Gulf of Mexico Hydrate Mapping and Interpretation Analysis

Project Area 5 Report
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This report satisfies Mapping and Prospect Identification within Project Area 5 for BOEM award Gulf of Mexico Gas Hydrate Mapping and Interpretation Analysis, which is Deliverable/Milestone #6 (Table 1).

Table of Contents

Table 1. List of required deliverables and figures.

	Deliverable	Figure #
1	A map showing the distribution of shallow turbidite channel levee systems and shallow salt bodies	4
2	A map showing the depth to the BSR and the spatial distribution of BSRs	3, 4, 5
3	Regional seismic cross sections showing the base of gas hydrate stability and the relationship of prospective reservoir intervals to channel levee systems, faults, salt, and other geologic features	7, 8, 11, 14, 15, 16
4	Regional seismic cross sections showing the base of gas hydrate stability as determined through mapping, modelling, and the integration of well log data	7, 8, 10, 12, 13, 14, 15
5	Subsurface geologic maps of one or more seismic reflectors within the gas hydrate stability zone (or that cross the gas hydrate stability zone) that have a high probability of containing coarse-grained sand based on well log analysis and the nature of the seismic reflector. Maps will include both structural and amplitude renderings.	6, 10, 11, 13, 14
6	Interpreted seismic lines that illustrate geologic features related to the prospective reservoirs including BSRs, faults, base of gas hydrate stability, and zones of interest.	7, 8, 10, 12, 13, 14, 15
7	If wells occur in the vicinity of the prospect, annotated well-logs at each gas hydrate prospect showing the thickness of hydrates within the stability zone, interpreted base of gas hydrate stability, and the presence of free gas beneath the gas hydrate stability zone.	7, 9, 14

1. Study Area and Data

Project Area 5 is located in the Garden Banks Protraction Area of the Gulf of Mexico at the edge of the Louisiana continental shelf and it is the most western Project Area (Figures 1A, 1B). A previous BOEM study identified multiple zones with bottom-simulating reflections in the region of Garden Banks (Shedd et al., 2012). Additionally, Milkov and Sassen (2003) confirmed the presence of hydrate existing at the seafloor and in the shallow subsurface in Garden Banks Blocks 387 and 388 (Milkov and Sassen, 2003) (Figure 1B). These occurrences were confirmed through core analysis, where hydrate was present as small nodules. Core analysis in this area indicates that hydrate is likely present in low saturations (<15 vol.%) and is hypothesized to occur over an area of ~3.2 km^2. This is due to an extensive network of faults that supply the gas in the hydrate stability zone. There is a wide range in estimated hydrate reserves for GB 387 and 388 due to uncertainty of the gas composition. The prospect summarized in Milkov and Sassen, 2003 is the only confirmed hydrate occurrence in Project Area 5.

In general, Project Area 5 is characterized by widespread salt diapiarism in both the subsurface and outcropping at the seafloor (Figures 1A, 1B). Salt-induced normal faulting is common in this area, especially in the western portion of the study area. These faults likely serve as a fluid migration pathway through the subsurface and up to the seafloor and faults occur near mapped bottom-simulating-reflections (BSRs) in multiple locations. Areas with active fluid flow, including mud volcanoes previously identified by BOEM, are also present near zones of interest. In the southern portion of Project Area 5, there are numerous narrow channel features, some of which lead into and occur in zones with BSRs. BSRs in this area are located near salt, faults, and occasionally channel features, each of which can provide conditions required to form high saturations of hydrate (>40%) that may be detectable through seismic (Yun et al., 2005).

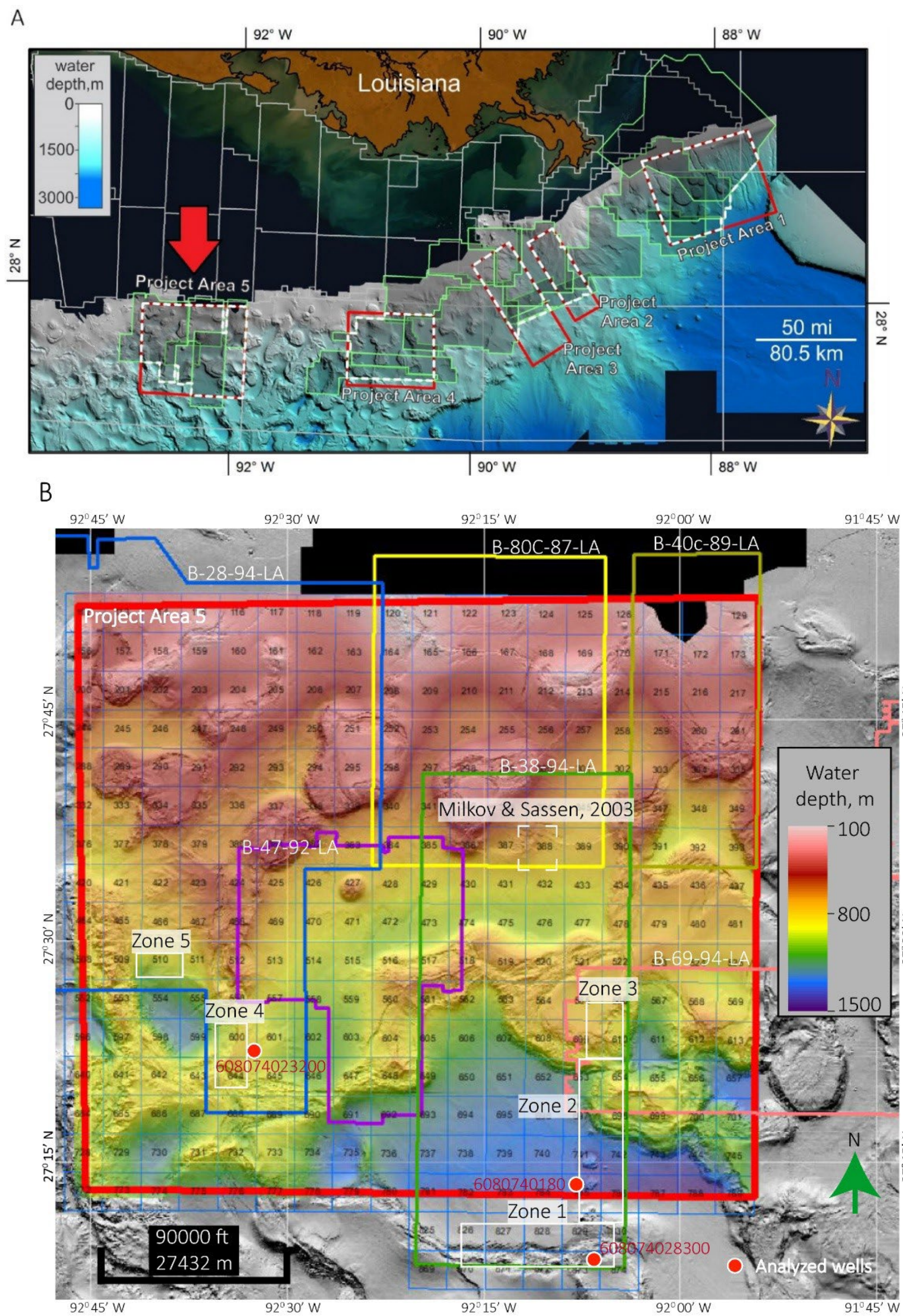

Figure 1. A) A bathymetry map (Kramer and Shedd, 2017) of the northern Gulf of Mexico showing the location of the five Project Areas. The location of Project Area 5 is denoted with the red arrow. B) The bathymetry map and the location of six 3D seismic surveys selected for interpretation. See Table 2 for details. White polygons represent five zones described in this report. Garden Banks blocks are outlined in blue and labeled with the block number. The location of the 2003 Milkov and Sassen study is shown with a white box.

Table 2. Details on the 3D seismic surveys uploaded for data interpretation in Project Area 5. All available surveys were used for data interpretation.

Survey Number	Survey Name/BOEM Identifier	Project Area #	Year	Number of 3D volumes	Area of Seismic Survey (km^2)	Frequency Range (Hz)	Survey quality	Bin size (m)	Projection	Comments
1	B-38-94-LA/L94-038	5	1994	3	2065	5 – 70	Excellent	20 x 12.5	15N NAD27, feet	
2	B-40c-89-LA/L89-040	5	1989	2	799	7 – 50	Fair	25 x 13.3	15N NAD27, feet	
3	B-80C-87-LA/L87-080	5	1987	9	1435	7 – 50	Poor	25 x 13.3	SPCS 27, feet	Different projection
4	B-28-94-LA/L94-028	5	1994	7	3487	8 – 50	Poor	20 x 12.5	15N NAD27, feet	
5	B-47-92-LA/L92-047	5	1992	4	925	7 – 50	Fair	20 x 12.5	15N NAD27, feet	Phase at -90°
6	B-69-94-LA/L94-069	5	1994	7	4797	8 – 50	Good	25 x 12.5	15N NAD27, feet	

Within Project Area 5, six seismic surveys were available and downloaded from the NAMSS database (Triezenberg et al., 2016) for data quality assessment: B-38-94-LA, B-40c-89-LA, B-80C-87-LA, B-28-94-LA, B-47-92-LA, and B-69-94-LA (Figure 1B, Table 2). The total area of Project Area 5 is 6146 km^2 of which 82.26% had 3D seismic data coverage.

2. Using RMS for mapping bottom simulating reflections

To identify the BSRs in Project Area 5, in addition to other distinguishing features such as buried channels and salt diapirs, regional root-mean-square (RMS) amplitude calculations were performed independently within the six selected 3D seismic surveys listed in Table 2 (Figures 2, 3). For the purpose of regional RMS analyses, the reference horizon used was the seafloor horizon. As explained in the Project Area 1 report, the study area was divided into three separate domains based on water depth (500-750 m, 750-1000 m, and >1000 m) and assuming an acoustic velocity in water of 1500 m/s. This division of the RMS maps allowed us to target certain subseafloor depth intervals at the approximate base of gas hydrate stability zone (GHSZ) where BSRs may exist (please refer to Chapter 2 of the Project Area 1 report for more technical details).

We generated one major RMS map at the approximate base of GHSZ to search for areas with anomalously high amplitudes that can indicate gas or channel deposits. The blue-white region in the northern part of the RMS maps (Figures 2, 3) represents water depths of <500 meters, indicating that this area is outside of the GHSZ. Distinguishing features such as the narrow channels seen in the southeastern portion of the RMS map (Figures 2, 3) are readily apparent on the higher-quality surveys, while surveys of lesser-quality required line-by-line interpretation.

