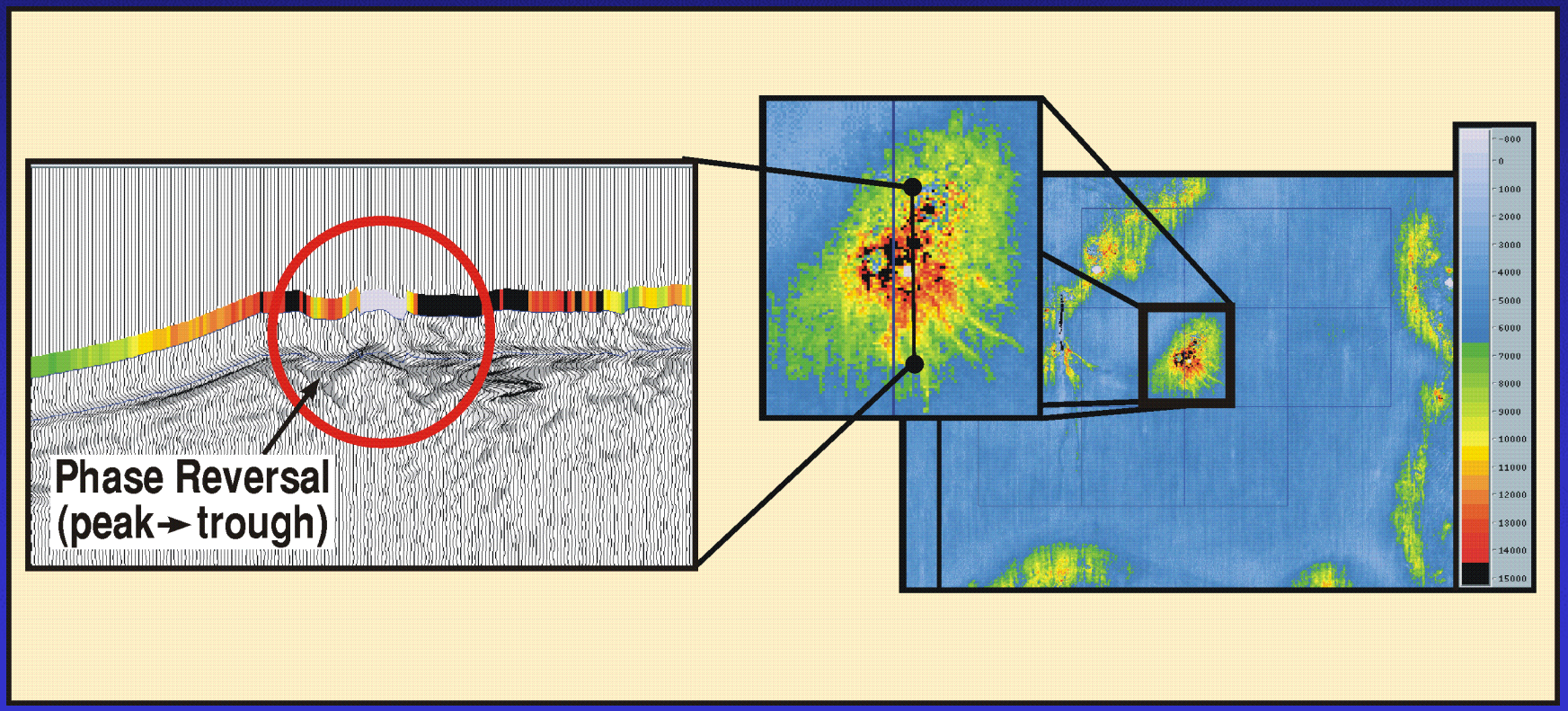

92°14'W
92°12'W
92°10'W
92°08'W
27°38'N
27°36'N
Acoustic Amplitude
0
5000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
50,000
55,000
60,000
W
E
soft bottom muds
hydrates & oil saturated muds
saturated muds
gas saturated muds
hydrate mound
gas vent / gas saturated muds
gas vent / gas saturated muds
0
4000
8000
feet
A


