BOEMRE

Bureau of Ocean Energy Management, Regulation and Enforcement

UNITED STATES DEPARTMENT OF THE INTERIOR

Geophysical Indicators of Natural Oil & Gas — Types, Distribution, and Numbers of Seafloor Amplitude Anomalies in the Gulf of Mexico

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Bureau of Ocean Energy Management, Regulation and Enforcement

INTRODUCTION

- Since 1988, BOEMRE staff (formerly MMS) have mapped over 21,000 geophysical amplitude anomalies on the seafloor.

- Those that have been visited by submersibles, ROVs, AUVs, camera sled surveys and trawls have been found to be caused by natural hydrocarbon seepage.

- Three types of seeps have been recognized:
  - High positive amplitude anomalies
  - Low positive/negative amplitude anomalies
  - Pockmarks

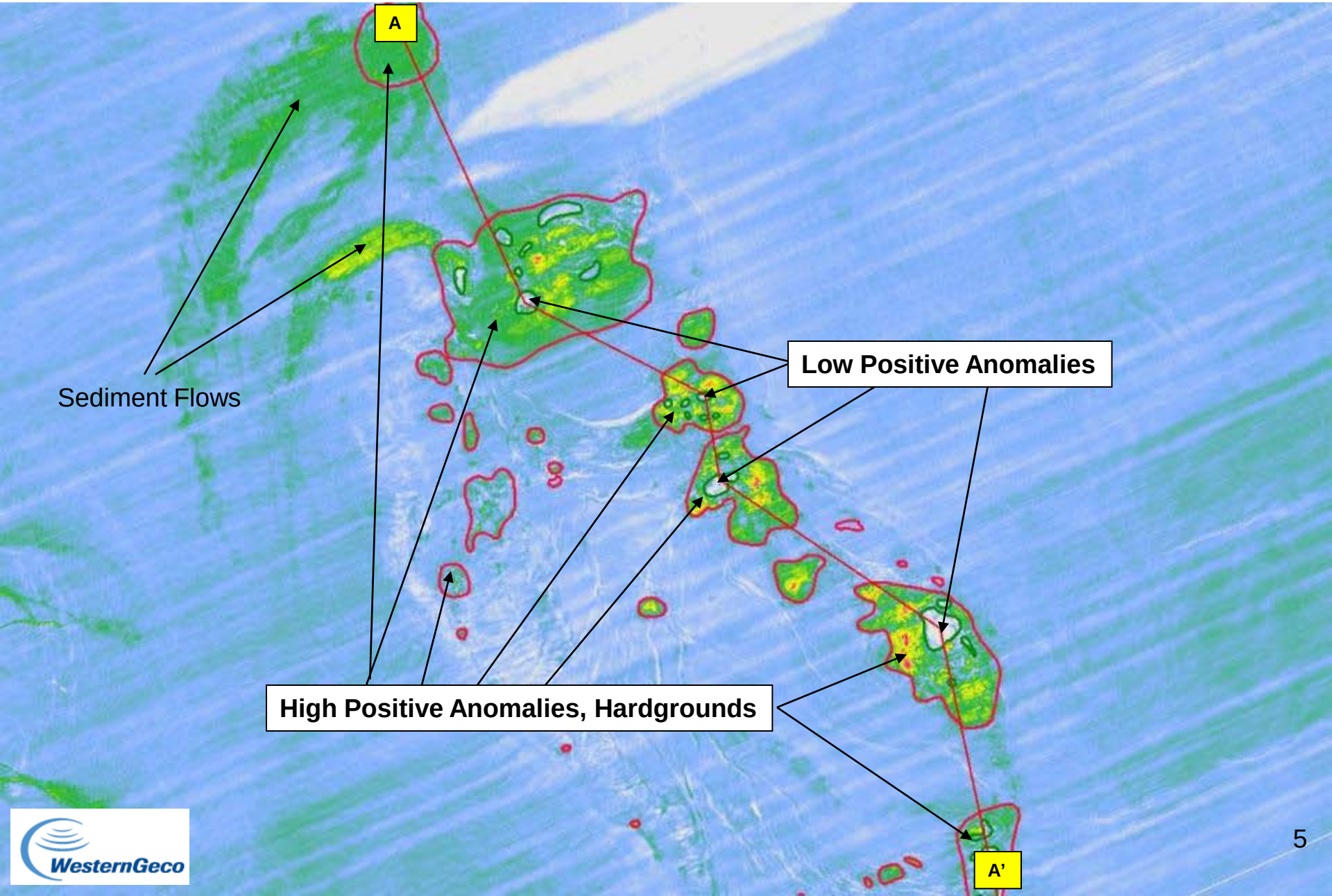
HIGH POSITIVE AMPLITUDE ANOMALIES

- High positive amplitude anomalies have been shown through direct observations to be caused by authigenic carbonate hardgrounds – thin pavements, boulder fields and thick outcrops – caused by low to moderate flux seepage.
- Occasionally, lithified sediment or sand flows from active vents have a high positive amplitude but do not display subsurface migration conduits on seismic cross-sections.
- To date, 16,278 high positive anomalies have been identified, all of which are potential substrates for chemosynthetic and coral communities.

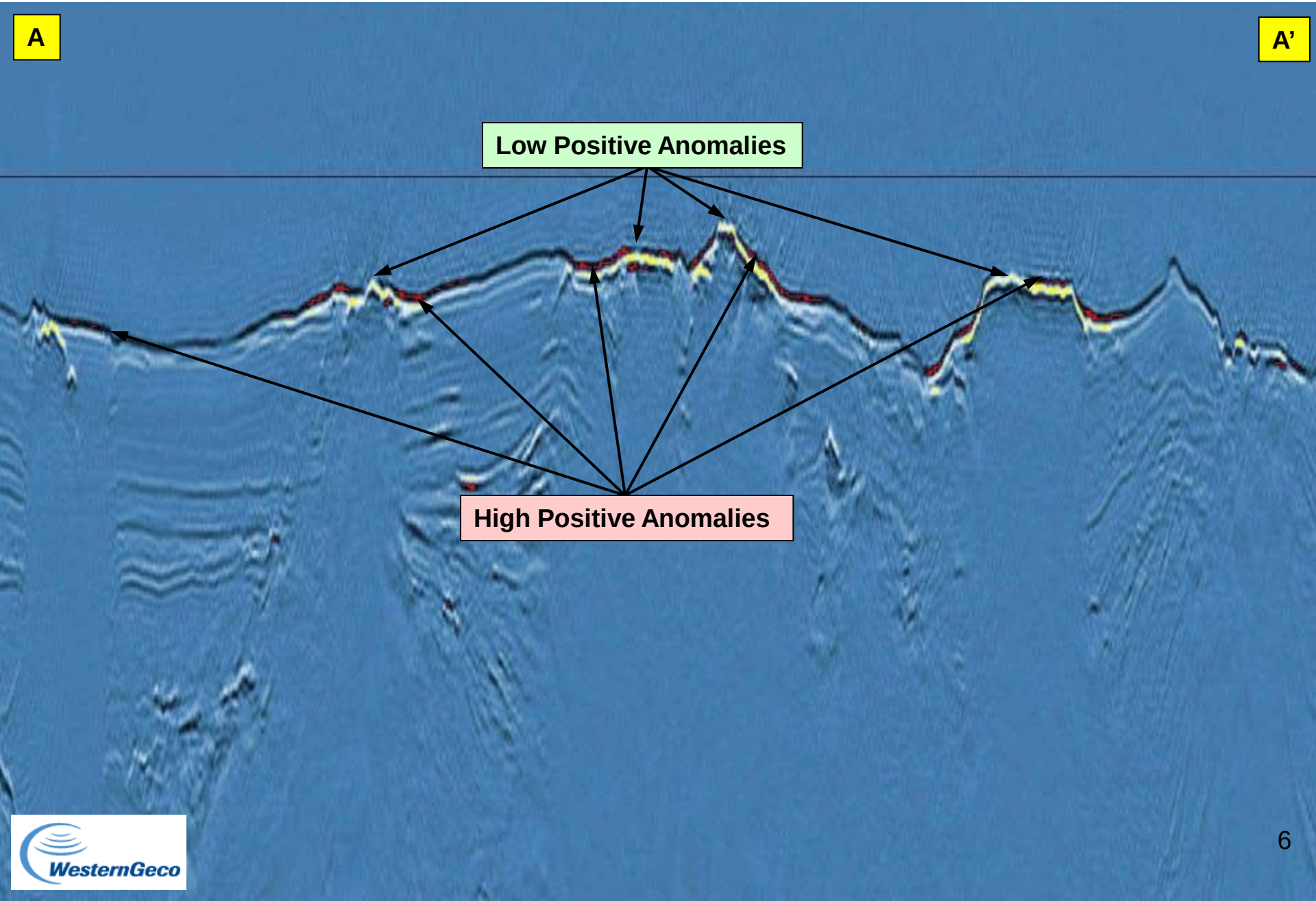
LOW POSITIVE/NEGATIVE ANOMALIES

- Low positive/negative amplitude anomalies have amplitude response less than background amplitudes of soft-bottom mud and sometimes are acoustically slower than water and have been shown through direct observation to be mud volcanoes (where sediment accompanies the hydrocarbon) and high flux vent fields.
- To date, 2,271 negative amplitude anomalies have been identified.

