FINAL REPORT

Underwater Test Bed for Technology Demonstration – Processing and Interpretation of Shallow Water Stratigraphy Data

SERDP Project MR20-3058

JANUARY 2022

John Goff
Steffen Saustrup
University of Texas

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
12-01-2022

2. REPORT TYPE
SERDP Final Report

3. DATES COVERED *(From - To)*
12/15/2020 - 11/23/2022

4. TITLE AND SUBTITLE
Underwater test bed for technology demonstration: Processing and Interpretation of Shallow Water Stratigraphy Data

5a. CONTRACT NUMBER
21-C-0010

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
John A. Goff, Steffen Saustrup

5d. PROJECT NUMBER
MR20-3058

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
University of Texas Institute for Geophysics
10100 Burnet Rd., Bldg. 196
Austin, TX 78758

8. PERFORMING ORGANIZATION REPORT NUMBER
MR20-3058

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Strategic Environmental Research and Development Program
4800 Mark Center Drive, Suite 16F16
Alexandria, VA 22350-3605

10. SPONSOR/MONITOR'S ACRONYM(S)
SERDP

11. SPONSOR/MONITOR'S REPORT NUMBER(S) MR20-3058

12. DISTRIBUTION / AVAILABILITY STATEMENT
DISTRIBUTION STATEMENT A. Approved for public release: distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The primary objective of this project is to provide high-resolution stratigraphic characterization of an unexploded ordnance (UXO) test site in the surf zone offshore of Shell Island, Florida. The test site is being set up for research into technologies and applications for UXO removal, and requires a detailed environmental characterization of the sedimentary properties in the shallow subsurface. After a successful reconnaissance chirp survey, the data were processed and interpreted to provide a geologic framework for the UXO test site.

15. SUBJECT TERMS
Sandbar, ebb tide delta, sand ridge, chirp, Shell Island, Panama City, Florida

16. SECURITY CLASSIFICATION OF:

a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**	**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**
UNCLASS	UNCLASS	UNCLASS	UNCLASS	19

19a. NAME OF RESPONSIBLE PERSON
John Goff

19b. TELEPHONE NUMBER *(include area code)*
512-471-0476

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

Table of Contents

List of Tables

List of Figures

List of Acronyms

kHz: kiloHertz

ms: Milliseconds

NRL: Naval Research Lab

NSWC: Naval Submarine Warfare Center

MAFLA: Mississippi-Alabama-Florida

TWTT: Two-way travel time

US-ACE: United States Army Corps of Engineers

UTIG: University of Texas Institute for Geophysics

UTM: Universal Trans-Mercator

UXO: Unexploded Ordnance

Keywords

Sandbar, ebb tide delta, sand ridge, chirp, Shell Island, Panama City, Florida

Acknowledgements

The PI thanks Joe Calantoni and Dave Bradley for inviting him to participate in this project.

Final Report for Project MR20-3058:
Underwater Test Bed for Technology Demonstration – Processing and Interpretation of Shallow Water Stratigraphy Data

John A. Goff and Steffen Saustrup
University of Texas Institute for Geophysics

Abstract

***Introduction**:* This project was initiated at the request of Dr. Joseph Calantoni (NRL) and Dr. Raymond Lim (NSWC) in connection to their pilot study (MR20-5116) to assess the efficacy of operating a chirp subbottom system and vibracorer to stratigraphically characterize the underwater UXO test bed location off Shell Island, Florida. The water depths in the test bed (shoreline to 5 m) and surf zone conditions represent a significant challenge for towing a chirp instrument. In May, 2021, Dr. Calantoni ran a highly successful test survey operating a pole-mounted Edgetech 3400, 2-16 kHz chirp subbottom sonar from a shallow-water capable boat, collecting a reconnaissance grid survey as well as a more focused grid in the UXO test bed. UTIG's contribution to this effort is focused on processing and interpreting the chirp data, for the purpose of characterizing the sedimentary environment and shallow stratigraphy of the test bed.
Objective: Provide high-resolution stratigraphic characterization of an unexploded ordnance (UXO) test site in the surf zone offshore of Shell Island, Florida. The test site is being set up for research into technologies and applications for UXO removal, and requires a detailed environmental characterization of the sedimentary properties in the shallow subsurface. The shallow depths and surf-zone setting make this objective challenging.
Technical Approach: In collaboration with members of NRL and NSWC, this pilot project aimed to test the efficacy of utilizing chirp subbottom acoustic reflection data. To overcome challenges associated with shallow water depths, the project will manufacture and test a floating mount that keeps the towfish submerged near the sea surface, allowing operation in shallow water. The component of the project conducted here focused on processing and interpreting the chirp data to assess the usefulness of the data collected.
Results: The chirp data were successfully processed and interpreted by UTIG personnel. The UXO test bed location off Shell Island, Florida consists of three principal sedimentary units in the shallow subsurface. The substrate consists of the MAFLA marine sand sheet, which is organized into oblique-to-shore sand ridges, and which merges with the barrier island sands of Shell Island. Along the lower shoreface/inner shelf, this substrate is overlain by an ebb tide unit associated with sands exiting through Land's End Canal, the 1930's-era ship channel constructed by the US-ACE for access to Saint Andrews Bay. The ebb tide delta is prograding along shore to the SE, as evidenced by the internal dipping reflectors, and consistent with the measure sediment transport direction. Along the upper shoreface, the substrate is overlain by the

nearshore sandbar, organized into crescentic morphology of alternating highs and lows with a spacing of ~750 m alongshore. These sediments are assumed to be highly mobile above the basal reflector imaged in the chirp data.
Benefits: This project proved that a cost-effective, off-the-shelf technology (chirp) can be utilized in very shallow water environments.

Objective

The primary objective of this project was to provide high-resolution stratigraphic characterization of an unexploded ordnance (UXO) test site in the surf zone offshore of Shell Island, Florida. The test site is being set up for research into technologies and applications for UXO removal, and requires a detailed environmental characterization of the sedimentary properties in the shallow subsurface. The shallow depths and surf-zone setting make this objective challenging.

Background

This project was initiated at the request of Dr. Joseph Calantoni (NRL) and Dr. Raymond Lim (NSWC) in connection to their pilot study (MR20-5116) to assess the efficacy of operating a chirp subbottom system and vibracorer to stratigraphically characterize the underwater UXO test bed location off Shell Island, Florida (Figure 1). The water depths in the test bed (shoreline to 5 m) and surf zone conditions represent a significant challenge for towing a chirp instrument. In May, 2021, Dr. Calantoni ran a highly successful test survey operating a pole-mounted Edgetech 3400, 2-16 kHz chirp subbottom sonar from a shallow-water capable boat, collecting a reconnaissance grid survey as well as a more focused grid in the UXO test bed (Figure 2). UTIG's contribution to this effort is focused on processing and interpreting the chirp data, for the purpose of characterizing the sedimentary environment and shallow stratigraphy of the test bed. Researchers and technicians at the University of Texas Institute for Geophysics have extensive experience and expertise in processing and interpreting chirp data. This include many projects funded by the Office of Naval Research for the purpose of environmental characterization in support of acoustic experiments and mine burial studies.

