Subsurface Structure and Stratigraphy of a Transient, Fault-Controlled Thermogenic Hydrate System at MC-118, Gulf of Mexico*

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Abstract

Analysis of 3-D seismic reflection data and integration with industry well logs reveals the subsurface structural and stratigraphic architecture of a thermogenic hydrate system in the Mississippi Canyon area (MC-118) of the Gulf of Mexico. Like many hydrocarbon systems in the Gulf of Mexico, MC-118 is dominated by the presence and periodic movement of allochthonous salt within the sedimentary section. The deeply rooted northwestern flank of the salt body appears to tap depths suitable for hydrocarbon maturation, while the steep flanks of the salt body provide migration pathways for deep basin fluids. A radiating crestal fault structure above the salt creates a delivery system to the shallow subsurface and venting at the seafloor.

Development of seafloor hydrate/carbonate mounds shows a close spatial association with three shallow crestal faults, and suggests a temporal evolution of venting activity and mound creation. Such spatial and temporal transience may be the result of periodic formation and dissociation of hydrate in the vicinity of these shallow faults. Seismic bright spots appear throughout the 3-D volume, suggesting the abundant presence of free gas within the system. While some of these bright spots show evidence for either structural or stratigraphic trapping elements, the shallowest ones (~100-150 m) may be an expression of free gas at the base of the hydrate stability zone above the salt body.

Stratigraphic relationships indicate that the most recent period of salt mobilization was probably during the Late Pliocene, and subsequent Pleistocene time was characterized by relatively uniform, quiescent sedimentation over the mound site. Such relationships suggest that the hydrate system at MC-118 may be a geologically young feature.

References

Muza, J.P., 2000, Oceanographic history of the Japan Sea during the last one million years based on the calcareous nannofossil record derived from ODP Leg 128, Hole 798A cores: Journal of Nannoplankton Research, v. 22/2, p. 127-128.

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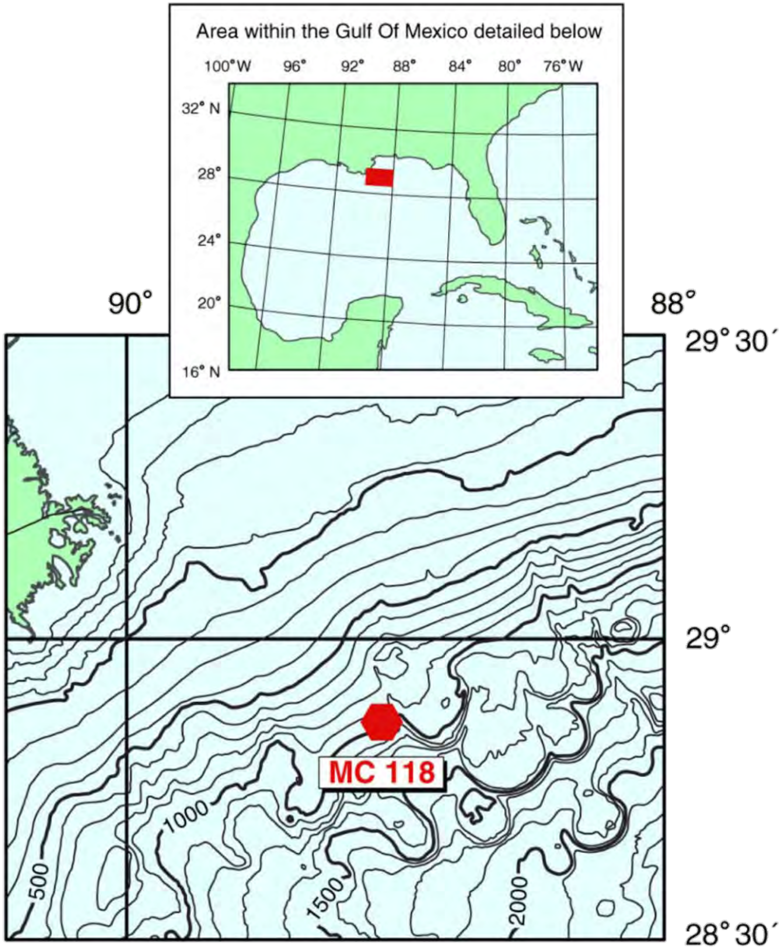
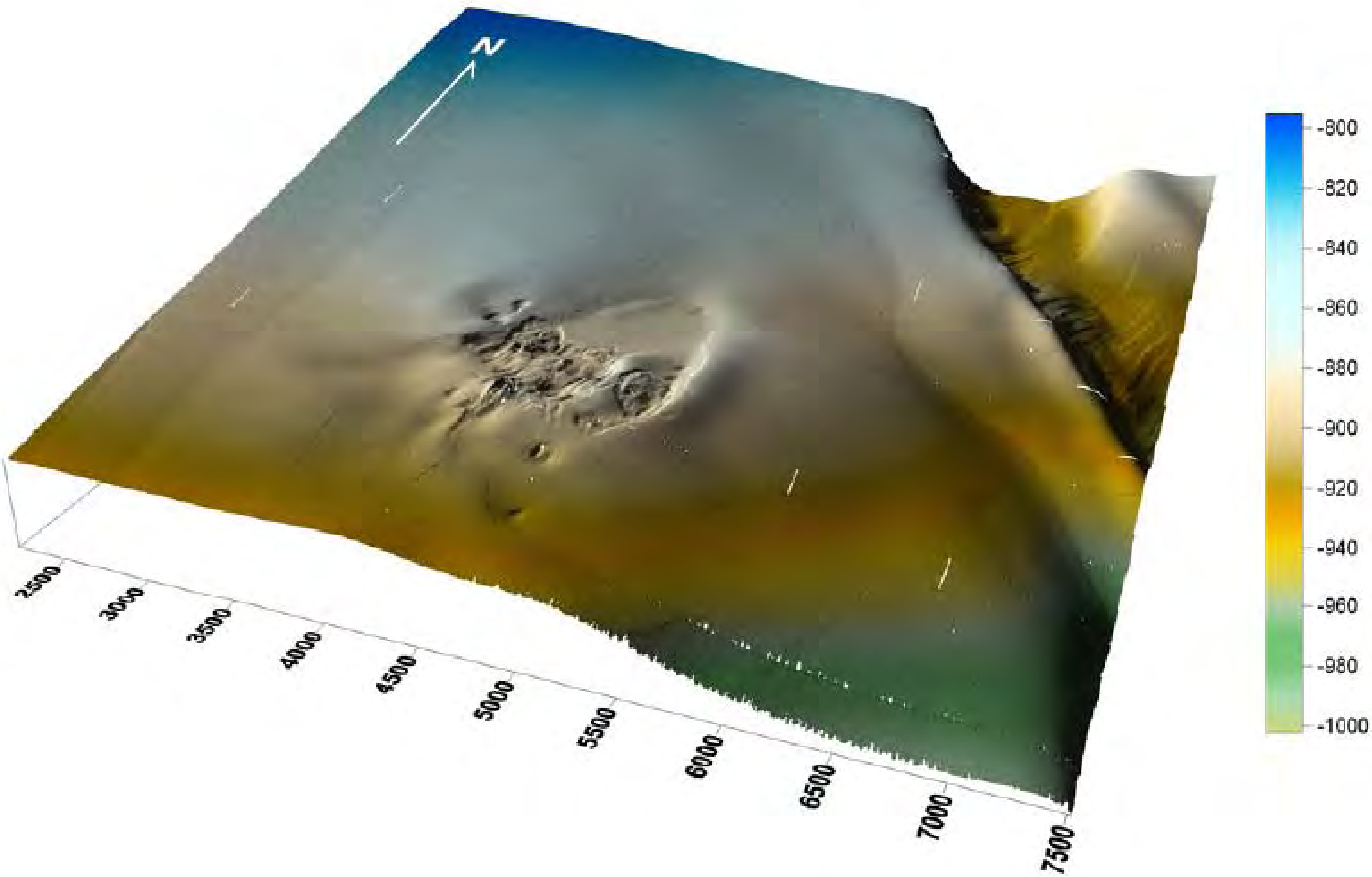
Summary Points

- Two temporally and kinematically distinct salt bodies present in MC-118
- Salt-related fault systems provide likely migration pathways for thermogenic hydrocarbons
- Fault locations, orientations, and geometries appear to correlate with surface bathymetry/activity
- MC-118 well by ARCO provides first-order constraints on stratigraphy and HSZ
- Latest Pleistocene was tectonically quiescent with relatively undisturbed sedimentation – fluid migration to mounds is probably very young

MC-118 Location Map

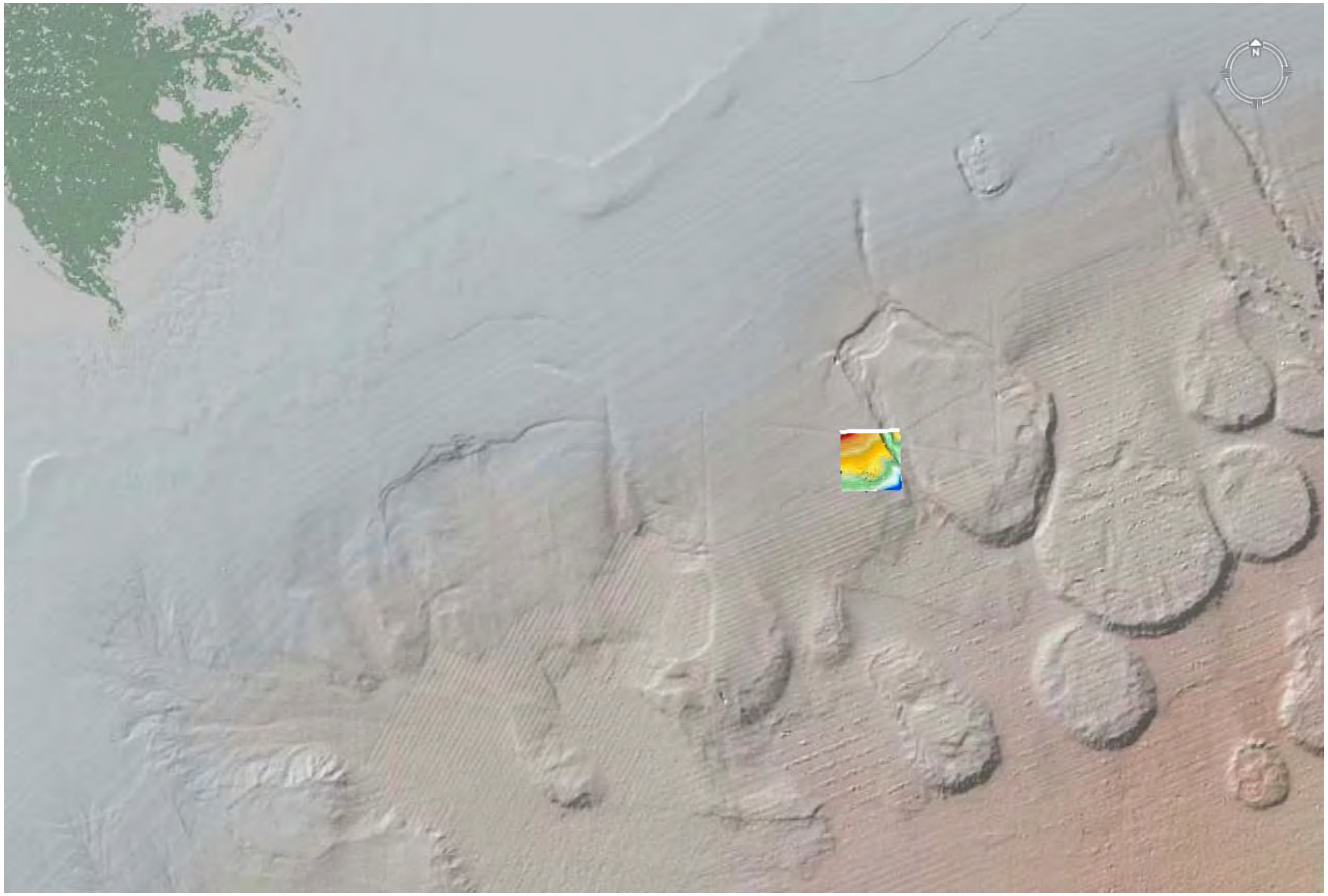


- Mid-slope of GOM
- Area heavily influenced by salt tectonics
- Major slump features evident in bathymetry