W
E
Gas Hydrate
Mound
Gas Vent
Gas Vent
0.75
1.00
1.25
1.50
1.75
Two-Way Travel Time (seconds)
B

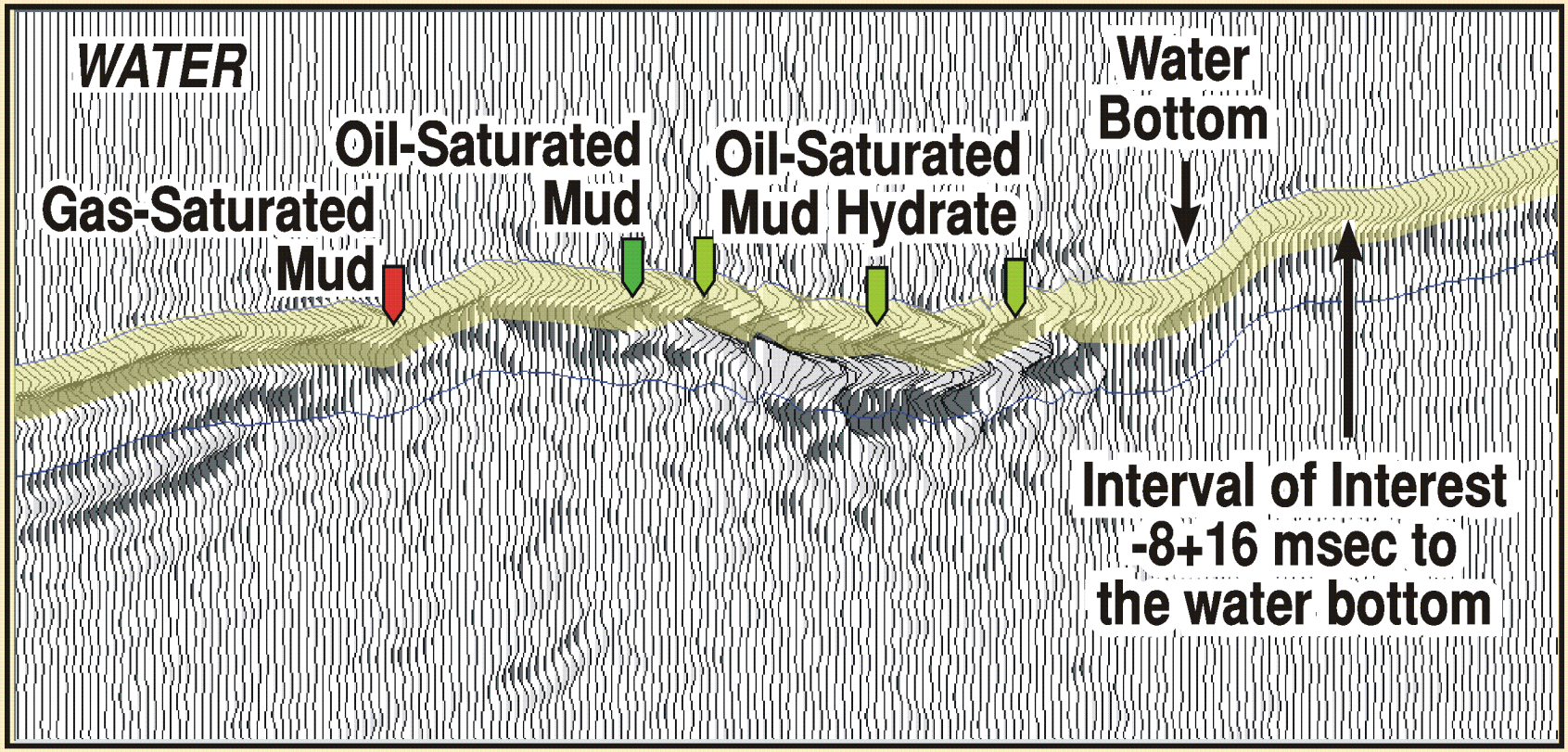
Structural Interpretation

• Conventional Horizon Attributes

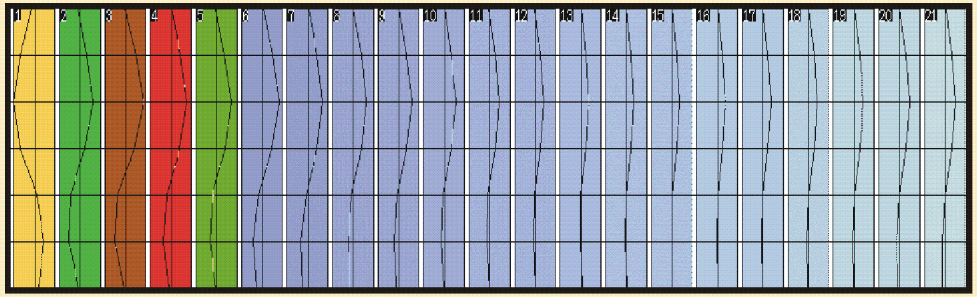
Amplitude map of the water bottom shows high amplitudes related to gas-hydrate systems with phase reversals at gas-saturated mud volcanoes.