Shell Island is the primary sand barrier separating Saint Andrews Bay from the Gulf of Mexico (Figure 1). The geographic history of the island is evident in historic maps going back to the late 1700s (Stapor, 1973). For most of this time, Shell Island was a barrier peninsula edging the northwest bank of the natural inlet to Saint Andrews Bay, which was a highly dynamic setting for coastline changes. That condition changed drastically with the digging of the artificial ship channel, Land's End Canal, by the US Army Corps of Engineers in the early 1930's (Figure 1). This cut created Shell Island from the southwest end of the former peninsula, and forced tidal flow in and out of the Bay to be concentrated in the Canal at the expense of the natural inlet (Stapor, 1973). The man-made inlet also forced changes to the nearshore sediment transport regime, creating a divide at Land's End Canal such that sediments are transported northwestward on the west side of the inlet, and southeastward on the east side, which is Shell Island (Stapor, 1973). The sedimentary impact of Land's End Canal is also evident in the regional bathymetric data, where we can observe a shoaling of the inner shelf and shoreface fronting Shell Island

(Figure 1). I interpret this feature as an ebb tide delta platform associated with the tidal flow out of Land's End Canal combined with southeastward alongshore transport. This deposit appears to affect the offshore sand ridges (Figure 1), which are oriented ~N-S, oblique to shore as is common for these features (Swift and Field, 1981). The sand ridges are associated with the MAFLA sand sheet (McBride et al., 1999; 2004; Goff, 2014), which covers the inner shelf from Mississippi to Florida along the Northwest Gulf of Mexico. To the west of the Canal, the sand ridges extend to the shoreface, whereas east of the canal they extend only so far as the ebb tide delta platform, suggesting that they have been recently buried by that feature.

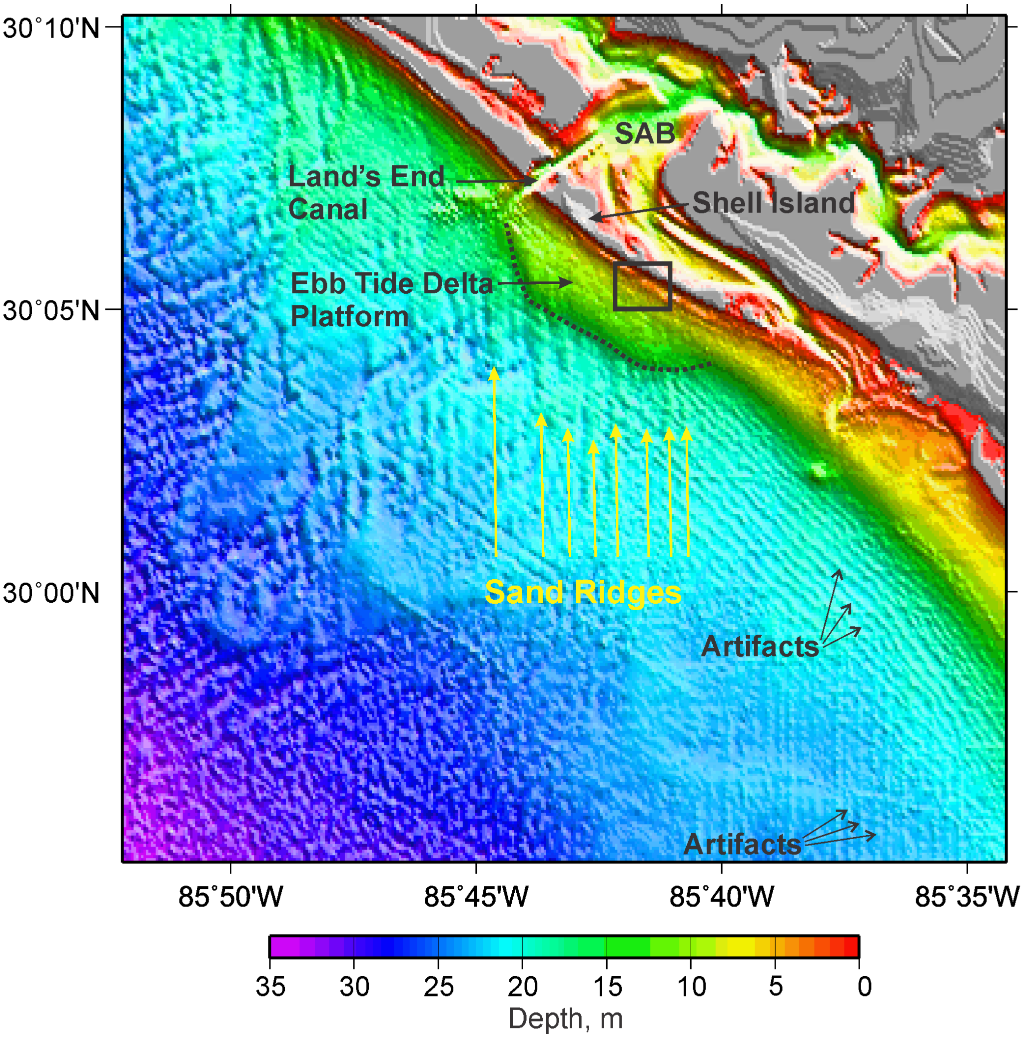

Figure 1: **Location Map.** Bathymetric map of the shoreface and inner shelf offshore of Saint Andrews Bay (SAB), Florida, adapted from Goff (2014). The lower shoreface is extended to the SE of the man-made Lands End Canal, suggestive of an ebb tide delta has formed since the Canal was dug. Sand ridges oriented ~N-S, oblique to shore, are evident in the regional bathymetry, and appear to be buried by the ebb tide delta platform. Box shows location of Figure 2 and subsequent interpretation maps.