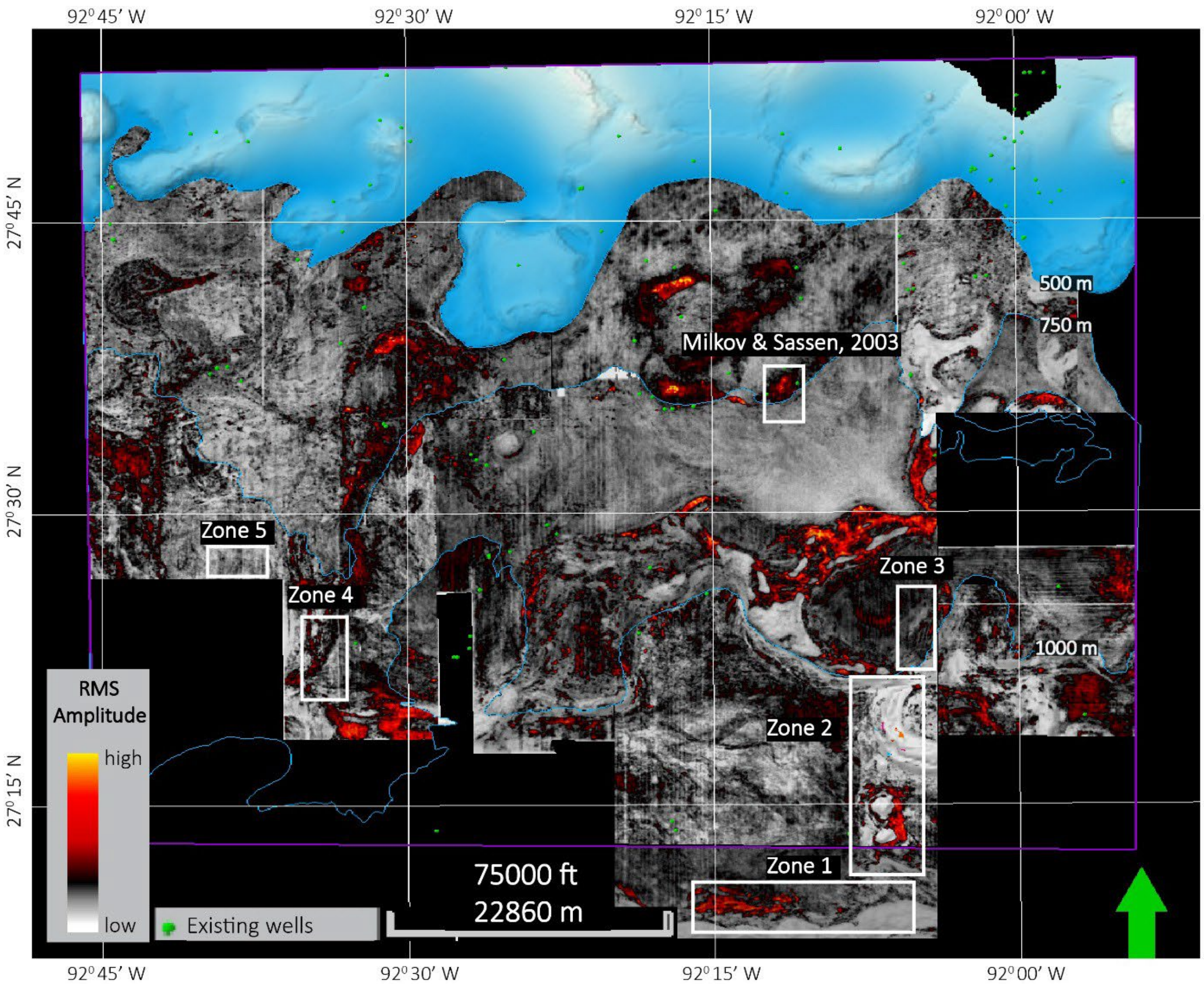

Figure 2. Major RMS amplitude map at the approximate level of the base of GHSZ within Project Area 5. Blue lines are bathymetric contours located at 500, 750, and 1000 mbsl that divide the area into three depth domains with different RMS amplitude search windows. Green dots show locations of wells drilled in the study area. The location of the 2003 Milkov and Sassen study is shown with a white box.

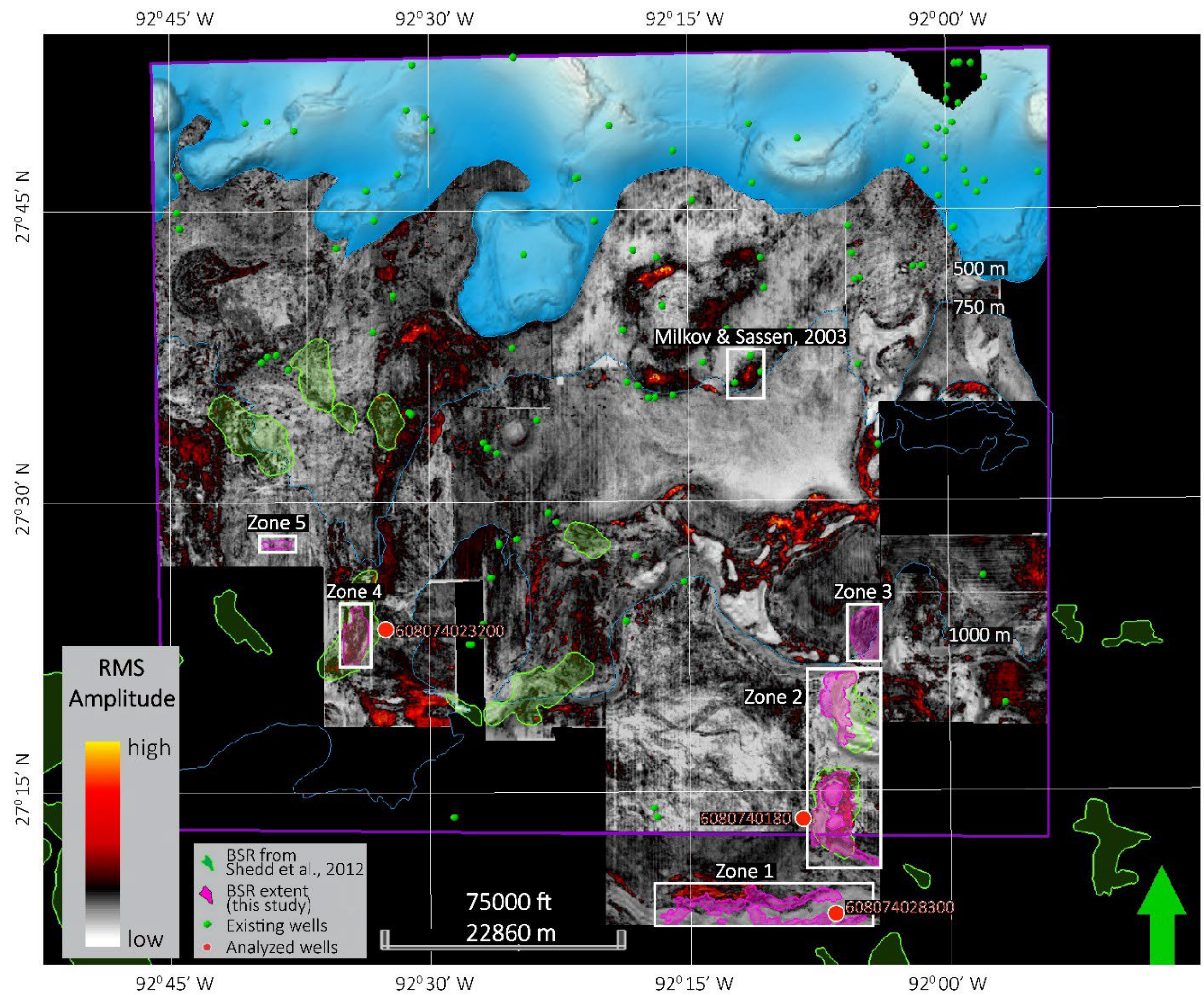

Figure 3. RMS amplitude map showing BSR extent within Project Area 5 (pink areas). Semi-transparent green areas show previously mapped BSR distribution (Shedd et al., 2012). Green dots show the surface well locations. Red circles show the surface locations of three wells selected for log data analyses. Five zones of interest are indicated with labeled white boxes. The location of the 2003 Milkov and Sassen study is shown with a white box.

3. Results in Project Area 5

3.1 Buried Channels

There are widespread buried channel systems throughout Project Area 5. The ability to map and delineate these channels depends on the data quality of the surveys, and some of the surveys in this area are of poor quality (Table 2). For example, RMS maps calculated from seismic volume B-38-94-LA provided the clearest demarcations of buried channel systems, while RMS maps derived from volume B-28-94-LA rarely showed locations of channels. Therefore, in poor quality datasets, channels that were unresolvable from the RMS maps were mapped manually in interpretation windows.

The western portion of the study area contains wider channels in comparison to the eastern portion, with some channels in this region spanning up to 2.5 km wide (Figure 4). These wide channels have significant levee complexes with likely coarse-grained sediments. Primarily, these channels exist at 300 to 400 msec below the seafloor.

In the southeastern part of the study area there is a channel-system, which fans downslope and contains at least eight meandering channels (Figure 4). These braided channels lead into zones of interest and increase the likelihood of the presence of coarse-grained sediments (Miall, 1977; Suter and Berryhill, 1985). The size of the channels in this area are much smaller in comparison to the western area, only ranging from ~150 to 300 meters in width. In addition, levee structures are not as well-defined in this area. These systems occur ~400 to 500 msec below the seafloor.