Oblique view of swath bathymetric image of MC118

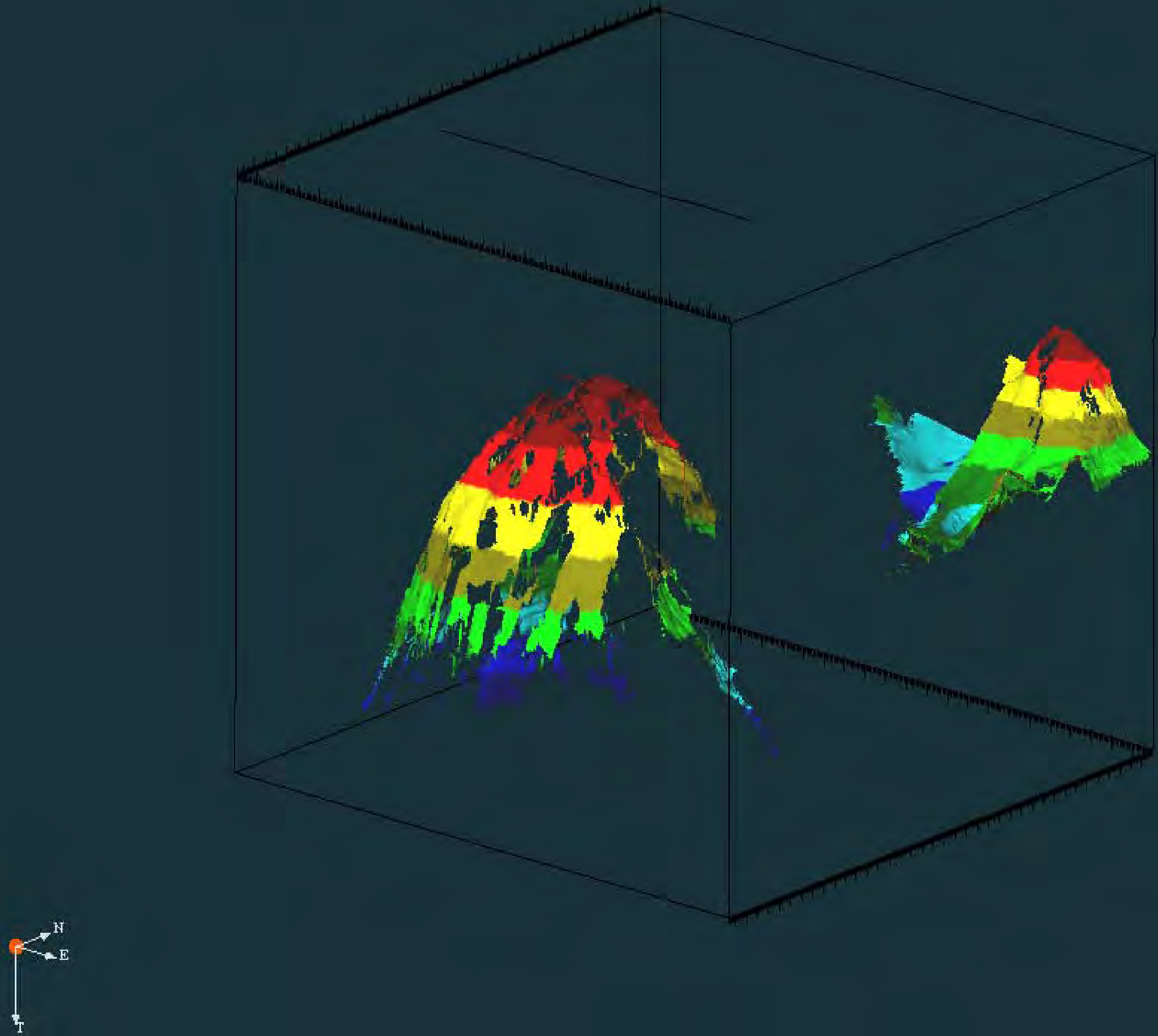
SW Margin of Massive Slump



Courtesy of B. Battista

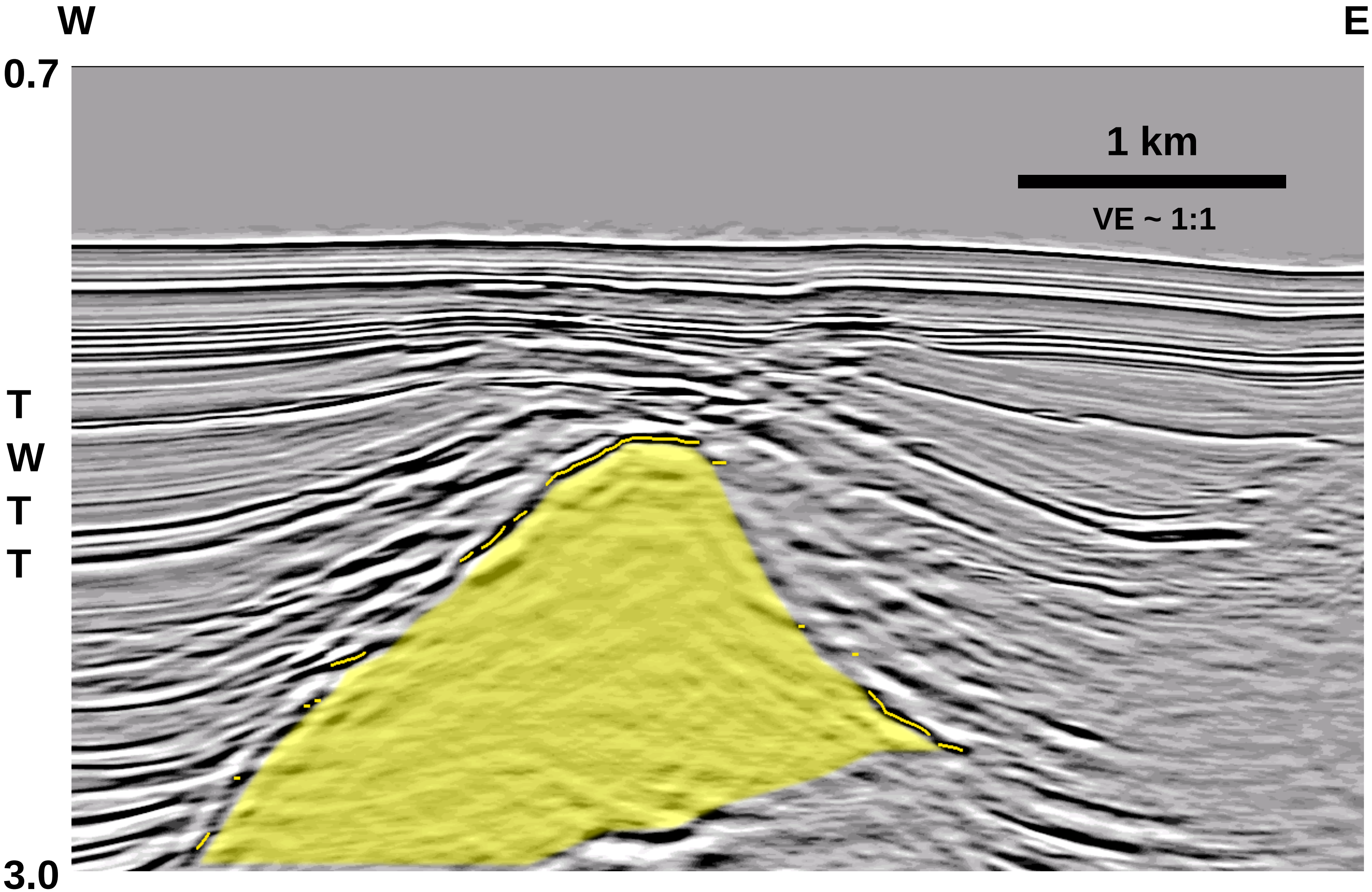
TGS-NOPEC 3-D dataset

- Covers entire block of MC-118
- Extracted from regional 3-D dataset
- Records truncated @ 3 s TWTT (~2000 mbsf)
- Interpreted with SMT Kingdom Suite
- Mapped to date:
  - SW and NE salt bodies
  - Key stratigraphic horizons
  - Crestal fault network