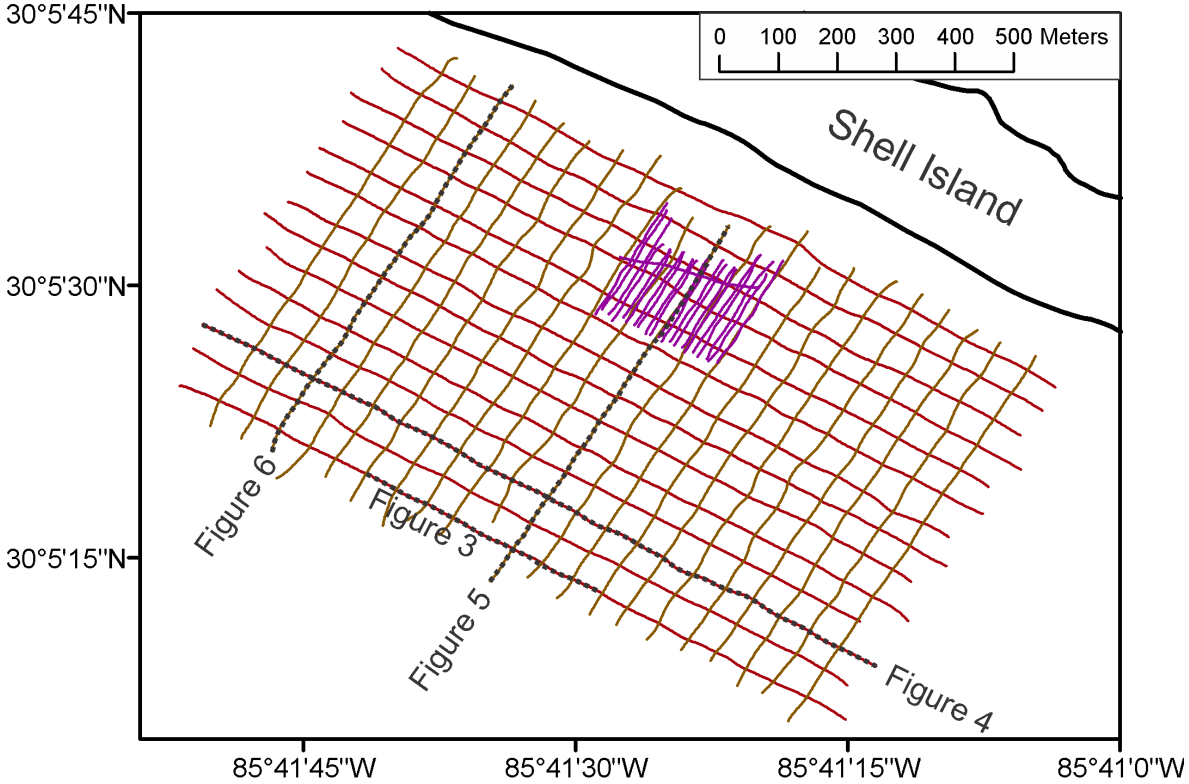

Figure 2: Track Lines. Track line map for the 2-16 kHz chirp data collection, which include both a coarser, regional grid (red & green) as well as narrowly-spaced lines focused on the UXO test site (purple). Location shown in Figure 1.

Materials and Methods

UTIG's lead seismic technician, Steffen Saustrup, has developed a robust workflow for processing chirp data to maximize image quality and interpretability (Saustrup et al., 2019). Processing steps include: towfish depth correction, heave filtering, trace equalization, water column muting, secondary deconvolution (to sharpen image), and layback correction. Saustrup participated in the pilot survey, and processed the data at UTIG. Figure 3 displays an example of pre- and post-processed data. In the pre-processed data (Figure 3A), the record is strongly affected by boat heave, which has two significant effects: (1) the reflectors artificially rise up and down sinusoidally with the changing altitude above the seafloor, and (2) the amplitudes of the records are modulated by the changing pitch on the pole-mounted instrument, which alters the angle of the outgoing acoustic beam with respect to horizontal. The processed image (Figure 3B) smooths out the heave artifact by filtering the seafloor arrival time, and evens out amplitude variations using a trace equalization.

The envelope record, as shown in Figure 3B, is the most commonly used chirp data product, but it is not the only one. Chirp instruments also produce a full waveform record (which is the basis for the envelope record), which we find is frequently a much better rendering of the most detailed information imaged by the chirp (Saustrup et al., 2019). In contrast, the envelope record is often superior for imaging stratigraphic structures at a larger scale, because it is essentially a filtered version of the seismic record. Our processing methodology is routinely applied to both envelope and full-waveform chirp data. Figure 3C displays the processed full-wave form data from the same section shown in Figure 3C. In this heavily sand-rich environment, we find no evidence of fine-scale structures that are imaged well by the full-waveform data that are not also well-imaged by the envelope data. Thus, for this application, the envelope records are deemed fully sufficient for interpretation purposes.

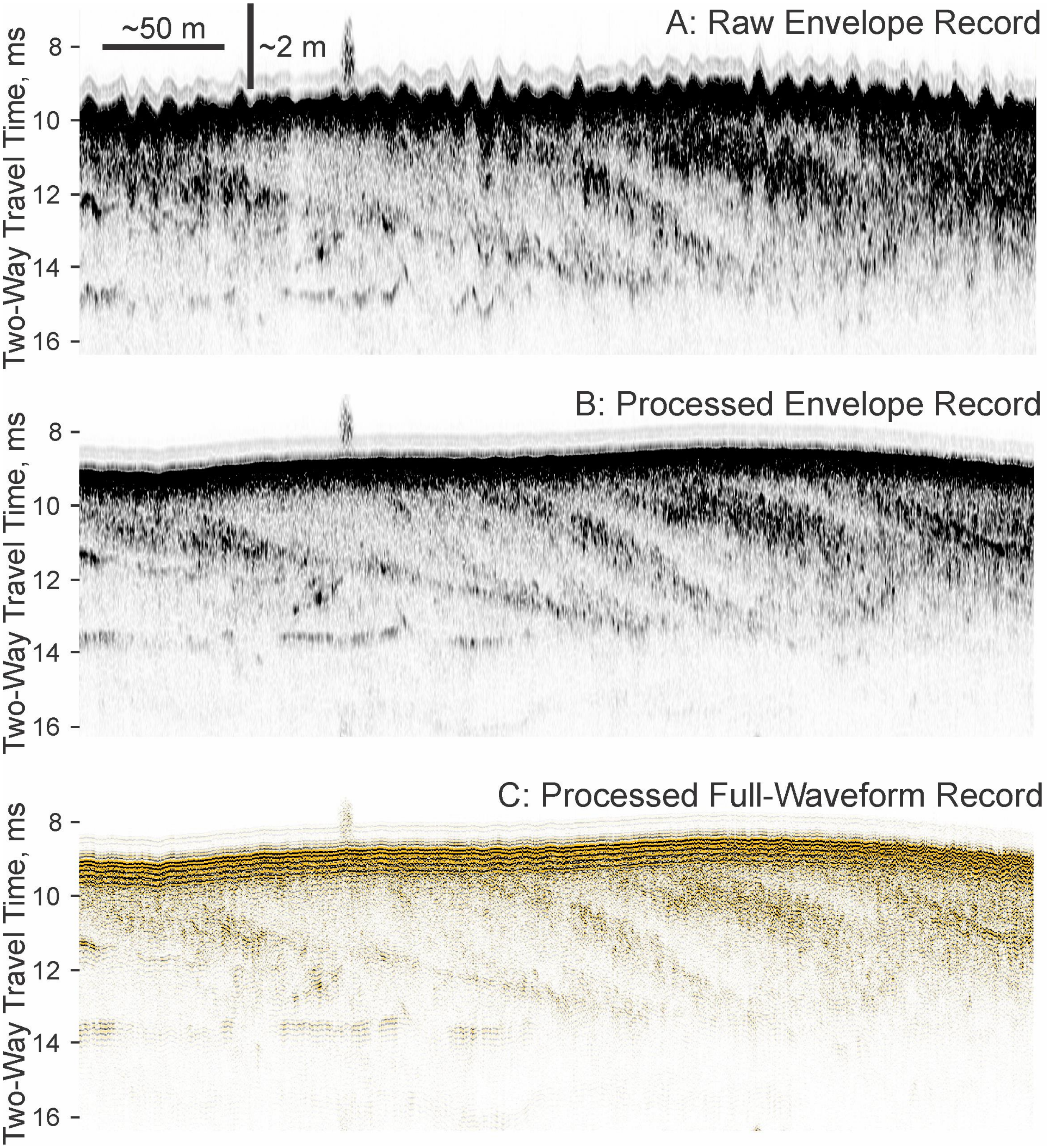

Figure 3: Chirp Processing. Example of (A) unprocessed and (B) processed envelope chirp data, as well as (C) processed full-waveform chirp data from the same section.

