BULLETIN

Corpus Christi
Geological Society

and

Coastal Bend
Geophysical Society

November
2023
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2023-2024
www.ccgeo.org

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2023-2024

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CCGS/CBGS JOINT MEETING SCHEDULE 2023-2024

September 2023

S	M	T	W	Th	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

2023-24 Membership Kickoff—
Nueces Brewing Co. Downtown,
Thursday Sept. 14
5:00p.m.-til 8:00p.m.

October 2023

S	M	T	W	Th	F	S
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29	30	31				

Meeting at Joe's Crab Shack Downtown. 11:00 Bar, 11:45 lunch, 12:00 speaker. Speaker: William DeMis—Rochelle Court LLC, "Commodity Super Cycle of Oil & Gas."

November 2023

S	M	T	W	Th	F	S
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Meeting at Joe's Crab Shack Downtown. 11:00 Bar, 11:45 lunch, 12:00
Speaker: Mohamed Ahamed/Grad Student

December 2023

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31						

January 2024

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Meeting at Joe's Crab Shack Downtown. 11:00 Bar, 11:45 lunch, 12:00 speaker
Speaker: Mark Thompson, Volcanoes role in opening of Gulf of Mexico

February 2024

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25	26	27	28	29		

Meeting at Joe's Crab Shack Downtown. 11:00 Bar, 11:45 lunch, 12:00 speaker
Speaker: Robin Dommisse/BEG

CCGS/CBGS Joint Meeting Schedule 2023-2024

March 2024							April 2024							May 2024						
S	M	T	W	Th	F	S	S	M	T	W	Th	F	S	S	M	T	W	Th	F	S
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31																				

Meeting at Joe's Crab Shack downtown. 11:00 Bar, 11:45 lunch, 12:00 speaker

Meeting at Joe's Crab Shack downtown. 11:00 Bar, 11:45 lunch, 12:00 speaker

Calendar Of Meetings and Events

Corpus Christi Geological/Geophysical Society.. Third Wed.—11:30a.m.
SIPES Corpus Christi Luncheons.. Last Tues.—11:30a.m.
South Texas Geological Society Luncheons.. Second Wed—noon San Antonio
San Antonio Geophysical Society Meetings.. Fourth Tuesday
Austin Geological Society.. First Monday
Houston Geological Society Luncheons... Last Wednesday
Central Texas Section of Society of Mining, Metallurgy & Exp............................... 2nd Tues every other month in San Antonio

Greetings to All

Happy November! The weather may give us a break and the holiday season is quickly approaching. Now it is time for my ramblings about the industries we represent. Gas and oil prices are holding firm. I think with winter approaching, gas should begin an uptick. and the demand for environmental professionals seems steady. I also think the uranium guys will have a bit larger presence in South Texas. What will the unrest in the Middle East do to our industries? While I was working, I could predict my company's activity to within 5%. However, my crystal ball for our products and services is a bit cloudy these days. (Is it cataracts or adult beverages …?)

Did anyone attend the Energy Professional Hiring Event in San Antonio October 17th? We are fortunate to have access to such events. Many universities and colleges host their own sessions in conjunction with hiring events like this one, and are especially helpful if you are looking for master's or Ph.D. opportunities. My own university, Missouri University of Science and Technology, held a social function within the hiring event. These encounters are a great way to connect (and reconnect) with the best in our industry, from rookies to veterans and everyone in between.

The Corpus Christi Geological Society/Coastal Bend Geophysical meeting and talk "The Coming Commodity Super Cycle" was well received on October 18th at Joe's Crab Shack in Corpus Christi. Bill DeMis was a big hit. We are lucky to get such quality speakers to enhance our intelligence and curiosities. Stay tuned to the bulletin for future talks and short courses.

On a lighter note, did you catch the annular eclipse? I was able to get some photos and will post them elsewhere in the bulletin. I also viewed the total eclipse of 2017 in central Missouri. The net total eclipse will be in April 8, 2023 and can best be viewed in Central Texas.

It's time to start thinking about 2024. I would like to see you all step up with volunteering in your community and/or area educational outreach programs So many opportunities are available to us, from university level to grade school level. Please participate in your local and regional geological societies and clubs. We are in charge of our future as a society. GET INVOLVED. Reminder! It's time to renew your CCGS and CBGS memberships. This is a good time to add a little extra donation for the scholarship fund. Additionally, there is a new twist for the luncheons this year for students. Student membership (which is free) is a MUST for students to receive the luncheon meeting meal at no cost.

Sponsors for the student lunch are Frank Cornish, Brent Hopkins and our newest sponsor Mary Nelis. These are people willing to support the future of our profession. Thank you vey much

It is an honor for me to be back as president. Please feel free to contact me with questions and/or concerns. Leave a message and I will return your calls or emails. Remember, the future is now, so please volunteer.

Dennis O. Moore--President CCGS 2023-24

Annular Eclipse, Corpus Christi, TX. 2023

Total Eclipse, Central Missouri 2017

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Contact Walter S. Light Jr.
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CBGS President's Letter

CBGS Board 2023-2024

- President- Dr. Mohammed Ahmed
- Vice President- Dr. Subbarao Yelisetti
- Secretary/Treasurer-Charles Benson

CBGS Scholarships

The board met to award student scholarships in the amount of $1,000 for the Fall 2023 semester. The board awarded scholarships as follows:

- Elora Afrin, Texas A&M-Kingsville
- Meghan Bygate, Texas A&M-Corpus Christi
- Ramadan Abdelrehim, Texas A&M-Corpus Christi

NOTE: The Texas A&M-K student declined her scholarship offer.

CBGS Business

- CBGS currently has 43 active members, 4 honorary members, and 40 student members.
- Raised $1,450 towards student scholarships through membership revenue this past year.

Academic Programs and Research Activities at TAMU-CC and TAMUK

- Texas A&M University-Corpus Christi (TAMU-CC) Geology program conducted the Field Geology course (i.e., field camp) during the Summer I semester in the Yucatan Peninsula, with focuses on karst hydrogeology, geochemistry, and structural geology. Great field work opportunities and lots of fun. For more information contact Dr. Valeriu Murgulet (Valeriu.Murgulet@tamucc.edu) at TAMU-CC.
- TAMU-CC's geology curriculum is constantly being refreshed with new courses but this academic year we are looking to add additional tracks such as Marine and Climate Geosciences, Planetary Geosciences and Biogeosciences. For additional information contact Dr. Valeriu Murgulet (Valeriu.Murgulet@tamucc.edu) at TAMU-CC.
- The Geophysics Lab at TAMU-CC is ready for students registering for the Spring Geophysics Class. Dr. Ahmed's lab includes the Geometrics G-858 magnetometer and gradiometer system, LaCoste & Romberg gravimeter, AGI SuperSting 1D, 2D, and 3D land resistivity system, GSSI SIR-4000 GPR system with 200 MHz and 350 MHz antennae, Geonics EM-31 frequency domain ground conductivity system, Geonics G-TEM time-domain system, Geometrics stratagem EH-4 magnetotelluric imaging system, Geometrics ES-3000 24-channel seismograph, Tromino passive seismic system, Trimble differential GPS system. The Geophysics Test Site (GTS) is being used in teaching this class (see https://library.seg.org/doi/abs/10.1190/tle40030208.1). Interested, contact Dr. Mohamed Ahmed (Mohamed.ahmed@tamucc.edu) at TAMU-CC.