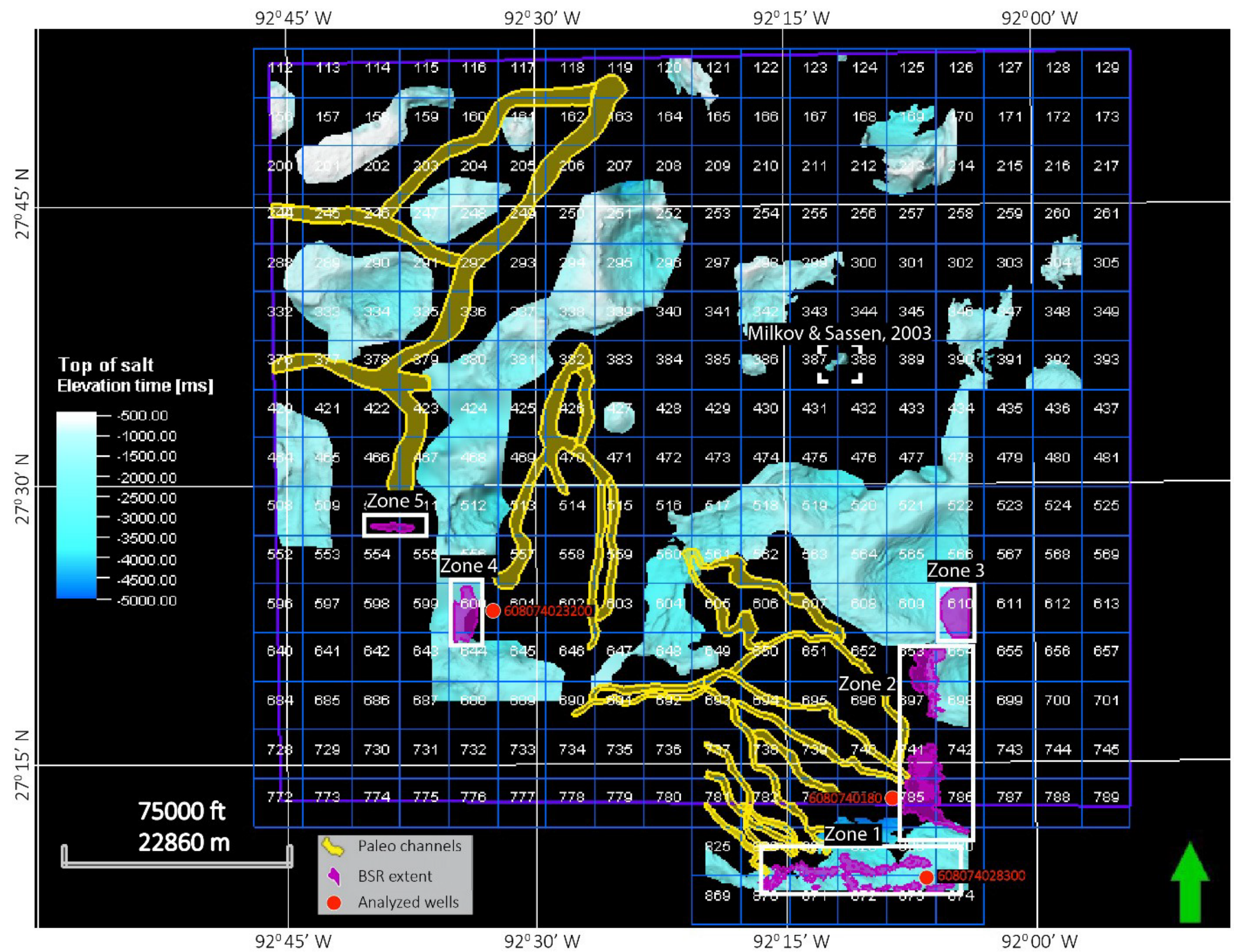

Figure 4. Top of salt depth (blue-teal-white), paleo-channels (yellow) near base of GHSZ and BSR distribution (pink). Features were interpreted from RMS amplitude maps and manual interpretation. Garden Banks blocks are outlined in blue and labeled with the block number. The location of the 2003 Milkov and Sassen study is shown with a white box.

3.2 Bottom-simulating reflections

We identified five distinct zones containing BSRs in the seismic data from Project Area 5 (Figures 3, 4, 5). BSRs in Project Area 5 are often present near salt bodies. Similar to the previous project areas, zones of interest containing BSRs are located in regions with anticlinal structures related to salt diapirism. Zones 1, 2, 3, and 4 contain BSRs that are either above salt or at the margins of salt-floored minibasins. Zone 5 is unique in the fact that the BSRs identified do not occur near areas with active salt diapirism. Zone 5 includes a BSR associated with a deep-rooted fault which supplies the gas identified as a prominent amplitude anomaly at the base of GHSZ.

Zones 2 and 4 are high-confidence areas where strong peak-leading amplitudes were observed. We identified a potential phase reversal in Zone 2, and a clear phase reversal in Zone 4. In these two zones, signatures of active fluid flow were identified in seismic. BSRs are associated with two prominent gas wipeout zones in Zone 2. In Zone 4, a mud volcano venting to the seafloor was identified adjacent to northern part of BSR.

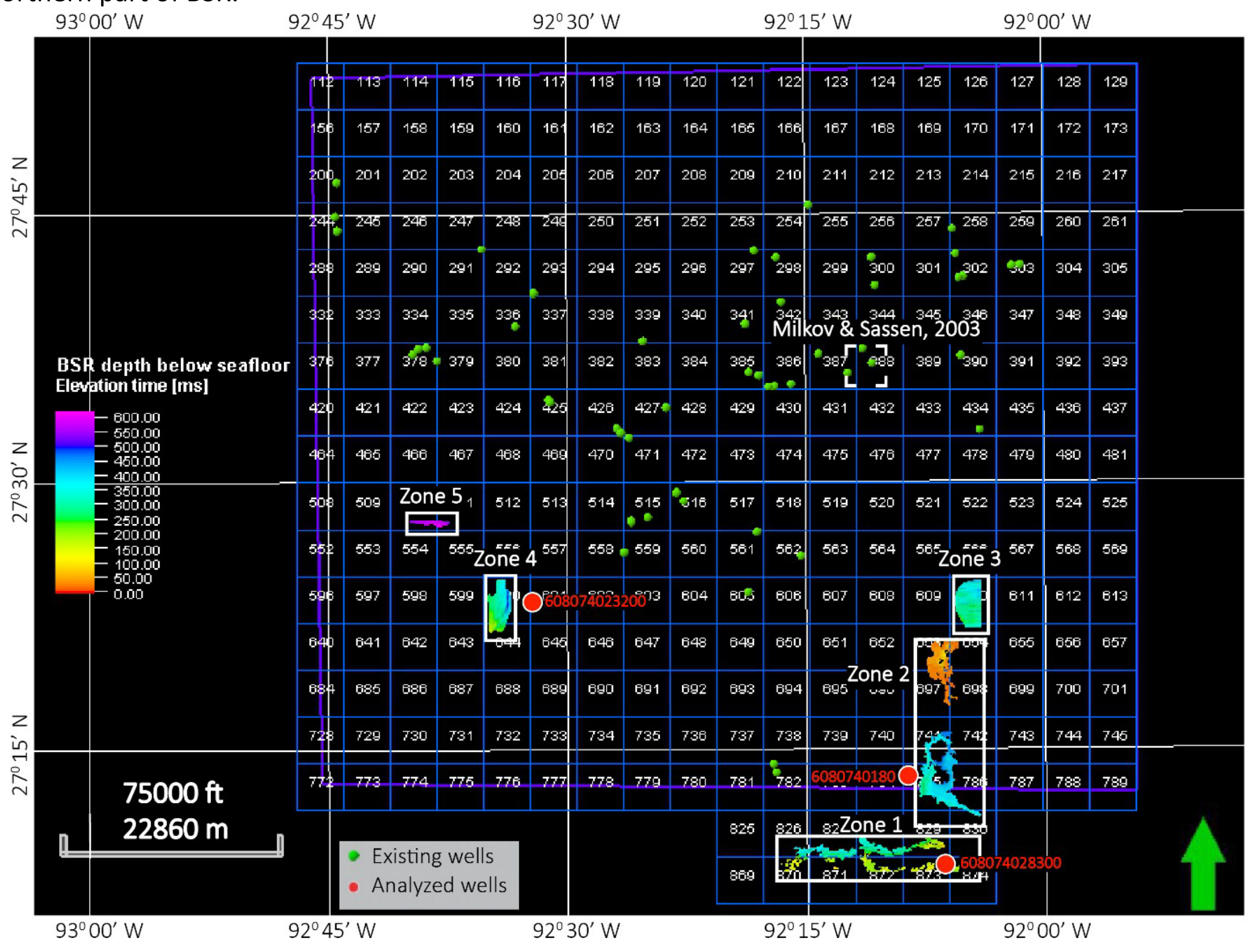

Figure 5. Depth below seafloor (msec, TWT) of manually and semi-automatically mapped BSR. Wells and zones of interest are indicated and labeled. Garden Banks blocks are outlined in blue and labeled with the block number. The location of the 2003 Milkov and Sassen study is shown with a white box.

3.3 Fluid flow features

Both seismic and bathymetry data suggest active fluid flow processes within multiple zones across Project Area 5. In Zone 2, there are two major areas with gas wipeout. High-amplitude peak-leading reflections are observed above the migration pathway in the subsurface. Mapped BSRs in this zone are located directly adjacent to the gas chimneys and span for multiple kilometers suggesting gas migration in this area is widespread.

Vertical fluid flow also is interpreted in Zone 4, where gas migrates along strata leading into a mud volcano. The vent in this location disrupts the seafloor and extends ~325 feet above the adjacent mudline. A phase reversal and strong peak-leading reflections occur above BSRs in this area.

In Zone 5, BSRs are mapped near a fault that extends to the seafloor. The gas present in this area elicits strong negative amplitudes which are overlain by strong peak-leading reflections. While there is lower confidence that this fault would promote long-range vertical fluid flow in comparison to Zones 2 and 4, it is possible that it could serve as a sub-vertical migration pathway to the seafloor.

3.4 Well data

Within Project Area 5, there appear to be no publicly available wells that were drilled into mapped BSRs. We analyzed three wells that are located near either BSRs or channels to confirm the presence of sands that have the possibility of hosting high saturations of hydrate (Figure 5). Due to lack of acoustic data and checkshot surveys, the well logs analyzed were tied to seismic data using estimated P-wave velocity derived from Cook and Sawyer (2015). This estimation provides a reasonable velocity model for the shallow sub-seafloor area that is to be analyzed for hydrate presence.

Of the three wells that exist close to BSR systems, two of them contain data within the gas hydrate stability zone; Well API #6080740180, located near Zone 2, has no data in the gas hydrate stability zone. Well API #608074028300 is in the closest proximity to an identified BSR in Zone 1, although gamma ray and resistivity suggest presence of mud and minimal gas in the area where the well was drilled. The last well analyzed, API #608074023200 located near Zone 4, was drilled 2.5 km to the east of our mapped BSR prospect (Figure 5). The gamma ray units drop slightly at the base of GHSZ indicating there could be a sand-dominated depositional environment within the zone of interest.

4. Results in Zones

4.1 Zones 1 and 2

Zone 1 falls slightly outside of the scope of the project area but presents a new BSR system not previously mapped. The BSR system is approximately 15 km^2 and contains mostly continuous BSRs. Multiple meandering channels lead into the northwestern corner of this system (Figures 6A, 6B). There are several areas above the mapped BSR systems in this region that have strong positive amplitudes, suggesting possible hydrate presence (Figures 6C, 6D). The strongest BSR reflections in this location occur above salt and on the levees of a channel system (Figures 7A). These BSRs are present in ~1500 m water depth and are 90-375 msec TWT (~80-320 meters) below seafloor depending on the bathymetry and amount of salt uplift locally (Figure 7B). An approximate BSR depth in the shallow subsurface in meters was obtained using 1700 m/s P-wave velocity to convert from time. The geothermal gradient in this region is estimated to be ~40°C/km (assuming purely microbial gas composition), which is significantly impacted by the salt body underlying the base of gas hydrate stability.

