Abstract

3D MAPPING OF RADAR FACIES IN A LATE PLEISTOCENE CARBONATE PLATFORM DEPOSIT, BAHAMAS

HAZARD, Colby S., MCBRIDE, John H., RITTER, Scott M., TINGEY, David G., and KEACH, R. William II, Department of Geological Sciences, Brigham Young University, Provo, UT 84602, colbyhazard@gmail.com

Two 3D ground-penetrating radar (GPR) surveys collected on northwest Andros Island, Bahamas, facilitate understanding the architecture and evolution of carbonate sedimentary environments that are often unseen in 2D outcrop and core. A 200-MHz 3D GPR dataset was collected over Late Pleistocene (isotope stage 5e) bedrock at a schoolyard in northwest Andros over an area of 61 m x 61 m. This survey reveals a ~18-m wide oolitic barform that trends southwest-northeast through the study area with foresets dipping to the northwest and a ~12-m-wide tidal channel that trends north-northwest through the northeast part of the survey. These two prominent features are surrounded and underlain by low-energy mud deposits. A deeper radar surface can be seen at ~6.4 m depth dipping gently to the west, and is interpreted to be a sequence boundary. In order to better resolve the lateral and vertical spatial interaction between the shallower features (<3.5 m), a higher resolution, 35.8 m x 29.6 m 400-MHz 3D GPR dataset was collected with the survey direction optimized to image the barform and its foresets (i.e., the profiles were collected in the direction of dip). The interpretation of these features is enhanced by modern analogs found nearby at Joulters Cays, and by three cores and 56 thin sections collected through the crest and toe of the barform, and through the channel feature. The integration of geophysical and geological data enables the recognition and reconstruction of a Pleistocene depositional environment and its associated fine-scale process sedimentology, including changing current directions, barform accumulation patterns and non-depositional and erosional events.
3D MAPPING OF RADAR FACIES IN A LATE PLEISTOCENE CARBONATE PLATFORM DEPOSIT, BAHAMAS

Colby S. Hazard
John H. McBride
Scott M. Ritter
David G. Tingey
William R. Keach II

Brigham Young University, Provo, Utah
Outline

1. Introduction
2. Methods
3. The 3D Datasets
4. Advantages of Seismic Interpretation Software
5. The Cores
6. Radar Facies
7. Conclusion
Outline

1. Introduction
2. Methods
3. The 3D Datasets
4. Advantages of Seismic Interpretation Software
5. The Cores
6. Radar Facies
7. Conclusion
1. Introduction
1. Introduction
1. Location

- Little Bahama Bank
- Great Bahama Bank
- Andros Island

From www.bing.com/maps/ and http://corpsmap.usace.army.mil/cm_apex/cm2.cm2.map
Why the Bahamas?

• The formation of modern limestones can be studied immediately adjacent to Pleistocene limestones preserved onshore.

• The Pleistocene rock record reveals thousands of years of sedimentation patterns and how such patterns have evolved over time.

• Clean limestone has a high resistivity, making it great for GPR.
What is GPR?

- Remote sensing method of imaging the shallow subsurface
GPR vs. Seismic Reflection

Seismic

GPR

High Frequency Seismic

Sparks and Rankey, 2013

http://walter.kessinger.com/work/seisx_interpretation.html
GPR = High resolution

5-10 cm vertical resolution!
1. Introduction
2. Methods
3. The 3D Datasets
4. Advantages of Seismic Interpretation Software
5. The Cores
6. Radar Facies
7. Conclusion
Methods

• GPR Profiles and hand samples from eight other locations
2. Methods
2. Methods

- 200 ft x 200 ft (61 m x 61 m)
- 200 MHz survey
  - 2 ft spacing between profiles
2. Methods

• 200 ft X 200 ft (61 m X 61 m) 200 MHz survey
  • 2 ft spacing between profiles
• 117.5 X 97 ft (35.8 X 29.6 m) 400 MHz survey
  • 1 ft spacing between profiles
2. Methods

• 200 ft X 200 ft (61 m X 61 m) 200 MHz survey
  • 2 ft spacing between profiles

• 117.5 X 97 ft (35.8 X 29.6 m) 400 MHz survey
  • 1 ft spacing between profiles

• 3 Cores:
  • 38 ft, 11 in (12.5 m) total core from 3 holes
Outline

1. Introduction
2. Methods
3. The 3D Datasets
4. Advantages of Seismic Interpretation Software
5. The Cores
6. Radar Facies
7. Conclusion
3D 200 MHz Dataset (61 x 61 m)
3D 400 MHz Dataset
Two 3D GPR Data Sets:
200 MHz (~10 cm Vertical Resolution)
200 MHz Dataset

200 MHz
200 x 200 ft
(61 x 61 m)

N

0 m
Depth

Feet

200
(61 m)
Lagoonal Wack/Packstone

Tidal channel

Sand Wave

Lagoonal Wack/ Packstone

Feet

Depth

.6 m

200 MHz

200 x 200 ft

(61 x 61 m)
West-Dipping Karstified Exposure Surface

- 200 MHz
- 200 x 200 ft (61 x 61 m)
- 5.6 m Depth

Feet

0
100
200
(61 m)
West-Dipping Karstified Exposure Surface
Two 3D GPR Data Sets:
400 MHz (~5 cm Vertical Resolution)
.003 m
Depth