- At TAMU-CC's Center for Water Supply Studies and the Hydrogeology lab, both led by Dr. Dorina Murgulet (Dorina.Murgulet@tamucc.edu), students delve deeply into water-related studies of utmost relevance. Currently, we are actively working on projects funded by three substantial grants from the National Science Foundation, including the DISES project which examines groundwater pollution, extreme wet events, and their socio-economic impacts on unincorporated communities (NSF Award #2307996 - DISES: Through the Prism of Groundwater Pollution: The Interplay of Extreme Wet Events, Socio-Economic Well-Being, and Polity in Unincorporated Communities). Additionally, our partnership with the Texas General Land Office through the NOAA pass-through funding supports our research on the hydroclimatic influence on bacteria and nutrient input in Texas coastal waters. Altogether, our projects total over $3M.
- TAMU-CC students receive hands-on training experiences. They immerse themselves in rigorous fieldwork and laboratory exercises as part of directed independent studies, internships, or roles as undergraduate research assistants. Adding to our capabilities, we're proud to announce our recent acquisition of a state-of-the-art Portable Geoprobe System (7822DT). This system is equipped with subsurface sampling, logging, and imaging capabilities, further enhancing our geoscience research and educational offerings. For additional information, contact Dr. Dorina Murgulet (Dorina.Murgulet@tamucc.edu).
- The first cohort of the NSF-funded graduate training program on Stakeholder-Guided Environmental Science (NRT STAGES) at TAMU-CC started Spring term. This training program is designed to train the next generation of experts to conduct big data analyses in interdisciplinary research settings for a globally competitive workforce. Along the way trainees will receive training in science communication and also work with regional stakeholders to co-develop research questions of interest to the resiliency of our coastal communities and environments. NRT STAGES trainees (10) and some non-trainees (4) at TAMU-CC went on a field trip from the headwaters of the Nueces River to Corpus Christi Bay during Spring semester where they learned about hydrological, atmospheric, geologic, geographic, biological, and human connections within the watershed. The trainees planned the trip and collected samples for water and atmospheric chemistry at 11 sample sites over three days. TAMU-CC faculty and NRT STAGES trainees met with stakeholders from the coastal bend region in a two-day workshop to discuss the research needs of the community and potential collaborations. The NRT STAGES trainees formed into two groups, 1) rainfall prediction error assessment with the National Weather Service and 2) seagrass and ecosystem health around Ingleside on the Bay, and have continued to work with their respective stakeholders to refine their research questions as they assimilate and begin exploring the data. We added a course over the Summer semester on big data science to provide NRT STAGES trainees instruction and mentorship throughout the process of acquisition of big datasets, preparation for analysis, and potential analyses to consider. For more information about the NRT STAGES contact the project PI Dr. Dorina Murgulet (Dorina.Murgulet@tamucc.edu) or the program manager Dr. Audrey Douglas (Audrey.Douglas@tamucc.edu).
- Dr. Ingo Pecher at TAMU-CC recently acquired a portable sub-bottom profiler and multibeam echosounder system and is looking forward to deploying this system in shallow waters off the Texas coast. Next spring, he will be on a research cruise to the Ross Sea, Antarctica, with two of his students and other scientists from TAMU-CC and the University of Texas to acquire reflection seismic and ocean-bottom-seismometer data aiming at understanding possible gas hydrate dissociation in Antarctica. Contact Dr. Pecher for more details: ingo.pecher@tamucc.edu.

- Dr. Lindsay Prothro at TAMU-CC received over $700,000 in active grants from the National Science Foundation and the Matagorda Bay Mitigation Trust that are currently supporting projects with focuses ranging from Antarctic glaciomarine sedimentary processes to mercury distribution in Lavaca Bay sediment. This Spring, for our second consecutive year, she and one of her graduate students will sail on an icebreaking research vessel to collect seismic data, multibeam bathymetric data, oceanographic data, and sediment cores from the Ross Sea, Antarctica, to better understand triggers of past ice sheet instability. Reach out to Dr. Prothro for additional details: lindsay.prothro@tamucc.edu.
- Texas A&M University-Kingsville (TAMU-K) started its first cohort of MS Petrophysics program in Fall 2018. If you are interested in joining this program, please contact the graduate coordinator for MS in Petrophysics, Dr. Subbarao Yelisetti at Subbarao.Yelisetti@tamuk.edu.
- BS degree in Geophysics, Minor in Geophysics and Certification in Geophysics offered at TAMU-K since Fall 2017. Interested students can contact Dr. Subbarao Yelisetti (Subbarao.Yelisetti@tamuk.edu) for additional information.
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Meetings & Events

- The 2023 Fall AGU annual meeting will be held in San Francisco, CA from December 11-15th, 2023. See https://www.agu.org/Fall-Meeting
- The 2023 GSA Annual Meeting will be held in Pittsburgh, Pennsylvania, from October 15 to 18, 2023. See https://community.geosociety.org/gsa2023/home

Mohamed Ahmed
President, CBGS
Mohamed.ahmed@tamucc.edu

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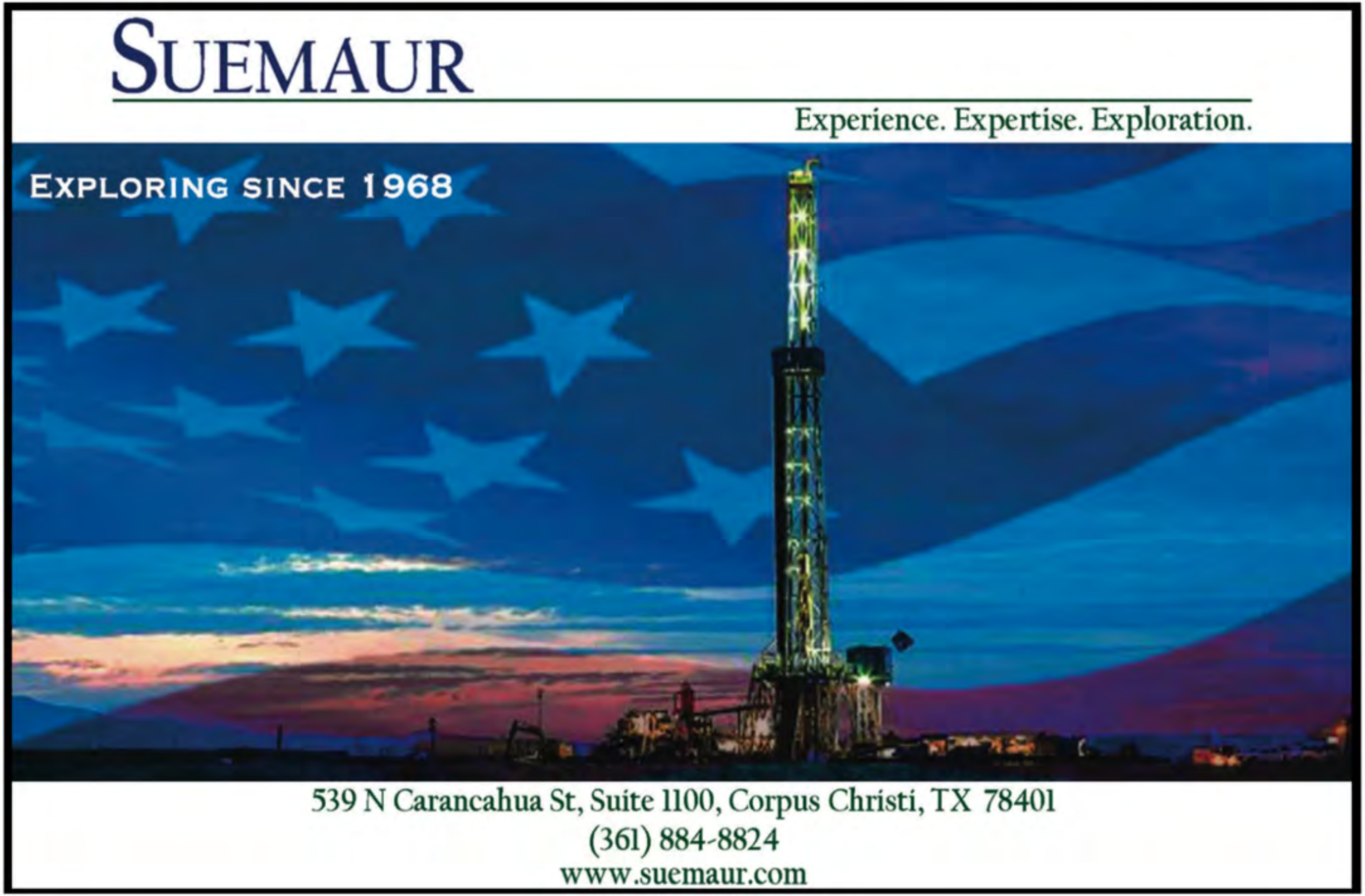
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CORPUS CHRISTI GEOLOGICAL SOCIETY
COASTAL BEND GEOPHYSICAL SOCIETY

LUNCHEON MEETING ANNOUNCEMENT

November 15th, 2023

Location:	**Joe's Crab Shack, 444 North Shoreline Dr., Corpus Christi, TX 78401**
Student Sponsor:	**Viper Exploration, Imagine Resources and Mary Nelis. Thank you!**
Time:	**11:30 AM Social, Lunch follows at 11:45 AM, Speaker at 12:00 PM**
Cost:	**$35.00 (additional $10.00 surcharge without reservation: NO SHOW may be billed.)**
Reservations:	**Please RSVP by 11:00 AM on Monday, November 13th before the meeting!**
	Email: arrangements@ccgeo.org

Please note that luncheon RSVPs are a commitment to Joe's Crab Shack (Shoreline Drive) and must be paid even if you can't attend the luncheon.

