A COMPARISON OF HIGH AND LOW RESOLUTION TWO-DIMENSIONAL SEISMIC DATA AT INTEGRATED OCEAN DRILLING PROGRAM EXPEDITION 308 SITE U1320, BRAZOS-TRINITY BASIN IV, NORTHWESTERN GULF OF MEXICO

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By

Mohamad Irfan Fuad

The Ohio State University

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Approved by

Dr. Derek E. Sawyer, Advisor

School of Earth Sciences

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ABSTRACT

This thesis links well data to seismic data in Brazos-Trinity Basin IV, Northwestern Gulf of Mexico, well log data from International Ocean Discovery Program (IODP) Expedition 308 in 2005 and publicly available seismic reflection data acquired in the year 1988. Currently, Expedition 308 well logs and cores have only been tied to a proprietary 2D seismic dataset owned by Shell Oil that is higher resolution (with peak frequency at ~300Hz yielding a vertical resolution of ~1m) than publicly available 2D data. Therefore, it is useful to know how the seismic units that have been defined in the higher resolution proprietary data link to the lower resolution but publicly available seismic data to aid in future research projects.

The study was conducted by performing a well-tie analysis using well log data (gamma ray, bulk density, resistivity, and compressional-wave velocity) and checkshot survey data. Six reflectors were identified from the well tie and all six reflectors were successfully identified and mapped in the 2D data.

The results suggest that the 2D publicly available data can be used effectively, especially for general results. Future work could include mapping the identified horizons to other 2D data in the basin and conducting detailed synthetic seismograms for a more rigorous analysis of the well tie correlation.

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Introduction

Brazos-Trinity Basin IV is a part of the Brazos-Trinity Fan, a large late Pleistocene sediment gravity flow system in the northwestern Gulf of Mexico (Flemings *et al.*, 2006). It is 250 km south-southeast of Houston, Texas, in water depths of approximately 1450 meters. Early work in the basin by Badalini *et al.* (2000) provided the original seismic interpretation and depositional model. This work was extended and further refined by Beaubouef and Abreu (2006) using a high-resolution, 3D seismic survey. Prather *et al.*, (2012) added proprietary high-resolution 2D data and tied the data to well data.

In 2005, Integrated Ocean Drilling Program (IODP) Expedition 308 drilled three sites in Brazos-Trinity Basin IV (Flemings *et al.*, 2006). The program was dedicated to study overpressure and fluid flow on the Gulf of Mexico continental slope. The well data and cores have been used by researchers to refine the stratigraphic history of the basin and to test fill-to-spill models for mini basins in the Gulf of Mexico (Beaubouef and Abreu 2010; Mallarino *et al.*, 2006; Schneider *et al.*, 2009; Prather *et al.*, 2012). However, Expedition 308 and the follow-on studies have utilized well ties that were based on proprietary seismic data. Despite the proprietary high-resolution 2D data being unavailable, there are lower resolution 2D seismic data that are publicly available.

The objective of this study was to provide a first attempt to understand how similar or different the 2D seismic-well correlations are with low-resolution, 2D seismic survey by mapping the same features that were mapped on high-resolution. I examined the site with the thickest penetration (Site U1320, to 299.6 mbsf), which is located very near to 2 crossing seismic lines. Ultimately, the goal is to assess the suitability of the low-resolution data for scientific studies.

Geologic Setting

The Brazos-Trinity system (**Figure 1**) is a set of latest Pleistocene salt-withdrawal basins that consist of onlap-fill successions in three mini basins (Basin I, II, IV) and a graben (Basin III) bounded by sub-vertical faults (Badalini *et al.*, 2000). The up-dip basins (I, II, III) are filled whereas the most down-dip basin (IV) is still under-filled (Badalini *et al.*, 2000). Sediment is sourced from the ancestral Brazos and Trinity rivers and associated shelf edge deltas, which form a late Pleistocene lowstand systems tract (Beauboeuf and Abreu, 2006).

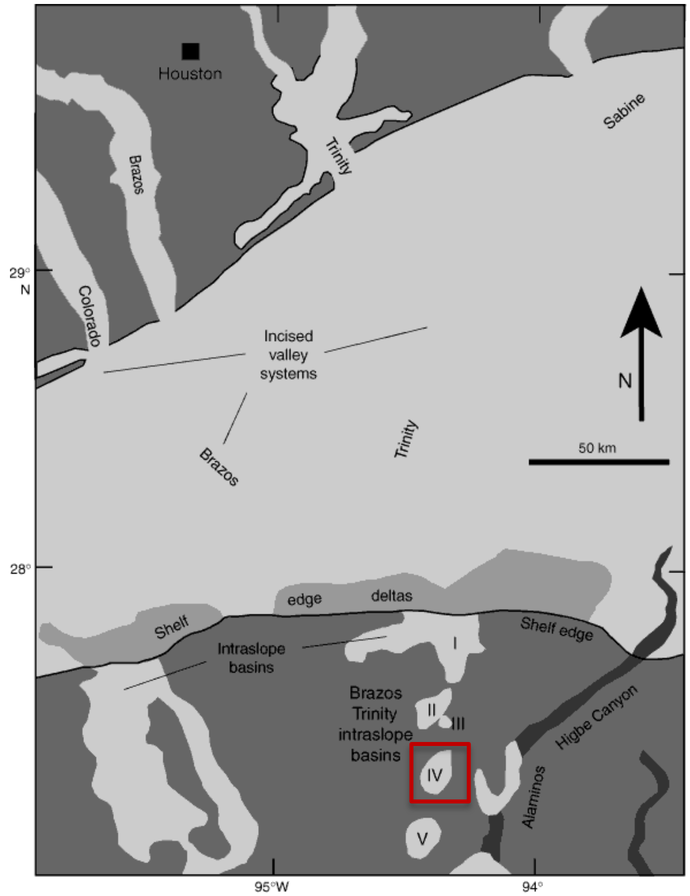

Figure 1: Simplified physiography and latest Pleistocene paleogeographic features offshore Texas showing the location of the Brazos-Trinity System. Study area is marked with red square. Modified from Flemings *et al.* (2006).