S-N Line Trough Gas-Hydrate Samples



Model Traces



Oil-Saturated Mud/Hydrate

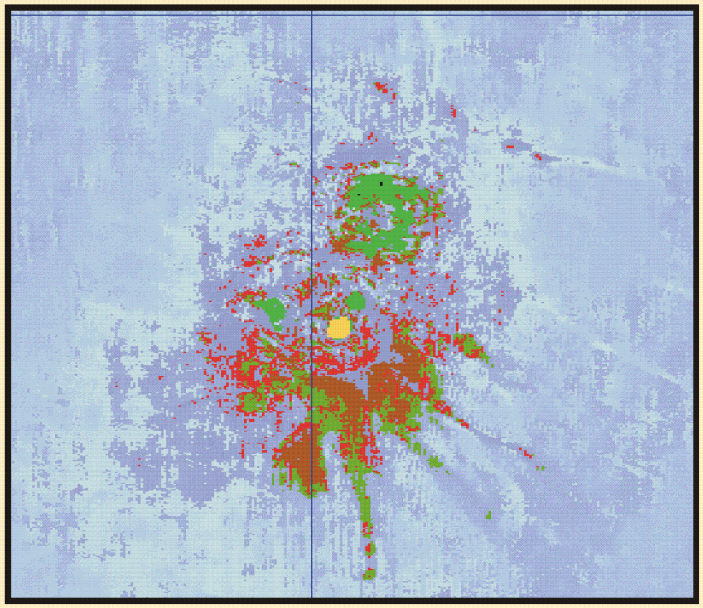
Gas-Saturated Mud

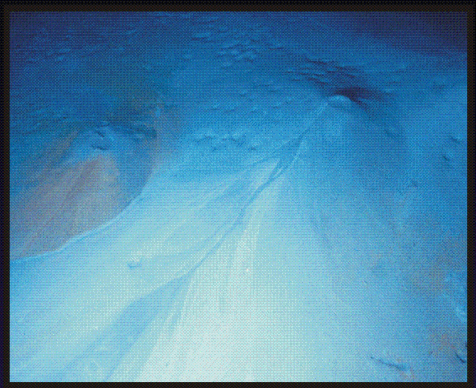