AMPLITUDE MAP OF SEAFLOOR SHOWING HIGH POSITIVE AND LOW POSITIVE/NEGATIVE ANOMALIES



SEISMIC CROSS-SECTION A-A' SHOWING ANOMALIES



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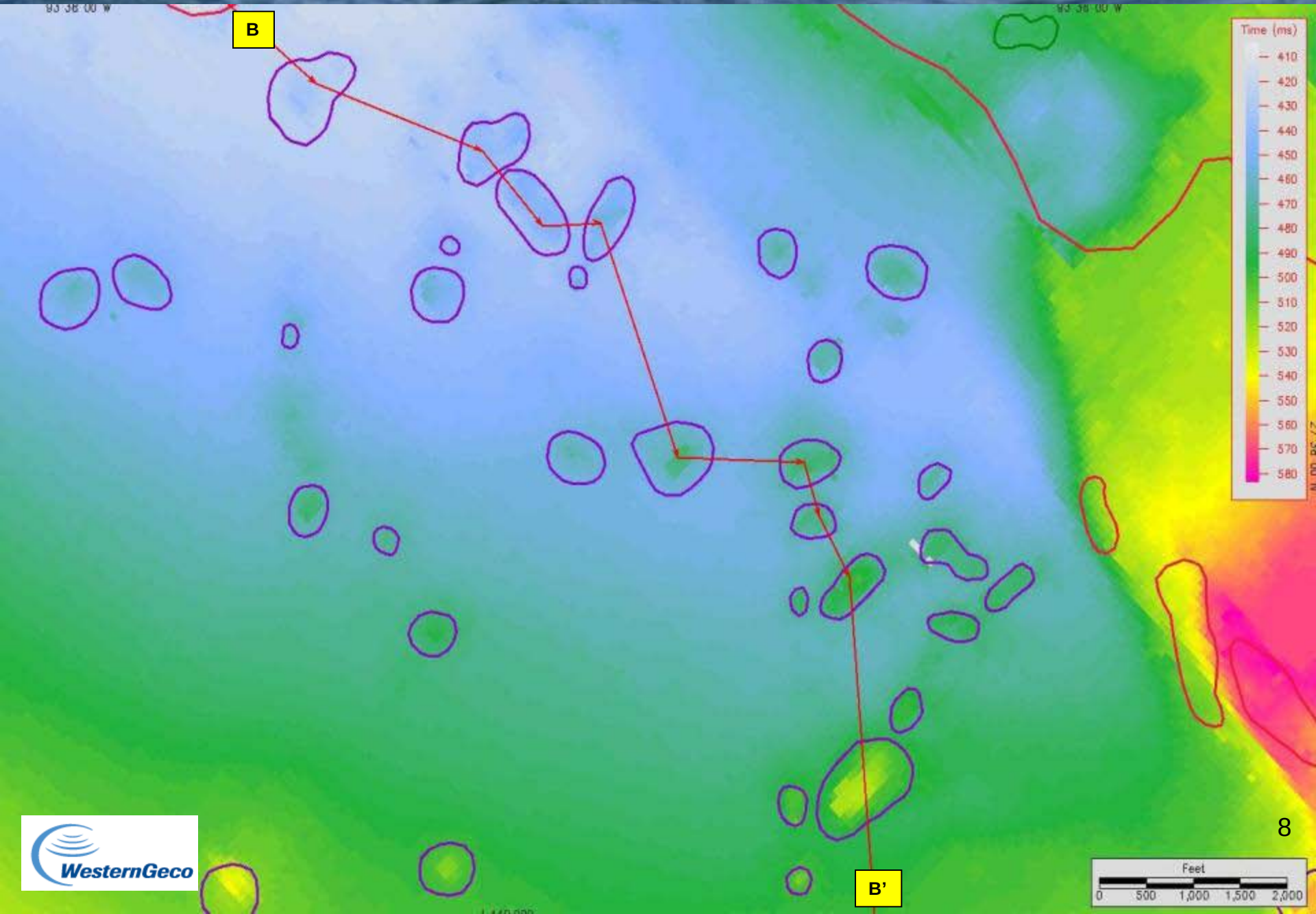
POCKMARKS

- Pockmarks are circular depressions where sediment has been removed, probably by rapid, explosive gas expulsion.
- Most are probably one-time events since very few have a high positive amplitude response or show active migration conduits in the subsurface.
- To date, 2,907 pockmarks have been identified.

TIME STRUCTURE MAP OF SEAFLOOR SHOWING "POCKMARKS"



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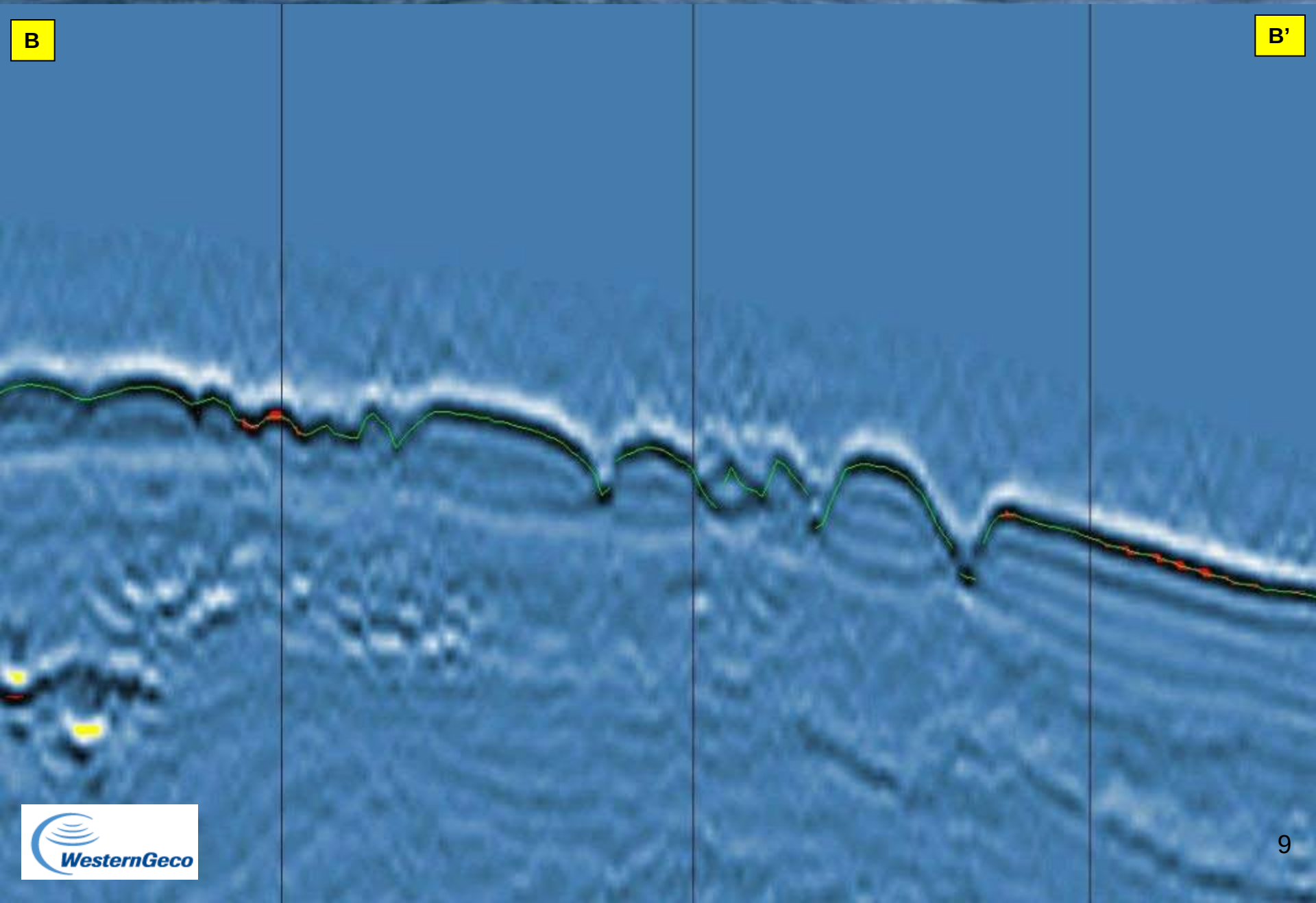
SEISMIC CROSS-SECTION B-B' SHOWING POCKMARKS