400 MHz
117.5 x 97 ft
(35.8 x 29.6 m)
.03 m
Depth

400 MHz
117.5 x 97 ft
(35.8 x 29.6 m)
06 m
Depth

400 MHz
117.5 x 97 ft
(35.8 x 29.6 m)
.3 m Depth
400 MHz
117.5 x 97 ft
(35.8 x 29.6 m)
.4 m
Depth

400 MHz
117.5 x 97 ft
(35.8 x 29.6 m)
.6 m Depth

400 MHz
117.5 x 97 ft
(35.8 x 29.6 m)
.7 m Depth

400 MHz
117.5 x 97 ft
(35.8 x 29.6 m)
.9 m
Depth

400 MHz
117.5 x 97 ft
(35.8 x 29.6 m)
1 m
Depth

400 MHz
117.5 x 97 ft
(35.8 x 29.6 m)
1.1 m Depth

400 MHz
117.5 x 97 ft
(35.8 x 29.6 m)
1.2 m Depth

400 MHz
117.5 x 97 ft (35.8 x 29.6 m)
1.3 m
Depth

400 MHz
117.5 x 97 ft
(35.8 x 29.6 m)
1.4 m
Depth

400 MHz
117.5 x 97 ft
(35.8 x 29.6 m)
1.5 m Depth

400 MHz
117.5 x 97 ft
(35.8 x 29.6 m)
1.6 m Depth

400 MHz

117.5 x 97 ft
(35.8 x 29.6 m)
1.7 m
Depth

400 MHz
117.5 x 97 ft
(35.8 x 29.6 m)
1.9 m
Depth

400 MHz
117.5 x 97 ft
(35.8 x 29.6 m)
2 m Depth

400 MHz
117.5 x 97 ft
(35.8 x 29.6 m)
2.1 m

Depth

400 MHz

117.5 x 97 ft
(35.8 x 29.6 m)
2.2 m Depth

400 MHz
117.5 x 97 ft
(35.8 x 29.6 m)
2.3 m Depth

400 MHz
117.5 x 97 ft
(35.8 x 29.6 m)
2.4 m
Depth

400 MHz
117.5 x 97 ft
(35.8 x 29.6 m)
2.6 m Depth

400 MHz
117.5 x 97 ft (35.8 x 29.6 m)
2.7 m
Depth

400 MHz
117.5 x 97 ft
(35.8 x 29.6 m)
2.8 m
Depth

400 MHz
117.5 x 97 ft
(35.8 x 29.6 m)
4. Advantages of Seismic Interpretation Software
Benefits of Using Advanced Seismic Interpretation Software
Benefits of Using Advanced Seismic Interpretation Software
Benefits of Using Advanced Seismic Interpretation Software
Benefits of Using Advanced Seismic Interpretation Software
Benefits of Using Advanced Seismic Interpretation Software
Benefits of Using Advanced Seismic Interpretation Software
Benefits of Using Advanced Seismic Interpretation Software
Benefits of Using Advanced Seismic Interpretation Software
Benefits of Using Advanced Seismic Interpretation Software
Benefits of Using Advanced Seismic Interpretation Software
Benefits of Using Advanced Seismic Interpretation Software
Benefits of Using Advanced Seismic Interpretation Software
Benefits of Using Advanced Seismic Interpretation Software
Benefits of Using Advanced Seismic Interpretation Software
Benefits of Using Advanced Seismic Interpretation Software
Benefits of Using Advanced Seismic Interpretation Software
1. Introduction
2. Methods
3. The 3D Datasets
4. Advantages of Seismic Interpretation Software
5. The Cores
6. Radar Facies
7. Conclusion
Three Boreholes

- RB1
- RB2
- RB3

- 200 ft. (61 m)
- 200 MHz
- 117.5 Ft. (35.8 m)
- 97 Ft. (29.6 m)
The Cores:
38 ft, 11 in. total (~12 m)

RB1 (Crest)

RB2 (Toe)

RB3 (Channel)
Core: RB1
(Crest of Sand Wave)
Core: RB2
(Toe of Sand Wave)
Core: RB3 (Channel)
Outline

1. Introduction
2. Methods
3. The 3D Datasets
4. Advantages of Seismic Interpretation Software
5. The Cores
6. Radar Facies
7. Conclusion
Radar Facies

NW

SE

depth (m) for $\varepsilon = 18.4$

vertical exaggeration = 1.43

5 m
Conclusion

• 3D GPR imaging captures the complex heterogeneity and process sedimentology of a carbonate paleoenvironment, which are often missed in 2D studies.

• Clean sediment from the sand wave is surrounded by muddy sediments, giving insights into aquifer/reservoir fluid flow and compartmentalization at the sub-seismic scale.

• The presence of a clean, oolitic sand wave on NW Andros Island indicates a relatively high-energy environment once existed in an area previously assumed to be a low-energy, back-shoal environment, and offers new insights where no outcrops are available.
Sequence Thicknesses for Thought

~5.5 m (18 ft)

Cruz, 2007 (Cat Cay)

~7.5 m (25 ft)

Sparks & Rankey, 2013 (Lily Bank)

~6.5 m (21 ft)

This Study
Acknowledgements

• My professors
• Landmark (Halliburton)
• BYU College of Physical and Mathematical Sciences
Thank You!
References


Why Ground-Penetrating Radar (GPR)?

Models vs. 3D GPR

Gonzalez and Eberli, 1997

Neal et al., 2008
“GPR can detect geological features thinner than the calculated vertical resolution (Grasmueck 1996; Lane et al. 2000), in this case “thin” beds (0.1 m ≥ 0.01 m) and laminae (< 0.01 m). Under these circumstances the radar response constitutes an interference pattern still providing useful information, namely the average dip angle and direction of crossbed sets or sets of laminae (Kruse and Jol 2003; Guha et al. 2005)” (Neal et al., 2008).
200 MHz and 400 MHz Antennas
Current/Future Sequence Boundary

Previous bedrock depositional surface (SB)