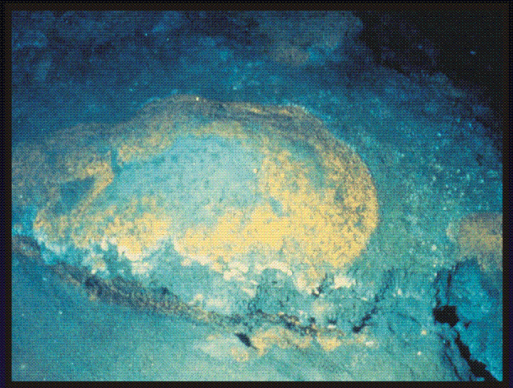
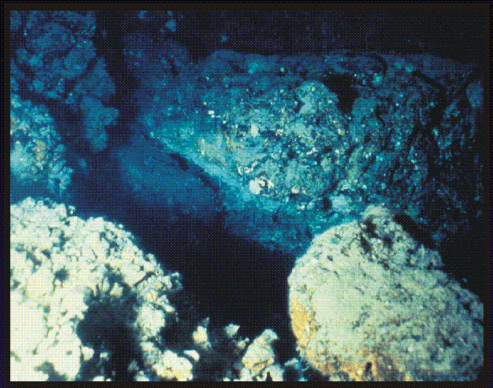
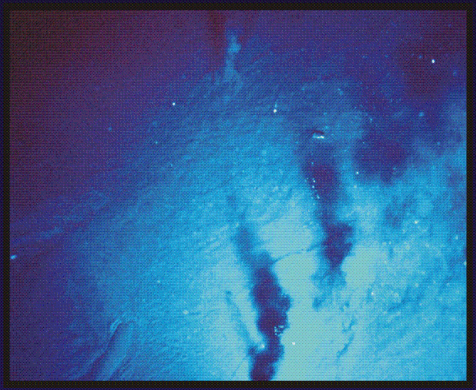
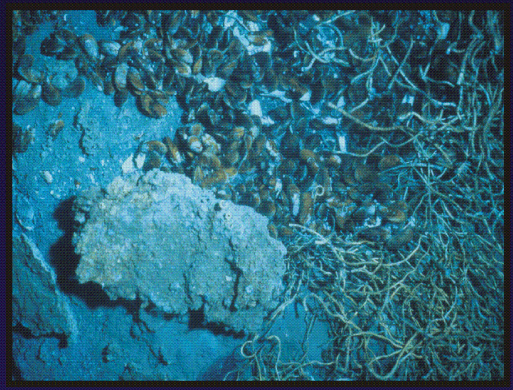
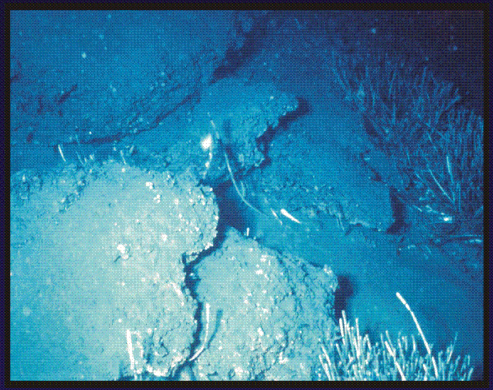
Hard-Ground Chemo