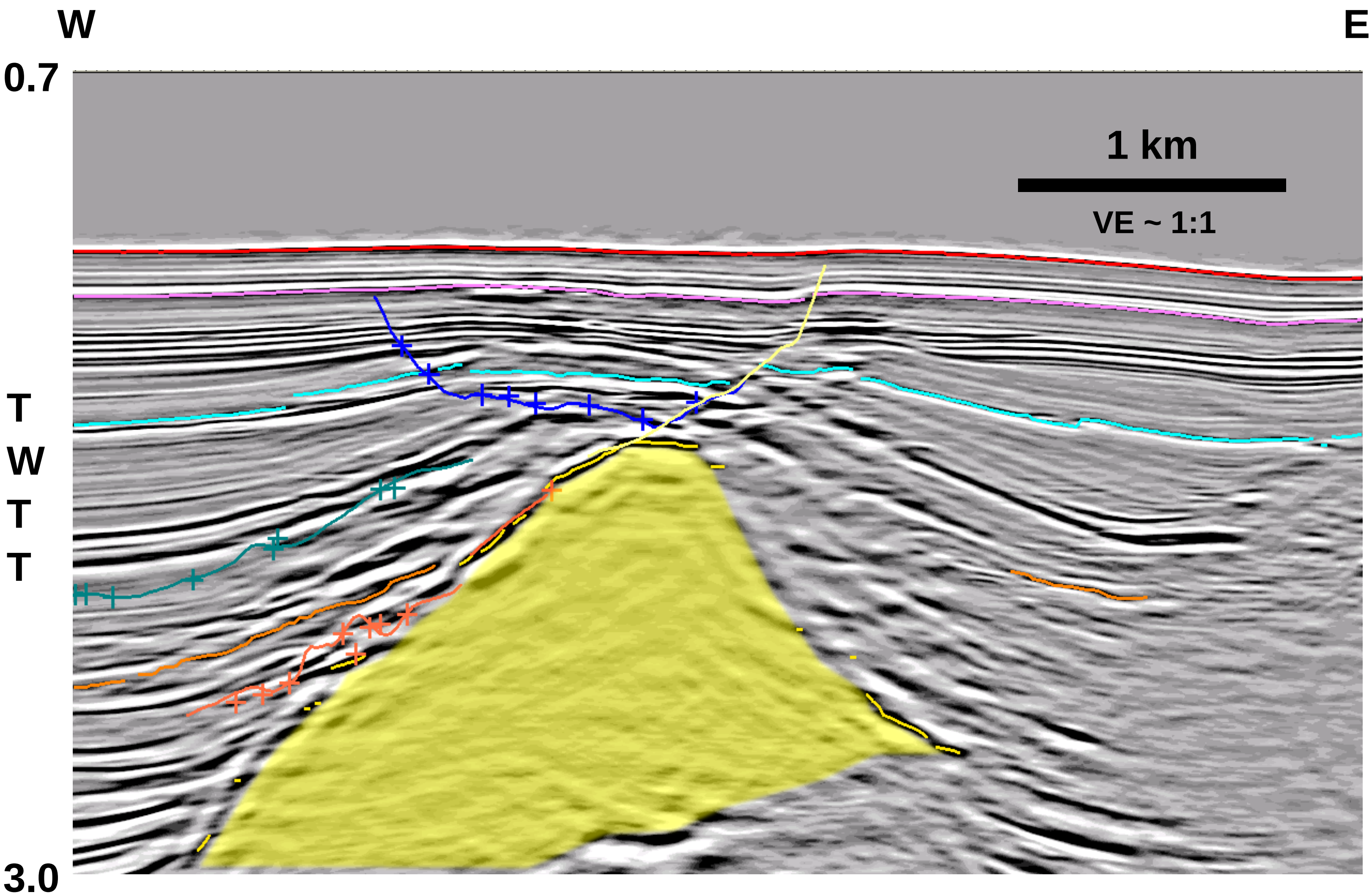


N
E
T

SW Salt Body – Top Salt

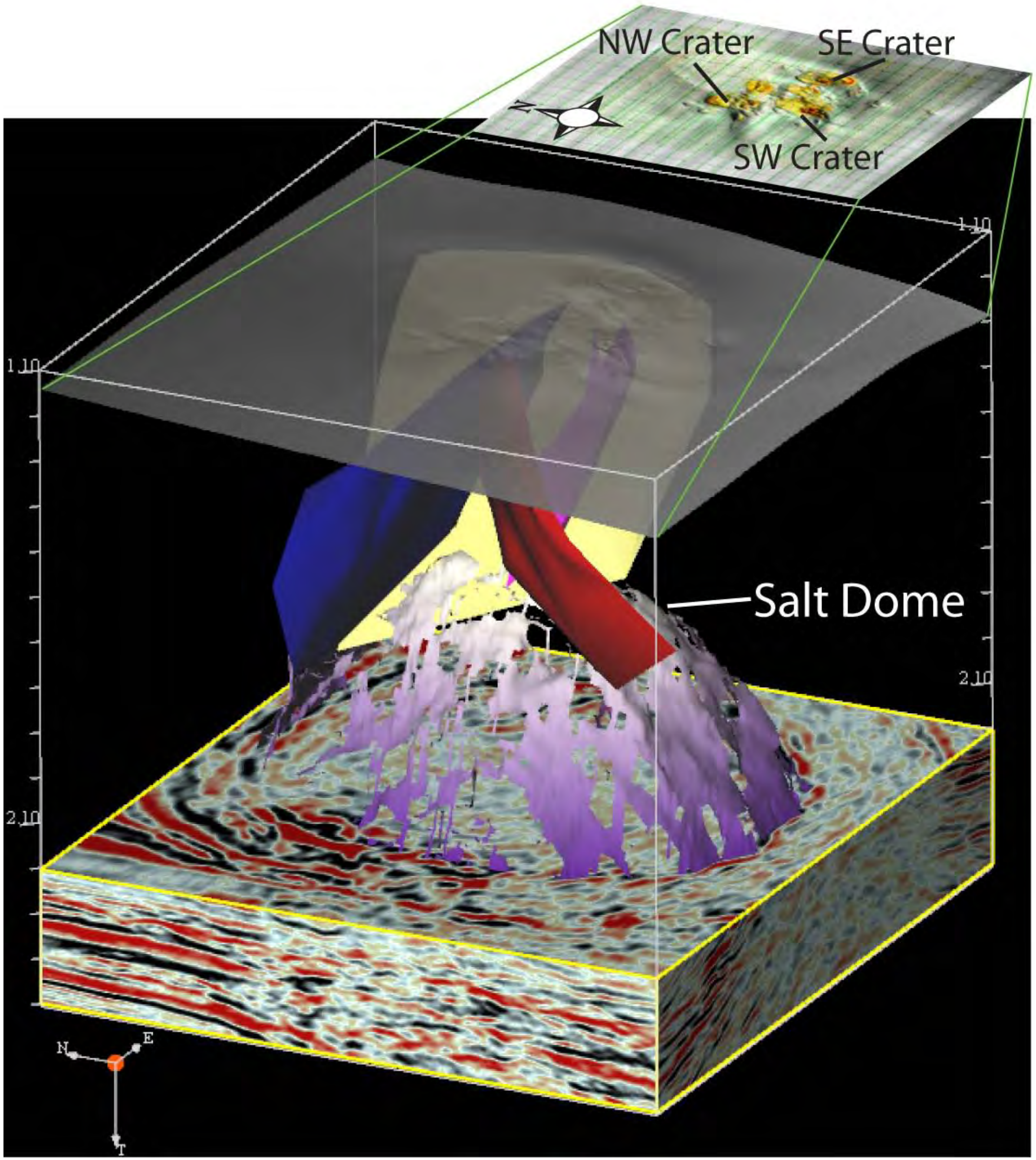


SW Salt Body – Horizons



Fault network – SW salt body

- Salt moves upward as it is loaded by sediment
- Major faults nucleate off of salt body
- Salt flank and associated faults provide vertical migration pathway for deep basin fluids
- Crestal structure dominated by radiating system of arcuate faults



Major surface features

Seafloor bathymetry

Crestal fault structure

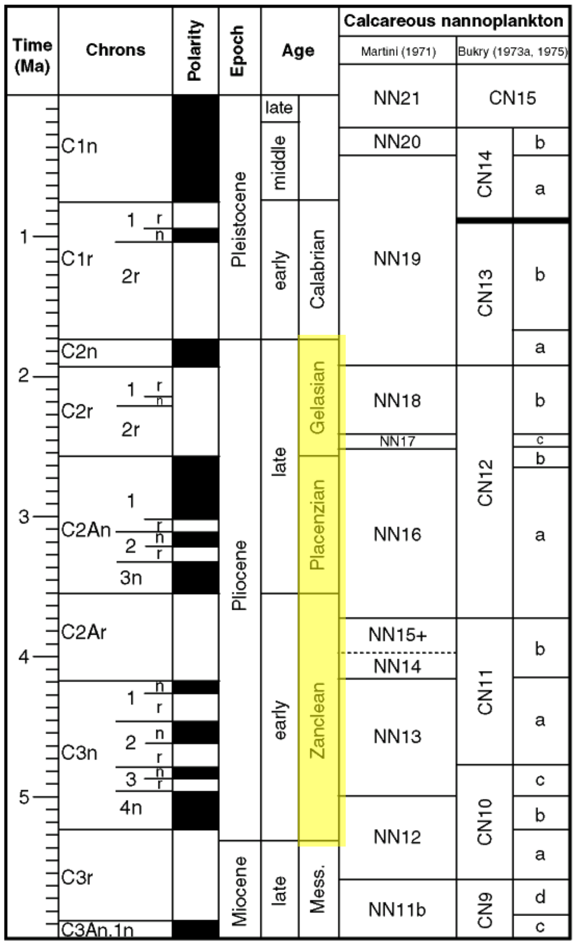
Salt body

3D volume

Well control from ARCO-1

- Exploration well drilled in December 1989
- Water depth: 2,782’
  Total depth: 8,900’
  Logged interval: 6,750’-8,900’
  Sidetrack: 11,850’
  Logged interval: 6,750’-11,850’
- Plugged and abandoned
- Inferred target was bright spots (gas)?