Publicly available 2D seismic profiles in Brazos-Trinity Basin IV are archived in the USGS National Archive of Marine Seismic Surveys (NAMSS) database (**Table 1**). The lines proximal to the primary site of interest (Site U1320) are north-to-south (Line 4508-32 from survey B-12-88-GM) and west-to-east (Line 3685-32 from survey B-13-88-GM) (**Figure 2**) (**Table 1**). The high-resolution 2D seismic survey that was used by IODP is oriented diagonally from Northeast to Southwest **(Figures 2 and 3**).

Table 1: Information of the seismic survey

Line	Survey	Year	Distance from Site U1320 (km)	Web link
4508-32	B-12-88-GM	1988	0.76	https://walrus.wr.usgs.gov/namss/survey/b-12-88-gm/
3685-32	B-13-88-GM	1988	1.84	https://walrus.wr.usgs.gov/namss/survey/b-13-88-gm/

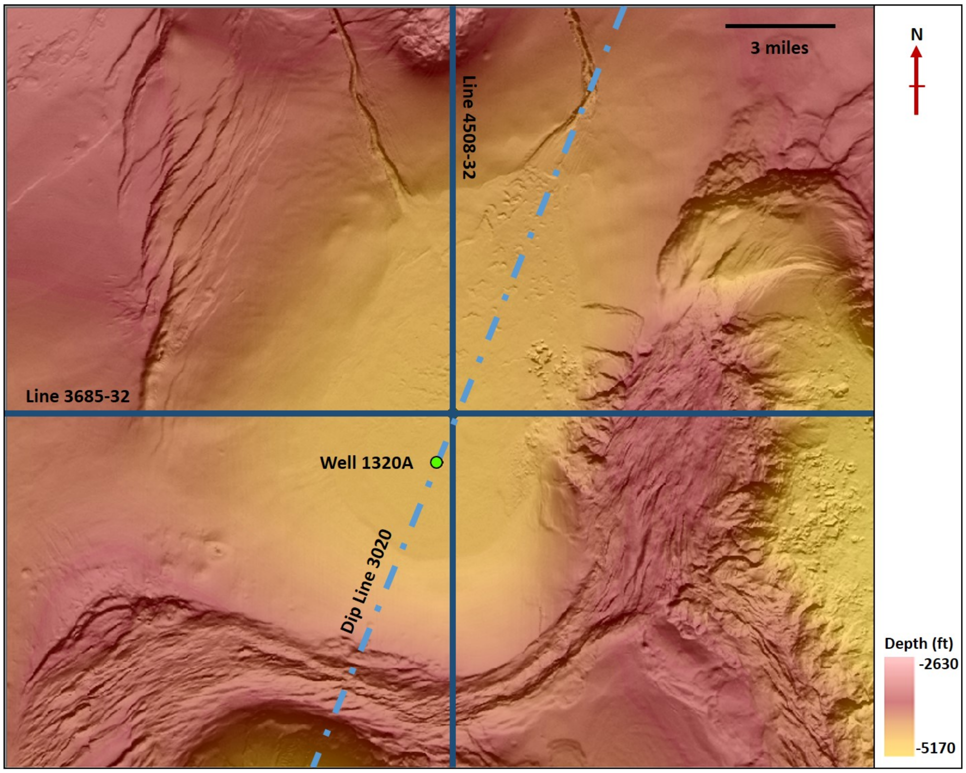

Figure 2: Bathymetric map of Basin IV showing the seismic line that were used for this study. Bathymetry data from Kramer and Shedd, 2017. Solid blue lines are publicly available Line 4508-32 and Line 3685-32. Light blue dashed-line is the approximate location and orientation of the 2D seismic data that is not available to the public (Dip Line 3020) (Figure 3) (Flemings *et al*., 2006).

