Combining Multicomponent Seismic Attributes, New Rock Physics Models, and In Situ Data to Estimate Gas-Hydrate Concentrations in Deep-Water, Near-Seafloor Strata of the Gulf of Mexico

Phase 1 Report: May 2006
Assessment of Hydrate Evidence Across the Study Area

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Disclaimer

Abstract

A research project has been initiated to determine whether concentrations of deep-water gas hydrate can be predicted using 4C OBC seismic data. The study area is located in a deep-water area of Green Canyon on the northern shelf of the Gulf of Mexico. To continue this research into Phases 2 and 3 of the project, evidence needs to be presented that confirms gas hydrate is present across the selected study area(s). This report describes that evidence.

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Introduction

Four constraints dictate which specific areas in the Gulf of Mexico (GOM) can be used for this gas hydrate research project: (1) water depths must be appropriate for hydrate stability, (2) multicomponent seismic data must be available across the area, (3) information needed to define near-seafloor geological conditions must be accessible, and (4) there must be compelling evidence that gas hydrate systems span the area. This report discusses all of these issues, with special emphasis on the evidence that gas hydrate exists at two sites where the study will be focused.

Executive Summary

The most compelling evidence that hydrate exists at a specific seafloor location are observations done by an experienced, skilled scientist who traverses the site in a deep submersible vehicle, visually inspects the seafloor, and performs seafloor sampling and experimental seafloor-based measurements that detect hydrates and/or hydrate byproducts. This report summarizes the evidence compiled by two such scientists, Dr, Roger Sassen of Texas A&M University (TAMU) and Dr. Harry Roberts of Louisiana State University (LSU), who have done deep dives to investigate the sites where this project's research effort will be done.

Experimental

No experimental work was done in preparing this report.

Results and Discussion

Large-Scale Study Area

The potential sizes and locations of study areas used in this gas-hydrate research are controlled by two factors:

- Factor 1: Water Depth – Water depths should exceed 500 meters across a Gulf of Mexico (GOM) hydrate study area to ensure hydrates will be present. Hydrates have sometimes been observed at water depths between 350 and 450 meters on the northern shelf of the GOM, but hydrates at these depths tend to be seasonal and unstable because of borderline temperature and pressure stability conditions. Hydrate systems exhibit greater stability at water depths of 500 meters or more in the GOM.

- Factor 2: Location of OBC Seismic Data – Ocean-bottom-cable (OBC) seismic data are the most critical part of the research database that will be utilized. Only WesternGeco has acquired multicomponent OBC data across a large area of the deep-water portion of the northern GOM shelf that are appropriate for this study. A limited amount of deep-water multicomponent seismic data has been acquired across a few small areas by other contractors for various GOM operators, but these latter data are proprietary and are not available for public research. WesternGeco has acquired two OBC surveys designated as Green Canyon North-Central (GCNC) and Green Canyon Northeast (GCNE). The locations of these two overlapping surveys are shown in Figure 1. The seafloor cables used in these data-acquisition programs had a maximum operating depth of 1,000 meters. This cable-depth limitation defines the position of the southern (deep-water) boundary of each survey.

Combining the constraints of these two factors leads to the definition of a *Target Fairway* shown in Figure 1. The north and south boundaries of this fairway are, respectively, the 500-meter and 1,000-meter bathymetry contours across the area, the water depths dictated by Factors 1 and 2 above. Any area selected for a focused gas-hydrate study in this project has to be positioned between the east and west extents of OBC surveys GCNC and GCNE within this fairway. This large-scale area in which smaller, focused study sites can then be selected has a north-south dimension of 15 to 25 miles and extends about 75 miles east-west across the Green Canyon area of the GOM.

Hydrate Evidence

There is abundant evidence that hydrates are present across the *Target Fairway* identified in Figure 1. This evidence comes from direct observations of seafloor features by two noted GOM gas-hydrate researchers: Dr. Roger Sassen (TAMU) and Dr. Harry Roberts (LSU).

Sassen Evidence

Roger Sassen is a geochemist who specializes in GOM gas-hydrate research. In his research, he has done deep dives at numerous sites across the GOM northern shelf (Sassen and others, 1999). Figure 2 shows a map Sassen presented at a gas-hydrate workshop in 2000, on which he documented sites where either hydrate outcrops or vents of hydrate snow and gas bubbles were observed in his deep dives. Both types of observations attest to the presence of subseafloor hydrates. An outline of seismic surveys GCNC and GCNE has been added to this Sassen map. Several of the sites where Sassen found direct evidence of hydrates are located inside this seismic grid, providing hard evidence that hydrates exist across the targeted study area. Examples of typical seafloor hydrate outcrops and gas/hydrate-snow vents found by Sassen along the targeted hydrate fairway are illustrated in Figure 3.