One well, API #608074028300, was drilled in the southeastern corner of Zone 1 (Figures 6C, 7C). There are gamma ray and deep phase resistivity measurements within the zone of interest. The high gamma ray measurements (>65 API units) from this well in the hydrate stability zone suggest that this portion of the mapped BSR system consists primarily of marine muds. Further work is required to determine the depositional systems across the entirety of this system. There is a minimal increase in resistivity, reaching approximately 2 Ωm above the mapped BSR. At the top of salt, the resistivity spikes to over 100 Ωm, which is a typical response in salt bodies. No individual prospect horizons were mapped or further delineated in Zone 1.

Zone 2 spans a large area in the eastern portion of survey B-38-94-LA and varies from fairly continuous and deep BSRs to shallow, discontinuous BSRs disrupted by salt (Figures 8A). Water depths in the southern part of Zone 2 range from 1300 to 1500 meters, with BSRs ranging from 300-450 msec TWT (~255 to 380 meters) below seafloor. A portion of the BSR mapped in this zone extends past the scope of Project Area 5. In the areas containing deeper BSRs, there is evidence of fluid flow and venting at the seafloor. The southern portion of Zone 2 contains continuous BSRs occurring along strata, with upward migration leading to gas wipeout at two prominent vents seen in seismic (Figure 8B). A possible phase reversal was also seen in this area, located on the edge of the area containing gas wipeout (Figure 8B, 8C).

Further north in Zone 2, water depth becomes shallower, ranging from 1000 to 1150 meters, and allochthonous salt becomes increasingly present near the BGHS. The BSRs in the northern part of this zone contrast from those in the southern zone in their lack of continuity. Depth of BSRs in this part of Zone 2 are between 30-100 msec, TWT (~25-85 meters) below seafloor and the depth is largely dependent on amount of salt uplift locally (Figure 8A).

The nearest drilled well to Zone 2 (API #6080740180) is approximately one kilometer from the prospect (Figure 9). Well logs start ~1000 meters below the BSRs observed nearby, therefore we cannot conduct any useful well log analysis from this data. Additionally, no individual seismic horizons are mapped in this area at this time and further delineation of the apparent phase reversal is required.

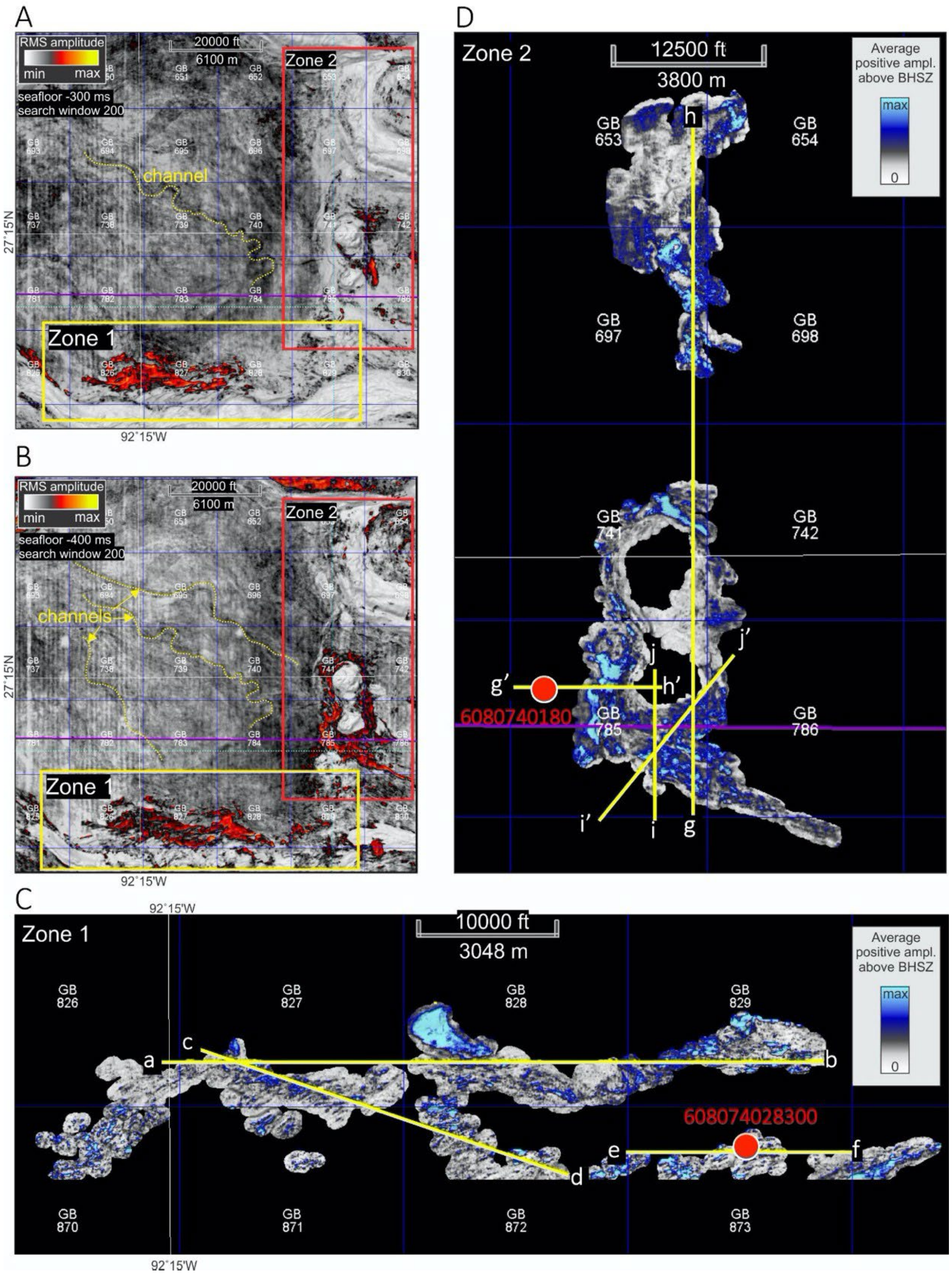

Figure 6. Images of Zones 1 and 2. A) A RMS map for Zones 1 and 2 with -300 ms shift from seafloor and 200 ms search window. B) A RMS map for Zones 1 and 2 with -400 ms shift from seafloor and 200 ms search window. C) An Average positive amplitude map above BGHS for Zone 1. Location of seismic sections in Figure 7 are shown in yellow. D) An average positive amplitude map above BGHS for Zone 2. Location of seismic sections in Figure 8 are shown in yellow.

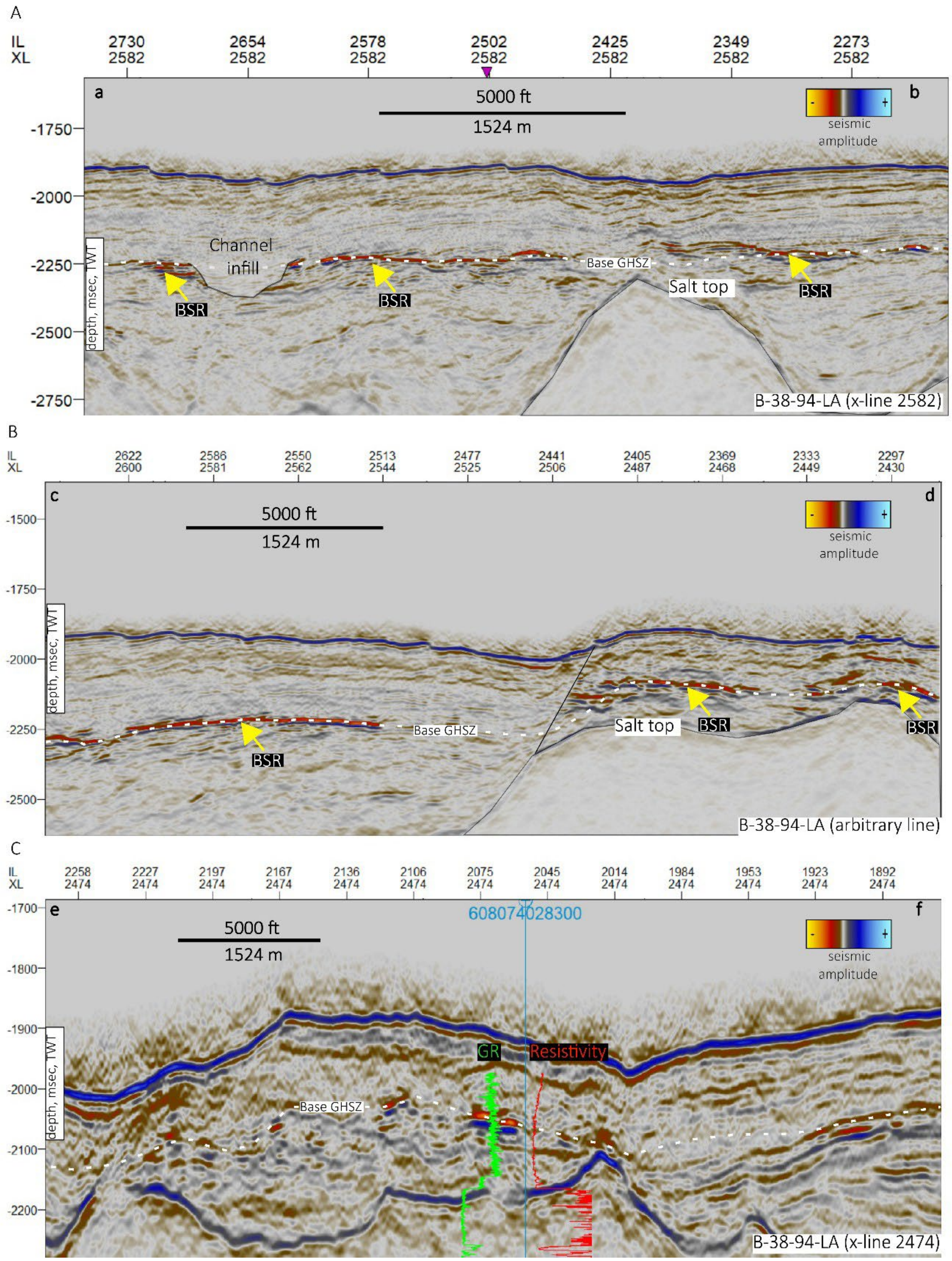

Figure 7. Seismic cross sections from Zone 1. Seismic line locations are shown on Figure 6. A) Seismic cross-section showing continuous BSR (crossline 2582). B) Seismic cross-section of arbitrary line showing continuous BSRs. All line orientations are shown on Figure 6. C) Gamma ray and deep phase resistivity logs in well API 608074028300 (crossline 2474).