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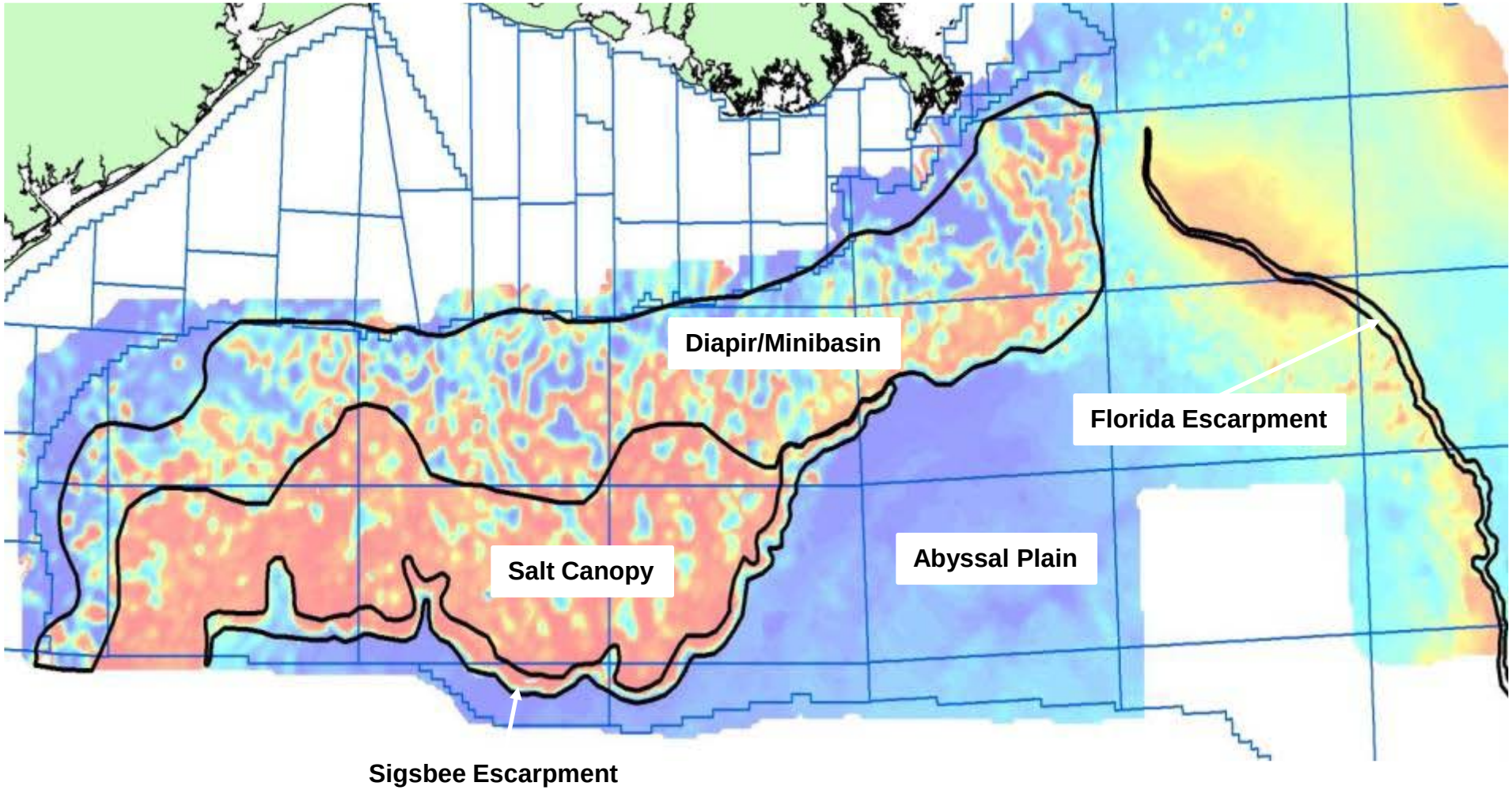
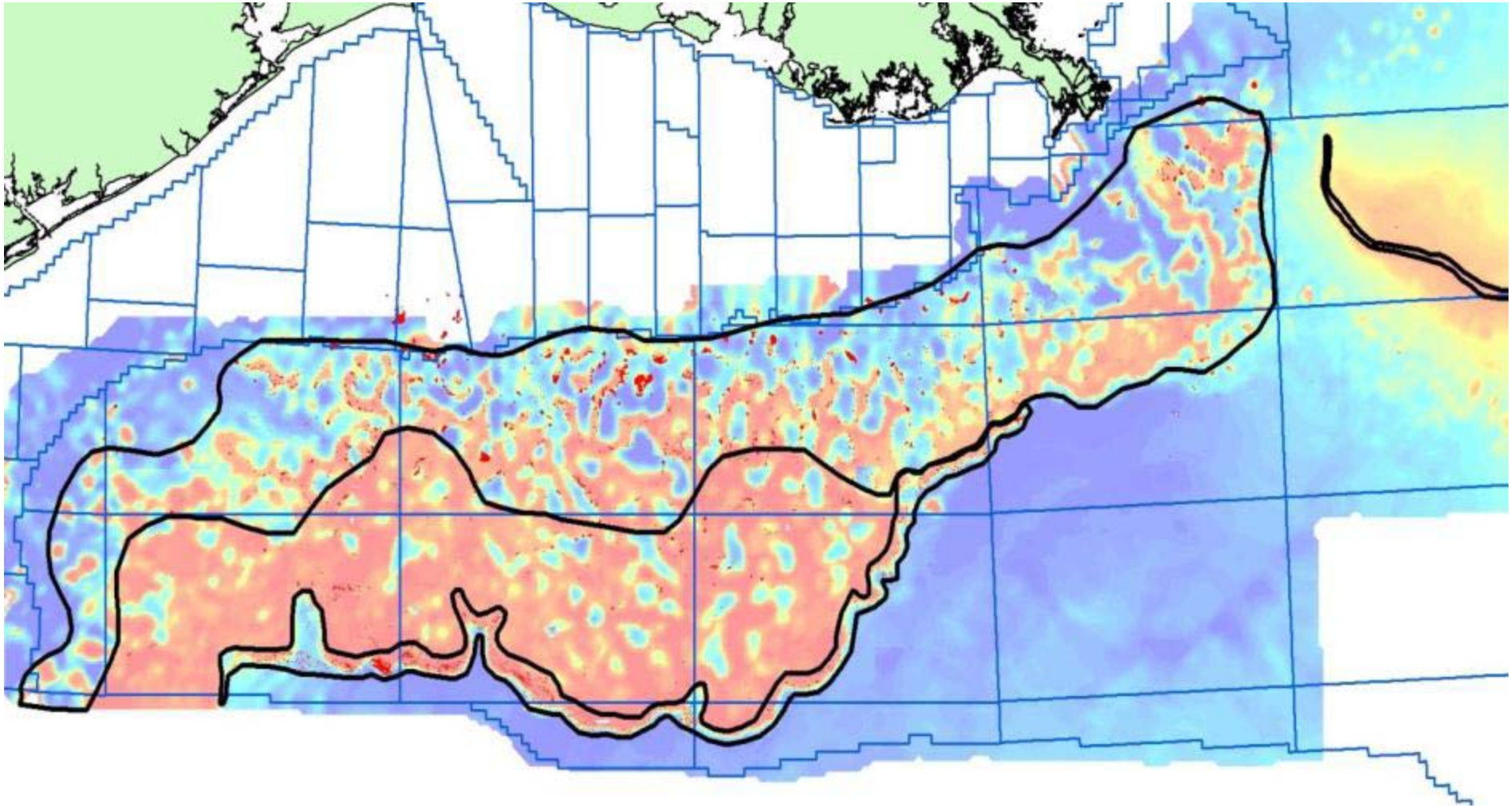
GEOLOGICAL PROVINCES OF ANOMALY OCCURRENCE

- **5 major geological provinces appear to be controlling the distribution of the 3 anomaly types:**
  - Upper slope salt diapir/minibasin province
  - Lower slope salt canopy province
  - Sigsbee Escarpment province
  - Abyssal plain province
  - Florida Escarpment province