Roberts Evidence

Harry Roberts is a geologist who has been involved in GOM gas-hydrate research for several years. Most of his research is sponsored by the Minerals Management Service (MMS) and has involved a large number of deep dives and direct seafloor observations. Roberts and MMS have found *bright seafloor reflectivity* to be a direct indicator of subseafloor hydrate systems. Their research philosophy is to interpret the massive 3D seismic data volumes MMS has amassed across the GOM and map locations where seafloor reflectivity brightens. They then dive at those sites to determine what causes the increase in seafloor reflectivity (Roberts, 2001). At most of these sites, they find the seafloor abounds with (1) chemosynthetic communities (clams, mussels, bacterial mats, and tube worms) that feed on methane and methane-generated sulfides, and (2) carbonate hardgrounds produced by methane-consuming microbes. These hardgrounds and/or thick layers of clam and mussel shells create a large-magnitude seafloor reflectivity. All of these organisms and their byproducts are considered by Roberts and MMS to be direct evidence of deeper gas-hydrate systems. They now believe this correlation to the extent that they automatically associate bright seafloor reflectivity in appropriate water depths with subseafloor hydrate systems. Only in a few instances have they found seafloor bright spots to be caused by factors other than hydrate-dependent biota. Roberts has provided our research team a list of lease blocks along the *Target Fairway* (Fig. 1) where bright seafloor reflectivity has been investigated with deep dives and led to the conclusion that a gas hydrate system underlies each block.

Combining the Evidence

Offshore blocks within or adjacent to the *Target Fairway* where Sassen and Roberts have documented their respective versions of direct evidence of gas hydrates are defined on the map shown as Figure 4. The large number of hard-evidence sites located within the fairway confirms gas hydrates are present in many lease blocks inside this targeted study area.

Specific Study Sites

Two questions need to be considered when selecting a specific study site for this project:

1. Are hydrates known to occur at the site?

2. Are data available to calibrate seismic attributes with subseafloor sediment and hydrate properties?

Question 1 is answered by the information displayed on the map of Figure 4. Question 2 is best answered by selecting study sites where production platforms have been constructed. Numerous seafloor borings are made at these platform construction sites to determine subseafloor porosity, mineralogy, and elastic moduli. Also, conventional well log data have been acquired across parts of the near-seafloor, hydrate-bearing interval at these sites as production drilling has been done. Locations of production platforms across the fairway area are shown on the map included as Figure 5 to indicate where critical calibration data exist to define hydrate-sediment properties.

Two areas labeled **Area 1** and **Area 2** are defined on the maps in Figures 4 and 5. These two areas will be the focused study sites for this research. Each area is known to have gas hydrates (Fig. 4), and seafloor borings and conventional well logs are available at each site (Fig. 5). In addition, chirp-sonar, multi-beam bathymetry, side-scan sonar data, and video traverses of the seafloor across these sites can be accessed at Roberts' research laboratory at LSU.

The outlines of **Area 1** and **Area 2** in Figures 4 and 5 are only suggestive. The exact boundaries of the two areas will be defined in the next report of Phase 1 that describes the research database. Tentatively, we have defined **Area 1** to extend across five lease blocks (45 mi^2 [115 km^2]) and **Area 2** to span eight lease blocks (72 mi^2 [184 km^2]).

Conclusions

Based on the evidence presented here, gas hydrate systems definitely exist within the boundaries of the two areas that have been selected for this research investigation. Both **Area 1** and **Area 2** include dive sites where Roberts and/or Sassen have documented hard evidence of gas hydrate. Equally important, the two areas encompass all of the critical data needed for the proposed research:

- 4C OBC seismic data,
- AUV chirp-sonar data,
- seafloor borings and geotechnical reports, and
- conventional well logs.

These facts lead to two uncontestable conclusions: (1) the two areas selected for this research have some of the most convincing evidence of the presence of gas hydrate that can be found across the northern shelf of the GOM, and (2) each study site has a superb research database. Examples of database elements from each site will be described in the next and last report of Phase 1, *Research Database*. We conclude no better sites can be found to conduct Phase 2 and Phase 3 of this research project.