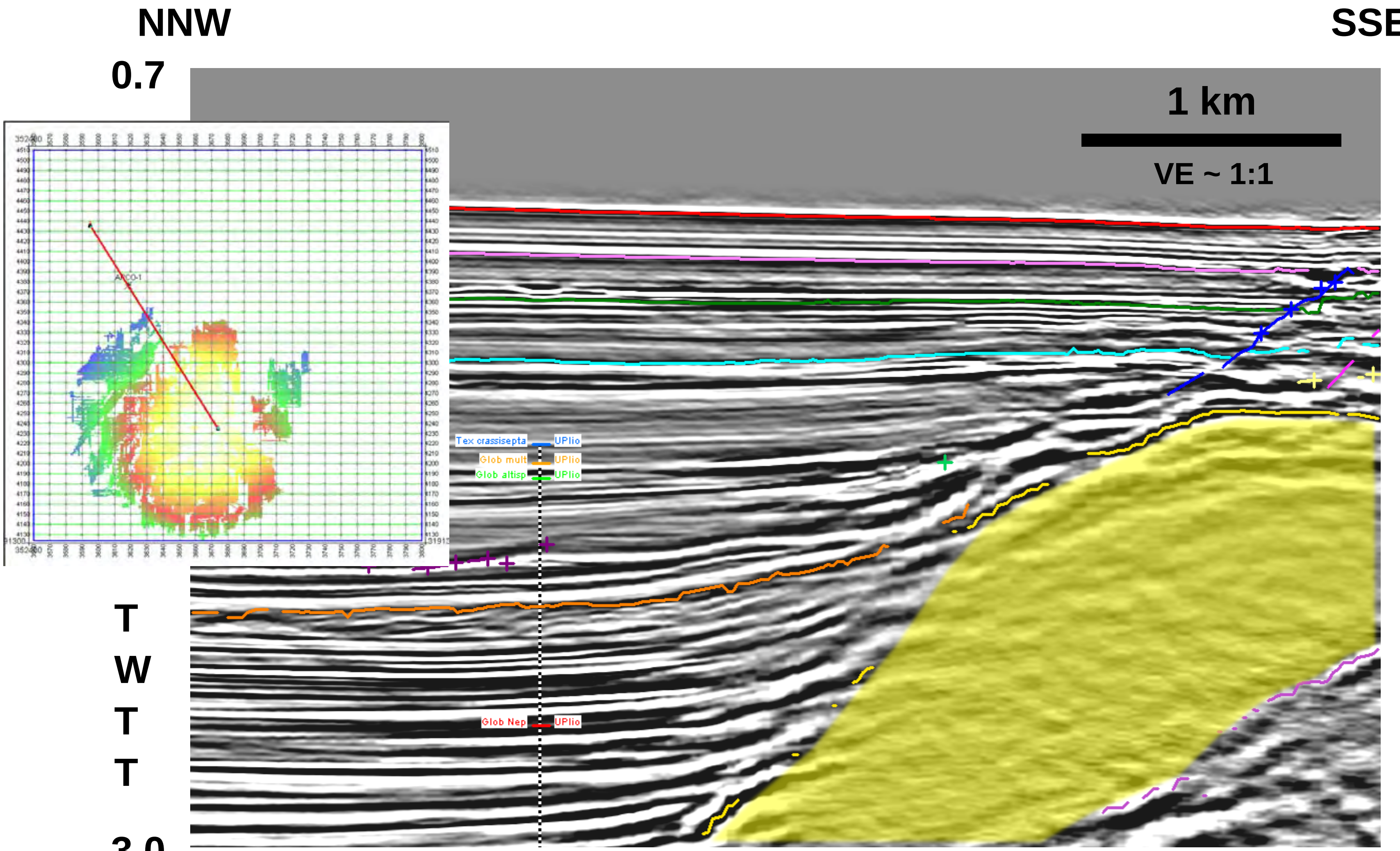
Stratigraphic Constraints



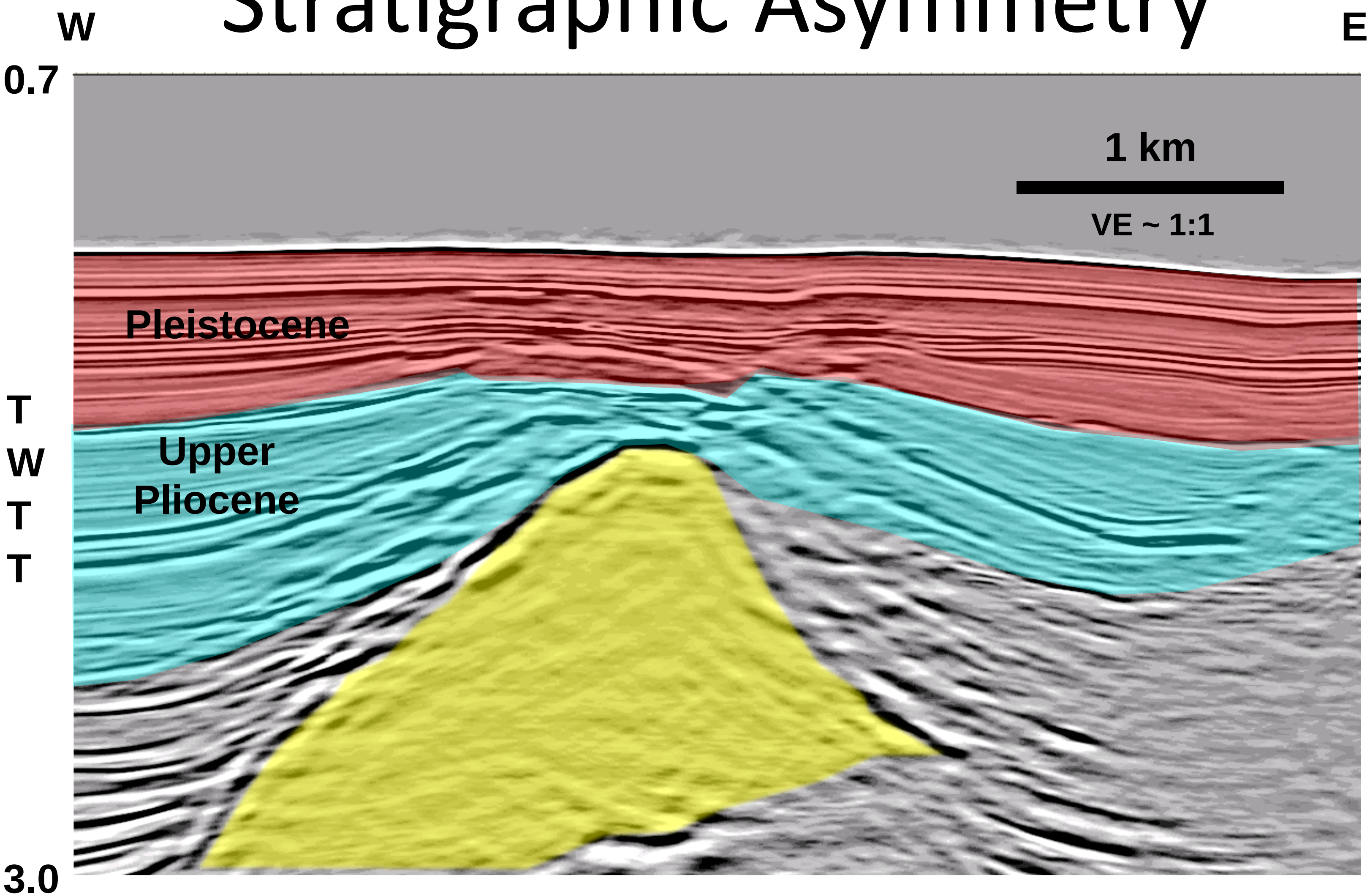
After Muza, J.P. (2000)

- All stratigraphic tops within Pliocene
  - Gelasian
  - Placenzian
  - Zanclean
- No older or younger paleontologic control