Processed chirp data were imported into Landmark DecisionSpace software, a commercial-grade seismic interpretation program. In this application, seismic reflection horizons can be traced and cross-referenced against crossing lines to generate an internally consistent, three-dimensional model of the seismic stratigraphy in the survey region.

Results and Discussion

The primary stratigraphic elements mapped in the survey area are illustrated on one shore-parallel and two shore-perpendicular chirp records in Figures 4, 5 and 6, respectively. Starting with the shore-parallel line (Figure 4), we observe that the unit directly beneath the seafloor is composed of an *en echelon* series of dipping reflectors of moderate to high amplitude. These reflectors are not sharply delineated, but rather are “fuzzy” in that they are often distributed across more than a milisecond of two-way travel time. In this shore-parallel image, the reflectors are dipping to the SE. The base of the dipping reflectors is marked by a weak to moderately strong reflection of highly undulating character. An additional, deeper, more flat-lying reflector is sporadically observed, which may identify the transgressive ravinement (erosional surfaced caused by landward migration of the shoreface) as observed further offshore in Goff (2014).

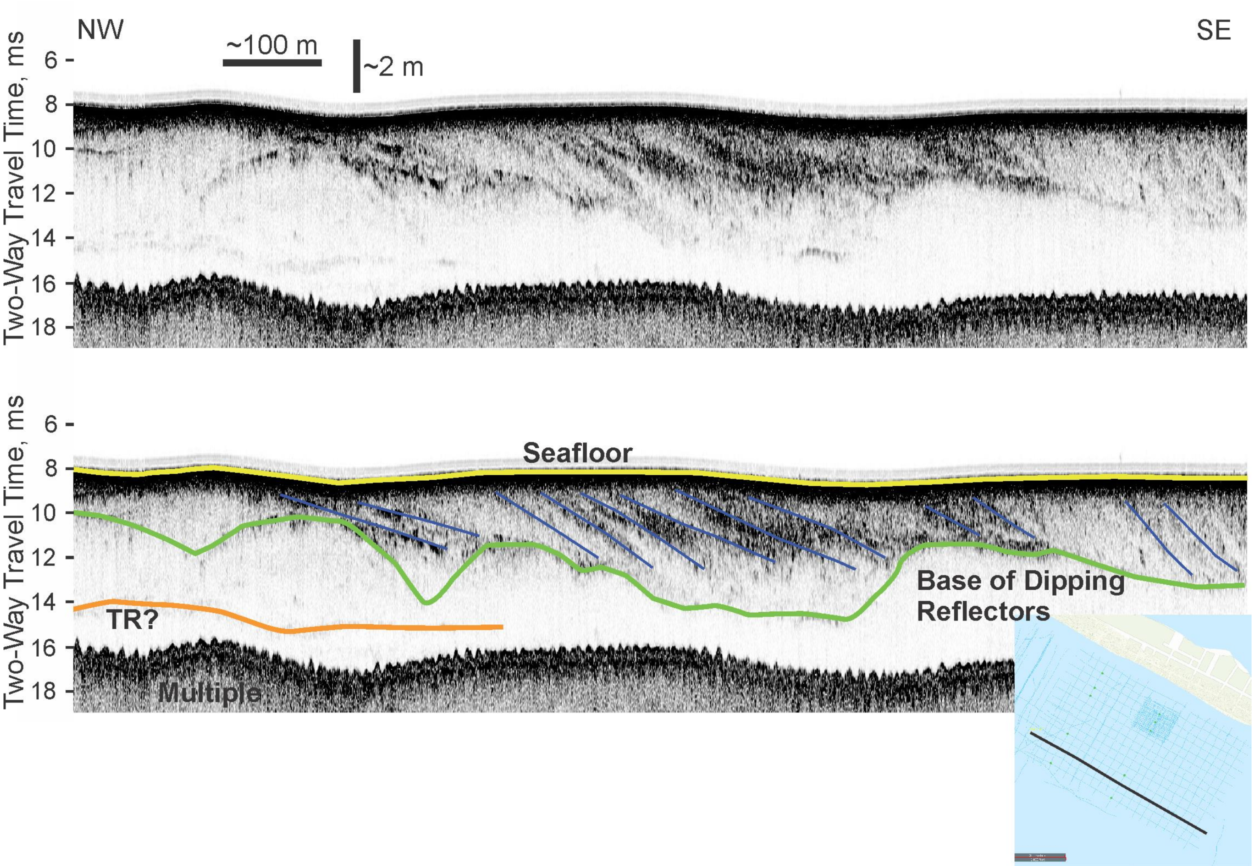

Figure 4: Shore-Parallel Chirp Line. (A) Uninterpreted and (B) interpreted chirp data from one of the shore-parallel track lines (see inset and location on Figure 2). TR = transgressive ravinement.