GEOLOGICAL PROVINCES

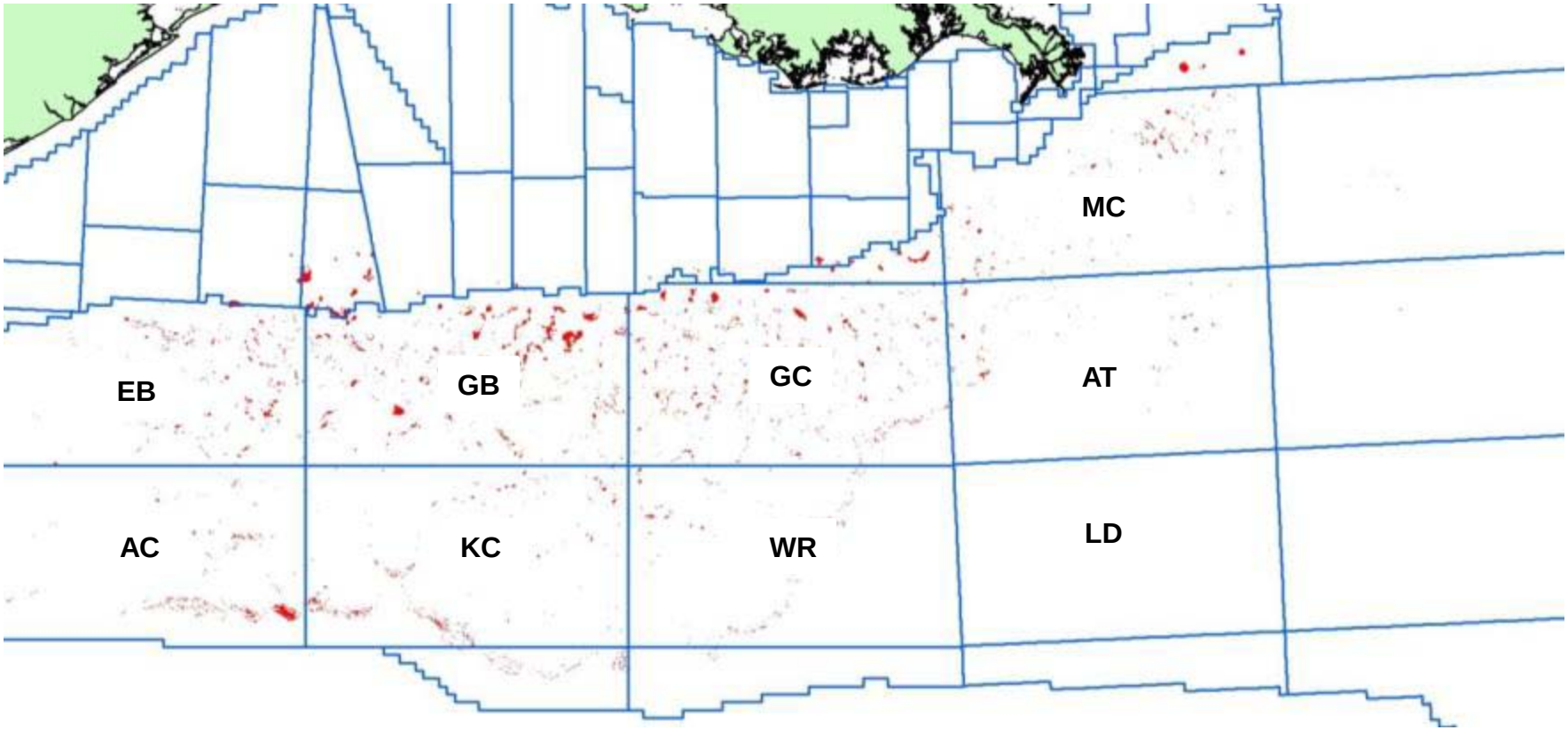


ALL ANOMALIES AS POLYGONS WITH SALT



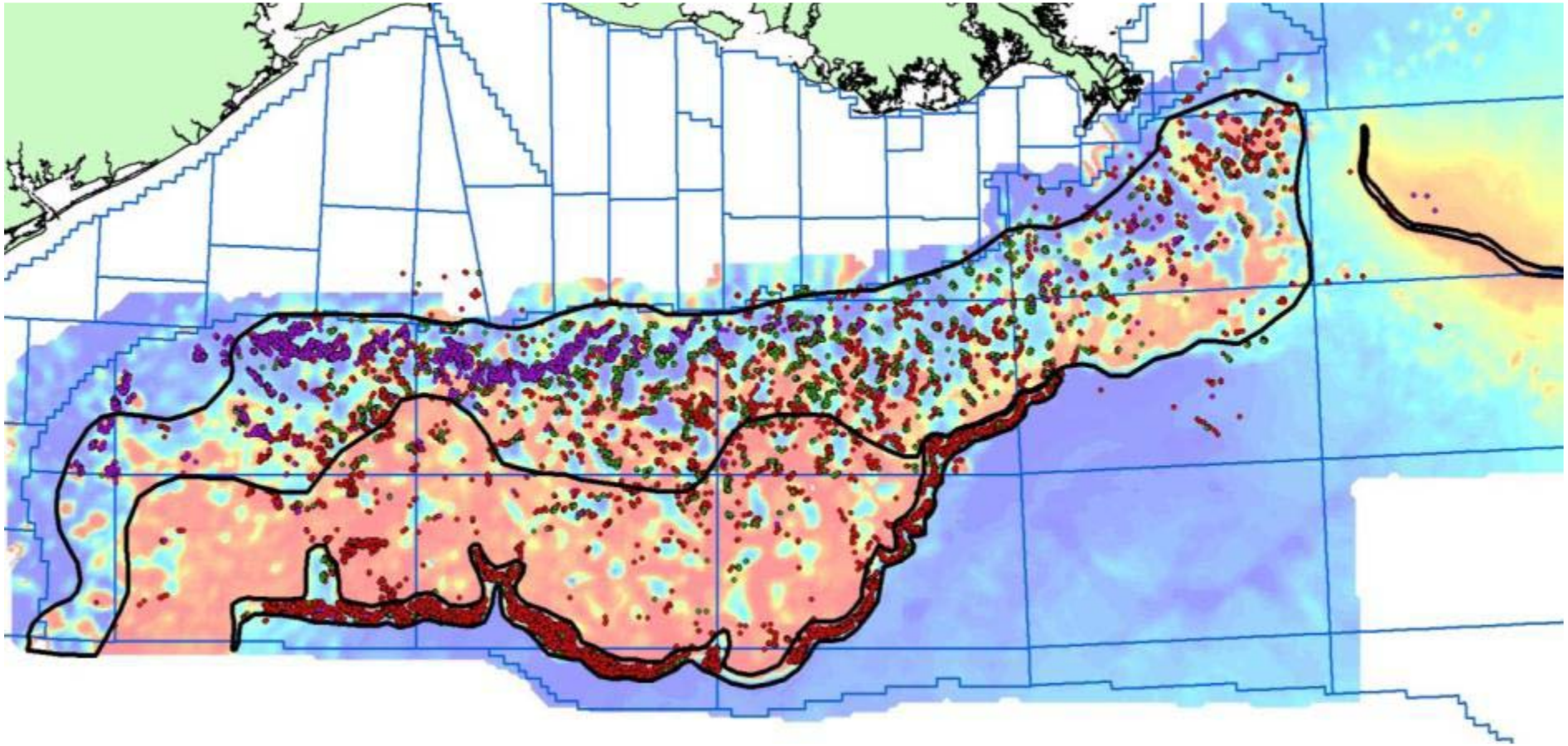
Anomalies are difficult to see at this scale.