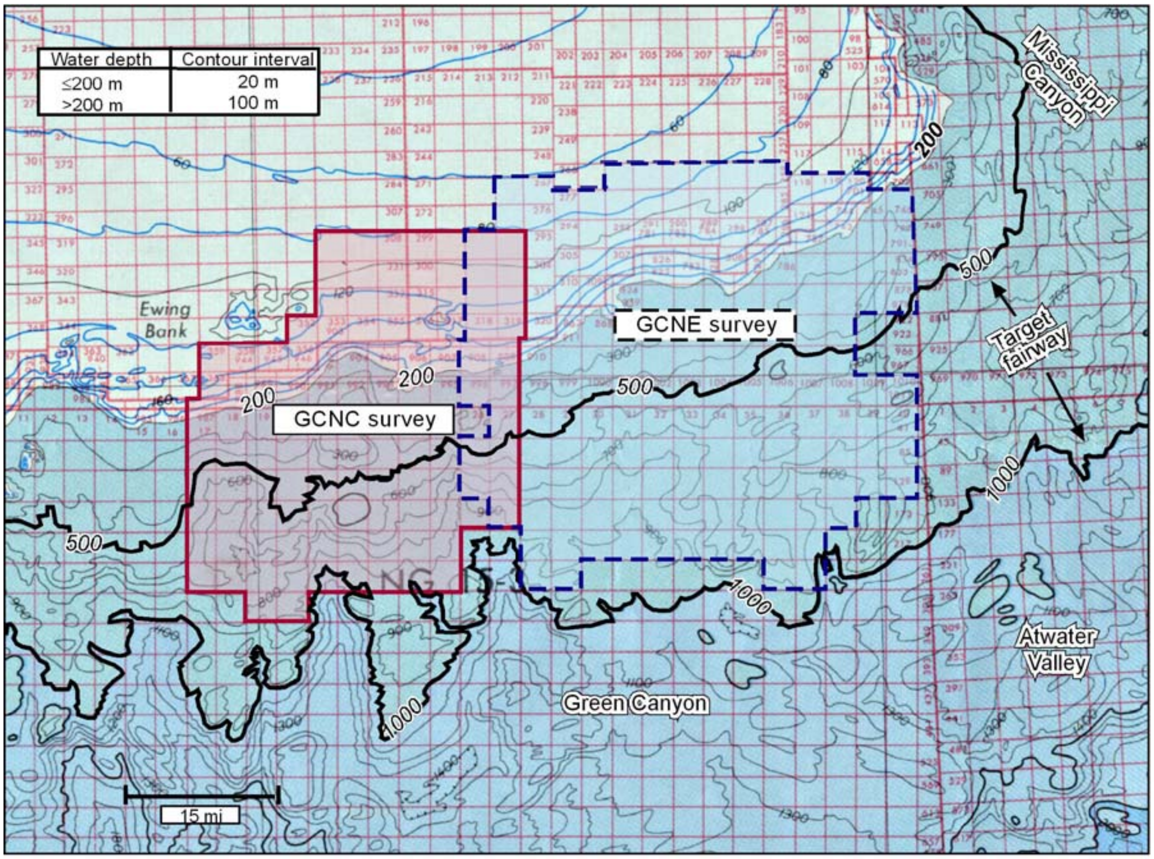
References

Roberts, H. H., 2001, Fluid and gas expulsion on the northern Gulf of Mexico continental slope - mud-prone to mineral-prone responses: Geophys. Monograph, 124, p. 145-161.

Sassen, R., Joye, S., Sweet, S., DeFreitas, D., Milkov, A., and McDonald, I., 1999, Thermogenic gas hydrates and hydrocarbon gases in complex chemosynthetic communities – Gulf of Mexico continental slope: Organ. Geochem., 30, p. 485-497.

Acronymns and Abbreviations

AUV: Autonomous Underwater Vehicle
GOM: Gulf of Mexico
LSU: Louisiana State University
OBC: ocean-bottom-cable
TAMU: Texas A&M University



U.S. Department of Commerce (1986)
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Figure 1. Large-scale Target Fairway across the Green Canyon area where specific study sites can be selected. The northern boundary of the fairway is the 500-meter bathymetry contour. The southern boundary is the 1000-meter bathymetry line.