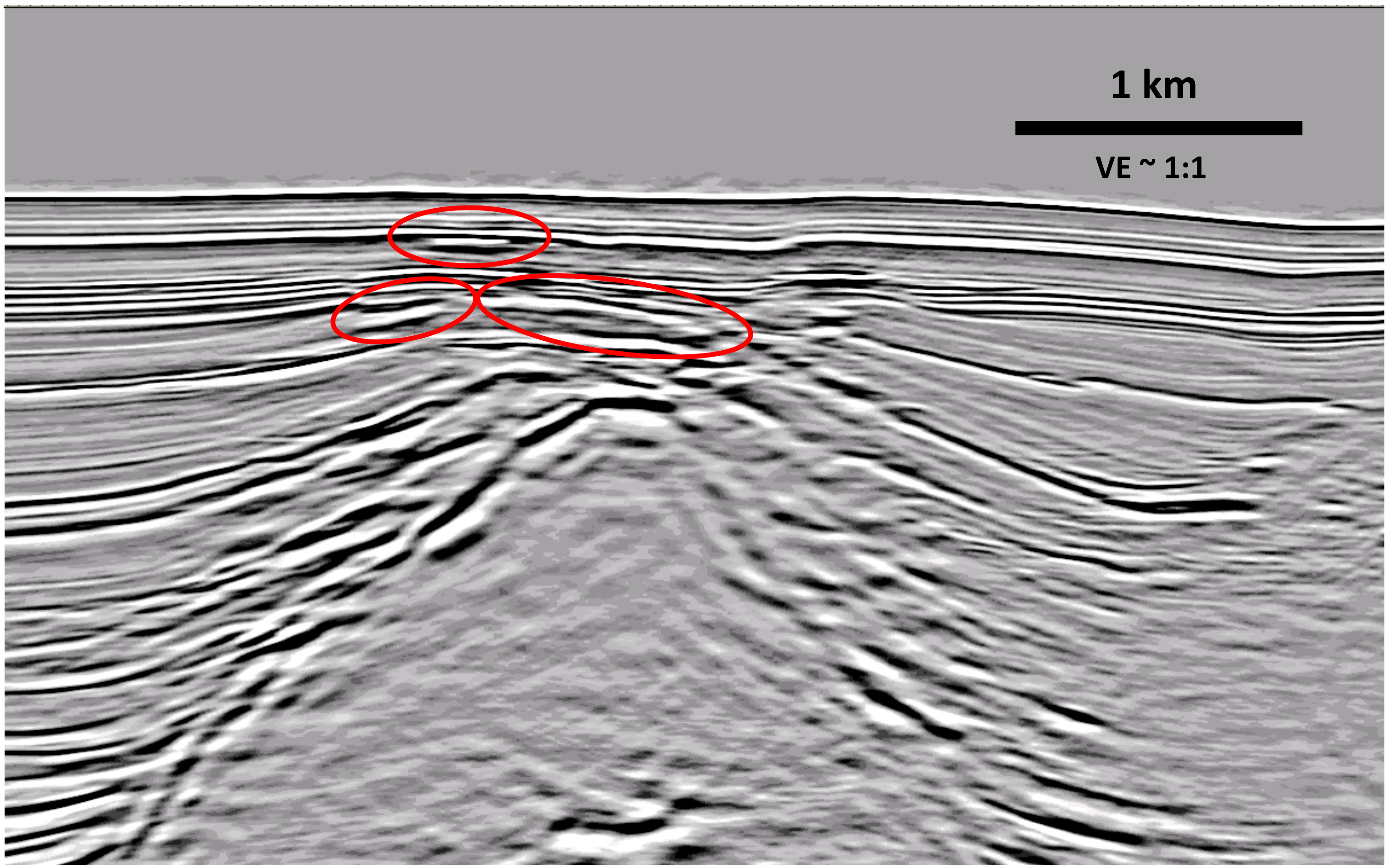
ARCO-1 Paleo Control

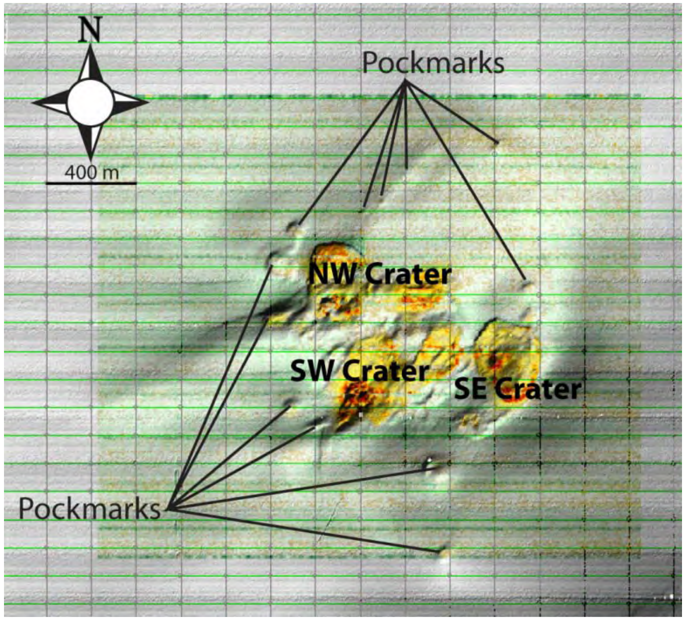


SW Salt Body
Stratigraphic Asymmetry

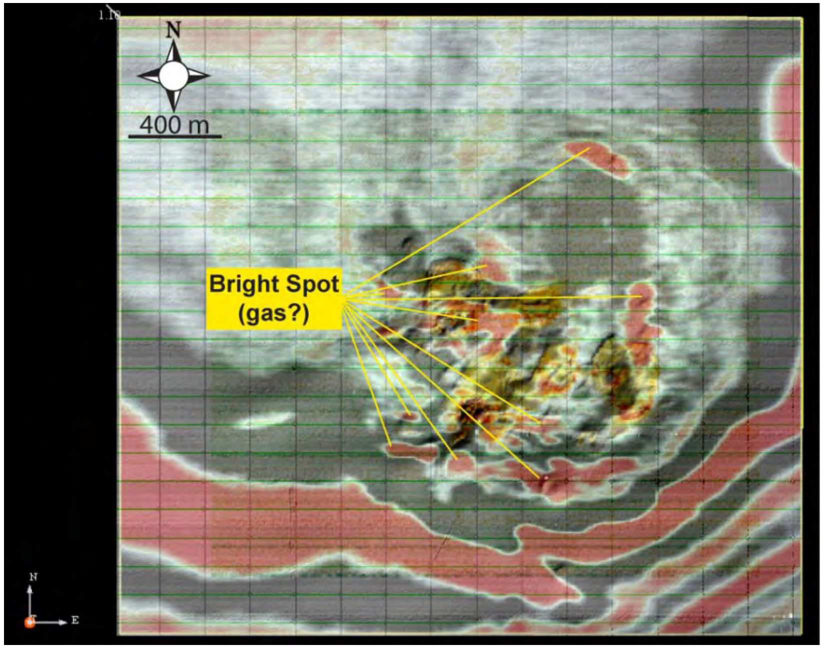


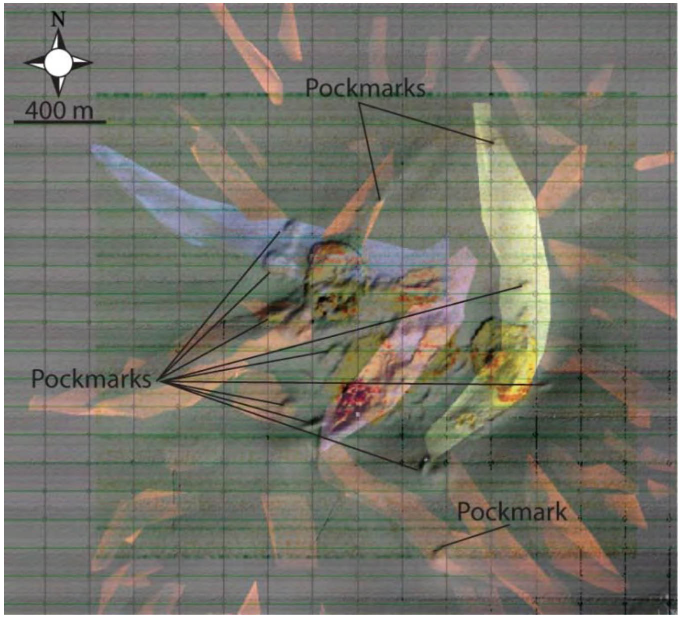
SW Salt Body – W-E Crossline



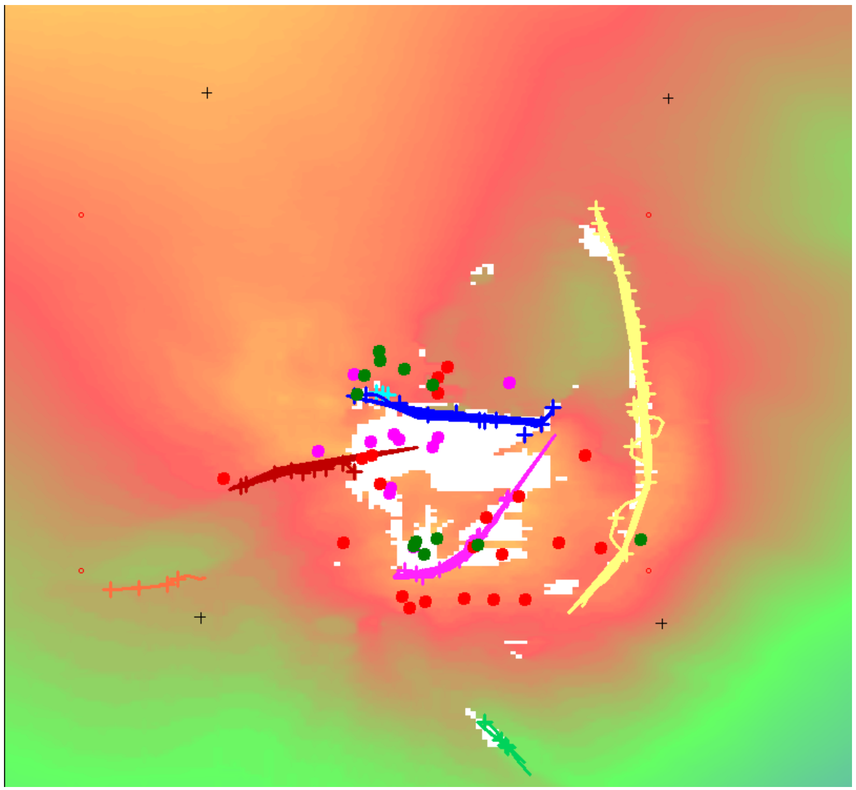


Seafloor features – crater complexes, fault scarps, pockmarks – correspond to the intersections of faults with the seafloor.



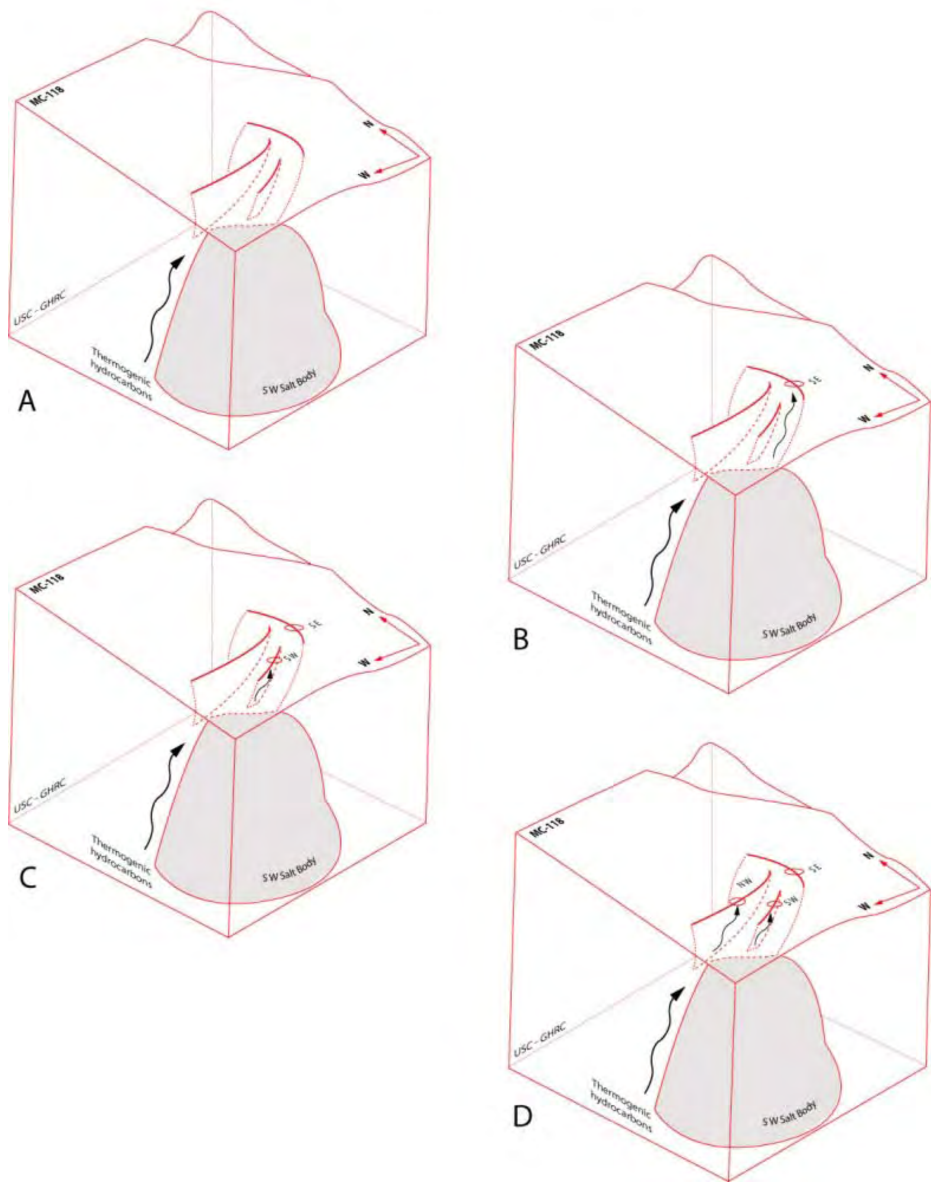


Microbial Activity



- Not all faults are associated with activity
- Activity is partitioned along faults which do have activity
- Spatial sampling bias may be an issue
- Surface activity shows temporal evolution from SE to SW to NW mounds

Evolution of Subsurface Fluid Migration
and Surface Mound Expression at MC-118



Evolutionary Model
MC-118 Hydrate System

Activity appears to have migrated from east to west, then north and now, perhaps east

MC-118 Sequence of events - I

- Highly asymmetric sediment loading, salt movement of SW salt body (Pliocene)
- Temporary cessation of major salt movement
- Development of regional unconformity
- Deposition of ~1800’-2400’ of relatively uniform stratigraphy across the entire region (Upper Pliocene-Pleistocene)
- Renewed crestal faulting above SW salt body

MC-118 Sequence of events - II

- Major slumping and mass movement of the slide block to the NE of MC-118
- Initiation of fluid flow and development of hydrate/carbonate mound system
- (Relative timing and relationship of last two events remains equivocal)

Summary

- Salt has dominant influence on geologic evolution of MC-118
- Periods of salt movement and quiescence can be interpreted from stratigraphic architecture
- Salt-flank/fault system provides likely migration pathway for deep basin fluids
- Latest Pleistocene interval blankets entire area, and is only broken by a few faults

