

INSIGHTS INTO EVOLUTION OF FIRE ISLAND AT ROBERT MOSES STATE PARK USING GPR AND OSL

By

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South shore of Long Island is characterized by well-defined system of barrier islands and spits which is common on passive margins with adequate sediment source. Barrier islands and spits are sediment deposits parallel to the shore line and are built by longshore transport of sediment. This type of coastal environment is sensitive to storm surges and sea level changes as the islands will migrate landward or be breached as a consequence. The proximity of Long Island's south shore to the most populated metropolitan area in the country means that every disruption of this system comes at a large cost to the local and regional communities as witnessed in the aftermath of some recent storms. Mapping out the behavior of this system in the past can tell us a great deal about past climate and sediment transport and such knowledge would greatly improve our prediction for their behavior in the future. In pursuit of interpretation of these paleorecords one has to study sedimentology and geomorphology of such environments in detail and accompany it with geochronology in order to put time constraints on various past events (Reimann, Lindhorst et al. 2012).

The sedimentology of underlying sediments in a beach and barrier island setting can be assessed directly by observing the sediments in sediment sections if they exist or by coring. However, a noninvasive technique like Ground Penetrating Radar (GPR) gives us a good idea of subterranean sediment structures by using electromagnetic waves to image subsurface. It has been widely used to identify subsurface structures in coastal studies with great success (Bristow, Chroston et al. 2000, Havholm, Ames et al. 2004, Buynevich, FitzGerald et al. 2007, Lindhorst, Betzler et al. 2008, Mallinson, Burdette et al. 2008, Lindhorst, FÜRstenau et al. 2010, Fruergaard, Moller et al. 2015). Also, GPR enables surveying subsurface of large areas and exposing the places of special interest or features that point to a past event and need to be sampled later for dating or other analyses thus reducing the amount of invasive exploration.

Fire Island is a large thin barrier island parallel to the south shore of Long Island (Figure 1.), New York. The island is approximately 50 km long and between 160 and 400 m wide with the area of about 25 km². Robert Moses State Park is located on the western part of the Fire Island. Historic maps, GIS and satellite images demonstrate that Fire Island has experienced a remarkable change over the last 150 years with the most notable expansion of the island westward by about 7 kilometers to its present position (Itzkin 2016).



Figure 2. Fire Island shown in green. Robert Moses State park is the western most part of the Fire Island shown in white (U.S. Department of Interior, National Park Service, modified by Franz Gstättner).

The Park has been extensively studied with GPR as a part of a senior thesis study done by Michael Itzkin and Dan Davis (Itzkin 2016). They have covered the area of the Park with almost 5 km of GPR lines running the length of the park in the E-W direction and two lines crossing the island from ocean side to the South to the bay side on the North as well as a few shorter cross lines along the 5 km long GPR line as shown in Figure 3.

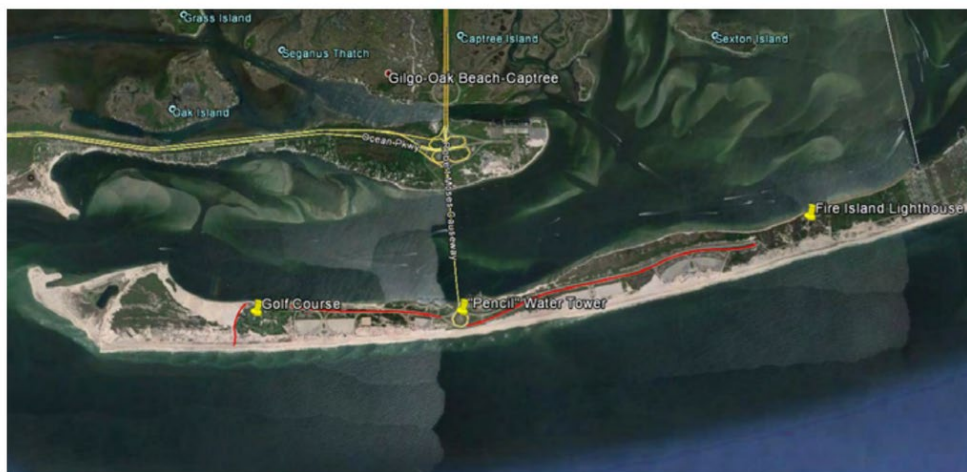


Figure 3. Current day satellite image of Robert Moses State park showing GPR lines shown in red. Robert Moses State Park Pitch and Putt Golf Course, the water tower and the Fire Island Lighthouse are marked with yellow pins (Itzkin 2016).