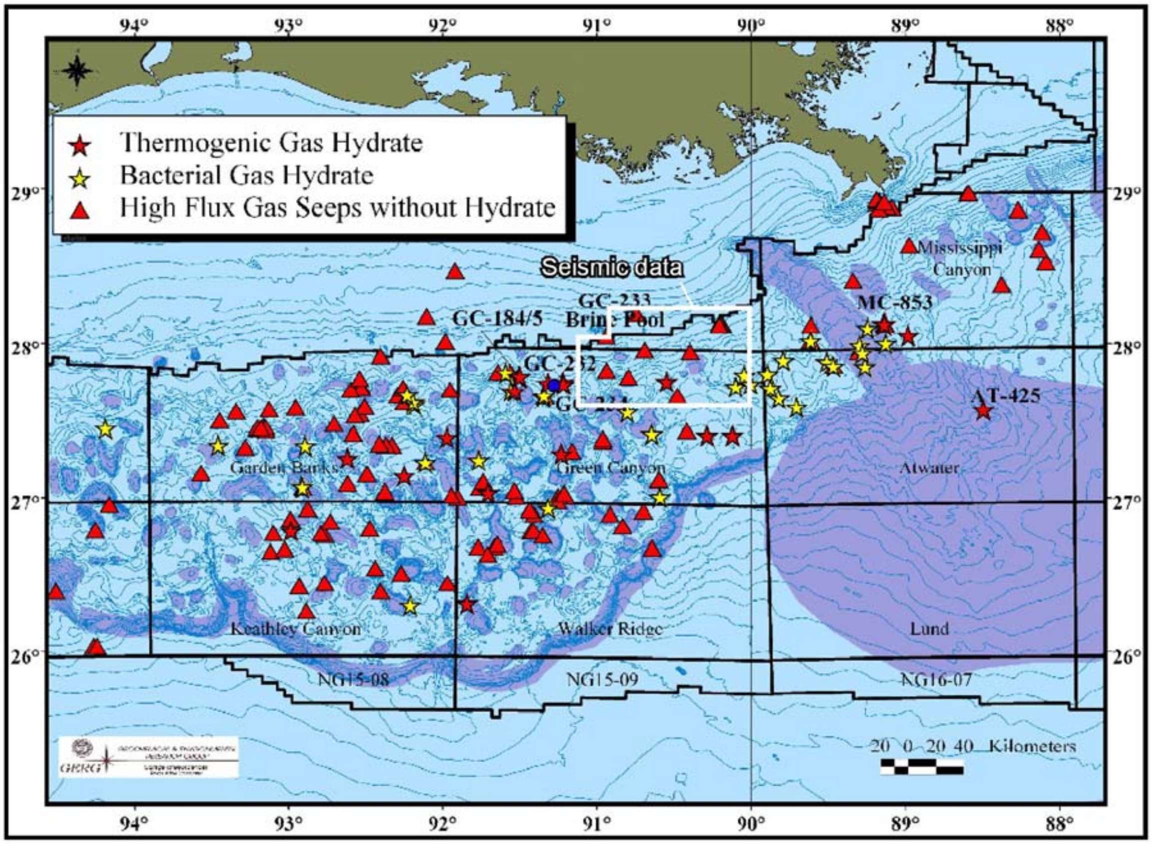

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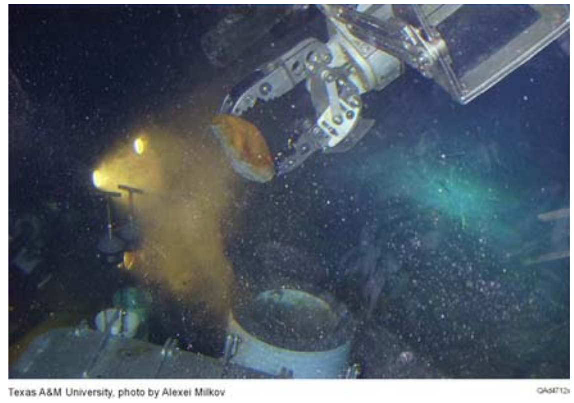
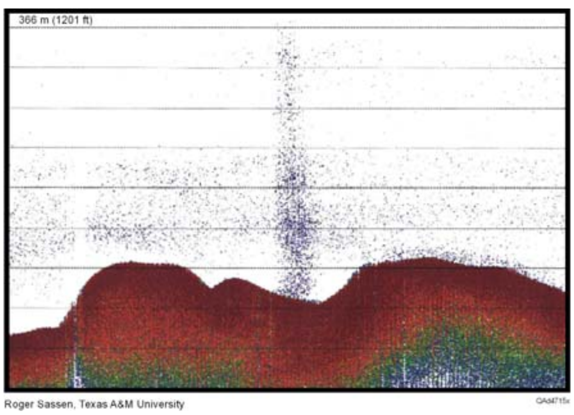
Figure 2. Map produced by Roger Sassen of Texas A&M University showing sites where hydrate outcrops and/or vents expelling hydrate snow and methane gas have been observed across the northern shelf of the Gulf of Mexico. The location of multicomponent seismic surveys available for this research is added to the map as the white rectangular outline to confirm some of these known-hydrate sites are positioned inside the seismic grid.