Acknowledgments

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- TGS-Nopec
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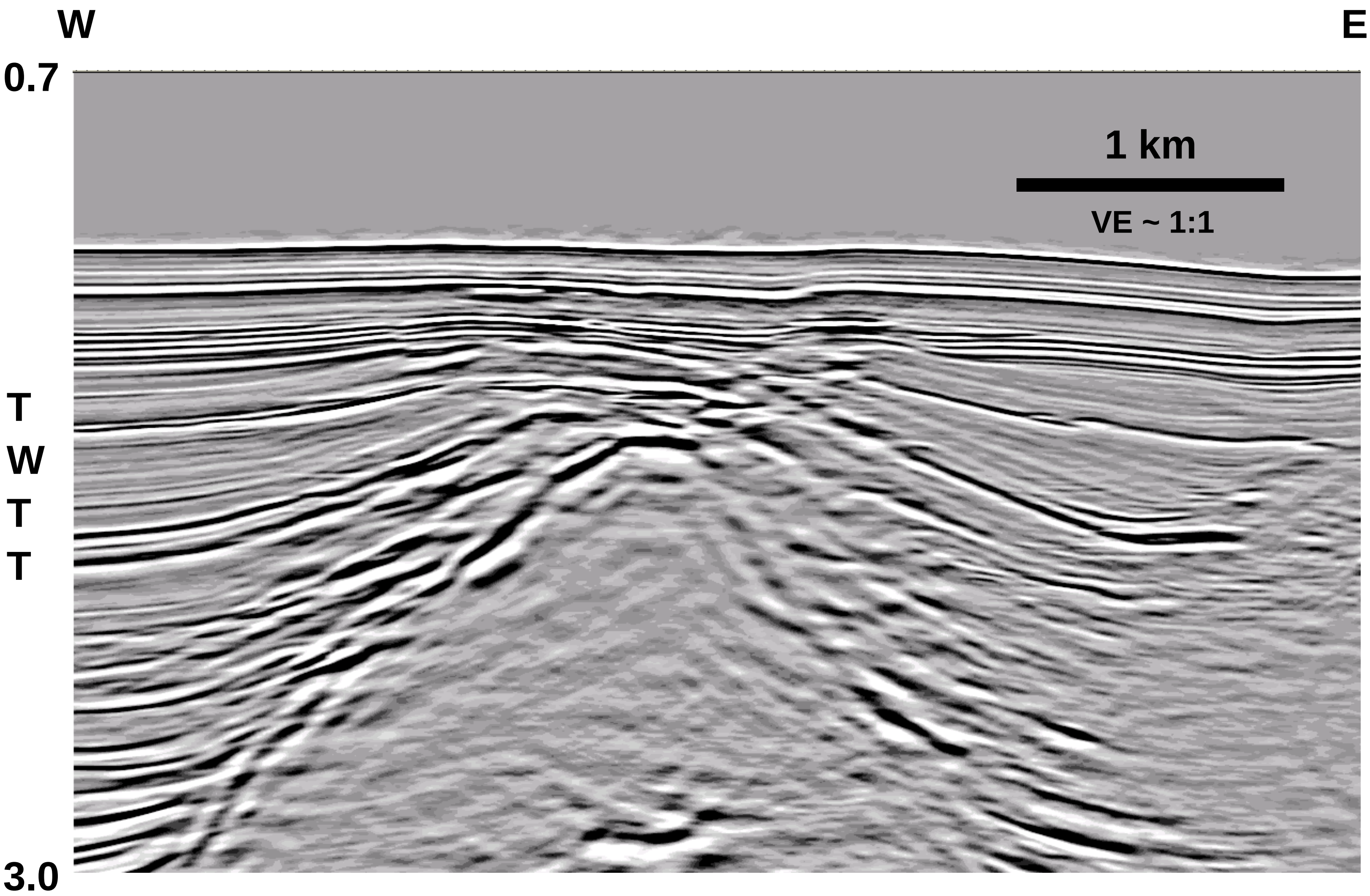
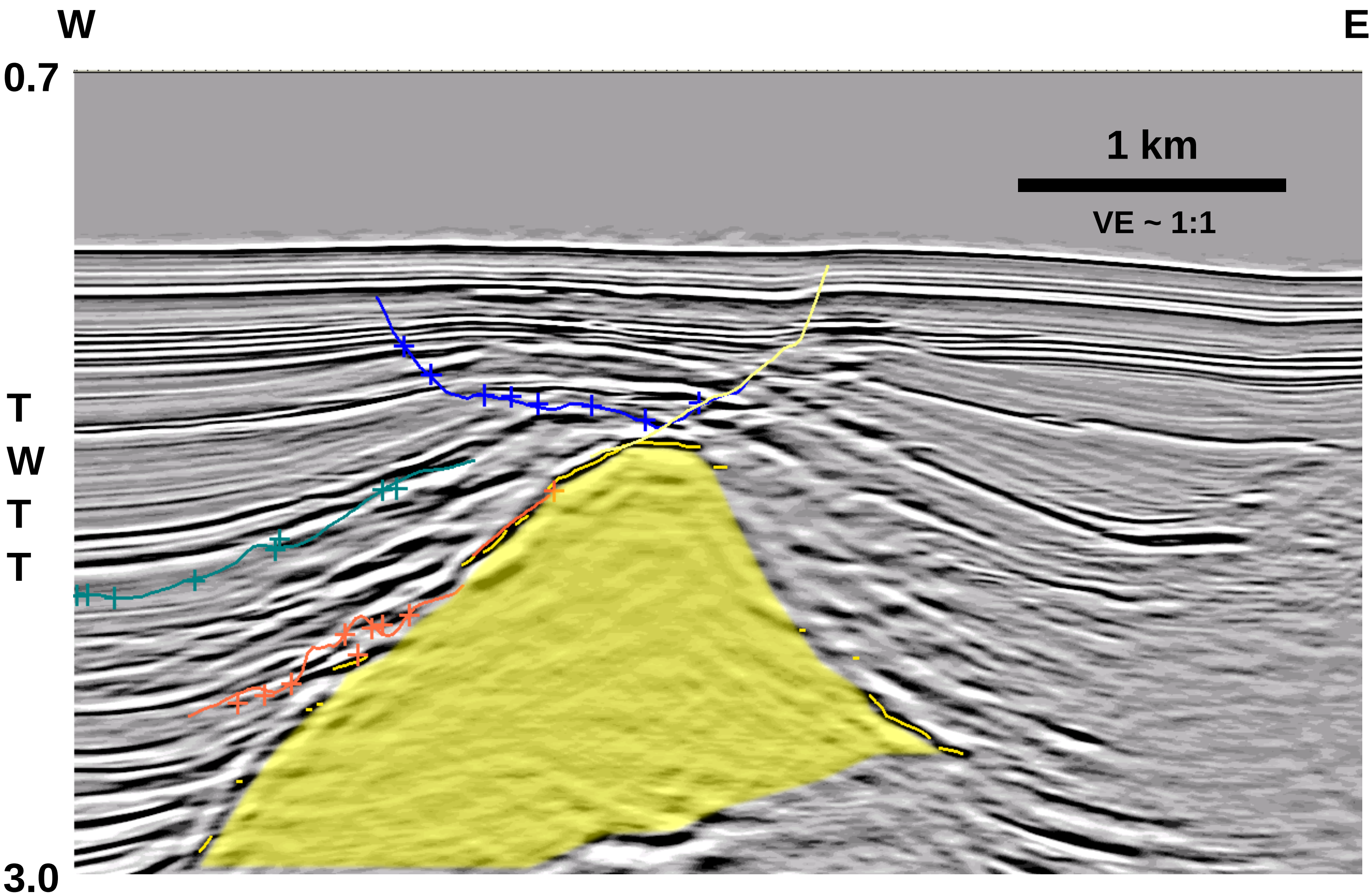
- U.S. Department of the Interior (MMS)
- Seismic Micro-Technology, Landmark Graphics
- Lookout Geophysical Company