ALL ANOMALIES WITHOUT SALT



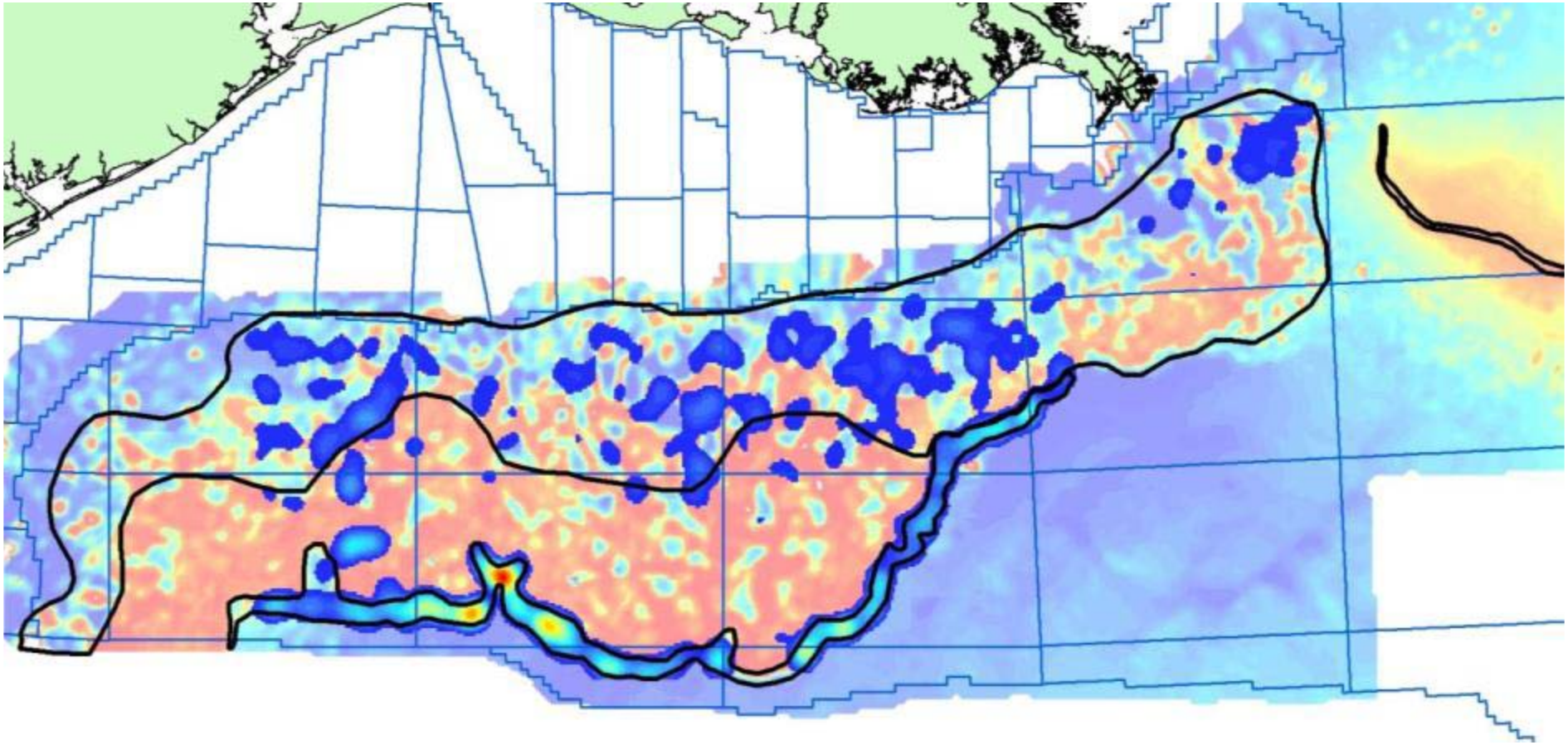
Most anomalies occur in eastern EB, GB, GC, and southern AC and KC.

ANOMALIES AS POINTS



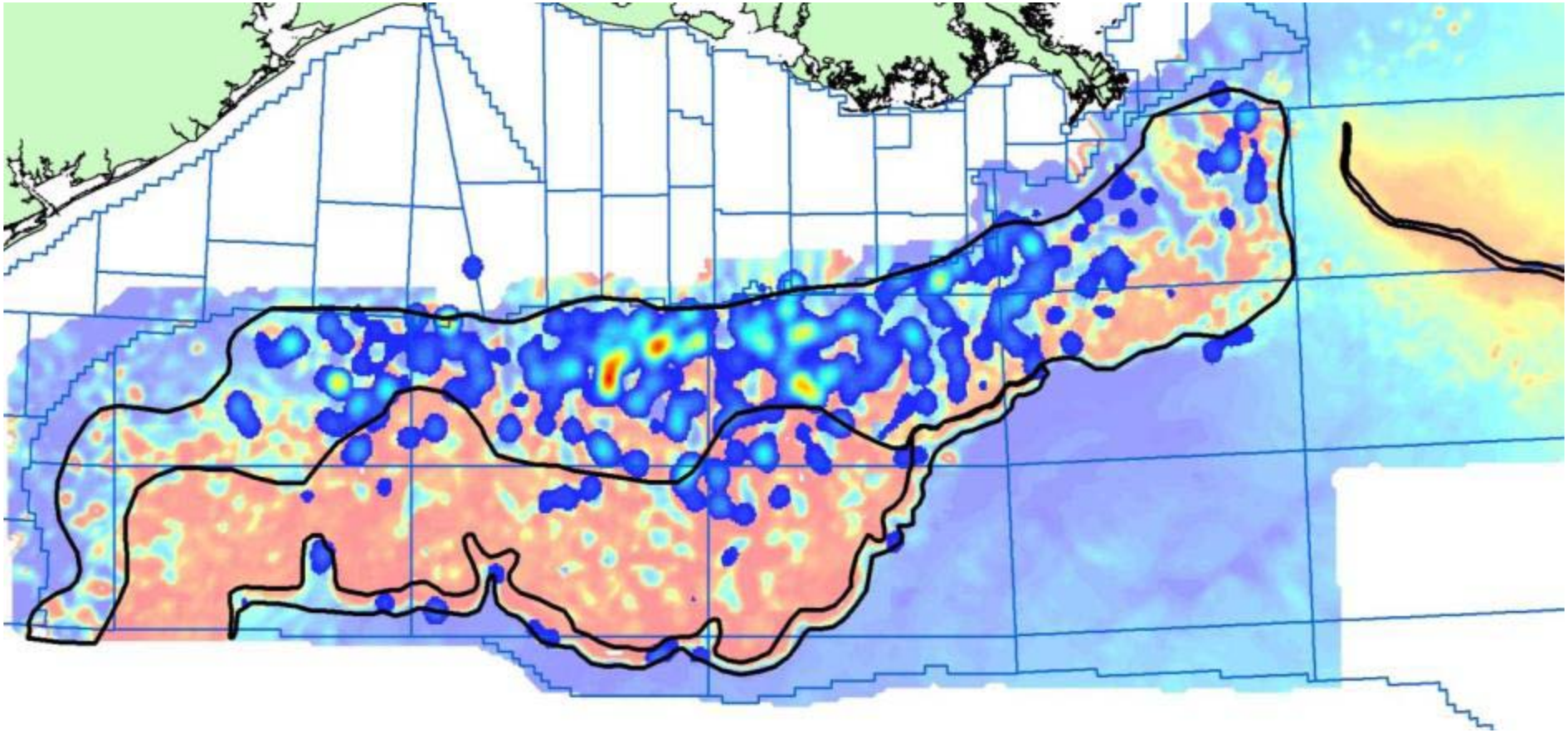
Exaggerates the smaller pockmarks and negative anomalies.

DENSITY OF POSITIVE ANOMALIES



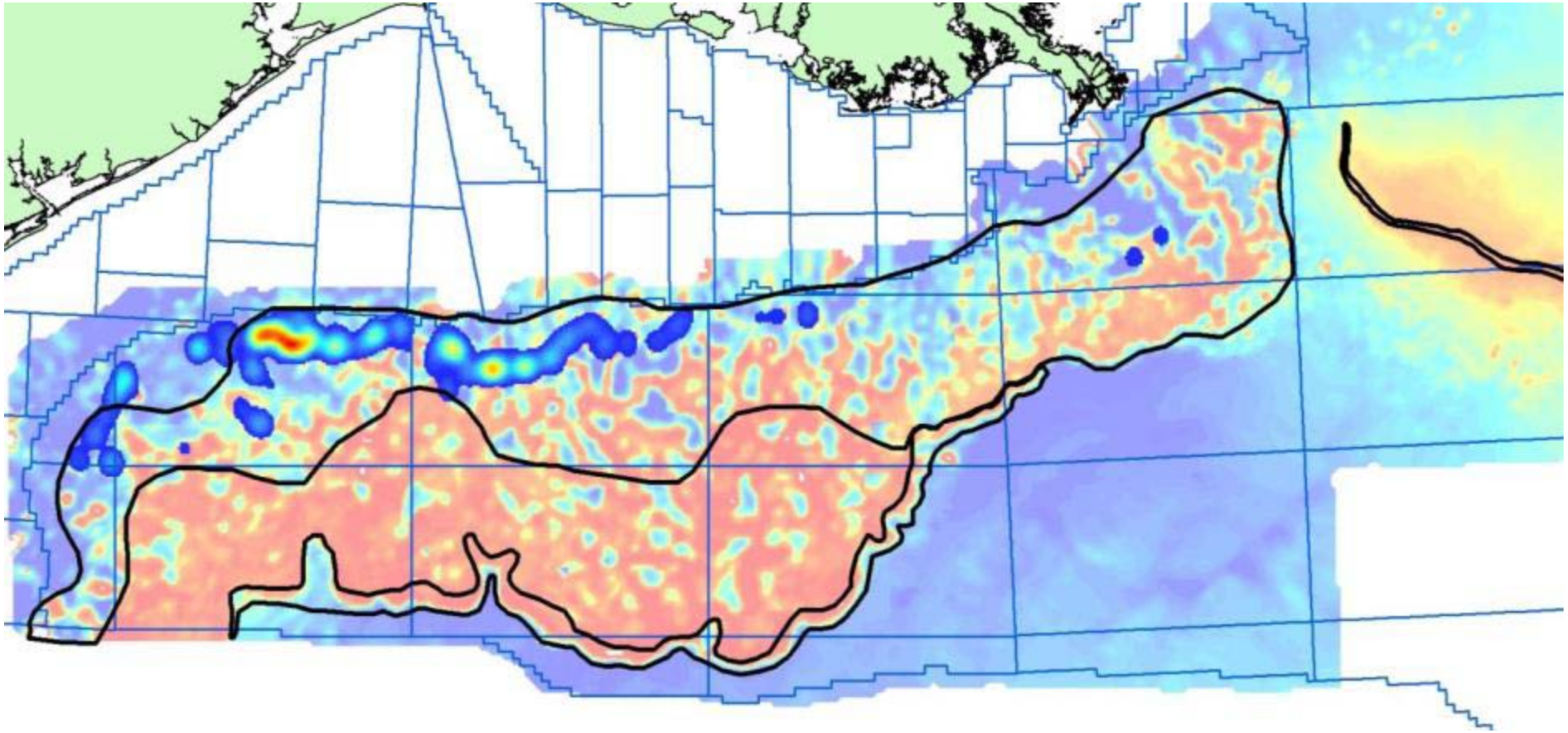
Most positive anomalies occur on the upper slope salt diapir/minibasin and on the face of the Sigsbee Escarpment where migration conduits for hydrocarbons are less restricted by salt cover.