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Factors Controlling Barrier Island Geomorphology: Insights from Geophysical Surveys

Ramadan Abdelrehim, Mohamed Ahmed

Department of Physical and Environmental Sciences, Texas A&M University-Corpus Christi.

Abstract:

Coastal regions within the contiguous United States hold significant economic importance, despite encompassing less than 10% of the total land area. These areas are home to nearly 40% of the U.S. population. However, coastal communities face distinct challenges due to escalating risks from flooding, hurricanes, sea-level rise, and broader climate change. Padre Island, situated along the Gulf Coast is an important coastal system that plays a pivotal role in protecting the well-being and sustainability of southeast Texas' coastal communities. Central to its protective function, Padre Island's dunes act as a first line of defense shielding the mainland from the impacts of extreme events such as hurricanes and storms. However, the morphological features of the island and its dunes, encompassing aspects like height, shape, and volume, depend on the underlying subsurface geologic conditions. These conditions comprise elements such as lithology, stratigraphy, structures, and soil water content characteristics. Understanding the relationship between the subsurface features and the dune morphology is critical in protecting the island as well as the inland communities. In this study, we use several geophysical techniques, including Ground Penetrating Radar (GPR), Time Domain Electromagnetic (TEM), Frequency Domain Electromagnetic (FDEM), and Electrical Resistivity Tomography (ERT) to study the subsurface characteristics and to explain the complex relationship between the island geomorphology and subsurface conditions. Preliminary results indicated that the beach region, denoted as Zone I, displays the highest recorded apparent electric conductivity (289.7 ± 66.3 mS/m) alongside the lowest elevations (1.4 ± 0.2 m). These patterns are primarily attributed to the close proximity of the beach to saline groundwater and the occurrence of maritime floods. In contrast, the foredune area, referred to as Zone II, showcases the lowest apparent conductivity (19.0 ± 3.4 mS/m) and the greatest elevation (4.5 ± 0.4 m). These characteristics are a result of the greater distance from saline waters, deeper groundwater levels, and relatively dry soil conditions in this zone. Human activity has had a notable impact on Zones III (located in the east-central area) and IV (located in the west-central area). This impact is evident in the increased apparent conductivity (Zone III at 40.3 ± 21.8 mS/m; Zone IV at 159.5 ± 83.0 mS/m) and the decreased elevation (Zone III at 2.1 ± 0.5 m; Zone IV at 1.3 ± 0.4 m) observed in these zones. Anthropogenic activities have modified hydrologic patterns, introduced conductive materials, and altered vegetation cover and soil composition. This study unveils the intricate relationship among subsurface electrical

conductivity, surface morphology, and the influence of human development on the shape of barrier islands. These findings offer essential understanding for the management and preservation of coastal areas.

Short Biography

Ramadan Abdelrehim is currently a Ph.D. student at Texas A&M University-Corpus Christi. He is working in the Geophysics Lab with Dr. Mohamed Ahmed. His current focus involves the extensive use of geophysical techniques to study the characteristics of barrier islands, such as Padre Island. The goal is to gain insights into the intricate relationship between the island's subsurface geological structure and its surface geomorphology and their impact on the island’s response to storms and hurricanes. Ramadan previously worked as a research assistant at the Desert Research Center in Cairo, Egypt, from 2014 to 2021. During this period, he actively employed various geophysical and remote sensing methods for groundwater exploration and sustainable development studies, primarily within arid regions of Egypt. His background includes substantial fieldwork experience, totaling over 200 days, in diverse environments. Furthermore, he enriched his expertise through international exposure during a year-long tenure as a Visiting Research Scientist at Chiba University in Japan. This opportunity was made possible by the Egypt-Japan Education Partnership (EJEP) scholarship. It allowed him to delve into the realm of environmental remote sensing and engage in multidisciplinary research that harnessed remote sensing and geophysics to address environmental challenges and contribute to sustainable development strategies. His academic accomplishments include a master's degree in applied Geophysics from Ain Shams University in Cairo, Egypt, along with a bachelor's degree in Geophysics from Sohag University, Egypt.

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LUNCHEON MEETING ANNOUNCEMENT

January 17th, 2024

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The Balcones Igneous Province of South Central Texas: Revisions To The Age Of Volcanism and Suggestions For An Emplacement Mechanism

Mark E. Thompson Geologist

San Antonio, Texas

PRESENTATION ABSTRACT

Exposures of Cretaceous alkalic igneous rocks along the northern margin of the Texas Gulf Coast have been well documented since the earliest geological surveys of Texas. Intrusive exposures extend southward into the subsurface where igneous deposits become characterized by extrusive volcanic tuff mounds. All igneous deposits, both intrusive and extrusive are collectively known as the Balcones Igneous Province (BIP). The general geology of the BIP rocks is discussed along with a description of their composition which is dominated by ultramafic classifications.

Data obtained on the subsurface portion of the BIP from an active, ongoing oil and gas exploration program is used to prepare a series of detailed stratigraphic cross sections which permit dating of the volcanic events by stratigraphic methods. Volcanic eruptions in the BIP are documented to have commenced significantly earlier in the Cretaceous and to occur over a much longer duration of 24 Ma (late Cenomanian to early Maastrichtian) than the 8 Ma duration from age dates (late Santonian to Mid Campanian) offered by recently published geochronology studies. This revised age range for the BIP expands the time frame for BIP emplacement which has implications on geologic interpretations of Late Cretaceous plate movements in the northern Gulf of Mexico.

The tectonic history of south-central Texas is described and the relationship between the BIP and the Mesoproterozoic Llano Front, the late Paleozoic Ouachita Orogenic Front, and the early Mesozoic opening of the Gulf of Mexico is discussed.

Petrogenesis of the BIP requires eruption at the surface of deep-seated ultramafic magmatism on a passive continental plate margin with no evidence for the involvement of either subduction nor a "hot spot" thermal plume A suggestion is offered for an edge convection mechanism that satisfies this requirement.

BIOGRAPHY

Mark was born and raised in a very small dairy farming town in south-central Wisconsin. He attended the University of Wisconsin at Oshkosh where he received a Bachelor of Science degree in Geology and he then enrolled in graduate school at the University of Wisconsin at Milwaukee where he earned the Master of Science degree in Geology.

He has a 46-year career as a professional geologist which began in the mining industry in the Lake Superior area and continued in the oil and gas business in Texas. His years in Dallas, Houston and then in San Antonio involved employment by both large and small companies and also time spent on his own as an independent petroleum geologist. Mark owns Bastrop Energy Group, a San Antonio based exploration and production company, and in addition to operating oil properties he originates, leases and sells drill prospects in central Texas.

Mark is an active member of the South Texas Geological Society, AAPG, GSA and he has published numerous articles on the geology of south-central Texas. Mark and Jane, his wife of 44 years, have 2 children and 4 grandchildren.