Gas-Hydrate Mound

Gas-Saturated Mud Volcano

Seismic Facies Map



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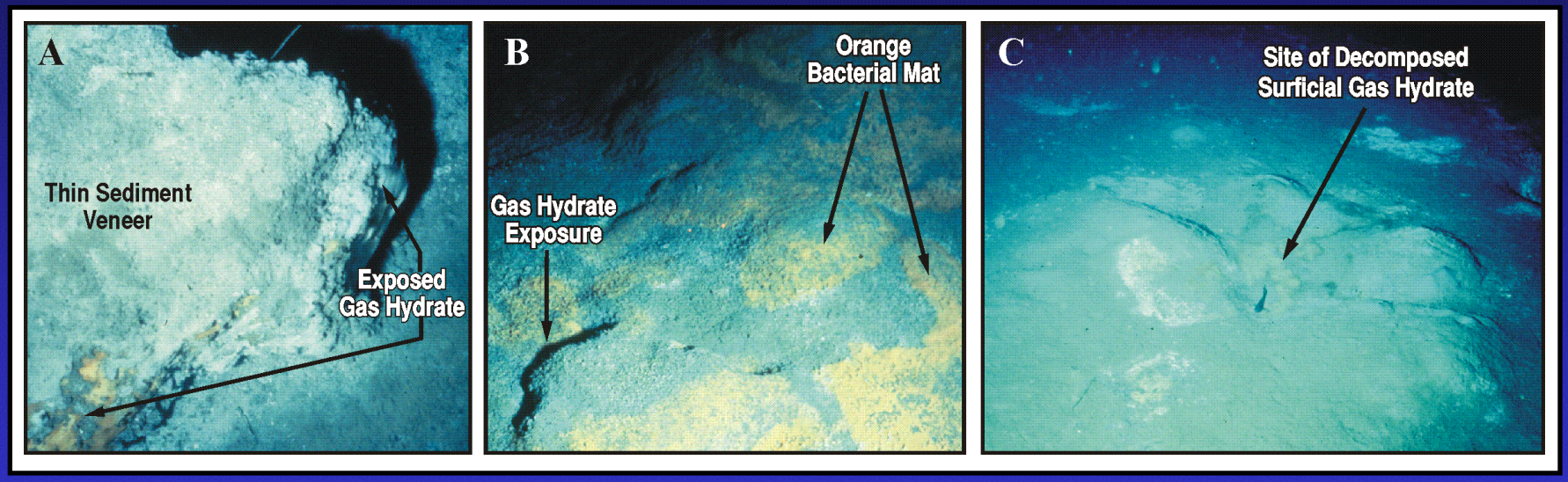