DENSITY OF NEGATIVE ANOMALIES



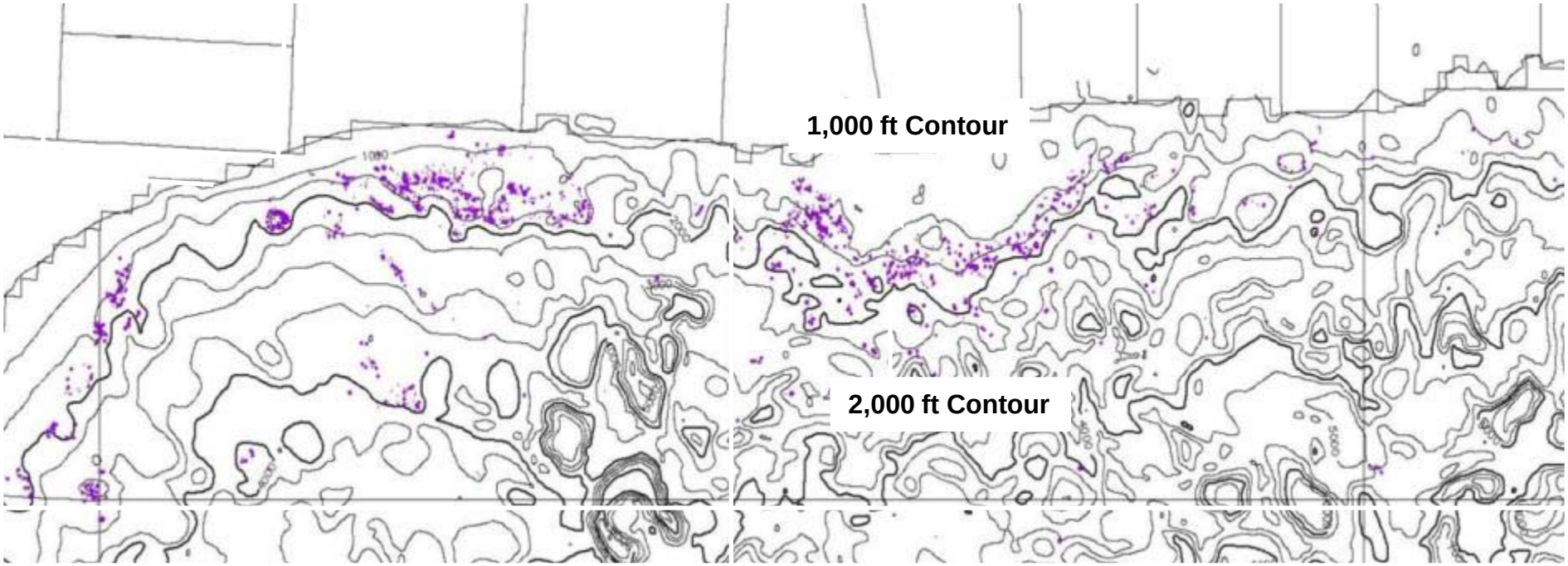
Most high-flux negative anomalies occur on the upper slope salt diapir/minibasin province, where migration conduits for hydrocarbons are less restricted by salt cover.

DENSITY OF POCKMARKS



Pockmarks are primarily located in northern East Breaks and Garden Banks, where gas production is prevalent.