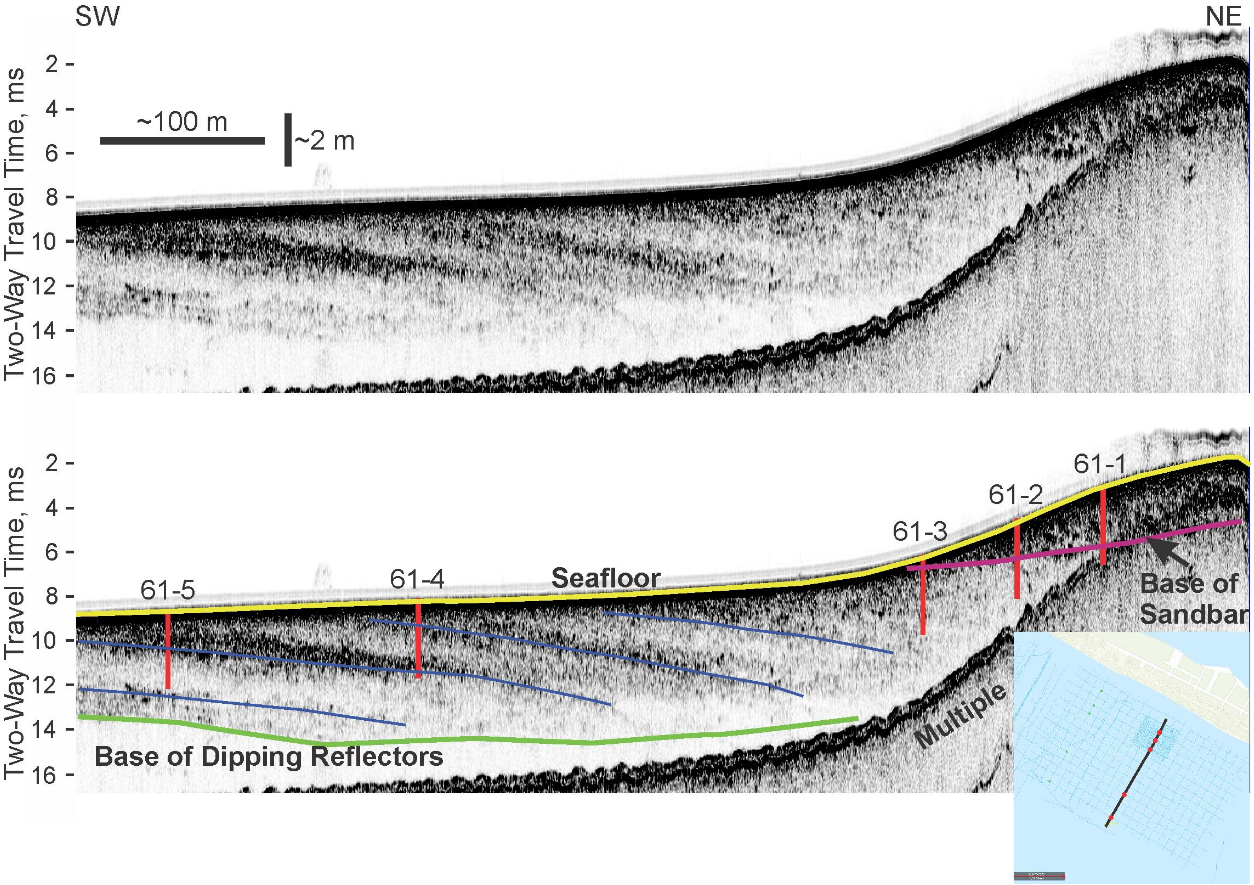

Figure 5: Shore-Perpendicular Chirp Line 1. (A) Uninterpreted and (B) interpreted chirp data from one of the shore-perpendicular track lines (see inset and location on Figure 2). Along this section, the sand bar is thick, wide and shallow, and the dipping reflectors unit is thick. Proposed locations for coring are shown on the interpreted sections as red lines.

The dipping reflectors unit and its base are also observed on the shore-perpendicular lines (Figures 5 and 6). The dip on these reflectors is landward, but angled more gently than on the shore-parallel lines indicating that, in 3-dimensions, the orientation (strike) of these surfaces is oblique to the shoreline but oriented more closely to shore-perpendicular than shore-parallel. The two shore-perpendicular lines shown provide contrasting examples of where the thickness of the dipping reflector unit is larger (Figure 5) and smaller (Figure 6). Further landward, the seafloor shoals rapidly, peaking out at a nearshore sandbar before rising again to the shoreline (Figures 5 and 6). The base of the sandbar is marked by a seaward-dipping reflector of variable, moderate to high amplitude. The interior of the sandbar unit is characterized by chaotic reflectivity. Figures 5 and 6 provide contrasting examples where the sandbar is either thick, wide and shallow (Figure 5), or thin, narrow and deep (Figure 6). This undulating character is indicative of "crescentic" sandbars, also referred to as rip channel systems because offshore-directed flows tend to be concentrated in areas where the sandbar is deeper (Ribas et al., 2017). Crescentic sandbars are highly dynamic and mobile features and tend to migrate alongshore in the direction of longshore currents (Ribas et al., 2017). We hypothesize that the seaward-dipping basal horizon beneath the sand bar marks the base of the mobile sands, and that the reflector itself is formed by lag deposits that would accumulate on this horizon through successive inflations and deflations of the sandbar unit during its migration process.

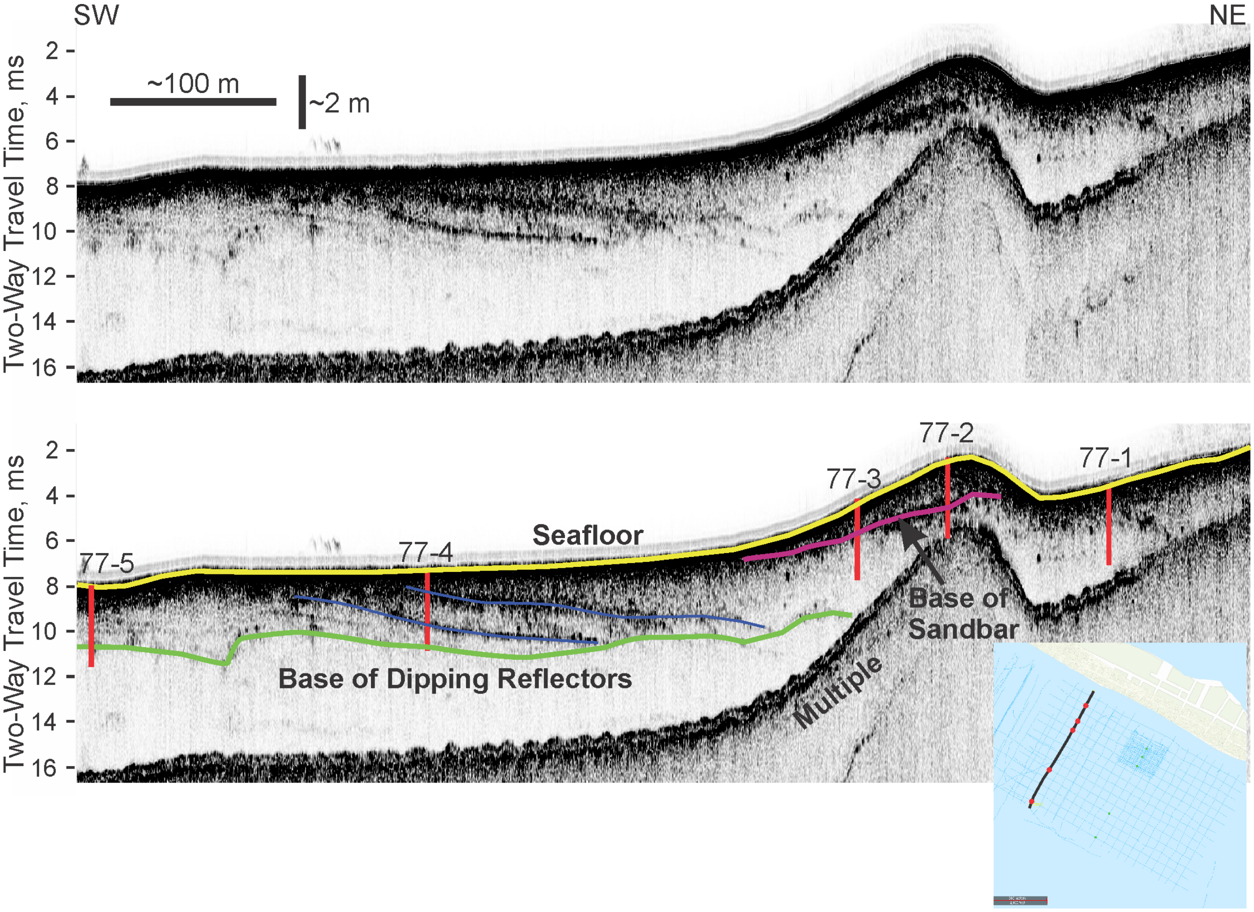

Figure 6: Shore-Perpendicular Chirp Line 2. (A) Uninterpreted and (B) interpreted chirp data from one of the shore-perpendicular track lines (see inset and location on Figure 2). Along this section, the sand bar is thin, narrow and deep, and the dipping reflectors unit is thin. Proposed locations for coring are shown on the interpreted sections as red lines.

The interpreted horizons from all lines were output and interpolated to make structure maps (surfaces) and isopachs (differences between surfaces, or unit thicknesses) over the region of the survey. The seafloor structure map is displayed in Figure 7, which clearly demonstrates the crescentic or scalloped morphology of the nearshore sandbar, with an approximately 750 m wavelength based on the single cycle observed in this map. The sandbar base structure map is displayed in Figure 8A, along with the sandbar isopach (difference between sandbar base and seafloor) in Figure 8B.