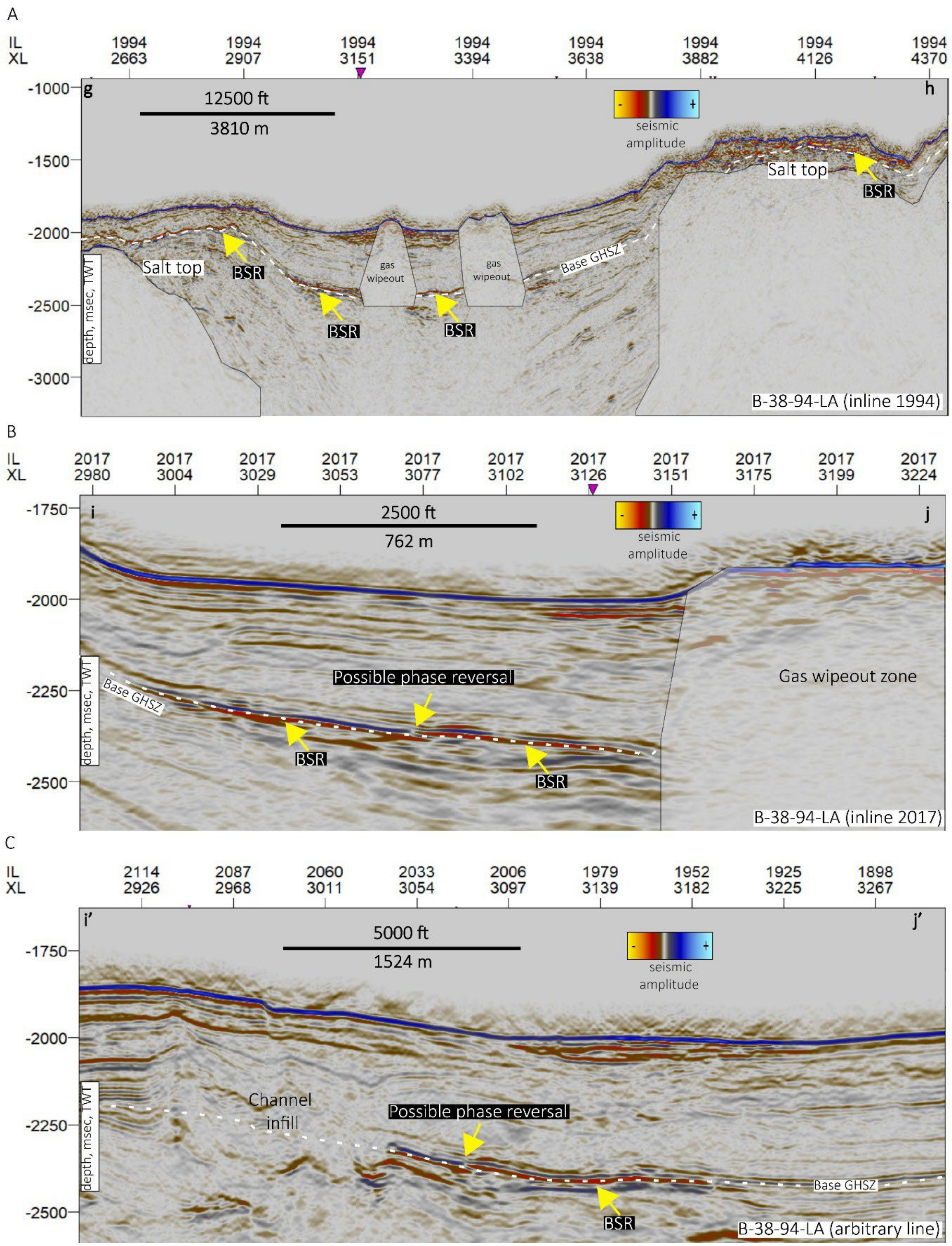

Figure 8. Seismic cross sections from Zone 2. A) Seismic cross section which spans Zone 2 from S-N (inline 1994). B) Seismic cross section showing possible phase reversal near gas wipeout zone (inline 2017). C) Arbitrary polyline showing possible phase reversal in Zone 2. All line orientations are shown on Figure 6.

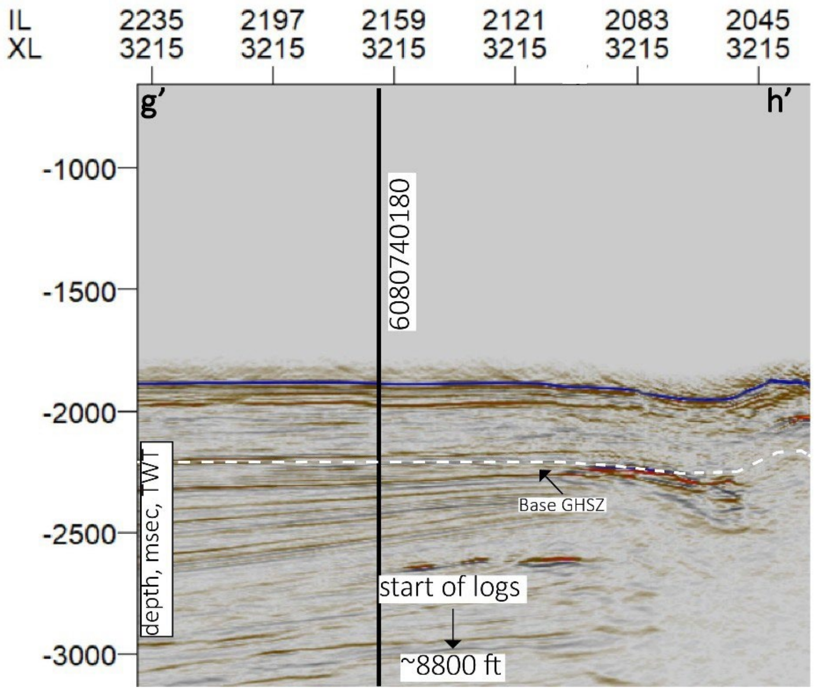

Figure 9. Well API #6080740180 location, showing start of logs well below base of gas hydrate stability in Zone 2. Line orientation is shown on Figure 6.

4.2 Zone 3

Zone 3 in Project Area 5 contains discontinuous BSRs in approximately 900 to 1,100 meters water depth spanning an area of ~12 km^2. Gas-charged dipping sediment layers are overlain by strong peak-leading reflections in certain locations, indicating possible gas hydrate accumulations (Figures 10A, 10B). The BSRs in this location are in a minibasin setting and occur approximately 220-420 msec TWT (~190-360 meters) below seafloor (Figure 10C). There are widespread negative reflections below the base of gas hydrate stability indicating presence of gas which could be a source for gas hydrate in this area (Figure 10D). The strongest positive amplitudes occur on the edge of the minibasin feature near an area with erosional truncation (Figures 10B, 10E). A geothermal gradient of 27°C/km was calculated for this zone. There are no wells near this zone which limited our ability to conduct in-depth analysis. No individual prospect horizons were mapped or further delineated in Zone 3.

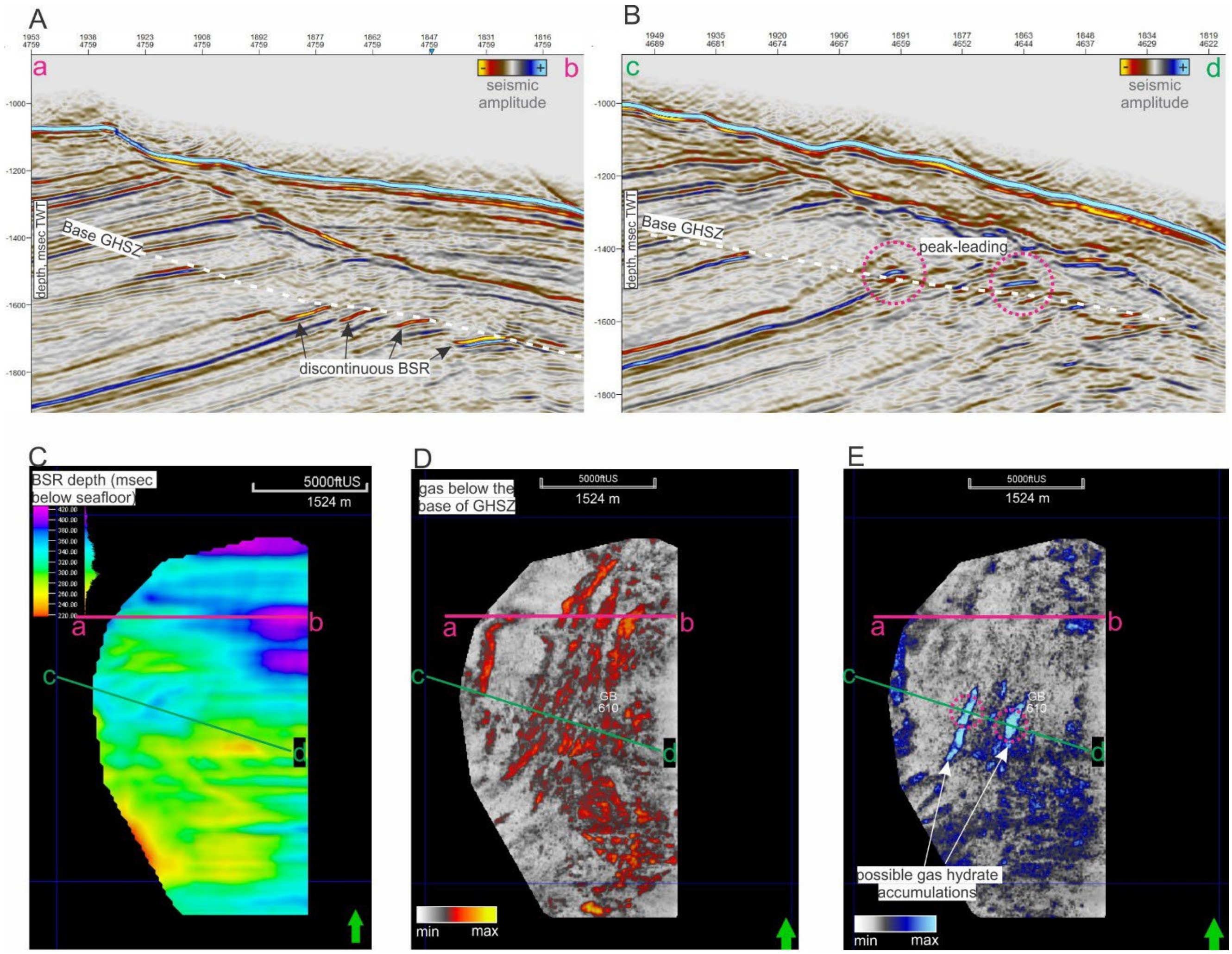

Figure 10. Zone 3 seismic sections and map renderings. A) Seismic cross-section showing discontinuous BSR at the base of GHSZ in Zone 3. B) Seismic-cross section showing strong peak-leading reflections above the base of GHSZ. C) Depth below seafloor to BSRs (msec, TWT) with line orientations labeled. BSRs occur at ~190-360 mbsf at this location. D) Gas below the base of GHSZ. E) Average positive amplitudes above mapped BSRs. Peak-leading reflections circled with dotted pink circles are denoted on B and E.