After processing, GPR lines running the length of the island showed shallow dipping beds extending westward with the dip angle of 4° which is indicative of prograding paleoshore as well as erosional surfaces and features suggesting past lobes of the island. GPR transect outlined in

red going from the ocean side in the south to the bay side in the north (Figure 3.) clearly showed erosional and depositional surfaces as well as the water table and salt/fresh water boundary outlined in red and yellow in Figure 4. The depositional surfaces with the angle of 4° can be interpreted as past beach and the best explanation for the distinct erosional surfaces in the absence of more data is that they are erosional events of the past storms.

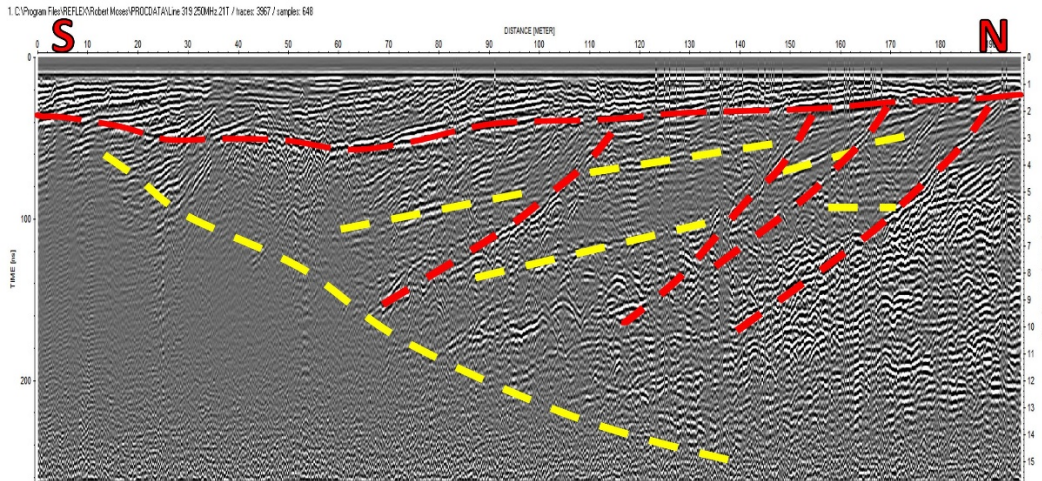


Figure 4. GPR line crossing the Fire Island at Robert Moses State Park. Ocean side is to the left.

This study provided some intriguing information about the subsurface of Fire Island and encouraged more GPR studies and sampling for Optically Stimulated Luminescence (OSL) dating.

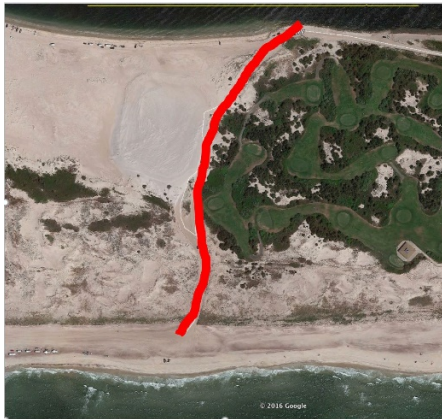


Figure 5. Outlined in red is a 500 m long truck path that crosses the Fire Island in the western part of Robert Moses State park from ocean to bay.

Several GPR lines were run the length of the path shown in Fig. 5. The resulting radar images provide a cross-section of the whole island from ocean side to bay side. Radar images clearly outline the salt/fresh water boundary (Figure 6.). In addition they show shallow dipping beds of beach deposits and steeper erosional surfaces as can be seen in Figure 7. These images were used to narrow down the area with multiple superimposed erosional and depositional surfaces that are of most interest for OSL sampling.

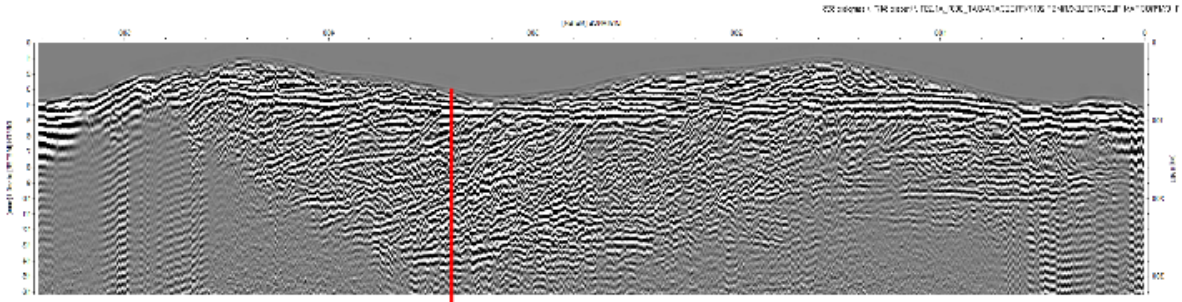


Figure 6. 500 m long GPR line at Robert Moses State Park spanning the island. Ocean side is on the left and bayside is on the right.