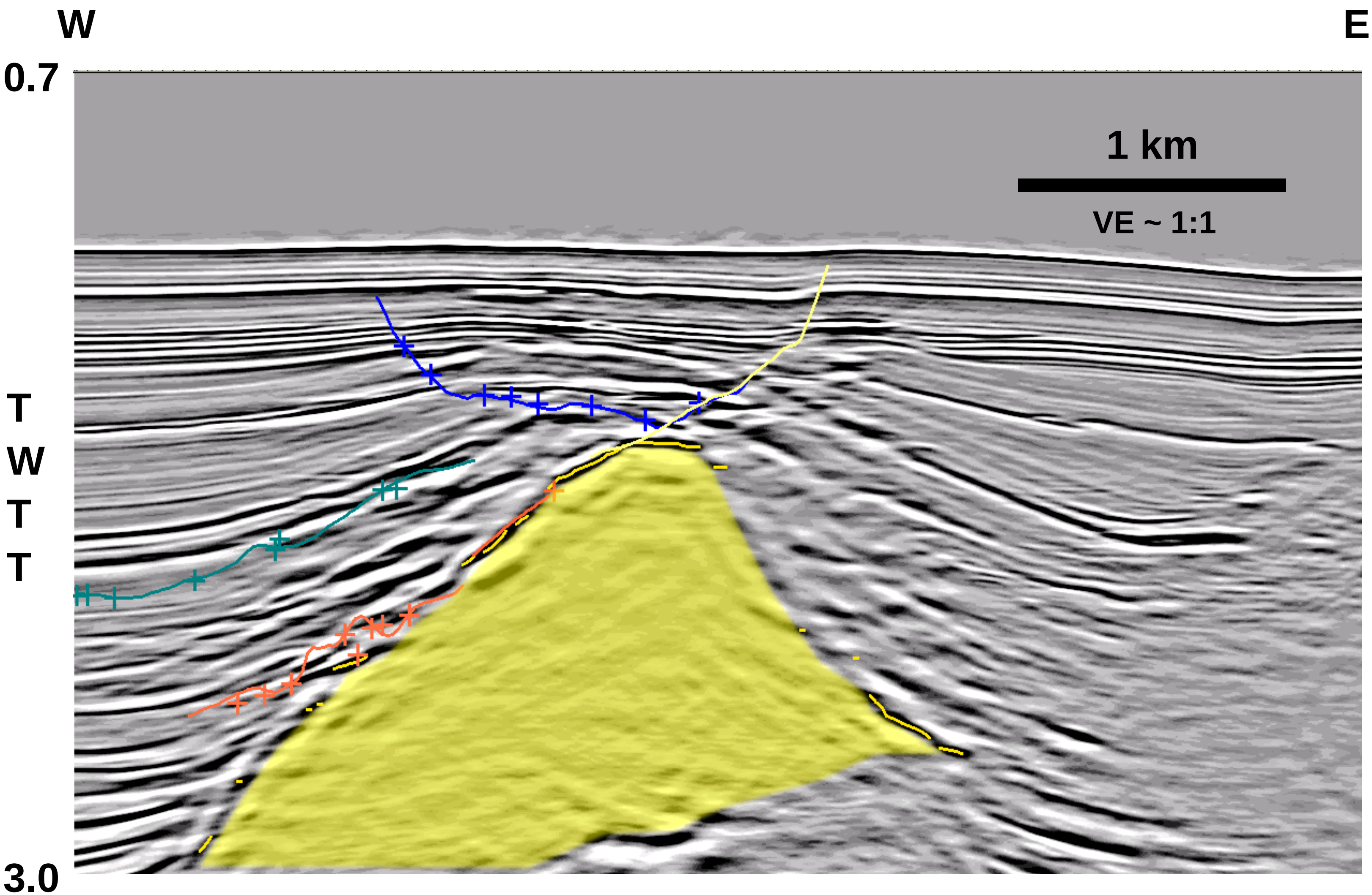
SW Salt Body – W-E Crossline



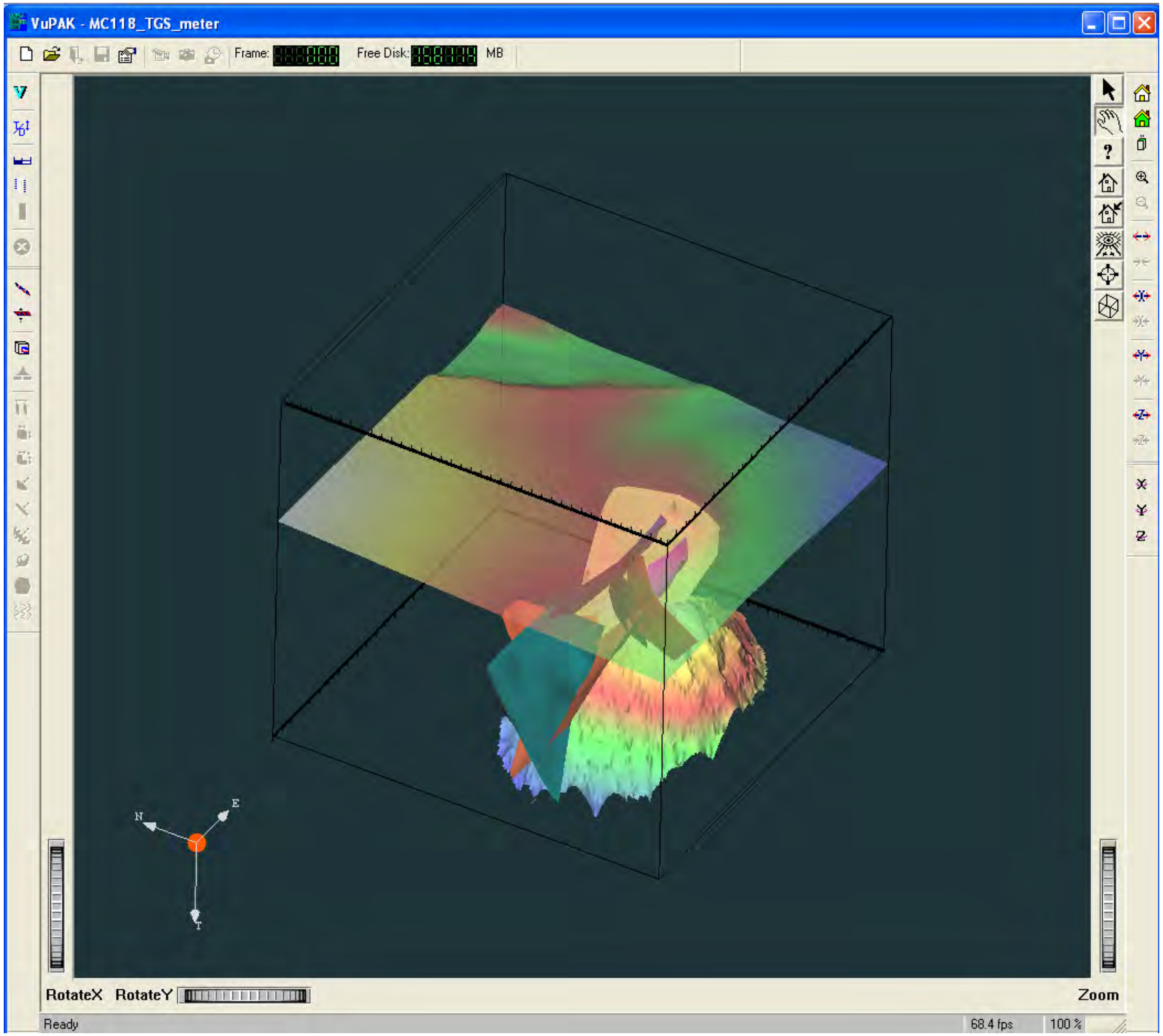
SW Salt Body – Faults



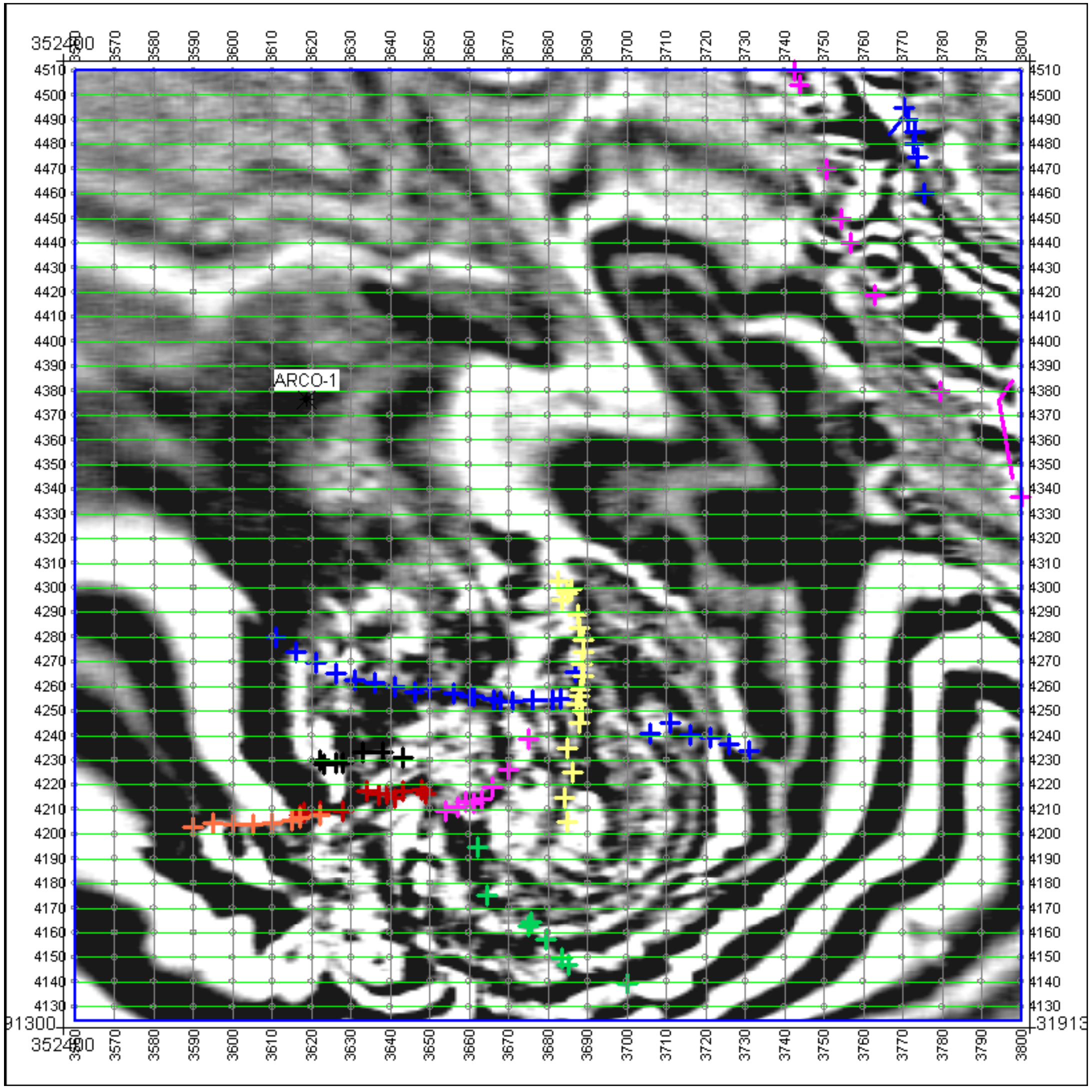
SW Salt Body – Faults



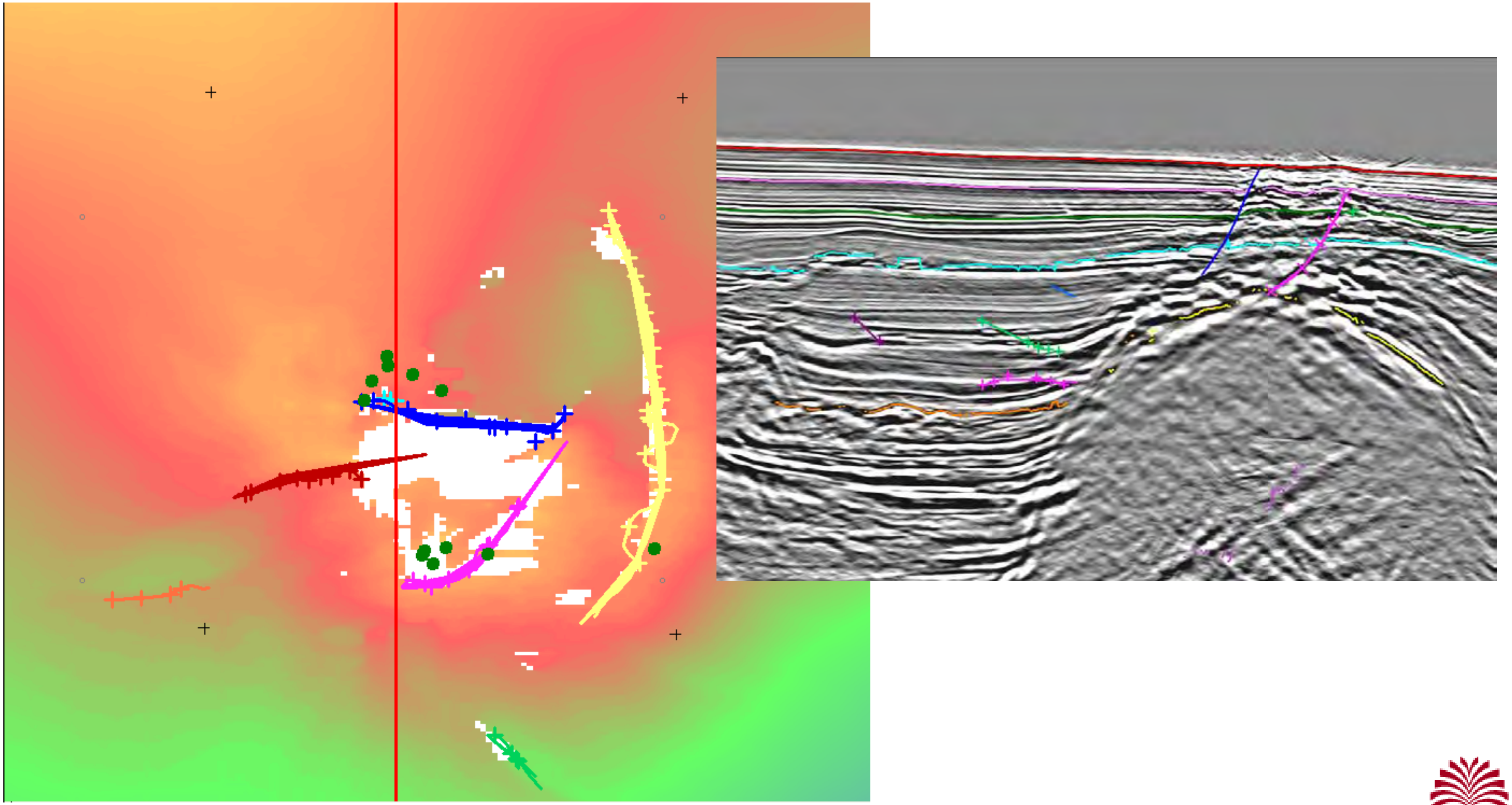
Shallow crestal faulting



Faults in plan view – 1500 ms

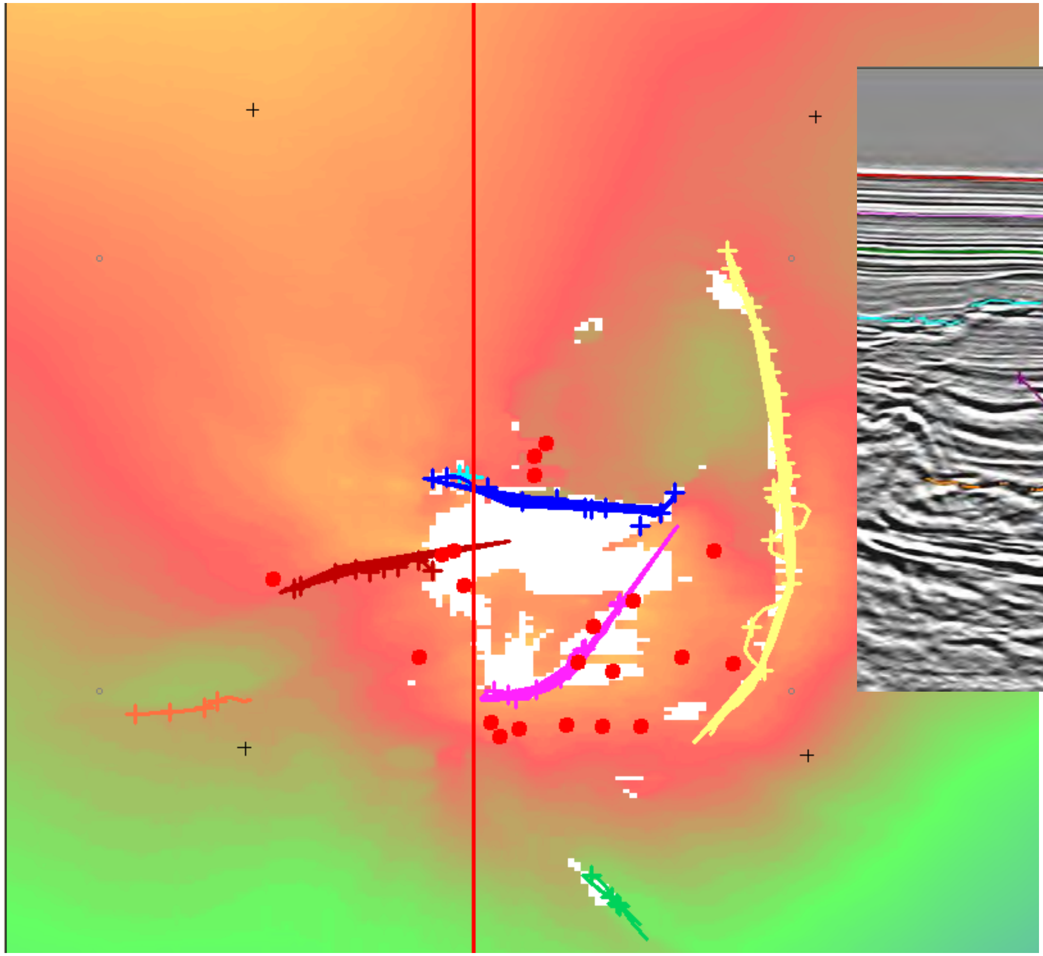


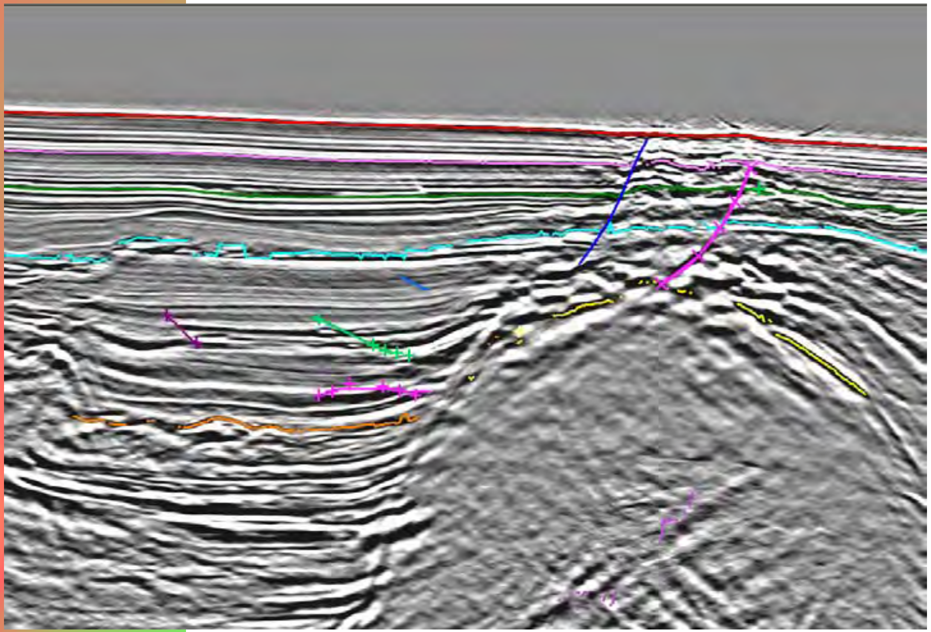
High activity – 3-D



Pink horizon (late Pleistocene) ~200 mbsf

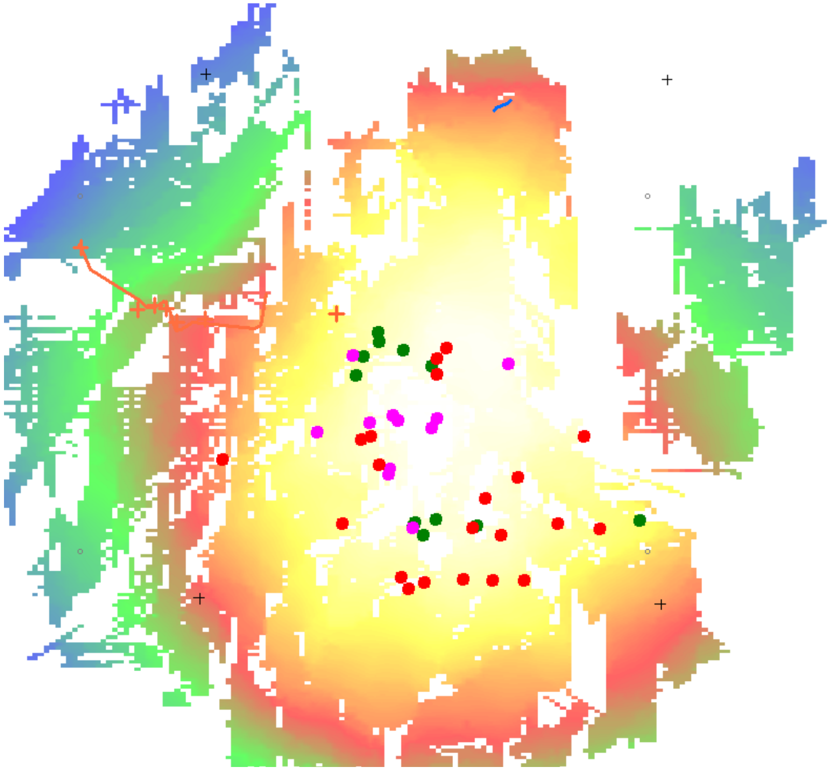
Low activity – 3-D





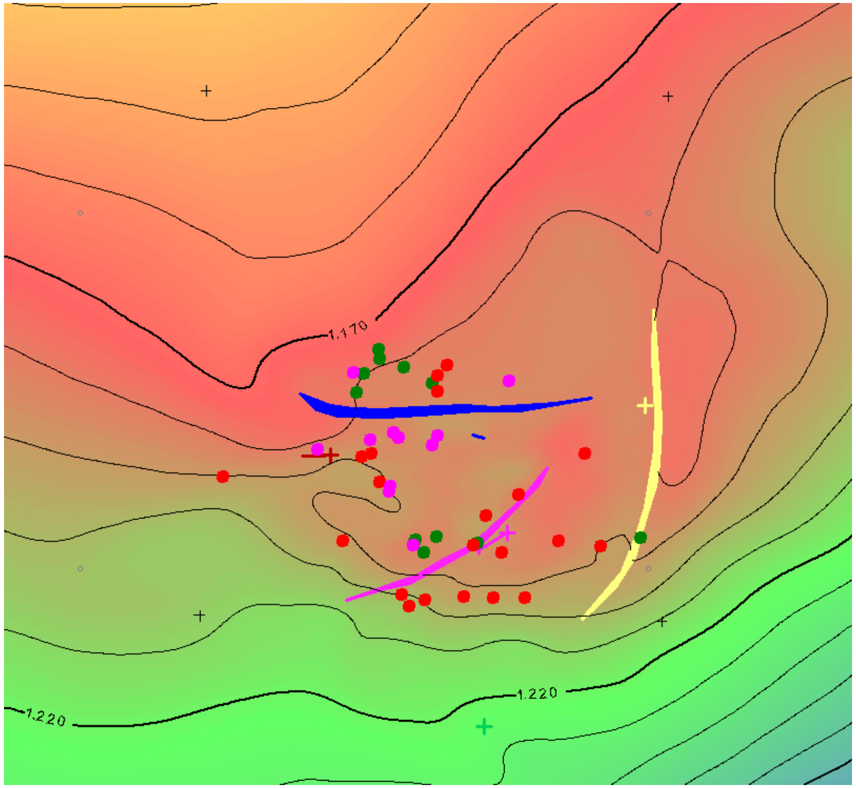
Pink horizon (late Pleistocene) ~200 mbsf

Microbial activity and salt