4.3 Zone 4

Zone 4 is in the southwestern portion of the study area where water depths range from ~850 to 1000 meters (Figures 11A). High RMS amplitude values in this area occur within a minibasin on the drapes of a salt diapir, with BSRs occurring 150-425 msec TWT (~130 to 360 meters) below seafloor (Figures 11B, 11C). Within the northern portion of the minibasin, continuous BSRs exist on the flanks of a mud volcano, with strong positive amplitudes above the BSR occurring near this fluid flow feature. (Figure 11D, 12A). The BSR becomes discontinuous in the southern portion of this system (Figure 12B). The geothermal gradient in this zone is ~35°C/km based on standard methane hydrate phase boundary and the depth of the BSR.

Within Zone 4, a phase reversal is present in the southern portion of this BSR system (Figure 13A). Two separate horizons were mapped to illustrate this phase reversal, with Horizon 1 in the southern area of interest (Figures 13B, 13C) and Horizon 2 in the northern area of interest (Figures 13D, 13E). The phase reversal can be identified in inline orientation with a polarity shift (positive above the BSR to negative below the BSR) along horizons with a discontinuous BSR (Figure 13F).

The most proximal well to this system, well API #608074023200, was drilled approximately 2.5 kilometers from the mapped BSR system. While this well is outside of the prospect, the gamma ray drops to approximately 40 API units at the base of gas hydrate stability (Figure 14). This indicates that there could be coarse-grained sediments in the areas with mapped BSRs. As expected, there was no resistivity spike in this well at the base of gas hydrate stability due to lack of BSRs in the area of the drilled well.

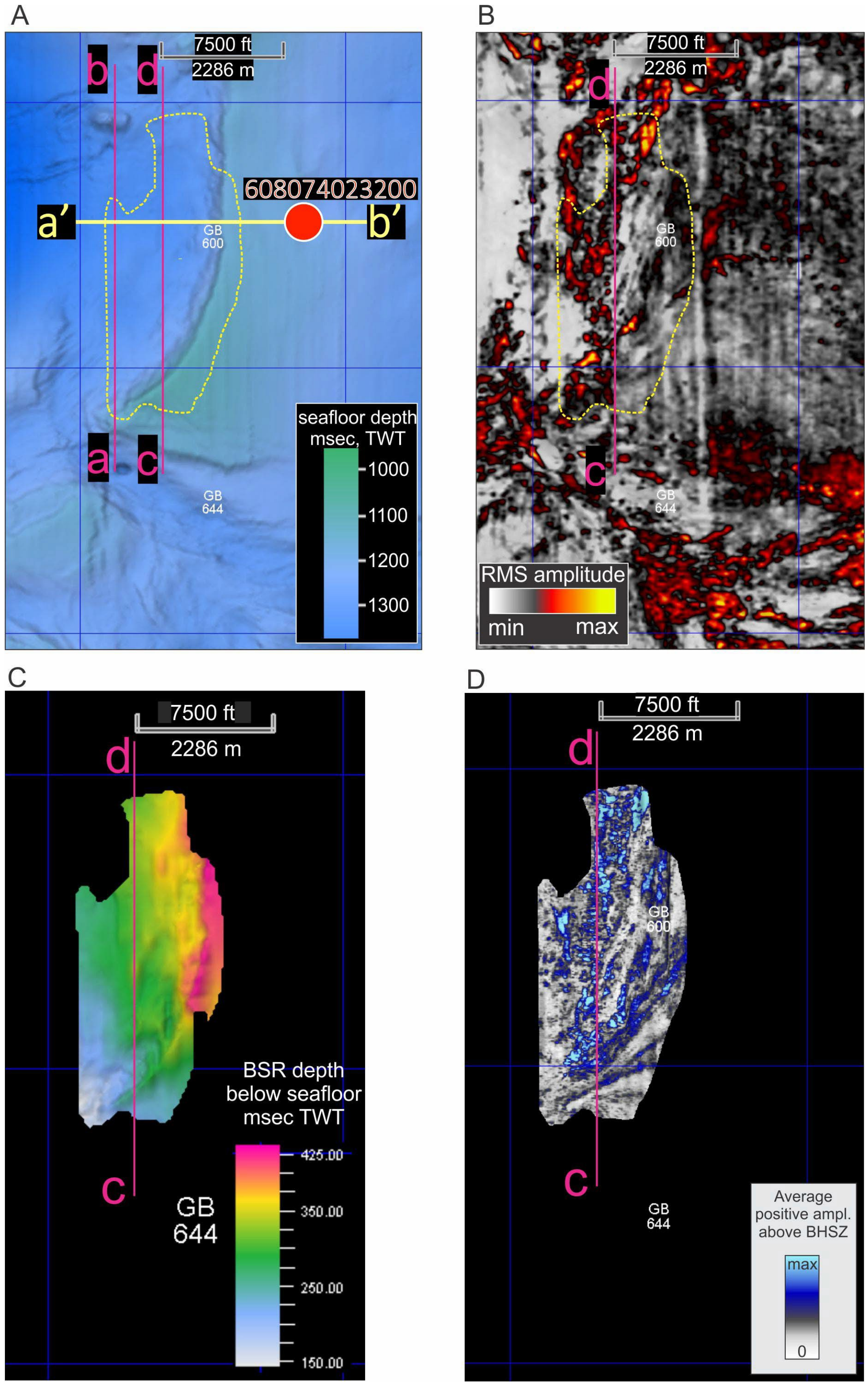

Figure 11. Map renderings from Zone 4 of the study area. A) Depth to the seafloor in Zone 4 with line orientations labeled; yellow dashed outline represents the extent of the mapped BSR. B) RMS amplitude map in Zone 4. C) Depth below seafloor (in time, msec) to mapped BSRs in Zone 4. BSRs at this location occur at ~130-360 mbsf. D) Average positive amplitude above mapped BSRs.

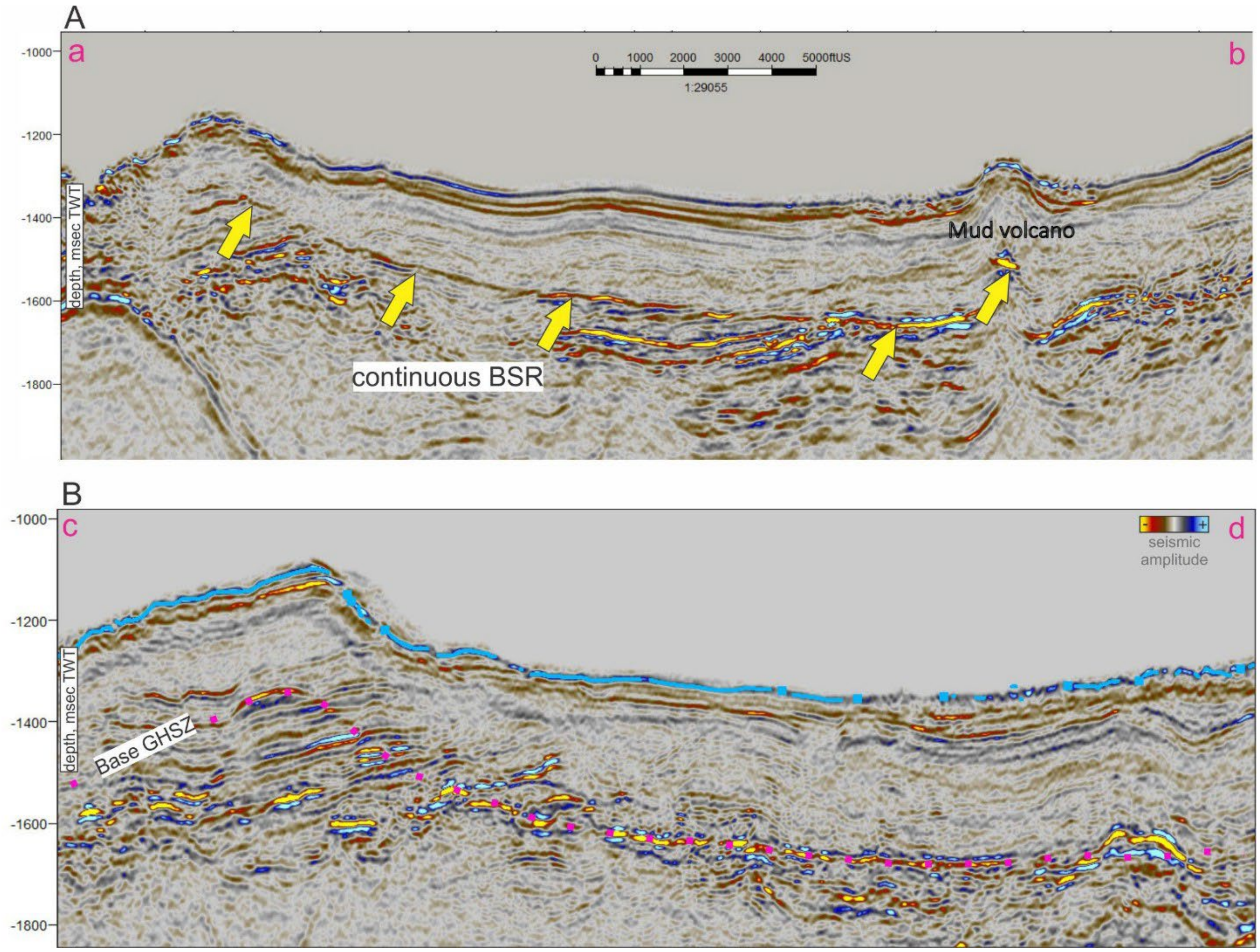

Figure 12. Seismic sections from Zone 4 of the study area. A) Seismic inline a-b showing continuous BSRs in a bowl-shaped minibasin with a mud volcano. B) Seismic inline c-d showing continuous BSRs further to the east.