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Hydrogeologic controls on barrier island geomorphology: Insights from electromagnetic surveys

Ramadan Abdelrehim[1,2], Mohamed Ahmed[1], and Mark E. Everett[3]

https://doi.org/10.1190/tle42090608.1

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Abstract

Barrier islands provide a first line of defense for coastal communities against storms, hurricanes, and sea-level rise. The geomorphology of barrier islands exerts a major control on storm impact and island recovery. In turn, barrier island geomorphology is affected by subsurface hydrogeologic conditions. In this study, we investigated the relationship between subsurface hydrogeologic conditions and geomorphology of Padre Island, with a focus on the influence of human development. We measured apparent electrical conductivities using frequency-domain electromagnetic (FDEM) surveys and spatially correlated them with the island's morphology. The latter was generated from a 1 m resolution digital elevation model. Four distinct zones were identified from the observed variations in apparent conductivity and elevation, revealing their inverse correlation. The beach area (Zone I) exhibits the highest apparent conductivity (289.7 ± 66.3 mS/m) and the lowest elevations (1.4 ± 0.2 m). These trends are largely due to the proximity of the beach to saline groundwater and maritime floods. Conversely, the foredune area (Zone II) presents the lowest apparent conductivity (19.0 ± 3.4 mS/m) and the highest elevation (4.5 ± 0.4 m) due to a greater distance from saline waters, deeper groundwater levels, and relatively dry soil conditions. Human development has significantly impacted Zones III (east central zone) and IV (west central zone), contributing to an increase in apparent conductivity (Zone III: 40.3 ± 21.8 mS/m; Zone IV: 159.5 ± 83.0 mS/m) and a reduction in elevation (Zone III: 2.1 ± 0.5 m; Zone IV: 1.3 ± 0.4 m). Anthropogenic activities have modified hydrologic patterns, introduced conductive materials, and altered vegetation cover and soil composition. This research elucidates the interplay between subsurface electrical conductivity, surface morphology, and the impact of human development on barrier island geomorphology, providing crucial insights for coastal management and conservation efforts.

Introduction

Approximately 600 million individuals (about 10% of the global population) reside in coastal regions that are less than 10 m above sea level. Population growth, urbanization, and coastward migration are all projected to increase (Nicholls et al., 2007; Baztan et al., 2015). Coastal communities are confronted with unique challenges compared to their inland counterparts including heightened risks associated with natural hazards such as high-tide flooding, hurricanes, tsunamis, and sea-level rise. These challenges are expected to be complicated by ongoing climate and anthropogenic forcings (NOAA, 2023).

Barrier islands provide a first line of defense for coastal communities against the aforementioned maritime hazards (Ruggiero et al., 2018; NOAA, 2021). Barrier island geomorphology plays a crucial role in determining the response of these systems to extreme events (Wernette et al., 2018). For example, an island's width and elevation exert a major control on its ability to absorb storm surges (Houser et al., 2008). The height, width, and vegetation cover of dunes help shape the impact of extreme events by dissipating wave energy and mitigating inland flooding (Sallenger, 2000; Nott, 2006; Houser and Hamilton, 2008). The availability of sediments beneath an island and the nearshore environment also influence recovery from extreme events (Leatherman, 1976; Houser and Hamilton, 2008).

The geomorphology of barrier islands results from complex scale-dependent interactions over wide ranges of time and space. Factors affecting island geomorphology include antecedent geologic structures and processes, sea-level changes, wave and current dynamics, sediment supply, vegetation cover, and human activities (Cooper et al., 2012; Wernette et al., 2018). We are interested in investigating how subsurface hydrogeologic conditions and human development contribute to the geomorphology of barrier islands. Padre Island, a major barrier system off the Texas Gulf Coast, was selected as a representative test site (Figure 1).

Study area

Padre Island, located off the Texas Gulf Coast, is the world's longest barrier island at 182 km in length. Roughly 3 km wide, it stretches from the city of Corpus Christi in the north to the resort community of South Padre Island in the south (Pendleton et al., 2004). The island is oriented north–south and is bordered by the Gulf of Mexico on the east and hypersaline Laguna Madre on the west (Figure 1). The southern and central part of Padre Island are preserved as the Padre Island National Seashore, which is approximately 108 km in length. A portion of the lower island (South Padre Island) is protected as part of the Laguna Atascosa National Wildlife Refuge, which is approximately 56 km in length. The study area of this research spans the northernmost 20 km of the island, including both developed and protected undeveloped stretches (Figure 1).

Padre Island's origin and geologic history have been discussed in detail (Brown et al., 1977; Garrison et al., 2010; Houser et al., 2018; Wernette et al., 2018). Briefly, during interglacial stages of the Pleistocene, inland rivers and streams discharged to a network of deltas along the Gulf Coast shoreline. The Pleistocene ravinement surfaces were deeply eroded by headwater tributaries of entrenched valley systems. Pleistocene river deposits now underlie the modern wind-tidal flats. As sea levels rose during the Holocene and flooded the pre-existing stream valleys, some of them became bays and

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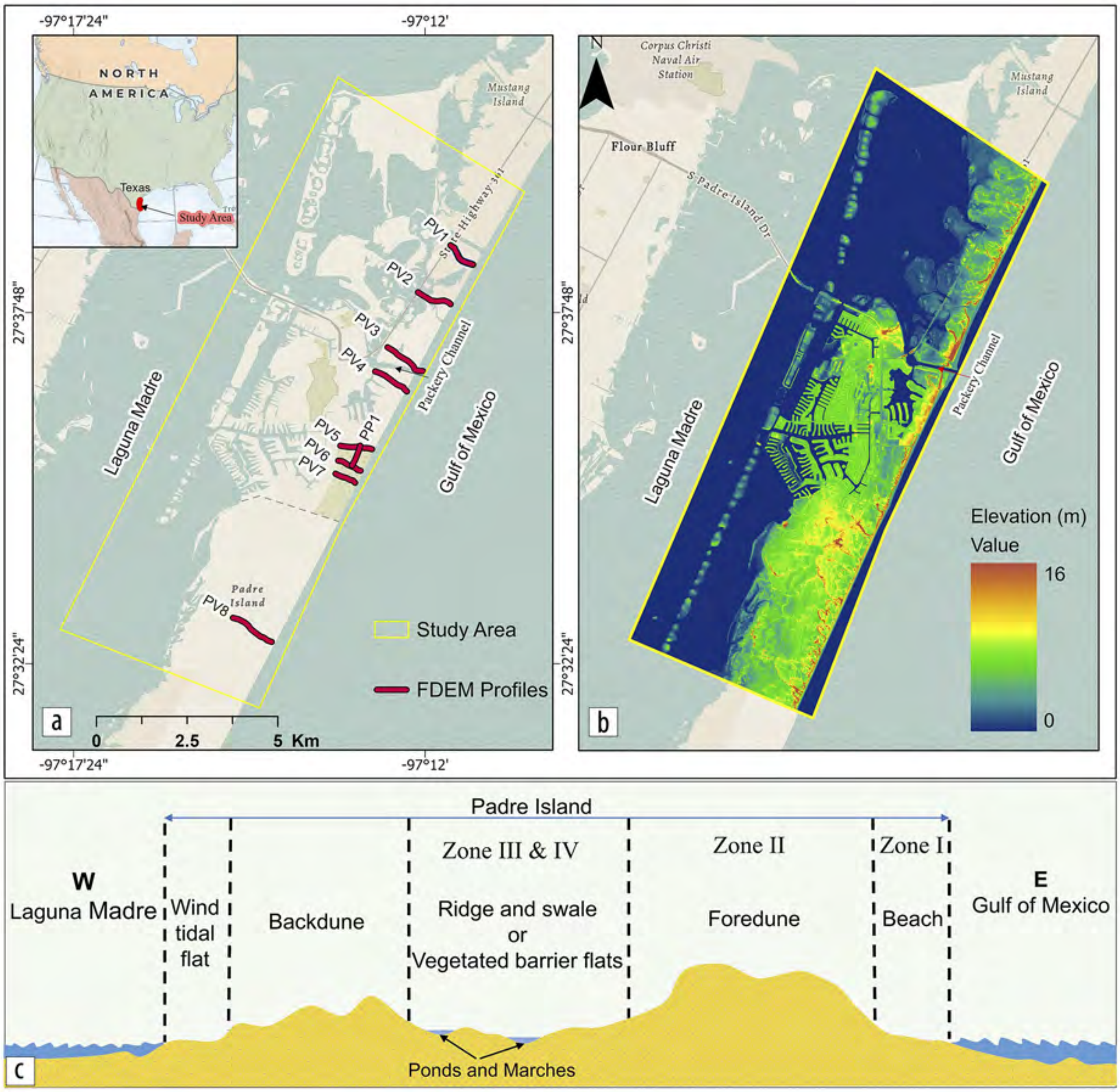

Figure 1. (a) Location map showing Padre Island and locations of the FDEM profiles. (b) LiDAR-derived DEM illustrating the diverse topographic variations across the study area. (c) A typical barrier island profile demonstrates the various characteristics that can be observed from the gulf side to the lagoon shoreline.

estuaries. Once sea levels stabilized, sand shoals and offshore bars between the drowned river valleys began to merge. In the Late Holocene, the shoals emerged from the sea to become a series of low discontinuous sandy islands aligned parallel to the mainland shoreline.