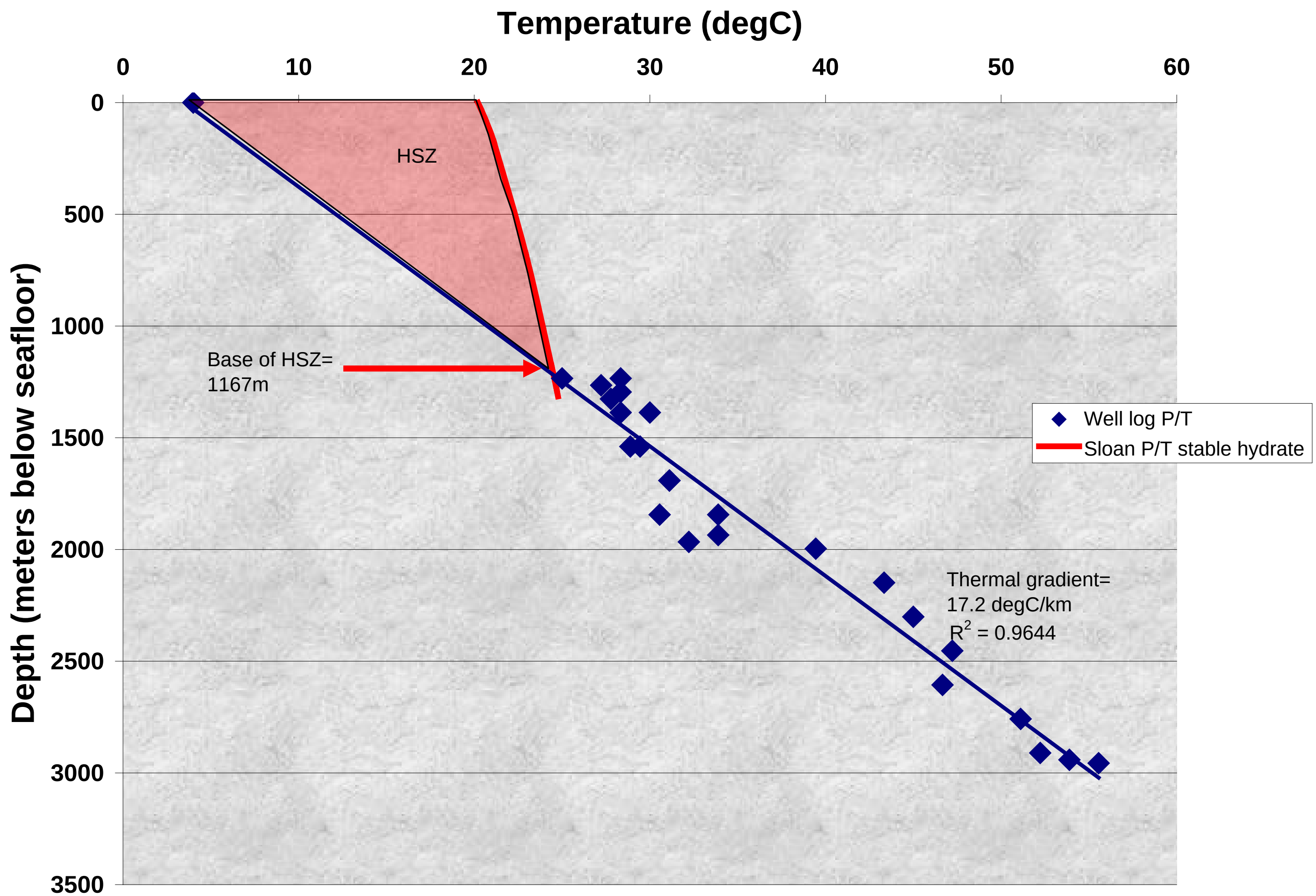
- Surface activity is not correlated with position relative to underlying salt body

Activity and Bathymetry



- Activity is not clearly correlated with mound bathymetry

Estimate of HSZ from MC-118 well



Courtesy of L. Lapham, FSU

Future Priorities

- Refine fault geometries, especially shallow
- Integrate interpretation of 3-D and Hi-Res and CHIRP with geochemical and surface data
- Establish web-based GIS database
- Migration (Hi-Res) and depth conversion of both datasets
- Modeling of HSZ with T and salinity constraints
- Refocus observatory on specific faults?
- Shallow drilling in/near shallow faults?