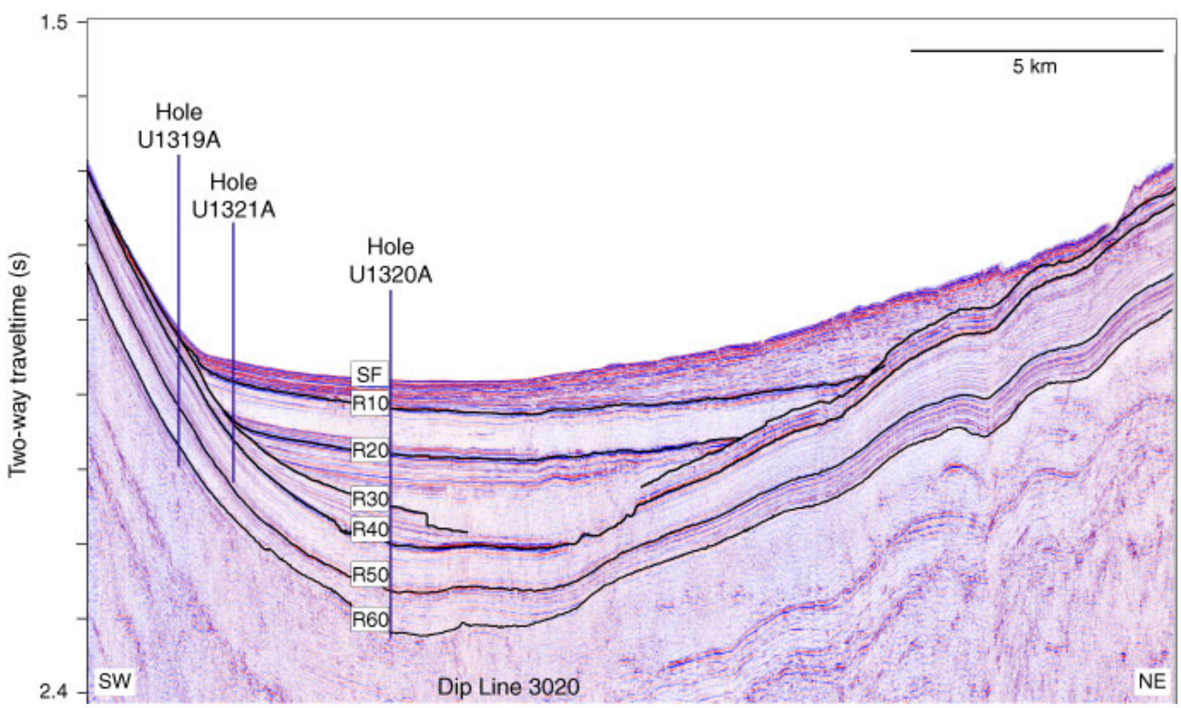

Figure 3: Interpretation of seismic dip line 3020 from high-resolution proprietary 2D seismic showing the location of Sites U1319, U1320, and U1321 including the seismic reflectors (R10 – R60). SF = Seafloor. Modified from Flemings *et al*. (2006).

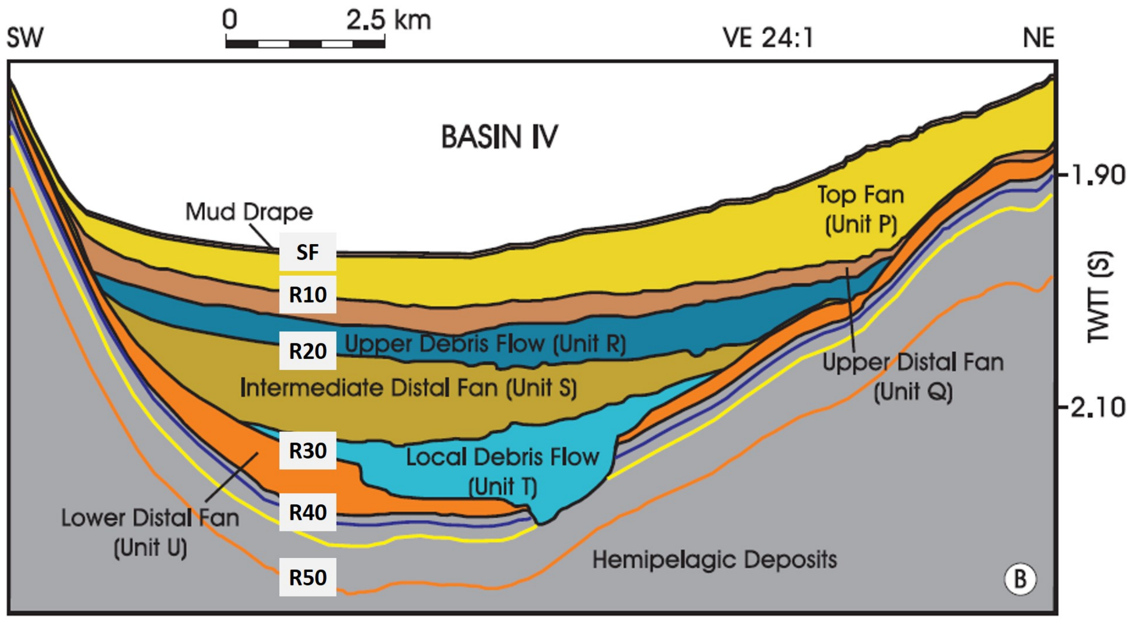

Figure 4: Interpretation of 2D seismic survey by Badalini *et al.* (2000) with reflectors that were identified from IODP. SF = Seafloor. Obtained and modified from Badalini *et al.* (2000).

Stratigraphy

Based on the seismic line of Brazos-Trinity Basin IV, six units (**Figure 4**) are identified and mapped by Badalini *et al.* (2000). The shallowest unit is a top fan (Unit P), which is a sand-rich unit located between SF and R10. Below Unit P is an upper distal fan between R10 and R20 (Unit Q), upper debris flow (Unit R), and intermediate distal fan (Unit S). The local debris flow (Unit T) is located between R20 and R30. In between R30 and R40 is a lower distal fan (Unit U), which is made of a thin muddy turbidite alternating with dominant hemipelagic deposit. Lastly, from R40 to R60 is a hemipelagic deposit, which represents the base of Brazos-Trinity Basin IV infill. This unit is the deepest.

METHODS

The two seismic lines nearest to Site U1320 were downloaded from the U.S Geological Survey (**Table 1**). The seismic surveys are 2D Multichannel Seismic (MCS) data acquired commercially for geophysical and geological exploration of oil and gas prospects on the U.S. Outer Continental Shelf (OCS) collected by the Bureau of Ocean Energy Management (BOEM). The survey was collected using an airgun and a hydrophone streamer. Line 4508-32 from a 1988 survey, B-12-88-GM, is a north-south line publicly accessible at this site (https://walrus.wr.usgs.gov/namss/survey/b-12-88-gm/). Line 3685-32 from a different 1988 survey, B-13-88-GM, is an east-west line publicly available here (https://walrus.wr.usgs.gov/namss/survey/b-13-88-gm/).