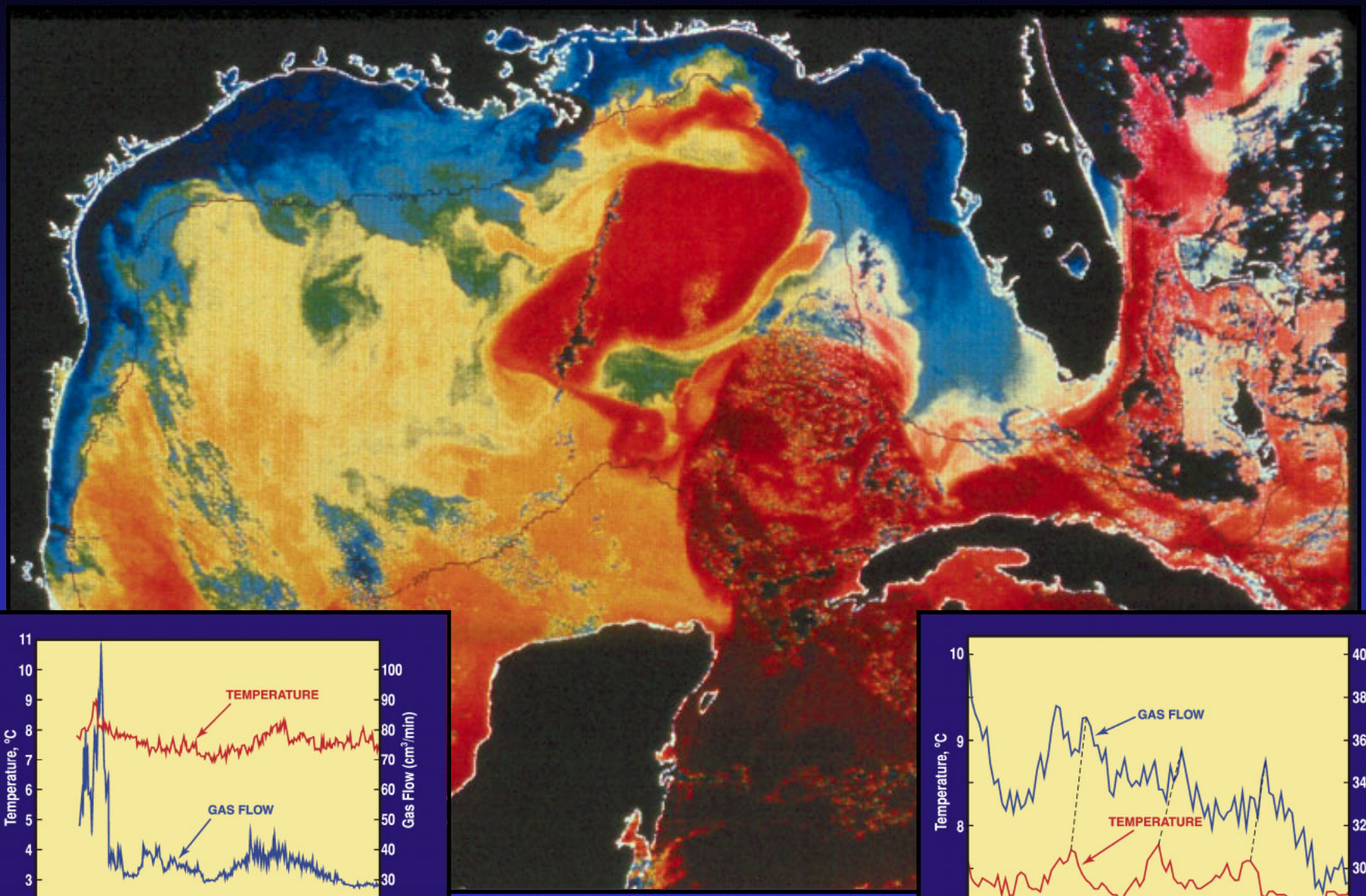
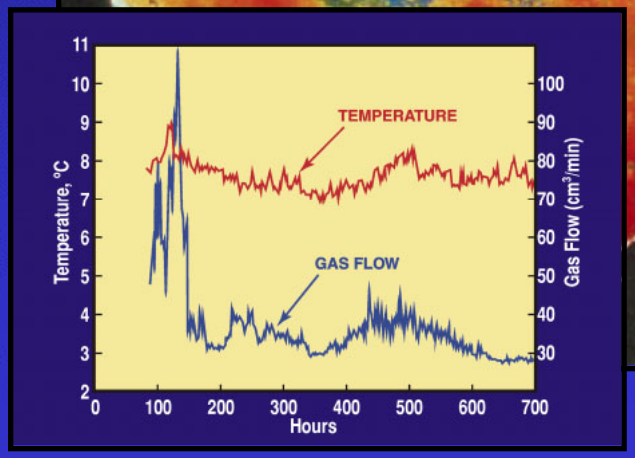
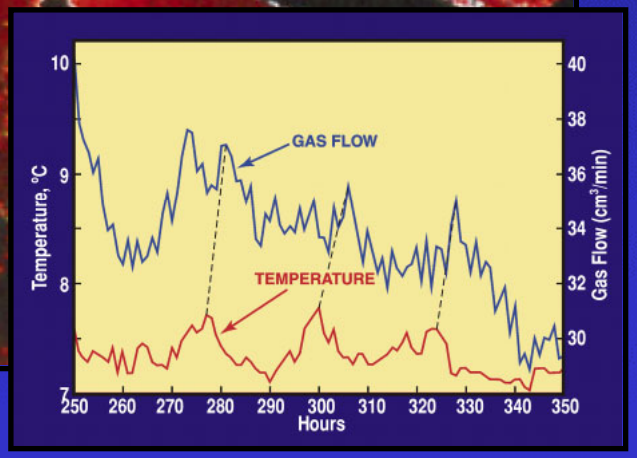
MUD-PRONE — **MINERAL-PRONE**