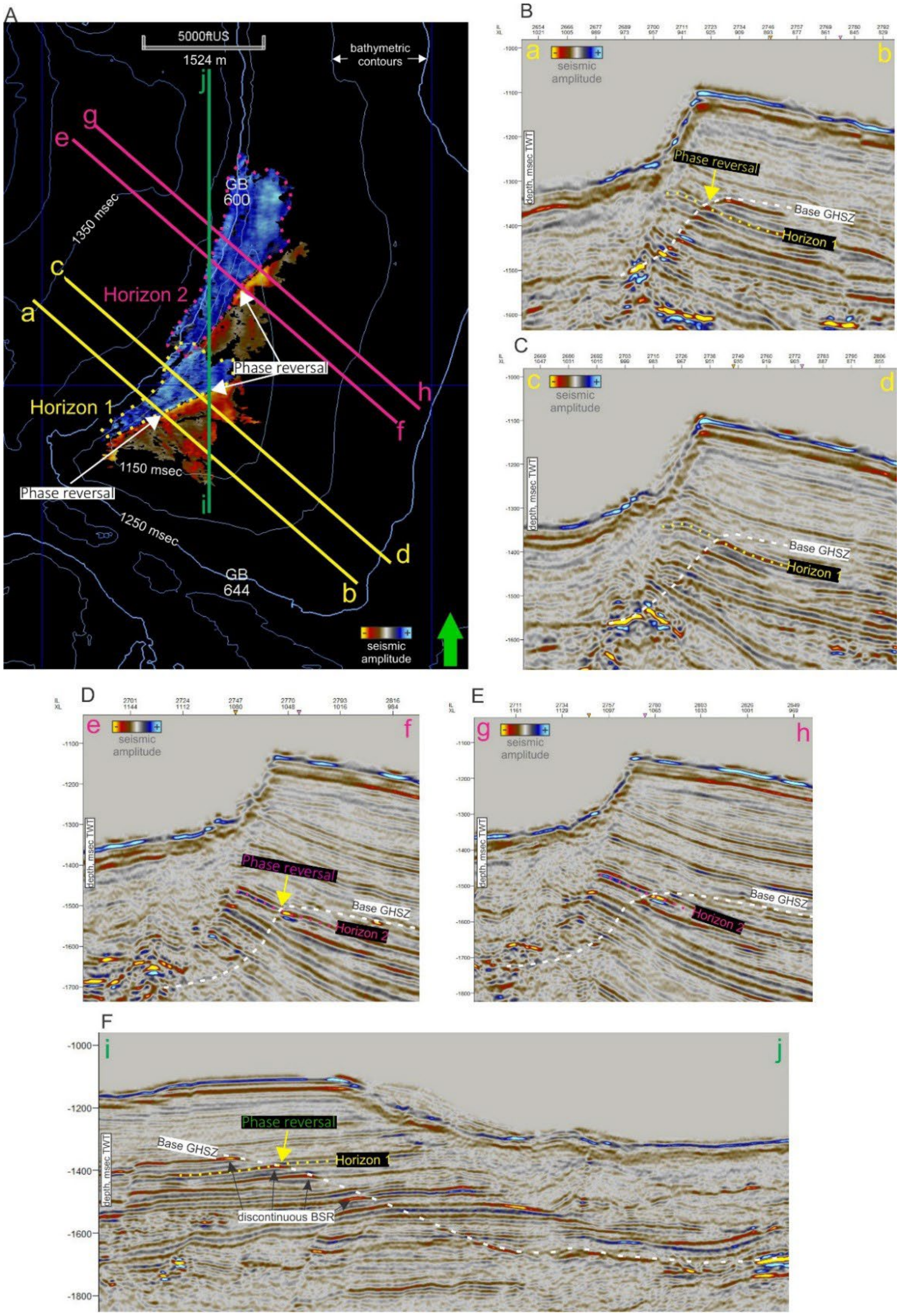

Figure 13. Basemap and seismic sections highlighting Zone 4 phase reversal. A) 2D basemap showing location of phase reversal in Zone 4. Locations of seismic cross-sections are denoted in A. B) Seismic cross-section a-b showing phase reversal in Horizon 1. C) Seismic cross-section c-d showing phase reversal in Horizon 1. D) Seismic cross-section e-f showing phase reversal in Horizon 2. E) Seismic cross-section g-h showing phase reversal in Horizon 2. F) Seismic cross-section i-j (inline) showing phase reversal in Horizon 1.

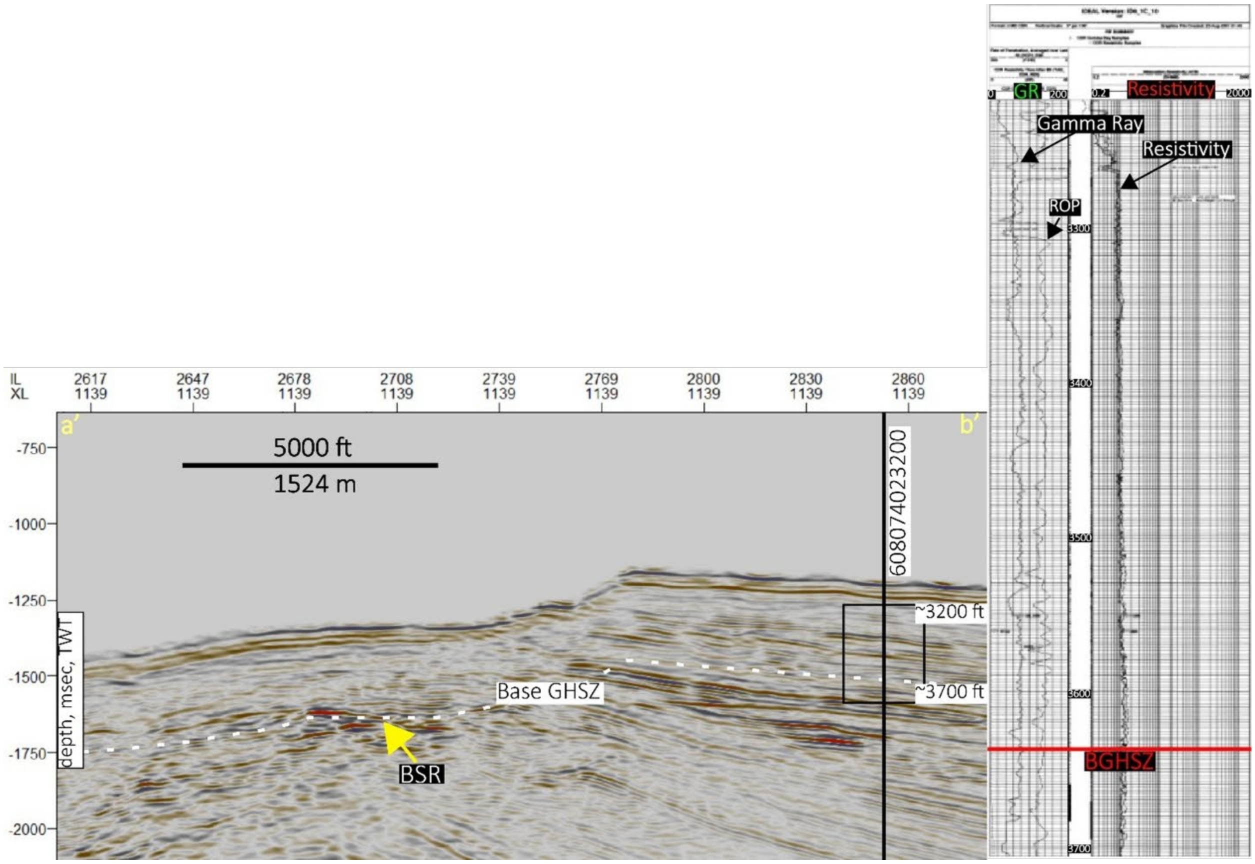

Figure 14. Gamma ray and resistivity measurements in well 608074023200 and approximate depth of selected log interval 3200-3600 ft MD in seismic cross section a'-b' (location in Figure 11A).

4.4 Zone 5

Zone 5 represents a small BSR system that spans an area of approximately 2 km^2. Although the area of this system is small in comparison to others in Project Area 5, there are strong RMS amplitudes at the base of gas hydrate stability indicating presence of free gas (Figure 15A). A paleo channel exists in close proximity to the identified BSR system at the base of gas hydrate stability, suggesting coarse-grained sediments could be present in the zone of interest (Figure 15A). A deep-rooted fault with ~30 msec offset dips north and crosscuts the BSR in this area (Figure 15B). This area of survey B-28-94-LA is in ~1000 meters water depth, with BSR depth ranging from 540-620 msec TWT (~460-530 meters) below seafloor (Figure 15C). The BSRs in this region are overlain by strong positive amplitudes which could indicate hydrate presence (Figure 15D). With a lack of well data in this area, hydrate presence cannot be confirmed.

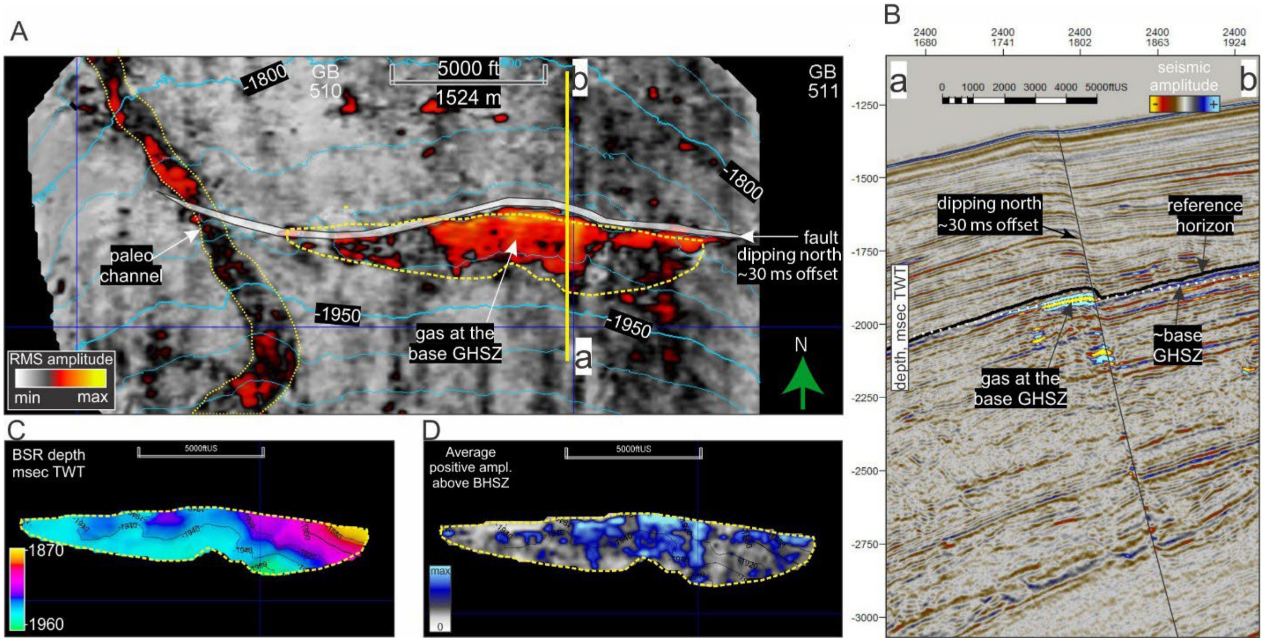

Figure 15. Basemaps and seismic section for Zone 5. A) An RMS amplitude map for Zone 5, with fault and paleo-channel denoted. Yellow dashed line indicates extent of interpreted BSR. Blue lines indicate OCS block boundaries. Light blue lines represent time-depth contours of the reference horizon indicated in Figure 15B. The orientation of seismic line a-b is also denoted. B) Seismic cross-section a-b (location is in Figure 15A) showing gas at the base of GHSZ. C) Depth below seafloor to BSR (msec, TWT) in Zone 5. The BSRs occur a ~460-530 mbsf. D) Average positive amplitude above base of GHSZ in Zone 5.