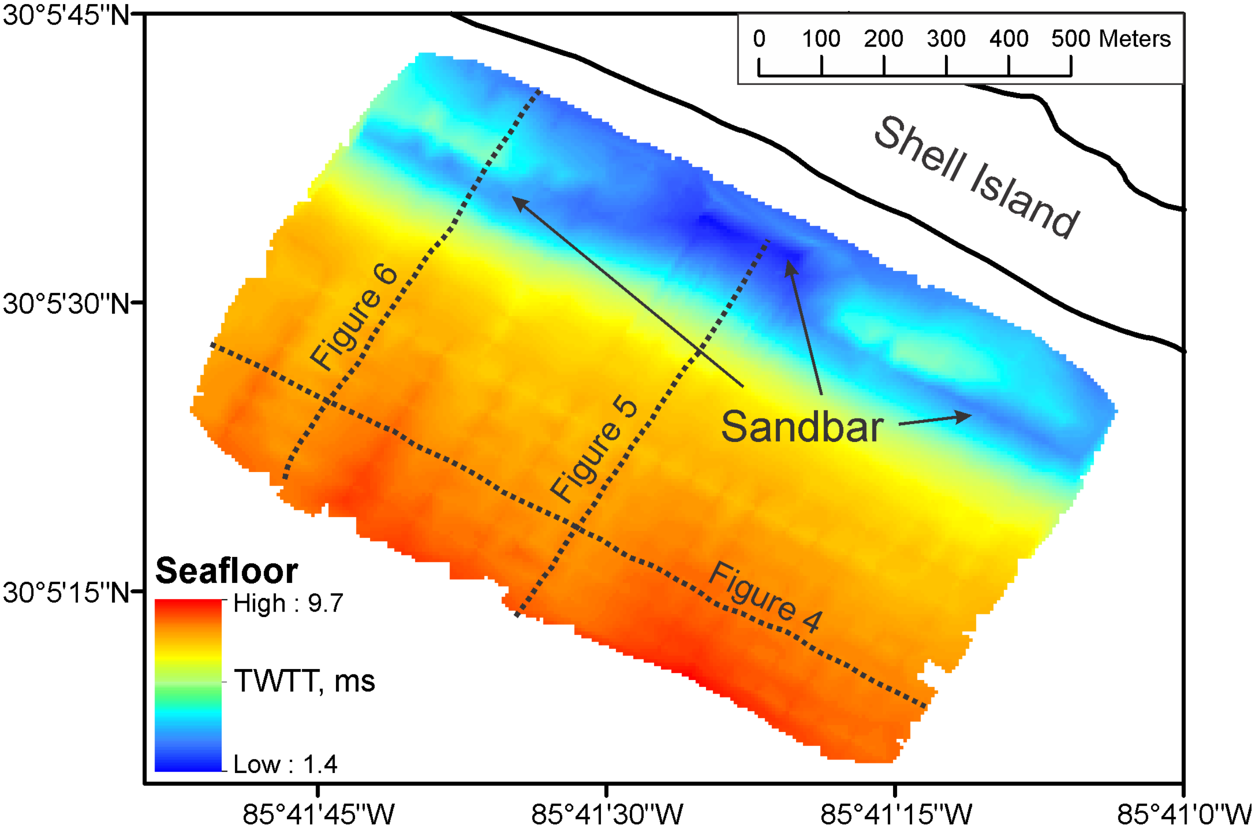

Figure 7: Seafloor Horizon. Structure map of the seafloor represented in two-way travel time (TWTT) below the sea surface.

The base of the dipping reflector unit is displayed in Figure 9A, along with the isopach formed by the difference of that reflector and the seafloor in Figure 9B. The structure map reveals this surface to be composed of corrugated undulations oriented nearly N-S, oblique to the shoreline of Shell Island. This orientation is identical to that of the sand ridges located both further offshore and nearshore on the east side of Land's End Canal (Figure 1). Therefore, we interpret this surface as a set sand ridges that have been buried by the overlying unit of dipping reflector, which I interpret as the ebb tide delta associated with the platform delineated in Figure 1. Twelve of the dipping reflectors were individually traced in the chirp data and structure maps for these are shown in map form in Figure 10A and in 3-dimensional perspective in Figure 10B. The *en echelon* geometry of these reflectors indicates that the ebb tide delta was deposited as a prograding system, progressing along shore from NW to the SE, consistent with the known sediment transport direction fronting Shell Island (Stapor, 1973). The orientation of these surfaces is revealed to be closely aligned with the underlying orientation of the buried sand ridges. This indicates that the underlying seafloor morphology and resultant accommodation pattern had a first-order influence on the development of the ebb tide delta.