The gamma ray, bulk density, resistivity, and compressional-wave velocity log data from Site U1320 were obtained from IODP (http://brg.ldeo.columbia.edu/logplot/php/). A checkshot survey, a measured travel time of seismic wave from source to the receiver within a well bore, is used for depth-to-time conversion. It was collected using an airgun and geophone that were lowered down into the well bore. All of these data were imported into IHS Kingdom Suite to tie the well data to seismic and interpret the seismic line.

Well-tie

Since the log data are in SI units but the seismic data are in Imperial units, the log data were converted into feet. Accurate site location and information of the well were loaded into the Kingdom Suite Project to ensure proper positioning. Then, using true vertical thickness (TVD) and corrected two-way traveltime (TWT) from the checkshot data collected from Site U1320, a depth-time chart was made to tie the well data into a correct time in the seismic data. To set the starting depth properly, the TVD 0 m is set to TWT of the seafloor. Since the well is not exactly on the seismic lines 4508-32 and 3685-32, which are about 0.76 km and 1.84 km respectively from the well site, the well needs to be projected in order for it to be seen on the seismic line. Log data (gamma ray, bulk density, resistivity, and compressional-wave velocity) are then loaded into the software. Using the log data, the reflectors (R10-R60) were identified if possible.

Data Interpretation

Seismic data are displayed using a greyscale with black representing a positive impedance contrast and white representing a negative impedance contrast (**Figure 5**). Based on the impedance contrast, a horizon was created by following the line formed by the seismic profile. The seafloor, which is the uppermost horizon with a strong positive impedance, was mapped. Then, the reflectors (R10 – R60) were mapped with the same method by using the produced well-tie and information provided by IODP as guidance. An annotated figure was created in PowerPoint to add scale bars and other annotations that were not easily made in IHS Kingdom Software.

Results

Figure 5 (a) is seismic line 4508-32 of Basin IV from north to south, while Figure 5 (b) is the image of Basin IV from west to east line 3685-32. Figure 6 is a side-by-side comparison of the 2D lines from this study and the Expedition 308 well tie from Flemings *et al*. (2006). The basin is divided into six reflectors (R10 - R60) consistent with seismic reflectors that are identified from Exp. 308 (**Figure 6**).