4.5 GB 387 and GB 388 previously described in Milkov and Sassen

Previous research from Milkov and Sassen (2003) confirmed the presence of gas hydrate in Garden Banks Blocks 387 and 388 (Figure 16A) via core analysis across multiple wells. The hydrate system in this location is characterized by strong positive amplitudes in the near seafloor and the seafloor. Extensive salt-induced faulting likely served as a migration pathway for free gas, indicated by acoustic attenuation in seismic, to travel to the shallow sediment near the seafloor and form gas hydrate (Figures 16B, 16C). It was assumed that gas hydrate exists over an area of ~3.2 km^2, centered around a network of faults that facilitate fluid migration into the GHSZ. Water depth in this area varies from 650 to 750 meters. A well (API #608074014500) which was drilled within this prospect was ordered for analysis, but the top log interval begins well below the area of interest. Estimates of gas hydrate volume in this area range from 3.1 to 23.7 BCM (Milkov and Sassen, 2003). These estimates were obtained by assuming a minimum gas hydrate saturation of 5 vol.% and a maximum hydrate saturation of 10 vol.% based on the core that was recovered. There is a wide range in the gas resource estimate due to the uncertainty of gas composition in this region.

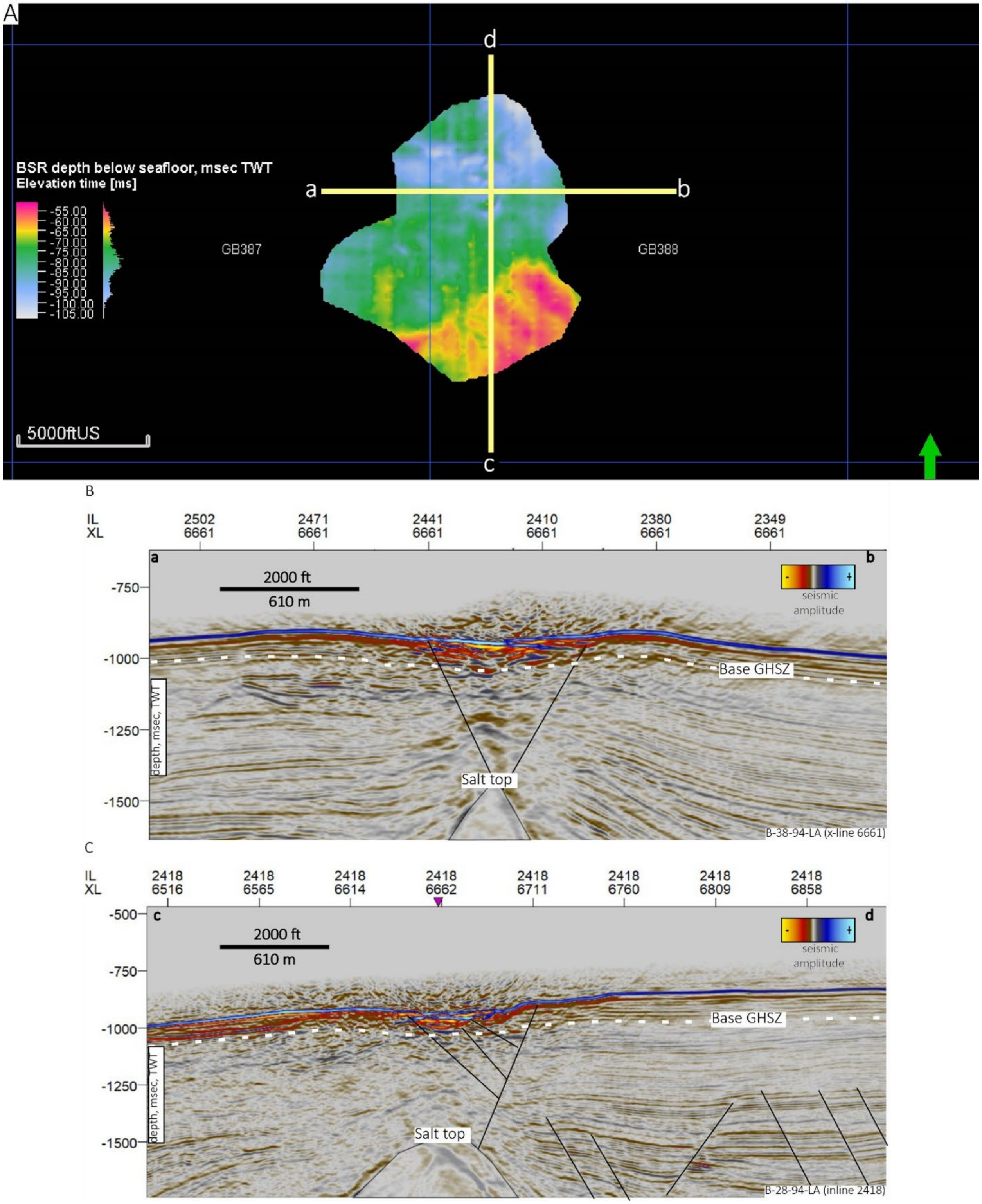

Figure 16. A) BSR depth below seafloor map for GB 387 and 388, with line orientations labeled. B) Seismic cross section showing location of a shallow hydrate system (crossline 6661). C) Seismic cross section showing location of the shallow hydrate system (inline 2418).

5. Gas resource estimates in Area 5

In Project Area 5, high saturations of 50 to 90% should be confined to peak-leading amplitudes, which cover a total of ~13.2 km^2. We used the same minimum and maximum porosity values (30% and 40% respectively) as in the Project Areas 1-4. We applied minimum and maximum thicknesses of hydrate-bearing units of 10 and 50 m. Similar to Project Areas 1-4, we used minimum and maximum gas hydrate saturations within these units of 50 and 90%. The high amplitude peak-leading areas in Project Area 5 may contain between 3.25 and 39 BCM of gas at STP.

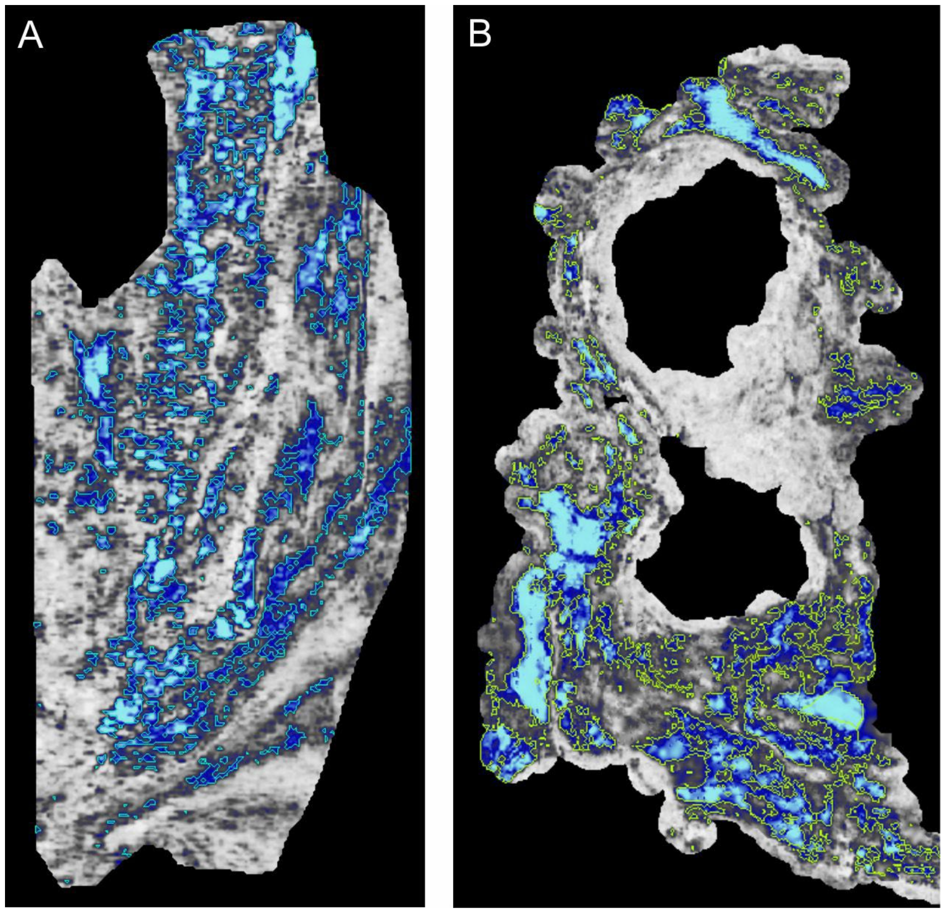

Figure 17. Examples of semi-automatic contouring of high-amplitude peak-leading reflections above the base of GHSZ (blue) from Zones 4 (A) and 2 (B) used for resource calculations.

6. Conclusions

Potential gas hydrate occurrences in Project Area 5 are associated with widespread salt tectonics and active fluid flow. In the southeastern part of the study area, where Zones 1, 2, and 3 are located, salt bodies create an anticlinal framework that traps gas at the base of GHSZ. Buried channels identified in this region give high confidence that sands are present near the base of GHSZ. In Zone 2, we see evidence of vertical fluid flow to the seafloor. The areas near these gas chimneys could supply gas to overlying hydrate systems. This makes Zone 2 a high-confidence area for containing gas hydrate. In Zone 4, a phase reversal was observed with strong trough-leading reflections below the BGHS and strong peak-leading reflections above. There is evidence of vertical fluid flow in Zone 4 with BSRs occurring adjacent to a mud volcano. Zone 4 represents a second high-confidence area for potentially holding gas hydrate.

The total gas resources estimated in this area (3.25 to 39 BCM of gas at STP) are higher than Project Areas 1, 3 and 4, but lower than Project Area 2. A lack of well data in Garden Banks prevented further in-depth analysis for the BSR systems identified. As more well data becomes available, a second look at this study area could be warranted.

7. References

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