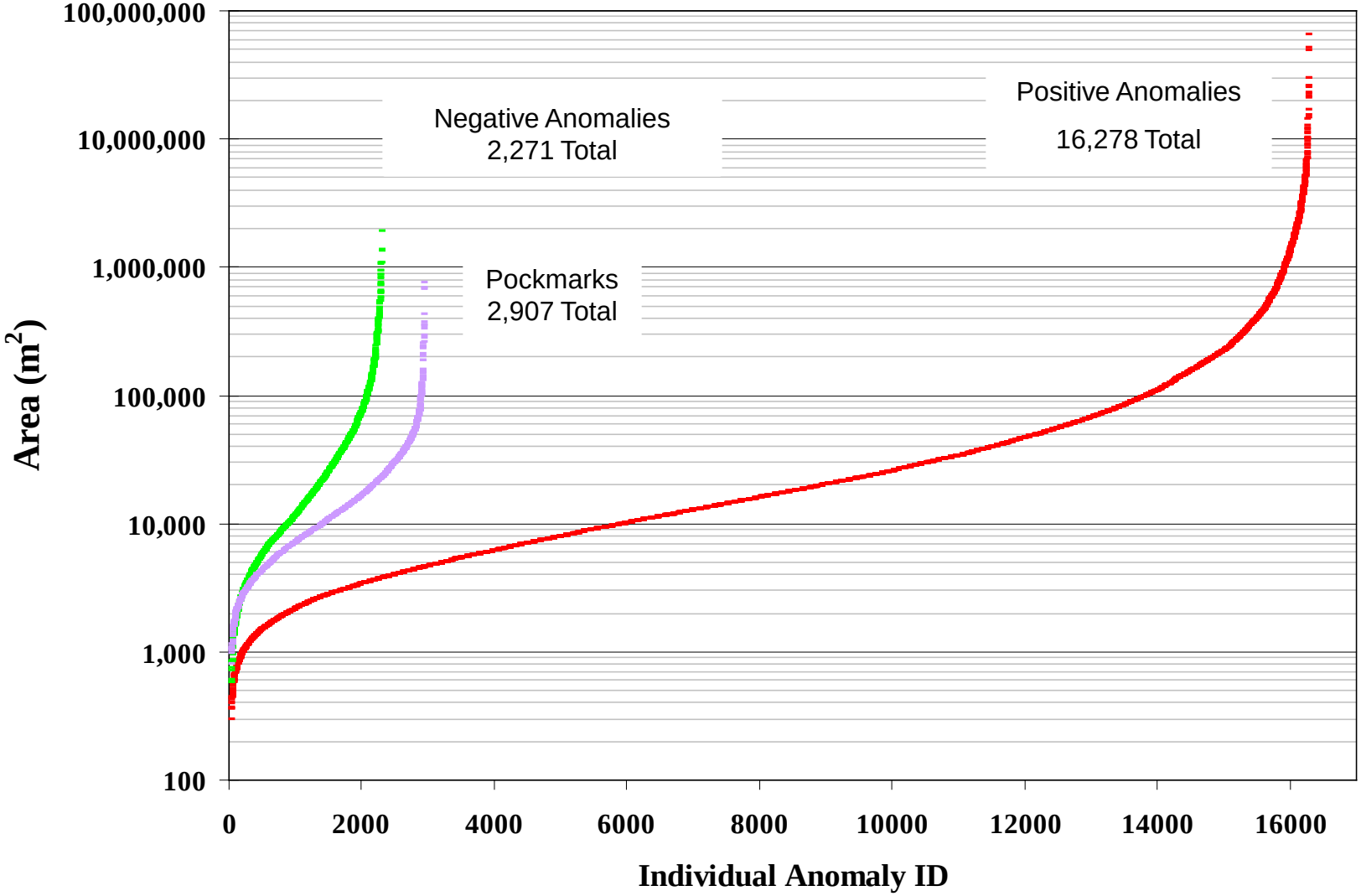
BATHYMETRY MAP WITH POCKMARKS



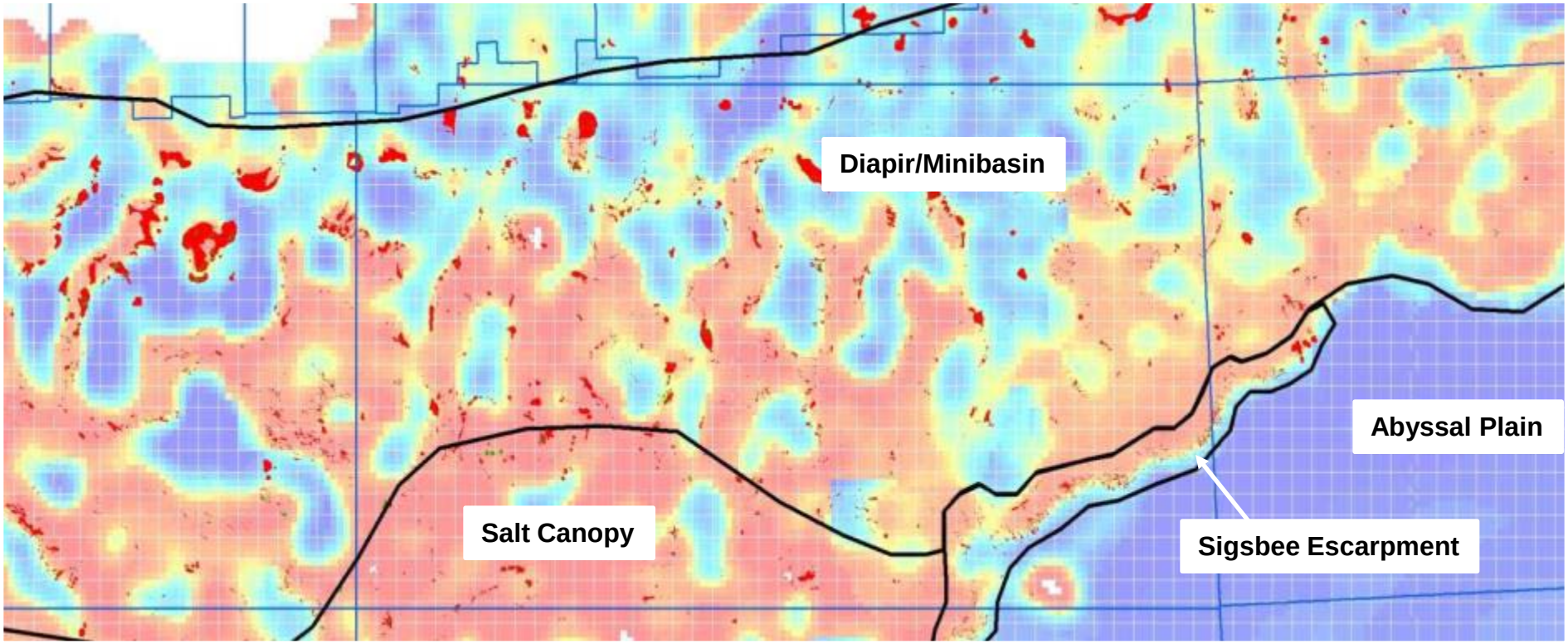
Most pockmarks occur between 1,000 – 2,000 feet water depth, around the present day updip edge of hydrate stability.

Are they the result of rapid dissociation of hydrates during the last glacial maximum, when sea level was over 300 feet lower than at present, and hydrates were, thus, less stable?

SEAFLOOR AREA OF AMPLITUDE ANOMALIES



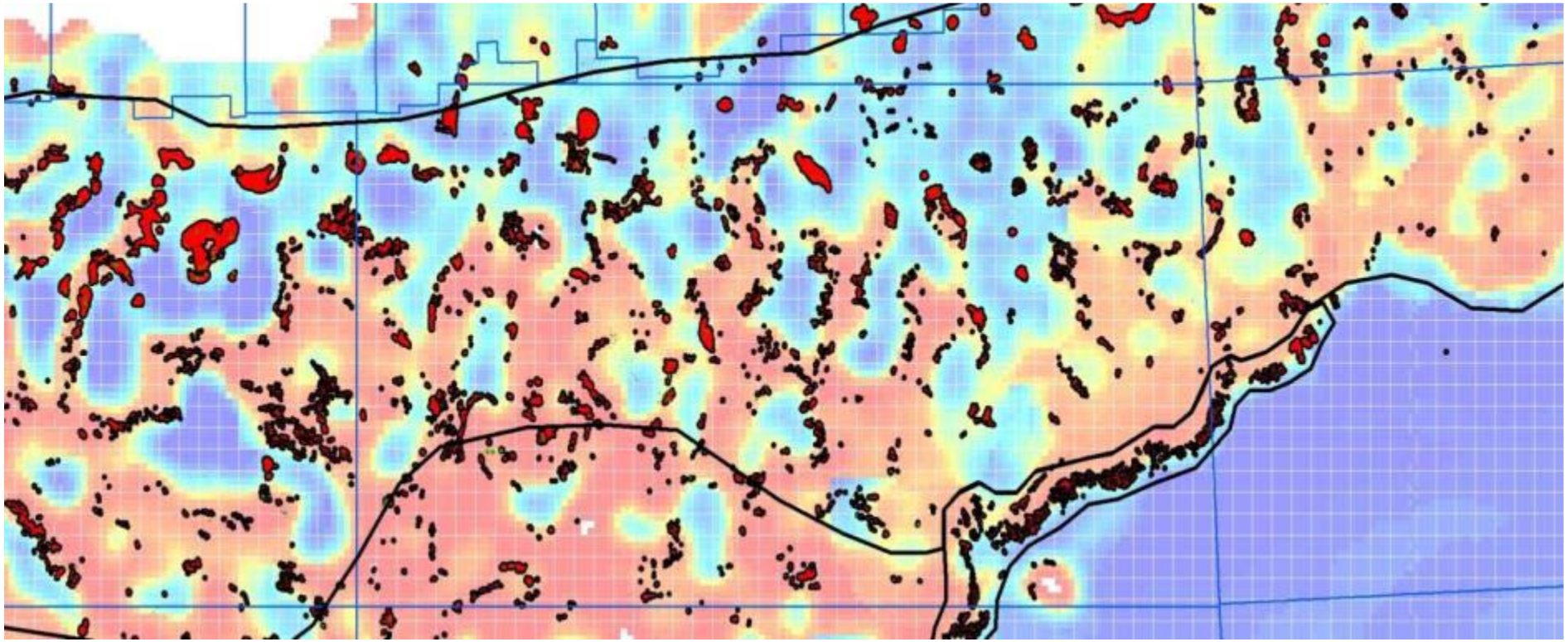
ZOOMED VIEW OF ALL ANOMALIES



Most anomalies in the diapir/mini-basin province occur over the flanks of salt, along the edges of mini-basins. Positive anomalies decrease in size with greater water depth.

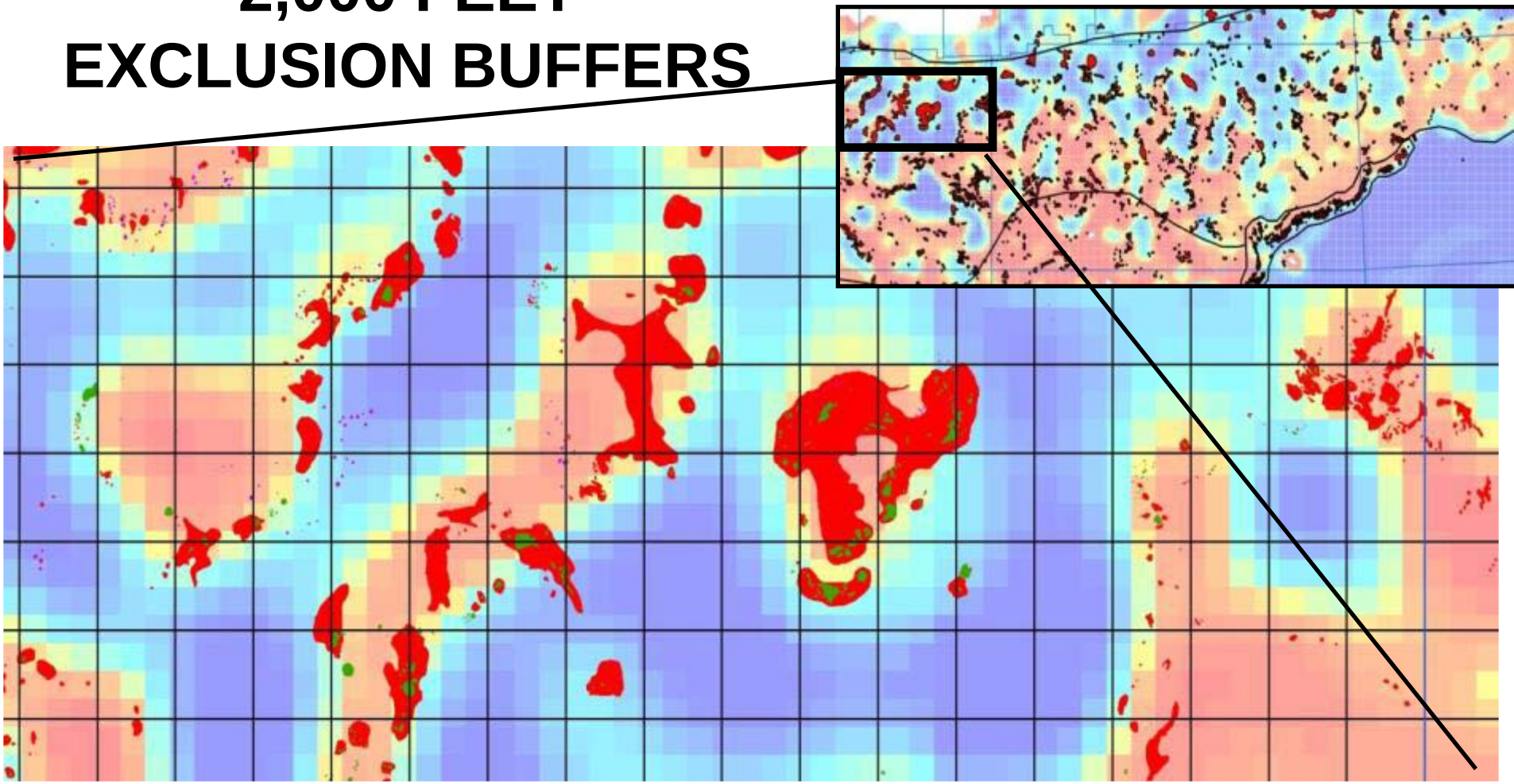
Due to stresses within the sediments above and along the flanks of salt, hydrocarbons migrate vertically through tilted strata and faults, providing a food supply for chemosynthetic organisms.