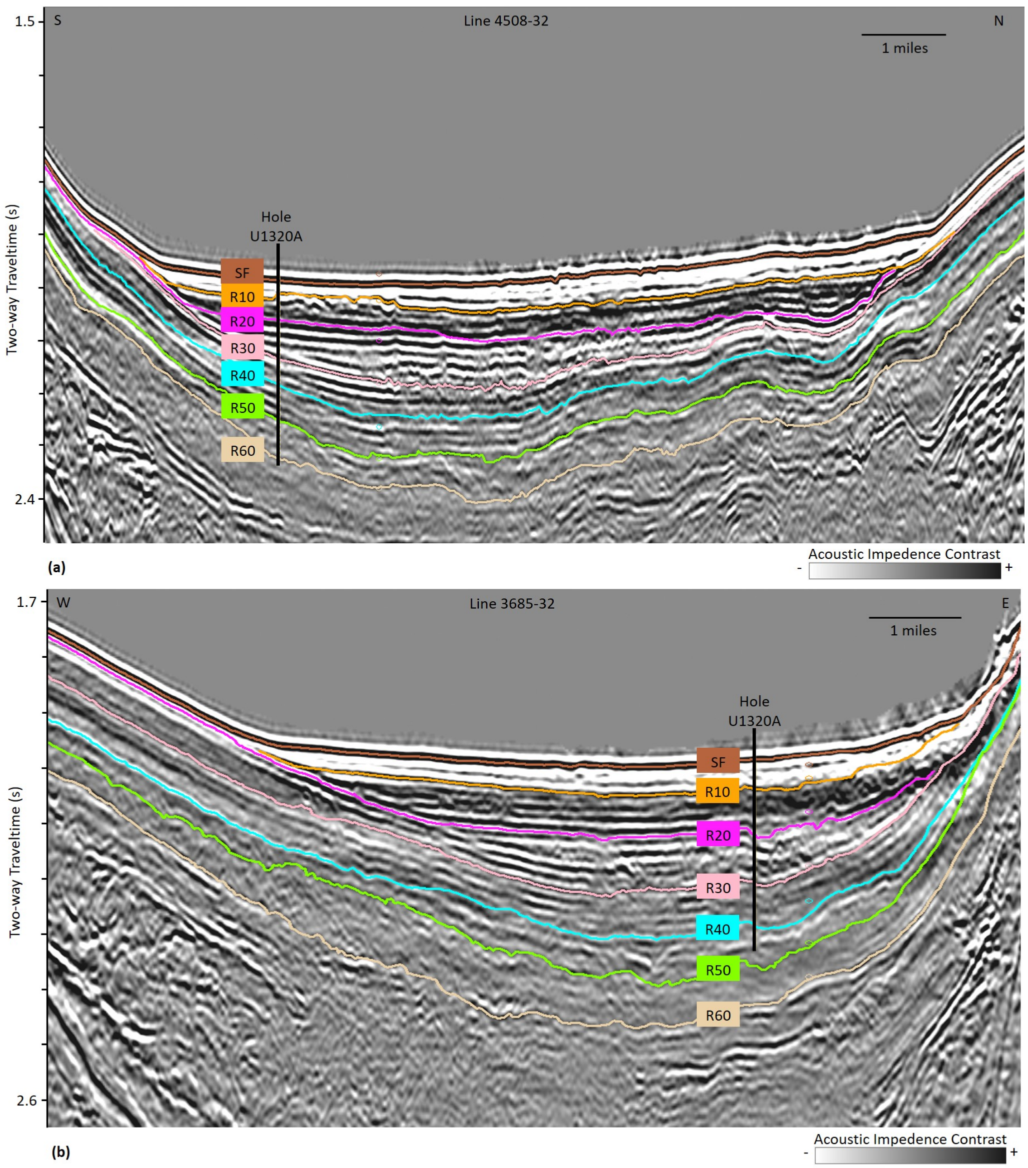

Figure 5: (a) Seismic line 4508-32 from South to North, and (b) Seismic line 3685-32 from East to West of the Basin IV. Seafloor is the uppermost part of the seismic line (brown) and are followed by R10 (Orange), R20 (Purple), R30 (Pink), R40 (Cyan), R50 (Green), and R60 (Tan). Hole U1320A location is projected into the seismic profile. SF = Seafloor.

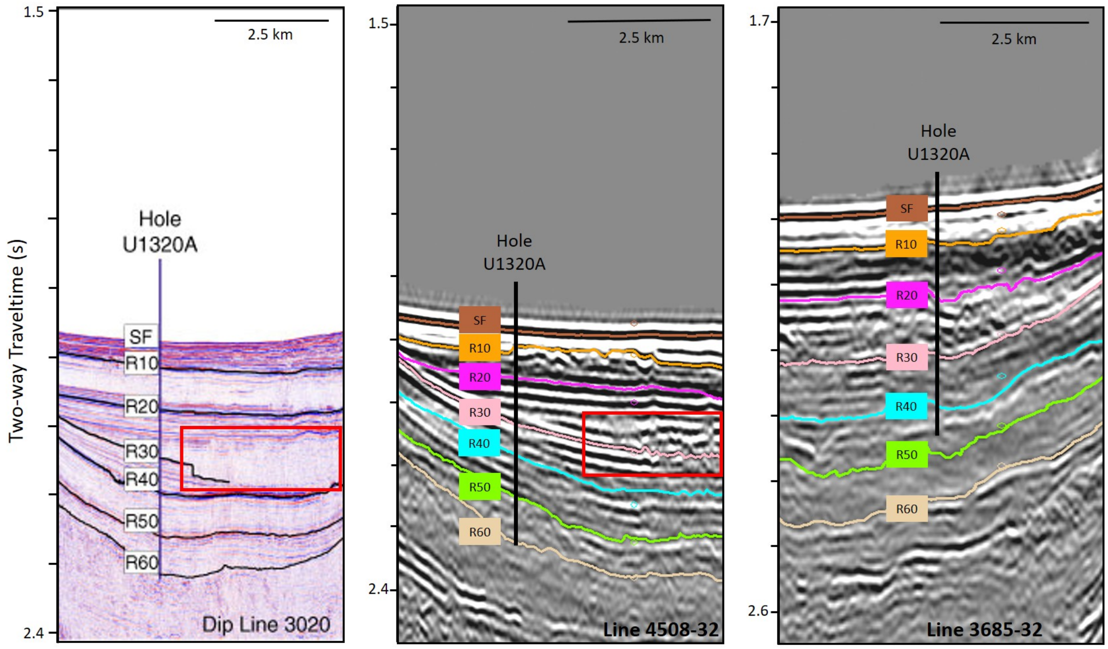

Figure 6: Side-by-side comparison of seismic dip line 3020, line 4508-32, and line 3685-32. SF = Seafloor. Each of the 7 reflectors can be identified in the publicly available 2D lines. The resolution is clearly better in the higher resolution proprietary 2D data, which allows for more detailed intra-unit interpretation and mapping. Red square is showing the location of mass transport deposit (MTD). Modified from Flemings *et al*. (2006).

The well log data (**Figure 7**) obtained from Site U1320 provide important information about the lithology. The gamma ray and bulk density are used to identify the lithologies, where high gamma ray indicates marine mud, and low gamma ray indicates sand. This information is used to assist in mapping the reflectors on the seismic line.