Stratigraphically, the base of the barrier-lagoon system consists of Pleistocene sand and mud overlain by shoreface sand and mud, washover and aeolian deposits, and lagoonal muds (Brown et al., 1977; Houser et al., 2018). The depth to the Pleistocene ravinement surface (in this case, the top of the Beaumont Formation) varies considerably along the length of the island. The thickness of modern deposits of shoreface sands is estimated to be 2–3 m, whereas the thickness of older shoreface sands and muds can be approximately 10 m or greater within the paleochannels (Garrison et al., 2010). A topographical analysis shows that Padre Island exhibits a range of elevations, extending from approximately 0 up to 16 m above mean sea level. Despite the wide range, the mean elevation of the island is relatively low, averaging only approximately 0.38 m. The study area ranges in elevation from 0 to 13.3 m, averaging 1.8 m (Figure 1b). Figure 1c presents a generalized cross section of Padre Island, delineating the diverse features that span from the Gulf of Mexico to the Laguna Madre, along with the distinct morphological zones identified in this study.

Methods

In this study, surface and subsurface data sets were collected to investigate how subsurface hydrogeologic conditions control the geomorphology of Padre Island. The research focused on understanding the relationship between subsurface electrical conductivity, which was determined using frequency-domain electromagnetic (FDEM) techniques, and the island's geomorphology. A 1 m resolution digital elevation model (DEM) was used to extract the island's geomorphologic features. Hydrogeologic conditions were inferred from electromagnetic

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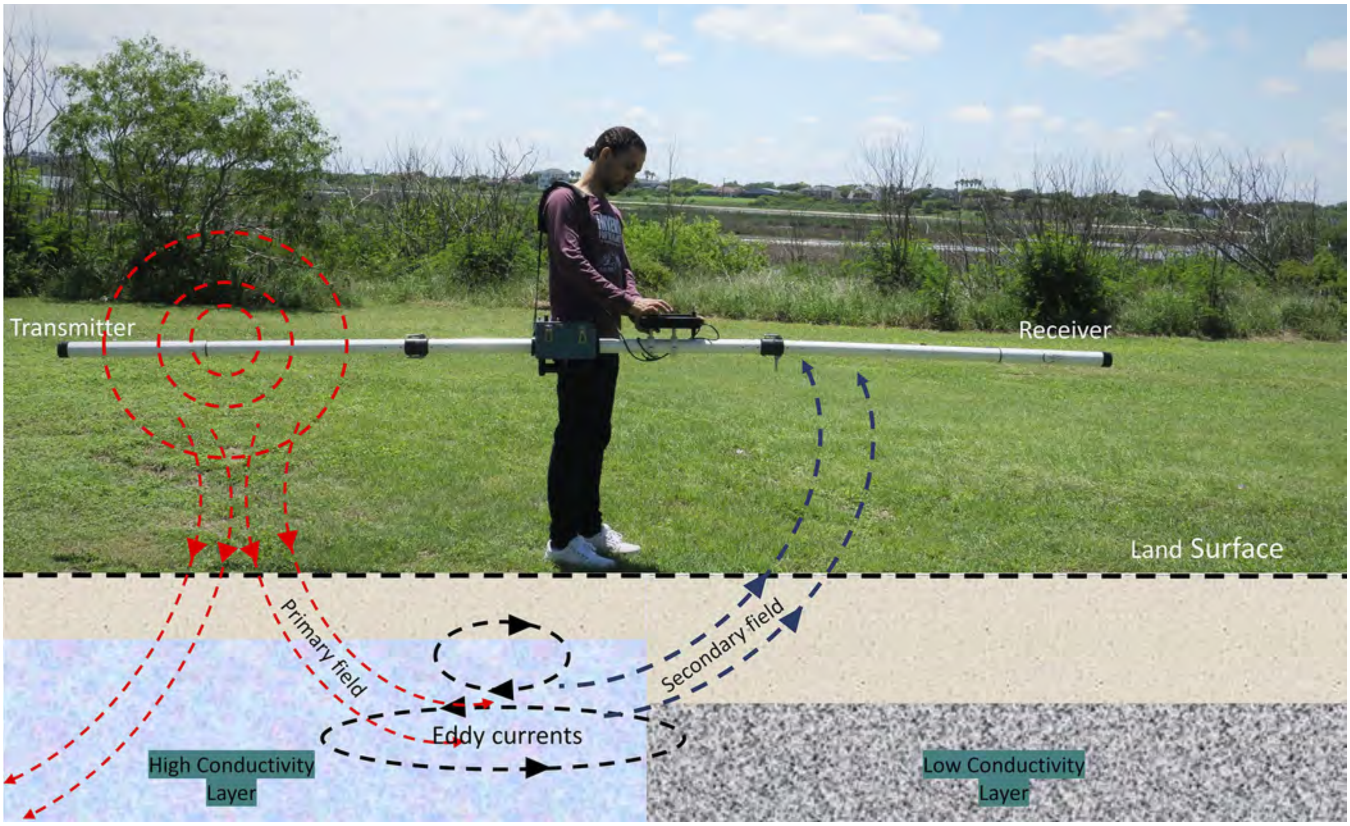

Figure 2. Field image and schematic representation of the Geonics EM-31 system configuration (Geonics Ltd., 1995), illustrating the operational methodology for acquiring apparent conductivity measurements along profiles.

measurements, as described later. Correlations were then established between hydrogeologic conditions and the island's surface morphology, considering both developed and undeveloped areas. The correlations provide insight into mechanistic connections between surface characteristics and subsurface structures and hydrologic processes.

Frequency-domain electromagnetic techniques. The terrain conductivity meter is a noninvasive geophysical instrument that operates on the principles of electromagnetic induction. Meter readings record lateral variations in apparent electrical conductivity (in mS/m) as the instrument is moved along a profile. Apparent conductivity is a measure of bulk electrical conductivity averaged over the instrument footprint. More precisely, apparent conductivity at a given location is simply the electrical conductivity of a hypothetical homogeneous half-space that would generate the observed meter reading at that location. The FDEM method has become a popular tool for near-surface geophysical applications because the one-person-portable terrain meters can cover large areas in a short period of time and are inexpensive compared to many other geophysical techniques (McNeill, 1980; Everett, 2013; Aly et al., 2018).

FDEM surveys were conducted using the Geonics Ltd. EM-31 instrument along the nine profiles shown in Figure 1a. These profiles were oriented perpendicular and parallel to the shoreline. One of the profiles (PV8) is situated in a pristine undeveloped area. The remaining profiles are located within developed regions of Padre Island (Figure 1a).

The EM-31 instrument (Geonics Ltd., 1995) (Figure 2) provides a rapid qualitative means to map apparent conductivity in coastal environments. The EM-31 is robust, efficient, and easy to operate. A time-varying magnetic field is generated by the transmitter coil. It penetrates the conductive ground and, according to Faraday's law, induces eddy currents to flow in the subsurface. The induced currents, in turn, generate a secondary magnetic field that is detected by the receiver coil and registered as a voltage. A simple formula converts the received voltage to apparent conductivity (McNeill, 1980). EM-31 operates at a fixed frequency (9.8 kHz) and fixed 3.66 m offset between transmitter and receiver coils. The depth of investigation is approximately 6 m, depending on the subsurface conductivity (McNeill, 1980; Reid and Howlett, 2001).

High-resolution terrain conductivity data were collected in this study. An average of 11 measurements were collected per profile meter in continuous acquisition mode. The nine profiles were lengths from 582 to 1234 m (Figure 1a). A thorough quality control was implemented to ensure reliability and validity of the measurements. Nonpositive apparent conductivity readings, herein attributed to interference from nearby man-made structures, were identified within the data set. These readings are presumed to be nonrepresentative of the naturally varying subsurface conditions and were systematically excluded from subsequent data analyses. This rigorous data-cleansing approach enhances the robustness of our interpretations by reducing the impact of potential anthropogenic signals.