DEEPWATER BENTHIC
2,000 FEET EXCLUSION BUFFERS



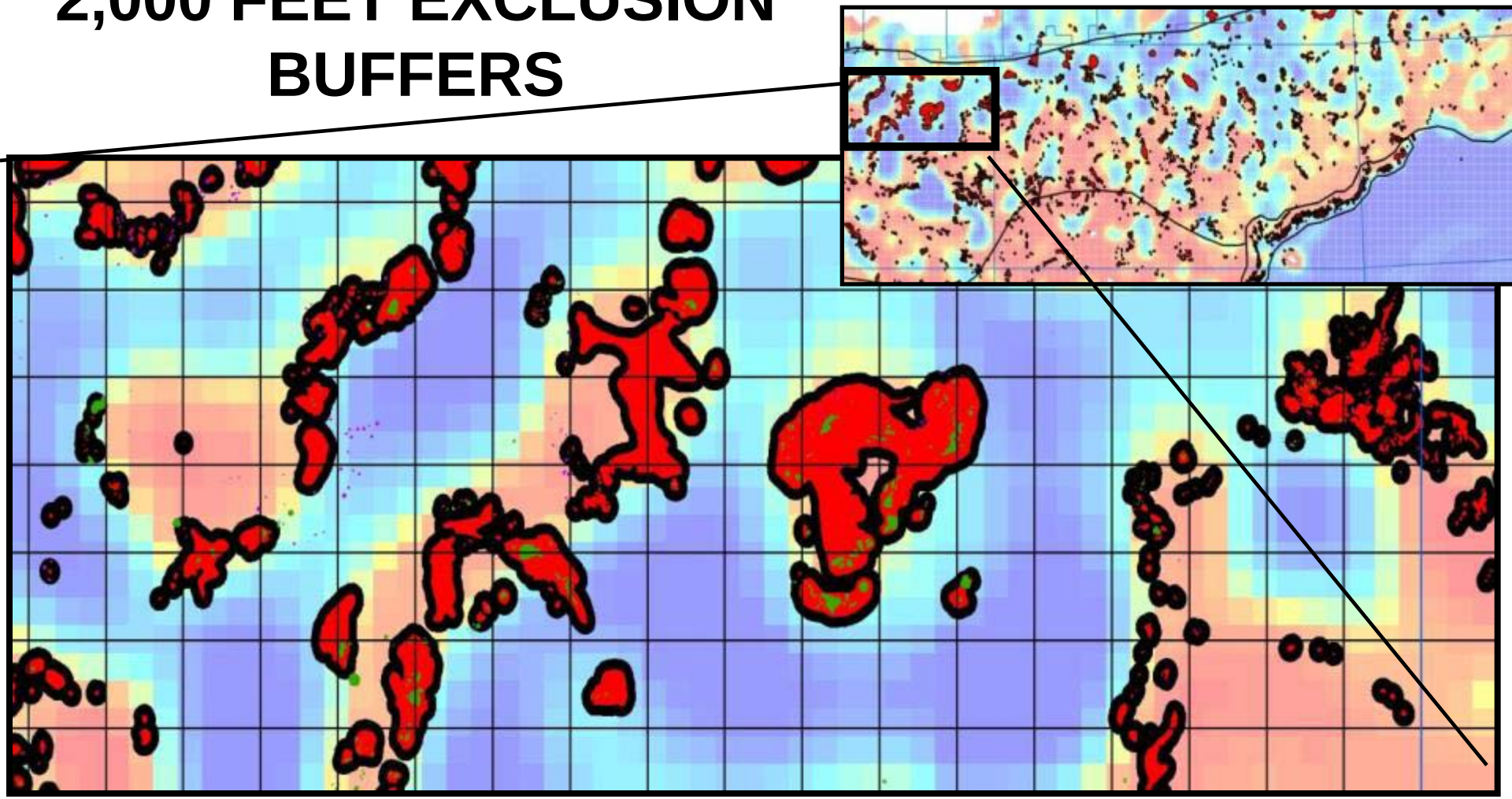
As per NTL 2009-G40, the oil industry's surface locations must be at least 2,000 feet outside of the outline of possible benthic communities, shown here as thick polygons around the positive anomalies.

DEEPWATER BENTHIC 2,000 FEET EXCLUSION BUFFERS



Note that while the total area increase for large anomalies (when the buffer is applied) is insignificant, the increase for small anomalies is very significant.

DEEPWATER BENTHIC 2,000 FEET EXCLUSION BUFFERS



Note that while the total area increase for large anomalies (when the buffer is applied) is insignificant, the increase for small anomalies is very significant.

SUMMARY

- The majority of the over 21,000 amplitude anomalies are high positive – 76% (10.5% negative anomalies and 13.5% pockmarks).
- The overwhelming majority of all anomalies occur where salt is not an impediment to migration – on the upper slope diapir/minibasin province and on the face of the Sigsbee Escarpment.
- Low to moderate flux seepage, that has been shown through numerous *in situ* investigations (submersible, ROV, AUV, piston cores and trawls) to form the carbonate hardgrounds that support chemosynthetic and coral communities, results in a high positive geophysical signature and is easily recognized.

SUMMARY (cont.)

- 3-D geophysical data is suitable to define the probable areas of substrate for benthic communities protected by federal regulation.
- The low positive areas have been shown by direct observations to be the result of high flux seepage of hydrocarbons and brine and sometimes sediment.
- On a flat or low slope, sediment can build mud volcanoes or positive bathymetric features; on steeper slopes, flows of sediment trend downslope.
- Where no sediment accompanies the fluids, vent fields develop, with a very low positive to negative response on the geophysical data.

SUMMARY (cont.)

- The low positive anomalies are probably underrepresented in BOEMRE's total count since they are often more subtle and hard to recognize.
- Pockmarks are circular-to-oval depressions that are probably the result of rapid gas expulsion, which leaves a depression rather than a mound, as with mud volcanoes.
- Most pockmarks occur in the same areas of the GOM where gas production in the subsurface is predominant.
- Most pockmarks occur between 1,000 to 2,000 feet, about the updip limit of gas hydrate stability, suggesting that those may have formed as a result of hydrate dissociation during the last glacial maximum, when sea level was more than 300 feet lower than present, causing hydrate instability.

SUMMARY (cont.)

- Many pockmarks are localized on structural highs where extensional fracturing and faulting would allow for gas escape from hydrate dissociation

PUBLICATION OF ANOMALIES ON BOEMRE WEBSITE

- BOEMRE is about to publish the shapefiles of the water bottom anomalies and associated metadata on its public website at the following link: http://www.gomr.boemre.gov/homepg/regulate/environ/ocean_science/index.html
  - The georeferenced ESRI shapefiles will be downloadable
  - A link to those anomalies that have been confirmed by direct observation (how, when, by whom, etc.) will be available in the near future.