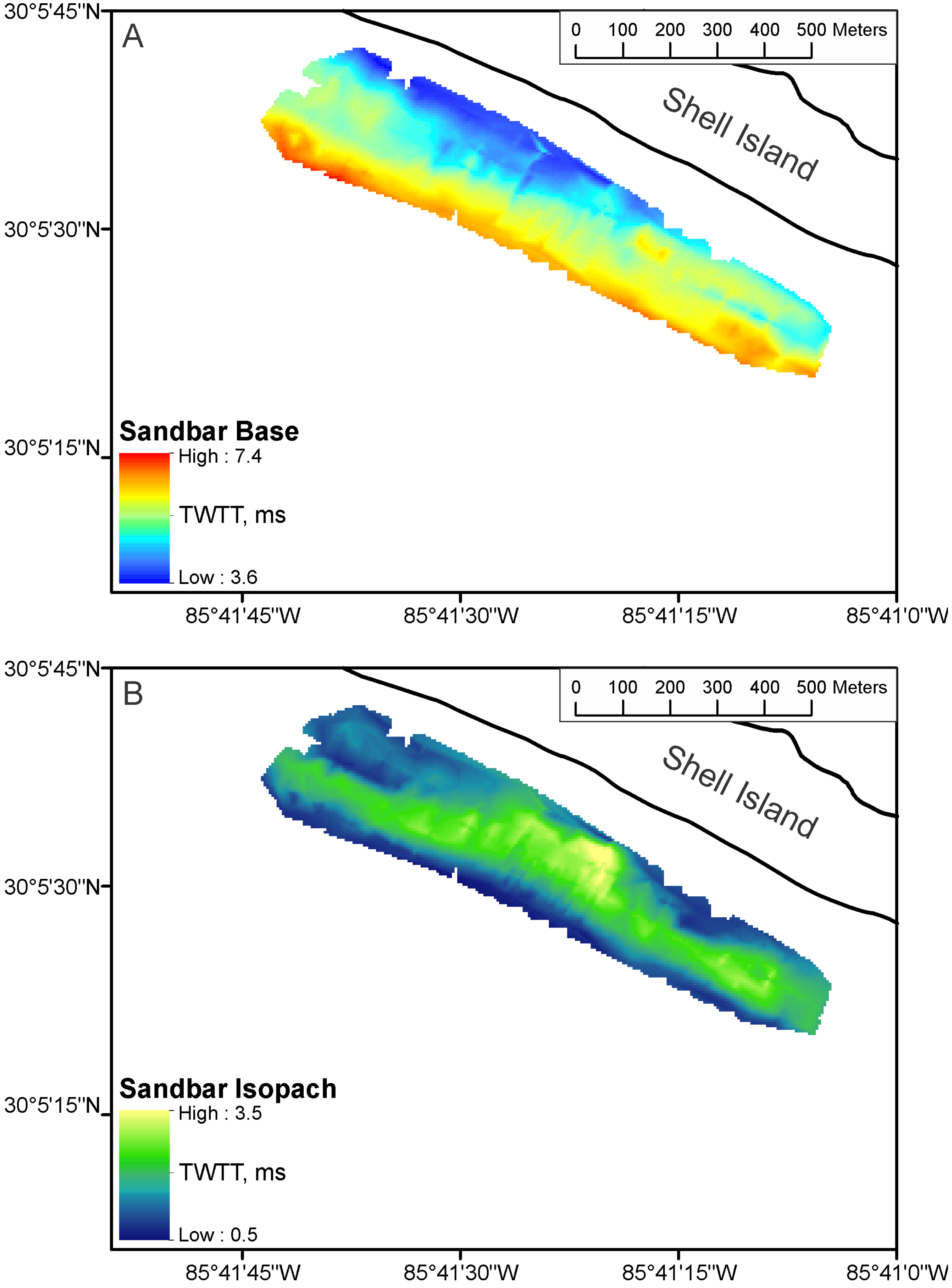

Figure 8: Sandbar Unit. (A) Structure map of the base of the sandbar, and (B) isopach map for the sandbar unit computed by subtracting the seafloor structure map (Figure 7).

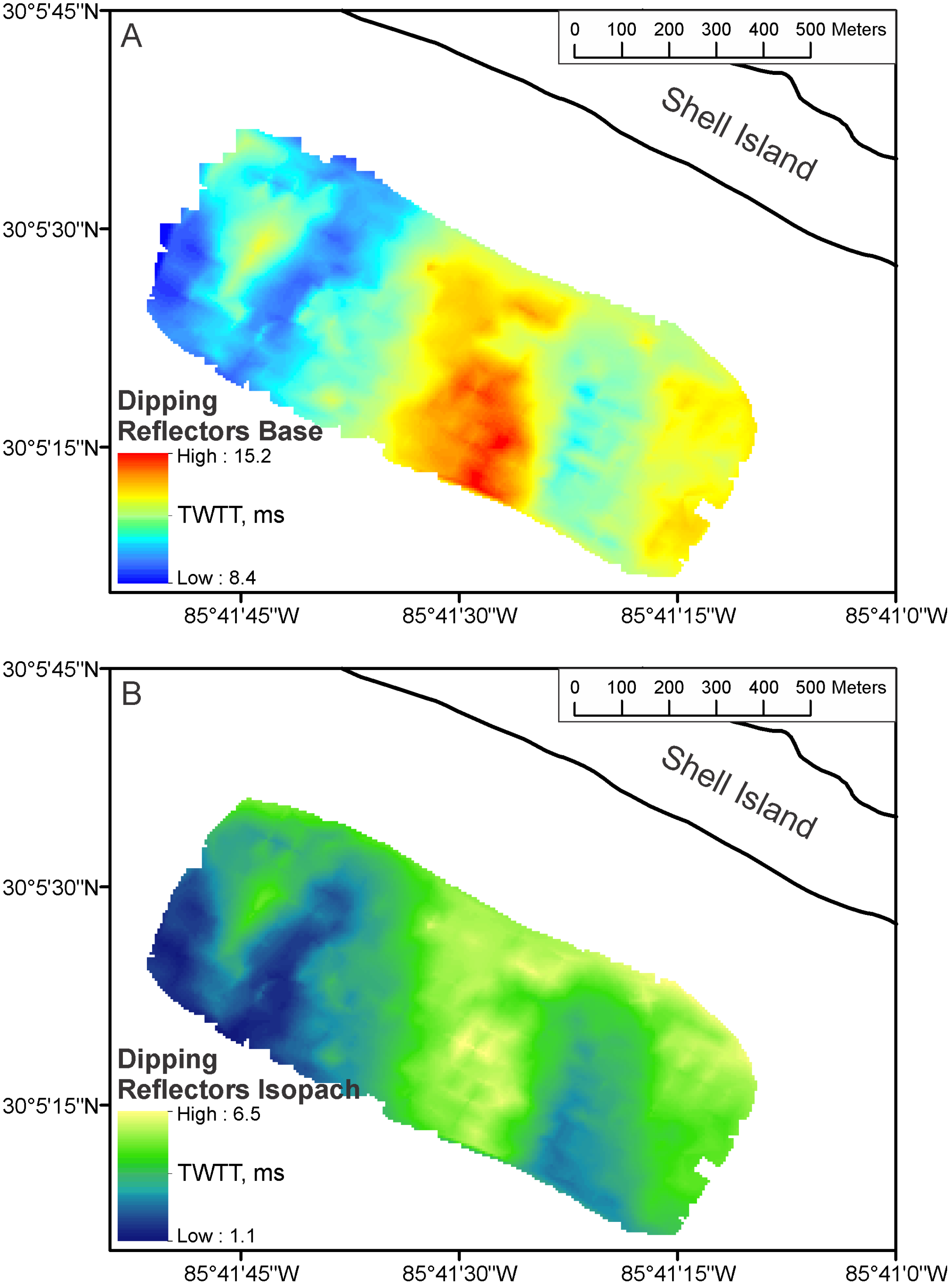

Figure 9: Dipping Reflectors Unit. (A) Structure map of the base of the dipping reflector unit (ebb tide delta), and (B) isopach map for the dipping reflector unit computed by subtracting the seafloor structure map (Figure 7).