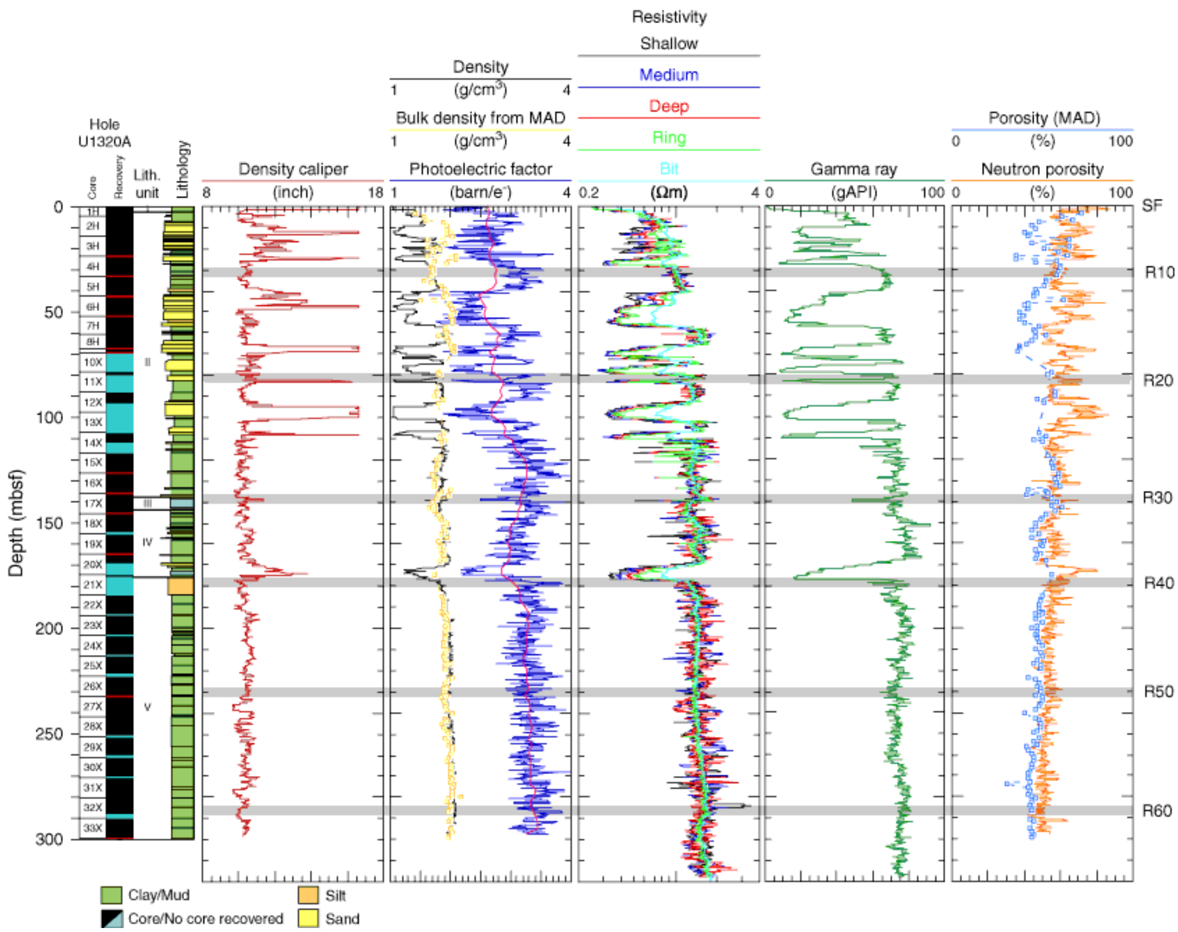

Figure 7: LWD density caliper, photoelectric factor (PEF), neutron porosity, resistivity and gamma ray logs recorded in Hole U1320B. SF = seafloor (Flemings *et al.*, 2006).