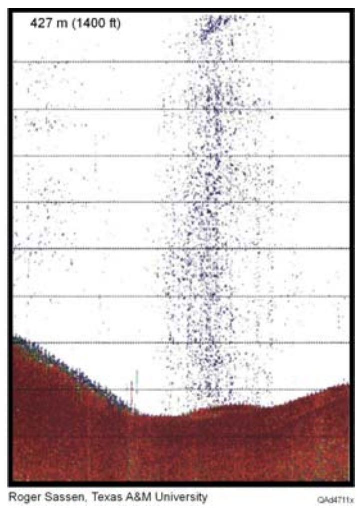
(a) Outcrop in Block GC234.



(b) Outcrop in Block GC232.



(c) Vent number 1 in Block GC234.



(d) Vent number 2 in Block GC234.

Figure 3. Examples of hydrate outcrops and seafloor venting observations used by Sassen to construct the map in Figure 2. These examples come from Blocks GC232 and GC234, immediately outside the western boundary of the GCNC seismic survey defined in Figure 1.

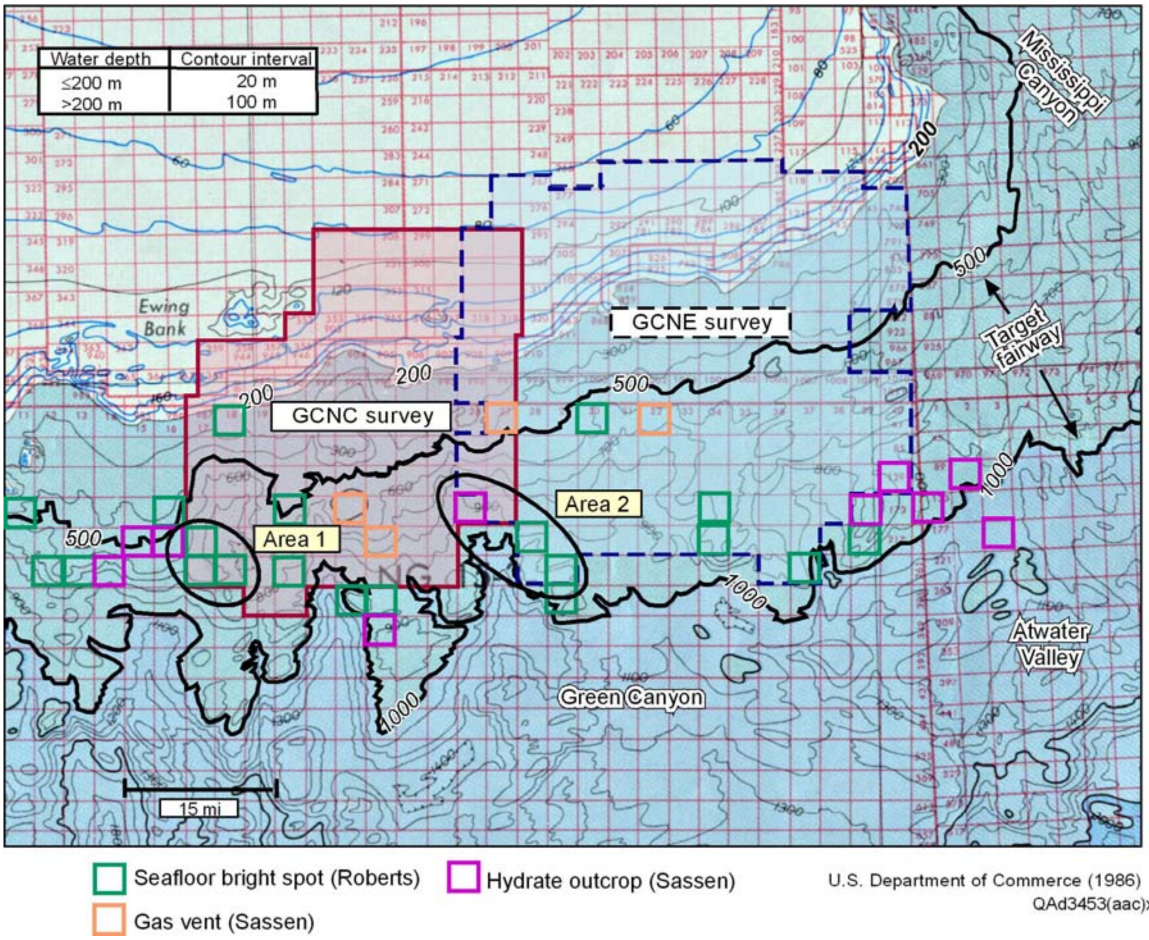