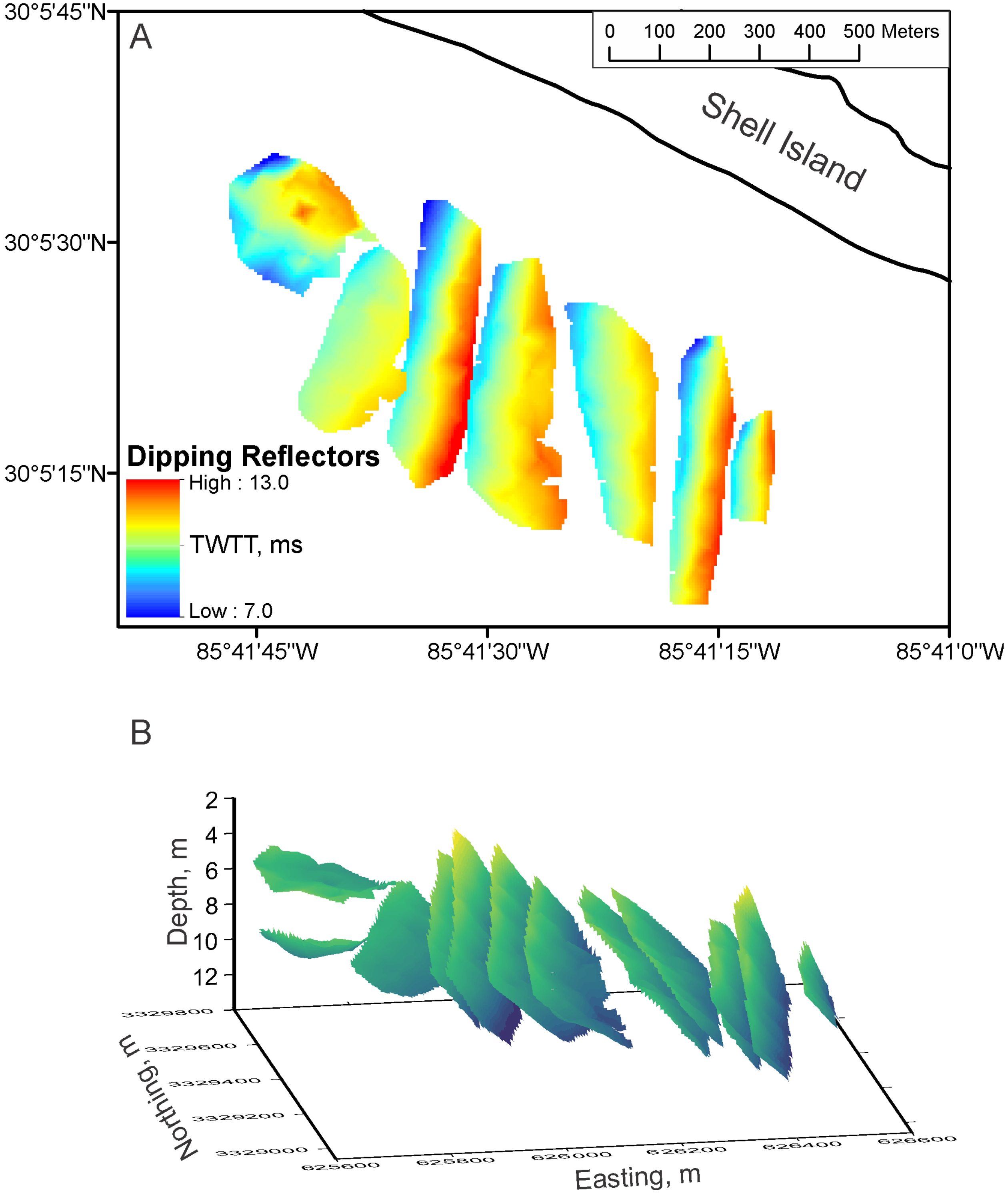

Figure 10: **Dipping Reflectors Geometry**. (A) Map view and (B) 3-dimensional perspective of the individual dipping reflectors mapped in the survey region. Twelve dipping reflectors were traced, of which seven are shown in (A) (to minimize overlap) and all of which are shown in (B). Depth in (B) was computed assuming a sound velocity of 1700 m/s. Tick marks in northing and easting in (B) are every 200 m, and coordinates are in UTM Zone 16.

Ten core locations were proposed on the basis of the preceding interpretation, and are displayed on Figures 5 and 6. These locations were chosen in order to sample all the principal sedimentary horizons and units observed. These include: (1) the sandbar, (2) the basal reflector below the sandbar, (3) the substrate below the sandbar, (3) the ebb tide delta, (4) dipping reflectors within the ebb tide delta, (5) the basal reflector for the ebb tide delta, and (5) the sand ridge deposits below the ebb tide delta. The two different lines also exhibit the noted contrasting characteristics of the ebb tide delta unit (thick versus thin) and sand bar (thick, wide, and shallow versus thin, narrow, and deep). Locations are tabulated in Table 1.

Table 1: **Proposed Coring Sites**. UTM coordinates are in Zone 16.

core_id	ping	utmx	utmy	Longitude	Latitude
61_1	8311	626260	3329695	-85.689744	30.091922
61_2	8156	626237	3329650	-85.689988	30.091518
61_3	7993	626210	3329601	-85.690274	30.091079
61_4	7143	626061	3329346	-85.691851	30.088793
61_5	6724	625987	3329219	-85.692633	30.087655
77_1	18470	625936	3329927	-85.693078	30.094048
77_2	18200	625892	3329845	-85.693545	30.093313
77_3	18051	625867	3329800	-85.693809	30.092909
77_4	17392	625739	3329585	-85.695163	30.090983
77_5	16880	625643	3329417	-85.696179	30.089477

Conclusions and Implications for Future Research

The UXO test bed location off Shell Island, Florida consists of three principal sedimentary units in the shallow subsurface. The substrate consists of the MAFLA marine sand sheet, which is organized into oblique-to-shore sand ridges, and which merges with the barrier island sands of Shell Island. Along the lower shoreface/inner shelf, this substrate is overlain by an ebb tide unit associated with sands exiting through Land's End Canal, the 1930's-era ship channel constructed by the US-ACE for access to Saint Andrews Bay. The ebb tide delta is prograding along shore to the SE, as evidenced by the internal dipping reflectors, and consistent with the measure sediment transport direction. Along the upper shoreface, the substrate is overlain by the nearshore sandbar, organized into crescentic morphology of alternating highs and lows with a spacing of ~750 m alongshore. These sediments are assumed to be highly mobile above the basal reflector imaged in the chirp data.

This test project proved that a cost-effective, off-the-shelf technology (chirp) can be utilized in very shallow water environments. The results will be of great benefit to UXO investigations in the Shell Island test area, providing geologic context for understanding the active sedimentary environment. The successful approach demonstrated by this project will also benefit future UXO test sites.

Literature Cited

Goff, J.A., 2014. Seismic and core investigation off Panama City, Florida, reveals sand ridge influence on formation of the shoreface ravinement. Continental Shelf Research 88, 34-46.

McBride, R.A., Anderson, L.C., Tudoran, A., Roberts, H.H., 1999. Holocene stratigraphic architecture of a sand-rich shelf and origin of linear shoals: northeastern Gulf of Mexico. In: Bergman, K.M., Snedden, J.W. (Eds.), Isolated shallow marine sand bodies: sequence stratigraphic analysis and sedimentologic interpretation, SEPM Special Publication No. 64, Tulsa, Oklahoma, pp. 95-126.

McBride, R.A., Moslow, T.F., Roberts, H.H., Diecchio, R.J., 2004. Late Quaternary geology of the northeast Gulf of Mexico shelf: sedimentology, depositional history and ancient analogs of a major shelf sand sheet of the modern transgressive systems tract. In: J.B. Anderson, F.H. Fillon (Eds.), Late Quaternary Stratigraphic Evolution of the Northern Gulf of Mexico Margin, SEPM Special Publication No. 79, Tulsa, OK, pp. 55–83.

Ribas, F., Falques, A., Garnier, R., 2017. Nearshore Sand Bars. In: J. Guillen et al. (Eds.), Atlas of Bedfroms in the Western Mediterranean, Springer International Publishing, Switzerland, pp. 73-79.

Saustrup, S., Goff, J.A., and Gulick, S.P.S. 2019. Recommended “Best Practices” for Chirp Acquisition and Processing. Austin, TX: US Department of the Interior, Bureau of Ocean Energy Management, OCS Report BOEM 2019-039, 15 p., https://doi.org/10.31223/osf.io/7csjh.

Stapor, F., 1973. History and sand budgets of the barrier island system in the Panama City, Florida, region. Marine Geology 14, 277-286.

Swift, D.J.P., Field, M.E., 1981. Evolution of a classic sand ridge field: Maryland sector, North American inner shelf. Sedimentology 28, 461–482.