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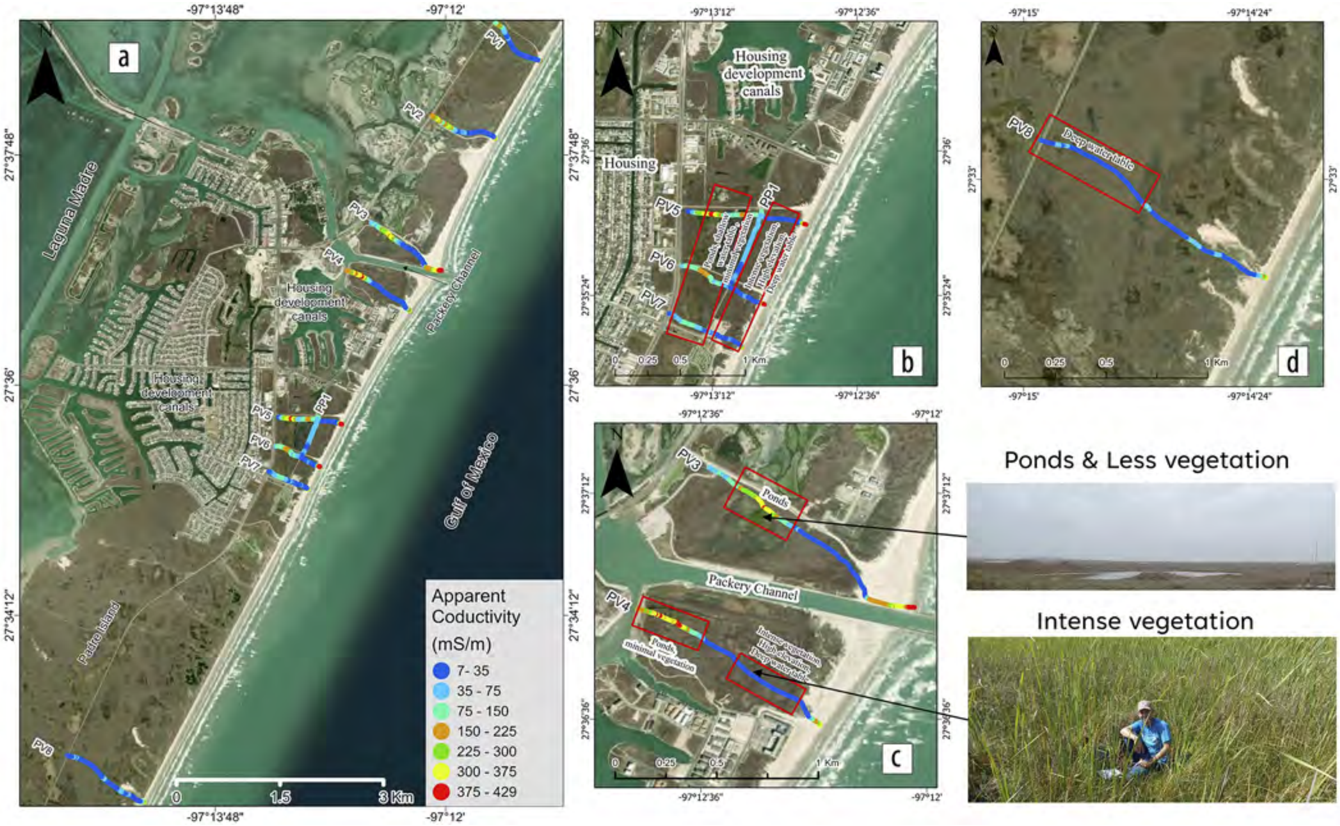

Figure 3. (a) Spatial variations in the apparent conductivity across Padre Island. Also shown are the spatial variability in apparent conductivity with (b and c) human development, (c and d) depth to water table, and (c) vegetation cover.

Digital elevation model. High-resolution (1 m) DEM data were used in this study to extract the island's geomorphology. This product was collected in 2018 through the U.S. Geological Survey 3D Elevation Program (3DEP) using light detection and ranging (LiDAR) technology (USGS, 2020). The 1 m DEM is the highest resolution offered in the 3DEP product suite. The DEM (vertical accuracy of ±0.53 m) represents the topographic bare-earth surface, excluding features such as buildings and vegetation (USGS, 2022).

Results

On Padre Island, four distinct zones were identified by breakpoints in the apparent conductivity and elevation profiles (Figures 3a and 4). Generally, elevation exhibited an inverse correlation with terrain conductivity (correlation coefficient of −0.69). Measurement statistics by zone are given in Table 1. Zone I (the beach) extends from the shoreline to the base of the foredune, with a highly variable length that averages 41.7 m. This zone displays a low elevation and the highest apparent conductivity of the four zones. Zone II, with an average length of 221 m, encompasses the foredune and exhibits the highest elevation and the lowest apparent conductivity. Extending beyond the foredune to the central parts of the island characterized by ridges and swales, Zone III has an average length of 335 m. The apparent conductivity and elevation in this zone are intermediate. Zone IV extends farther into the central parts of the island, with an average length of 286 m. This zone shares similar elevation with Zone I but exhibits lower apparent conductivity.

Apparent conductivity and, to a lesser extent, elevation within the identified zones exhibit significant spatial variability (Figure 4). The measurement statistics by profile (average conductivity and average elevation) subdivided into zones appear in Table 2. In the pristine undeveloped areas of Padre Island (PV8), Zone I exhibits a moderate apparent conductivity. Despite relatively similar elevations with those of the undeveloped areas, Zone I's apparent conductivity is considerably higher in the developed areas (PV5, PV6, and PV7). The apparent conductivity and elevation values in Zone II are comparable across both developed (PV4, PV5, PV6, and PV7) and undeveloped (PV8) areas. Zone III's apparent conductivity in the undeveloped area (PV8) is relatively lower than that of the developed area (PV5), whereas the opposite is true for elevation. The PP1 profile, operating within the scope of Zone III, maintains a direction parallel to the shoreline and stretches between the PV5 and PV6 points. Zone IV shows significant differences in both elevation and apparent conductivity between developed and undeveloped areas. Over the undeveloped area (PV8), Zone IV's apparent conductivity is low, while elevation is high. Over the developed areas (PV2, PV3, PV4, and PV5), the converse is true.

Discussion

The beach area (Zone I) exhibits the highest apparent conductivity compared to the other zones. The beach is in closest proximity to the saline waters of the Gulf of Mexico, which must play a significant role via enhancing the conductivity of groundwater underlying the shoreface. Zone I is also more prone to

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frequent maritime flooding caused by high tides and storm surges. The relatively frequent intrusion of saline water, infiltrating into the subsurface, should further enhance the apparent conductivity of Zone I. The continuous and repetitive back-and-forth movement of waves tends to level the beach area over time, resulting in the observed lower elevations.

The foredune area (Zone II) has the lowest apparent conductivity and the highest elevation among the identified zones. The combination of higher elevation, deeper groundwater level, infrequent occurrences of maritime flooding, infiltration of fresh precipitation, and presence of relatively dry soil collectively contribute to low electrical conductivity in this zone. As elevation increases, the near surface is less susceptible to direct contact with saline water. Moreover, the relatively greater distance from the shoreline results in reduced exposure to salts and other minerals that would increase subsurface electrical conductivity. In areas where the groundwater table is relatively deep, the dune environment becomes more conducive to the growth of freshwater-dependent plant species that are adapted to soils with limited exposure to saline water. Their presence and growth contribute to the stabilization of the dune system. As these plants establish themselves, their root systems help bind the soil, preventing erosion and maintaining a high dune elevation. As rainfall occurs, fresh water infiltrates the soil, diluting the concentration of salts and minerals and leading to a decrease in electrical conductivity in the foredune area. Finally, the relatively dry foredune conditions act as a barrier to the movement of electrical current, contributing to the observed lower apparent conductivity measurements.