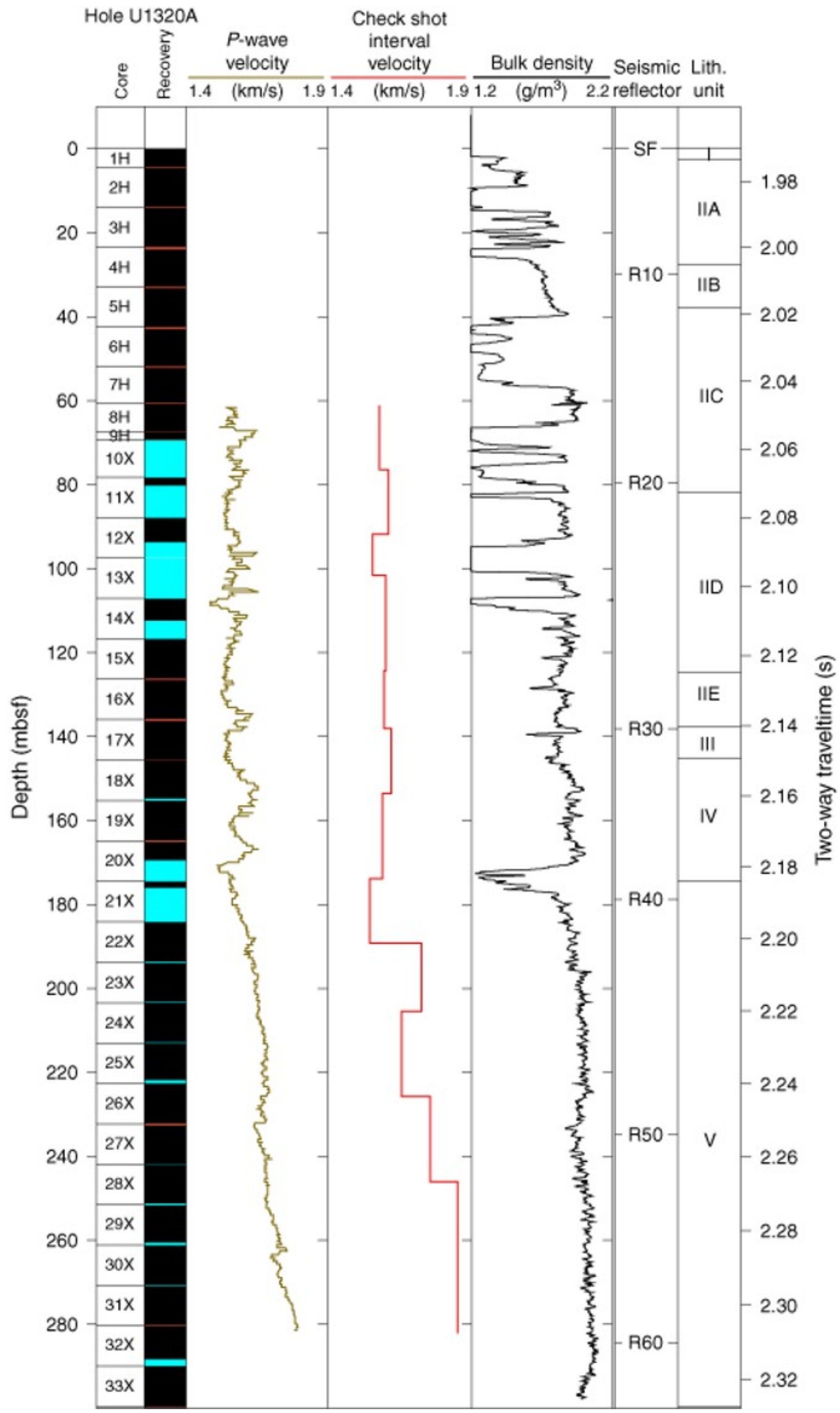

Figure 8: Compressional-wave velocity, and checkshot interval velocity from Hole U1320A, and bulk density logs from Hole U1320A. SF = seafloor (Flemings *et al.*, 2006).

DISCUSSION

A comparison of the seismic well-tie created on the line 4508-32 (**Figure 5a**) with the one created by IODP on Dip Line 3020 (**Figure 3)** shows that the same reflector can be identified (**Figure 6**). However, the reflectors' locations of line 3685-32 (**Figure 5b**) and Line 3020 are different (**Figure 6**). In this case, the locations of the reflectors of line 3685-32 are located deeper than the well. This is deduced by locating the reflectors mapped on the intersection of line 4508-32 and line 3685-32. Because the study area is a basin and the line is approximately one mile away from Well U1320, the result may be caused by the natural slope of the geological layers. The result may also derive from potential errors in the checkshot-derived time-depth relationship.

Vertical resolution

The publicly available seismic survey obtained from USGS (Line 4508-32 and Line 3686-32) has frequency content of 60 Hz maximum while the IODP seismic line (Dip Line 3020) has peak frequency of 300 Hz (Prather *et al.*, 2012), so the resolution is about 5 times higher in the proprietary data. As a result, a feature with a 2500 m/s velocity and a 60 Hz dominant frequency can only be resolved if it is 10.42 m thick, whereas if it has a 300 Hz dominant frequency, the feature can be resolved if it is as thin as 2.08 m (**Table 2)**. This limited resolution in the publicly available data will limit the ability to detect small features in the seismic data.

Table 2: Threshold of vertical resolution for 60 Hz and 300 Hz using formula $\lambda = v / f$ and $\lambda/4$.

Velocity (m/s)	Resolution (m)	
	60 Hz	300 Hz
1500	6.25	1.25
2000	8.33	1.67
2500	10.42	2.08
3000	12.50	2.50

Because of the frequency and resolution differences, the seismic image of line 4508-32 (**Figure 5a**) has thicker and fewer units compared to the dip line 3020 (**Figure 3**). Generally, a vertical resolution is a measure of how thick a unit must be in nature for both the top and base to be resolved in a seismic profile. This vertical resolution is typically assumed to be ¼ of the wavelength (Rafaelsen, 2006). Thus, the higher the frequency, the thinner the bed that can be resolved. By using a 60 Hz seismic survey, much detail will be missed, especially thinner beds. This will be a hindrance to detailed mapping studies.

There are several features that cannot be seen in seismic line 4508-32 but can be seen in the dip line 3020. This may be due to the frequency differences discussed above but also to the different orientation and positioning of the lines. The dip line 3020 went diagonally from Northeast to Southwest whereas line 4508 went from North to South (**Figure 2)**. Hence, differences in seismic features are to be expected. At reflector R30, there is a Mass Transport Deposit (MTD) mapped on dip line 3020 which is characterized by the transparent and chaotic facies (**Figure 6**), but this feature cannot be seen in line 4508-32. Distinctive reflections on a high-resolution section may be unnoticed on the low-resolution data because the beds are too thin for detection (Knapp and Anderson, 1995). Objectively, the features from both lines are almost identical where the lines in the area are chaotic. However, it was difficult to conclude that without the actual data of the dip line 3020.

It was easier to make a well-tie for the R10 to R20 reflector on the seismic data because of the strong reflection. Layered beds at shallower depths generally exhibit reflections with high frequency contents, which in this case, a high acoustic impedance contrast on the upper part of the seismic line can be seen (Nanda, 2016). However, it was more difficult to do a well tie down the line, especially the R60 reflector where the bed reflection cannot be seen clearly. This is explained by Nanda (2016) where older and harder rocks at deeper depths show relatively low frequency reflections. In other words, as the depth increases, the frequency will decrease while the velocity will increase, hence, causing the wavelength to also increase. Thus, the seismic resolution will decrease with increasing depth.

Table 3: The Depth and Two-way Traveltime of the Reflectors for Dip Line 3020, Line 4508-32, and Line 3685-32.