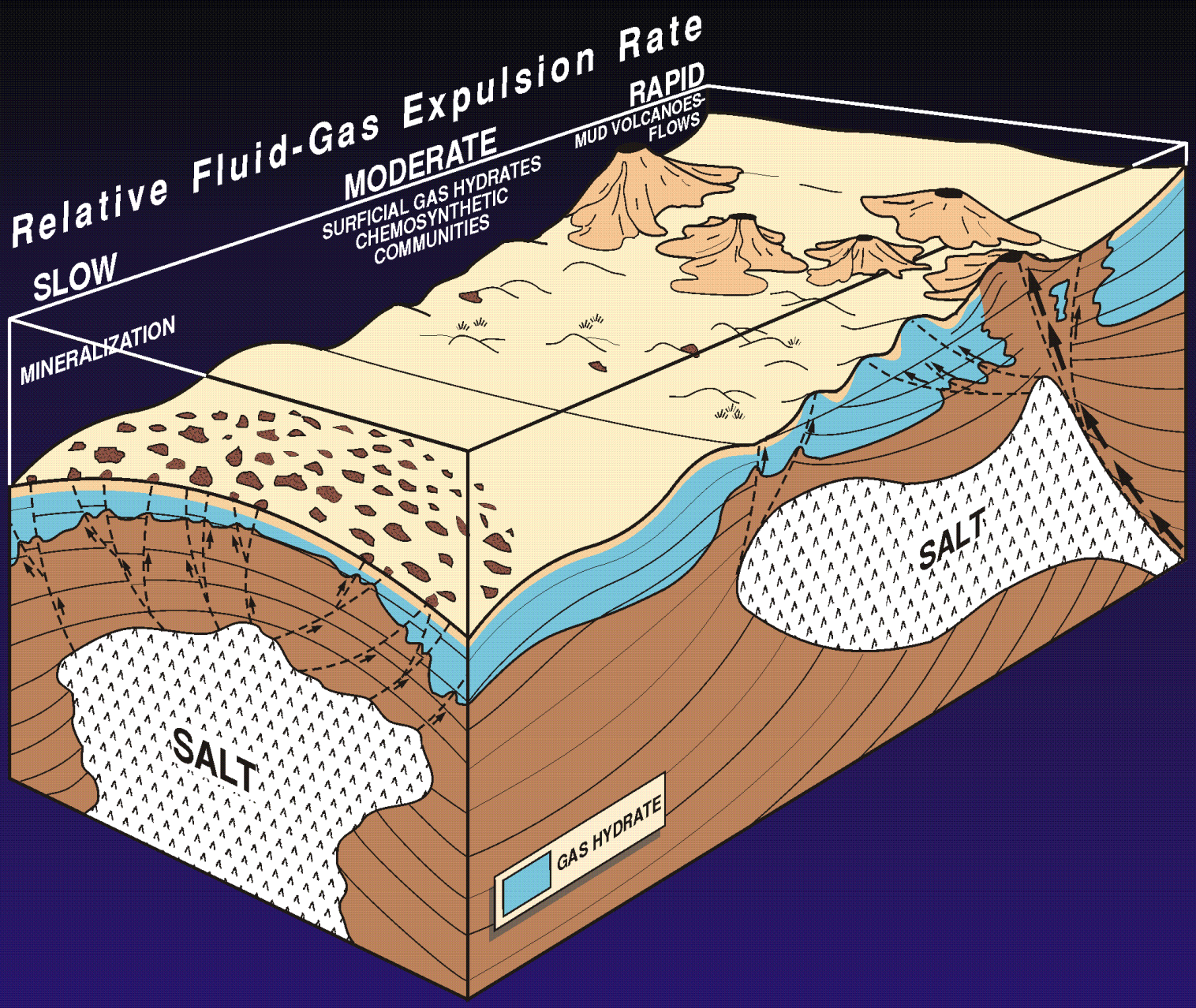
Dissociation of Gas Hydrate






TEMPERATURE
GAS FLOW
Temperature, °C
Gas Flow (cm³/min)
Hours
11
10
9
8
7
6
5
4
3
2
100
90
80
70
60
50
40
30
0
100
200
300
400
500
600
700


GAS FLOW
TEMPERATURE
Temperature, °C
Gas Flow (cm³/min)
Hours
10
9
8
7
40
38
36
34
32
30
250
260
270
280
290
300
310
320
330
340
350


Relative Fluid-Gas Expulsion Rate
SLOW
MODERATE
RAPID
MINERALIZATION
SURFICIAL GAS HYDRATES
CHEMOSYNTHETIC
COMMUNITIES
MUD VOLCANOES-
FLOWS
SALT
SALT
GAS HYDRATE

Summary

- Few simple BSRs – complex geological framework.
- Gas hydrates concentrated in intraslope basin margins.
  - Numerous faults
  - Salt-focused vertical fluid/gas explusion
- Fluid-gas expulsion rate controls seafloor response.
  - Rapid flux – mud prone
  - Slow flux – mineral prone
  - Surficial gas hydrates – intermediate flux

Summary

- Oceanic processes affect surface gas hydrates.
- Abundant supply of gas-fluid to regenerate surface hydrates.
- Long-term changes in gas-hydrates forced by global climate change (sea level and sediment supply).