Significant portions of Zones III and IV on Padre Island are affected by human development. Anthropogenic activity can modify natural hydrologic processes, introduce new sources of high conductivity such as metal infrastructure, influence vegetation dynamics, and alter the composition of soils and their fluid content and chemistry. For example, constructing waterway systems and housing-development canals disrupts groundwater flow patterns. The dredging of canals (e.g., Packery Channel and housing-development canals; Figure 1) can have significant consequences. By reducing the distance that groundwater must travel to its point of discharge to the sea, the construction of canals leads to lowered water-table levels, and subsequently, increased conductivity in the surrounding areas. For example, areas near Packery Channel and housing-development canals in PV3, PV4, and PV5 exhibit higher conductivity values within Zones III (44–95 mS/m) and IV (200–297 mS/m) (Figures 3b and 3c). This is in contrast to areas located farther

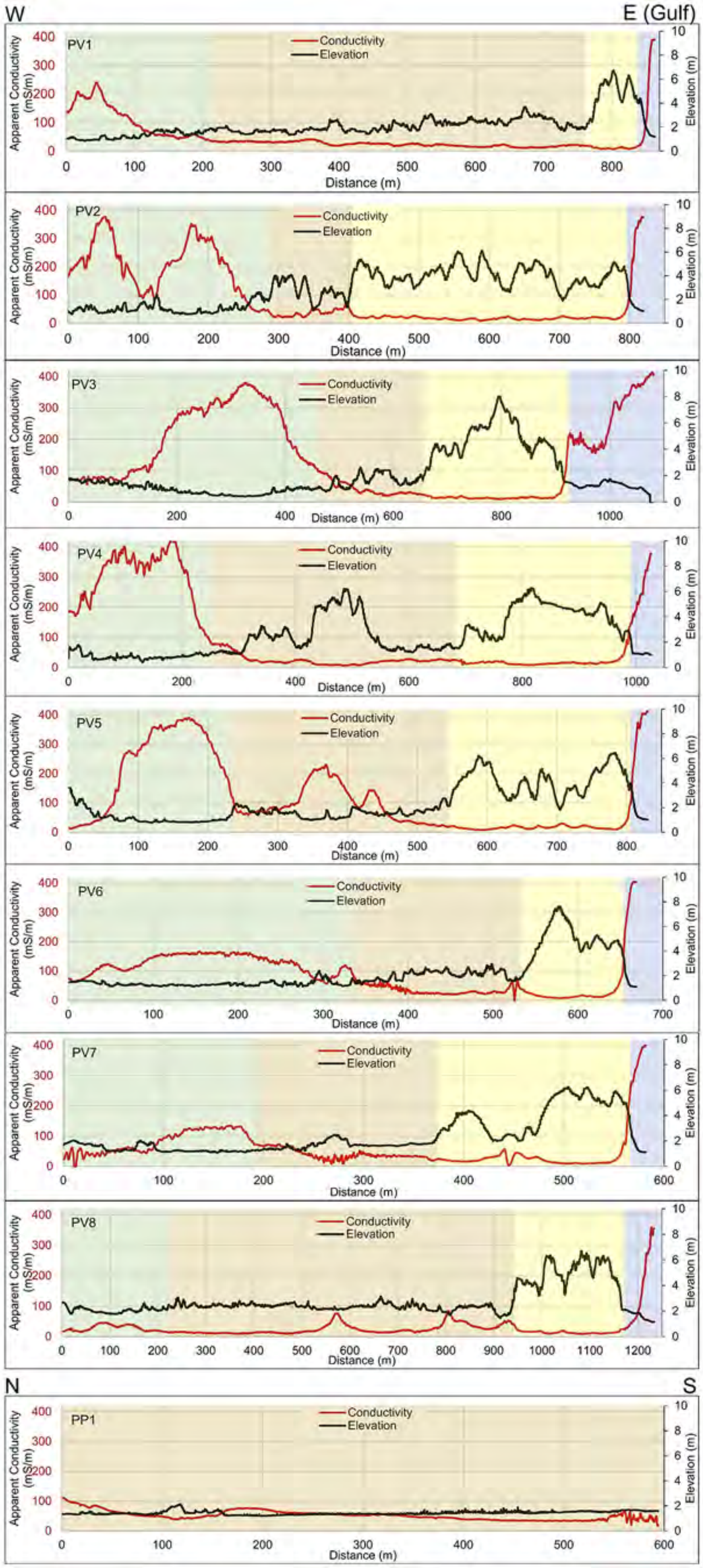

Figure 4. Spatial variations in apparent conductivity and elevation across Padre Island. The four distinct zones are shown with light colors (Zone I: blue; Zone II: yellow; Zone III: tan; Zone IV: green). Profile locations are shown in Figure 1a.

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Table 1. Measurement statistics by zone. Conductivity and elevation values were reported by mean ± STD.

Zone	Apparent conductivity (mS/m)	Elevation (m)
I (beach area)	289.7 ± 66.3 (highest)	1.4 ± 0.3
II (foredune area)	19.0 ± 3.4(lowest)	4.5 ± 0.4 (highest)
III (east central zone)	40.3 ± 21.8	2.1 ± 0.5
IV (west central zone)	159.5 ± 83.0	1.3 ± 0.4 (lowest)

Table 2. Measurement statistics by profile subdivided into zones. Measurements for the undeveloped area PV8 are shown in bold.

Zone	Profile	Apparent conductivity (mS/m)	Elevation (m)
I	PV1	293.1 ± 106.8	1.5 ± 0.2
	PV2	285.1 ± 95.5	1.4 ± 0.3
	PV3	272.3 ± 87.3	1.2 ± 0.4
	PV4	254.7 ± 70.2	1.1 ± 0.1
	PV5	382.0 ± 28.2	1.2 ± 0.1
	PV6	337.0 ± 73.5	1.6 ± 0.7
	PV7	344.6 ± 44.9	1.6 ± 0.5
	PV8	**148.8 ± 115.1**	**1.6 ± 0.3**
II	PV1	14.6 ± 13.4	5.0 ± 1.0
	PV2	18.2 ± 6.7	4.1 ± 0.8
	PV3	19.2 ± 26.5	4.6 ± 1.5
	PV4	18.8 ± 18.3	4.1 ± 1.2
	PV5	22.5 ± 34.2	4.1 ± 1.1
	PV6	18.5 ± 16.2	5.0 ± 1.2
	PV7	25.4 ± 28.5	4.1 ± 1.4
	PV8	**14.8 ± 6.2**	**4.9 ± 1.1**
III	PV1	23.9 ± 7.7	2.1 ± 0.5
	PV2	36.6 ± 13.1	2.9 ± 0.9
	PV3	43.8 ± 23.7	1.6 ± 0.5
	PV4	25.1 ± 17.5	2.5 ± 1.4
	PV5	94.8 ± 58.7	1.6 ± 0.4
	PV6	34.3 ± 13.1	2.1 ± 0.4
	PV7	39.9 ± 16.2	1.7 ± 0.3
	PV8	**23.8 ± 15.8**	**2.3 ± 0.2**
	PP1	52.8 ± 15.8	1.4 ± 0.1
IV	PV1	107.4 ± 60.9	1.3 ± 0.3
	PV2	199.6 ± 95.5	1.3 ± 0.5
	PV3	206.8 ± 109.7	1.0 ± 0.4
	PV4	297.2 ± 90.4	0.9 ± 0.2
	PV5	230.6 ± 134.3	1.2 ± 0.6
	PV6	124.1 ± 32.3	1.3 ± 0.2
	PV7	81.4 ± 37.1	1.4 ± 0.3
	PV8	**28.6 ± 9.8**	**2.1 ± 0.2**

away from them (24–29 mS/m) (Figure 3d). Additionally, the use of impervious materials in development reduces the recharge rate of water into the soil, increases runoff, and can create evaporation ponds with high salt and mineral content. In Figures 3b and 3c, it can be observed that areas in close proximity to these ponds display elevated conductivity values ranging from 95–230 mS/m within Zones III and IV. Conversely, areas situated at a greater distance from the ponds exhibit lower conductivity values ranging from 24–29 mS/m. A shallower water table can weaken the dune structure, lower its height, and make it more susceptible to erosion by storm events. If the water table is shallow, the growth of vegetation is impeded, further destabilizing the dune. Regions with a shallower water table exhibit higher conductivity values (95–230 mS/m) within Zones III and IV in contrast to areas located farther away from them (24–28 mS/m) (Figures 3c and 3d). Human development also introduces various conductive materials and substances into the environment such as metal, wiring, fertilizers, and industrial waste. These additions alter the composition of the soil, generally increasing its apparent conductivity. Moreover, changes in vegetation cover caused by human development can have significant implications. Vegetation plays a crucial role in regulating water balance, evapotranspiration rates, and nutrient dynamics. When natural vegetation is removed or altered, deeper infiltration can occur, potentially leading to increased electrical conductivity in the soil and groundwater. Areas with minimal vegetation cover exhibit higher conductivity values (250–380 mS/m) within Zones III and IV in contrast to areas with intense vegetation (15–25 mS/m) (Figure 3c).