Figure 4. Lease blocks inside the large-scale study region where Sassen and Roberts have documented their respective evidence of the presence of hydrates. Areas 1 and 2 are specific sites where this research will be focused.

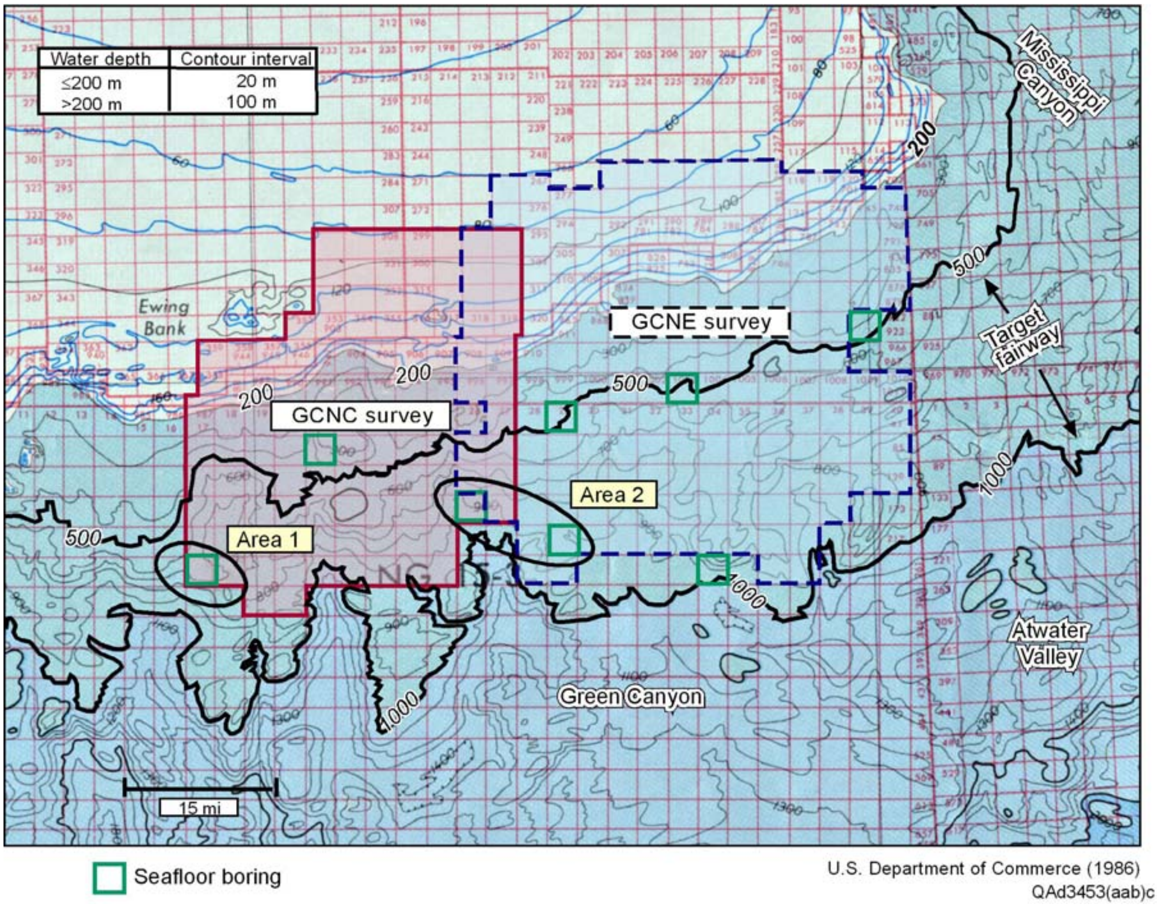


Figure 5. Locations of production platforms, seafloor boring tests, and conventional well log data across the study region. Areas 1 and 2 are specific sites where this research will be focused.