Reflector	Dip Line 3020		Line 4508-32		Line 3685-32	
	TWT (s)	Depth (mbsf)	TWT (s)	Depth (mbsf)	TWT (s)	Depth (mbsf)
SF	1.970	0.00	1.986	7.60	1.984	5.16
R10	2.008	29.90	2.011	29.54	2.037	53.32
R20	2.070	79.60	2.061	74.65	2.094	102.69
R30	2.141	138.20	2.135	135.61	2.206	193.82
R40	2.189	178.80	2.185	176.45	2.279	256.00
R50	2.254	229.60	2.252	232.53	2.357	307.27
R60	2.310	284.30	2.324	297.45	2.427	373.15

Time-Depth Correlation

Another aspect that needs to be looked into is the reflectors mapped in line 4508-32 did not match up at the same two-way time as the one in dip line 3020 (**Table 3**). The difference in two-way traveltime, which is averaged at around ±0.008s, is a cause for concern. This may be explained by attenuation. In general, frequency response decreases with depth due to attenuation which may result in mis-ties with a depth-to-time standard such as a velocity log, which will increase with decreasing frequency (Knapp and Anderson,1995). This mismatch in time will affect the actual depth of the bed when making an interpretation. For example, at R20, the depth at which the reflector is located in the 2D data (Dip Line 3020) is at 2.070 s which is about 79.60 mbsf whereas in 2D data (Line 4508-32), it is at 2.061 s which is about 74.65 mbsf (**Table 3**). The difference is about 4.95 m.

CONCLUSIONS

This study focuses on the correlation of 2D seismic data, which are publicly available, to a proprietary higher resolution 2D dataset over the Sites of IODP Expedition 308 in Brazos-Trinity Basin IV. By identifying the reflectors defined by IODP using high-resolution, 2D seismic, a benchmark of the capabilities of the low-resolution survey can be obtained. The conclusions of the study are as below:

- Overall, the main reflectors can be identified and mapped in the lower resolution 2D data.
- As expected, low frequency seismic data show a limit in vertical resolution as controlled by the different frequency content.
- The time for the mapped reflectors are slightly offset by less than ±5 m compared to the high-resolution survey.

Overall, the low-resolution 2D seismic survey proved to be capable of mapping the same reflectors as the high-resolution survey but will be limited in terms of resolving finer details within a given unit.

Recommendations for Future Work

This work represents a first step in the overall goal of assessing the suitability of the publicly available seismic data to correlate with Expedition 308 data and proprietary higher resolution data in Brazos-Trinity Basin IV. While this work shows initial promising results, some future work is recommended. One recommendation for future work is to conduct a synthetic seismogram using the bulk density, compessional-wave velocity, and a theoretical wavelet (e.g., Ricker) that matches the publicly available 2D data frequency of 60 Hz. This would allow for a more rigorous tie at the public data and then a better description of the comparison of the differences and similarities between the two surveys. Another study that could be done is doing a full interpretation of the basin using low-resolution, 2D seismic survey. This will allow for a more thorough study of the topic.

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Appendix

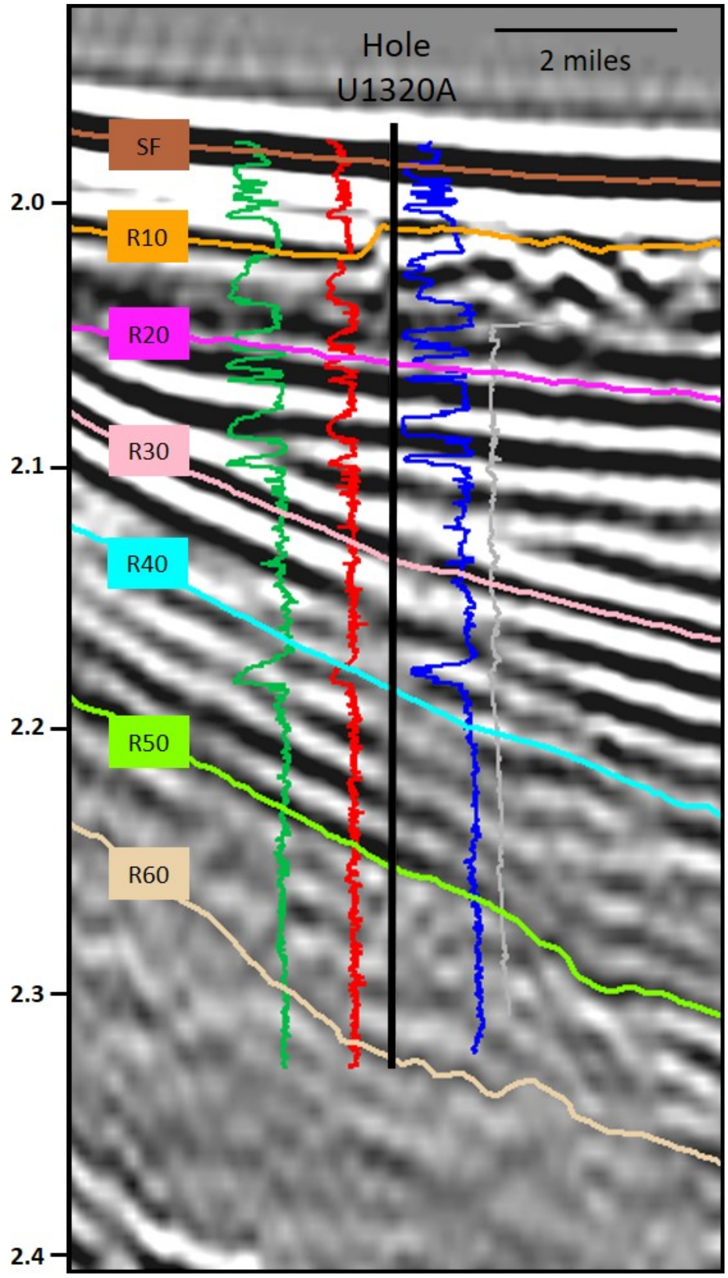

Figure 9: Seismic Line 4508-32 that was tied with well data. Gamma Ray (green), resistivity (red), bulk density (blue), and sonic log (gray). SF = Seafloor.