Conclusion

Barrier islands are critical defenses against natural hazards for coastal communities worldwide, and their importance is expected to increase due to anticipated population growth, urbanization, and sea-level rise. This research uses electromagnetic geophysical measurements to investigate the complex links between subsurface hydrogeologic conditions and barrier island geomorphology through a comprehensive case study at Padre Island. Four distinct zones were identified, each marked by distinct levels of conductivity and elevation. The beach area shows high conductivity and low elevations due to its proximity to saline groundwater and maritime floods. The foredune area, on the other hand, demonstrates the lowest conductivity and highest elevation, attributed to its greater distance from saline waters, deeper groundwater levels, and relatively dry soil conditions. The study also reveals the significant impact of human development on the island, as evident in the changes in conductivity and elevation in the east and west central zones.

The findings emphasize the significant role of anthropogenic factors in substantially altering surface and subsurface conditions and subsequently impacting island morphology. The findings also suggest that understanding the interactions between surface and subsurface conditions can help guide sustainable development practices, ensuring the resilience of the coastal environment. Future research is needed to further refine our understanding of the interactions between subsurface conditions, surface morphology, and human activities across

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different geologic settings and scales. By doing so, we can better predict the behavior of barrier islands in the face of changing climate and anthropogenic pressures, informing effective management and conservation strategies to safeguard our coastal communities. TLE

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Data and materials availability

Data associated with this research are available and can be obtained by contacting the corresponding author.

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NEW (2019)TYPE LOGS IN RED; lost now found

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Aransas Pass/McCampbell Deep
Bartell Pass
Blackjack
Burgentine Lake
Copano Bay, South
Estes Cove
Fulton Beach
Goose Island
Half Moon Reef
Nine Mile Point
Rockport, West
St. Charles
Tally Island
Tract 831-G.O.M. (offshore)
Virginia

BEE COUNTY
Caesar
Mosca
Nomanna
Orangedale(2)
Ray-Wilcox
San Domingo
Tulsita Wilcox
Strauch_Wilcox

BROOKS COUNTY
Ann Mag
Boedecker
Cage Ranch
Encintas
ERF
Gyp Hill
Gyp Hill West
Loma Blanca
Mariposa
Mills Bennett
Pita
Tio Ayola
Tres Encinos

CALHOUN COUNTY
Appling
Coloma Creek, North
Heyser
Lavaca Bay
Long Mott
Magnolia Beach
Mosquito Point
Olivia
Panther Reef
Powderhorn
Seadrift, N.W.
Steamboat Pass
Webb Point
S.E. Zoller

CAMERON COUNTY
Holly Beach
Luttes
San Martin (2)
Three Islands, East
Vista Del Mar

COLORADO COUNTY
E. Ramsey
Graceland N. Fault Blk
Graceland S. Fault Blk

DEWITT COUNTY
Anna Barre
Cook
Nordheim
Smith Creek
Warmsley
Yorktown, South

DUVAL COUNTY
DCR-49
Four Seasons
Good Friday
Hagist Ranch
Herbst
Loma Novia
Petrox
Seven Sisters
Seventy Six, South
Starr Bright, West

GOLIAD COUNTY
Berclair
North Blanconia
Bombs
Boyce
Cabeza Creek, South
Goliad, West
St Armo
Terrell Point

HIDALGO COUNTY
Alamo/Donna
Donna
Edinburg, West
Flores-Jeffress
Foy
Hidalgo
LA Blanca
McAllen& Pharr
McAllen Ranch
Mercedes
Monte Christo, North
Penitas
San Fordyce
San Carlos
San Salvador
S. Santallana
Shary
Tabasco
Weslaco, North
Weslaco, South

JACKSON COUNTY
Carancahua Creek
Francitas
Ganado & Ganado Deep
LaWard, North
Little Kentucky
Maurbro
StewartSwan Lake
Swan Lake, East
Texana, North
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JIM HOGG COUNTY
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Freebom
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Wade City

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Burnell
Coy City
Person
Runge

KENEDY COUNTY
Candelaria
Julian
Julian, North
Laguna Madre
Rita
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KLEBERG COUNTY
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Alazan, North
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Chevron (offshore)
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LA SALLE COUNTY
Pearsall
HAWKVILLE:EAGLEFORD

LAVACA COUNTY
Halletsville
Hope
Southwest Speaks
Southwest Speaks Deep

LIVE OAK COUNTY
Atkinson
Braslau
Chapa
Clayton
Dunn
Harris
Houdman
Kittie West-Salt Creek
Lucille
Sierra Vista
Tom Lyne
White Creek
White Creek, East

MATAGORDA COUNTY
Collegeport

MCMULLEN COUNTY
Arnold-Weldon
Brazil
Devil's Waterhole
Hostetter
Hostetter, North

NUECES COUNTY
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Arnold-David
Arnold-David, North
Baldwin Deep
Calallen
Chapman Ranch
Corpus Christi, N.W.
Corpus Christi West C.C.
Encinal Channel
Flour Bluff/Flour Bluff, East
GOM St 9045(offshore)
Indian Point
Mustang Island
Mustang Island, West
Mustang Island St.
889S(offshore)
Nueces Bay/Nueces Bay
West
Perro Rojo
Pita Island
Ramada
Redfish Bay
Riverside
Riverside, South
Saxet
Shield
Stedman Island
Turkey Creek

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Greta
La Rosa
Lake Pasture
Refugio, New
Tom O'Connor

SAN PATRICIO COUNTY
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Commonwealth
Encino
Enos Cooper
Geronimo
Harvey
Hiberia
Hodges
Mathis, East
McCampbell Deep/Aransas Pass
Midway
Midway, North
Odem
Plymouth
Portilla (2)
Taft
Taft, East
White Point, East

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Garcia
Hinde
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Rincon
Rincon, North
Ross
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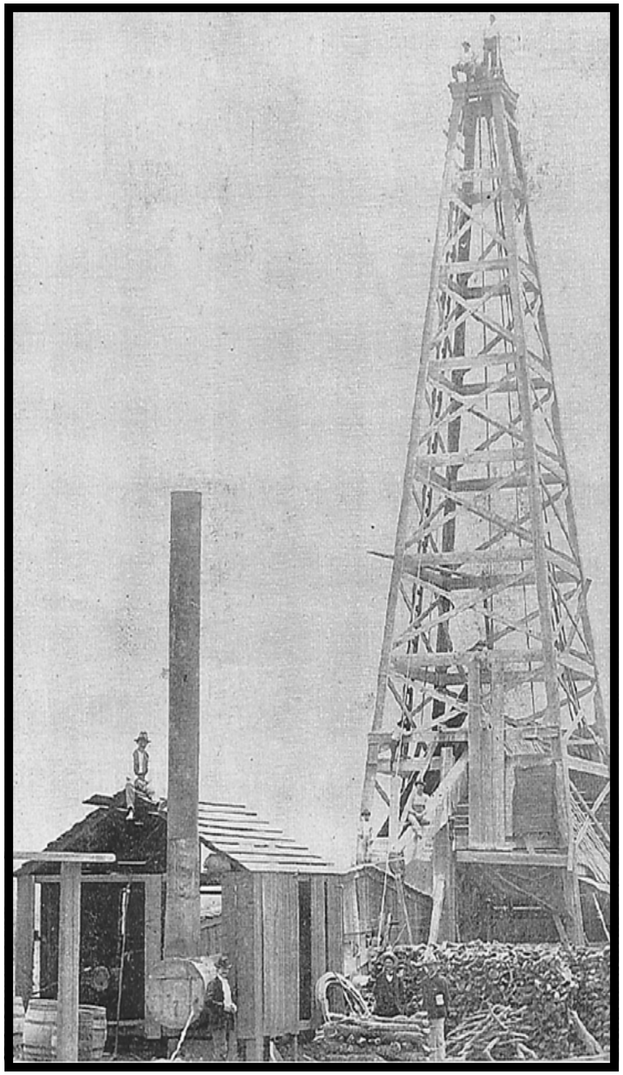

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