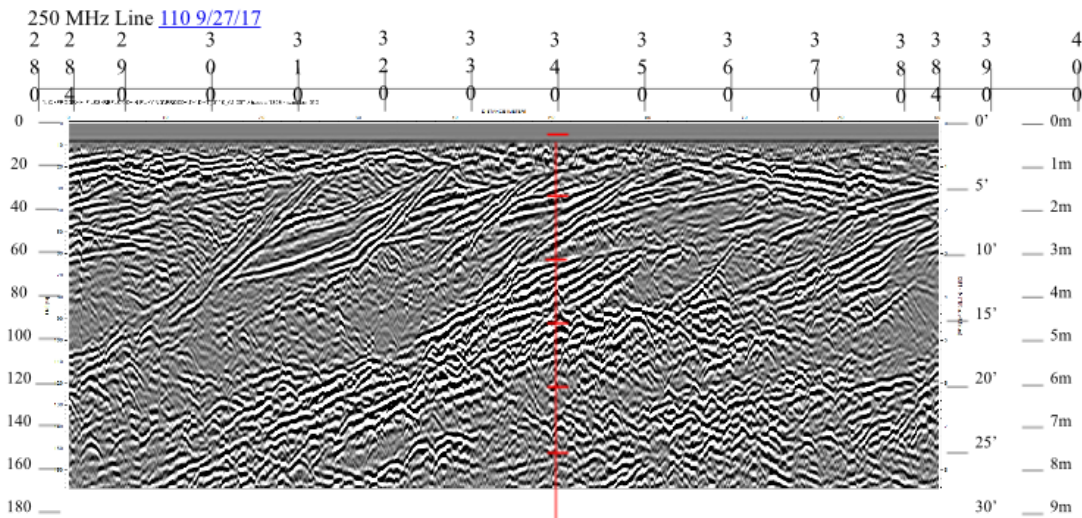


Figure 7. GPR image of the area chosen for sampling. Red line shows the position of geoprobe sample site.

Geoprobe is a truck-mounted coring device that uses pushing rather than drilling to force a core into the ground (Figure 8.). The core is taken in 6 ft increments that are lined with transparent plastic sleeves. Samples were collected up to the depth of ~8 meters at which point the probe came to a stop and the layer beneath was impenetrable for the probe.



Figure 8. Geoprobe sampling at Robert Moses State Park, Oct. 2017.

The cores were taken to the OSL laboratory in the Department of Geosciences at Stony Brook University for processing. Two dates from the very bottom of the extracted core were 130+/-20 and 130+/-30 years ago.

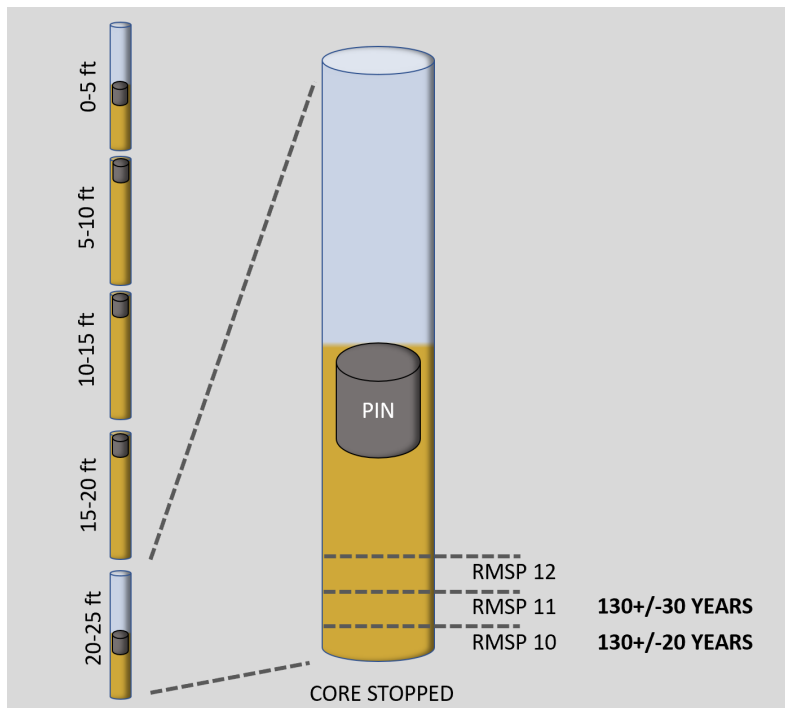


Figure 9. Diagram showing the core increments and position of the dates from the bottom segment.

The ages correlate well with the historical maps and the hypothesis that the Island in this area developed within last 150 years. The sudden stop in coring at ~8 m depth was explained by the possibility of compacted fine back barrier sediments that were overrun by the island sand migration (Fig. 9).

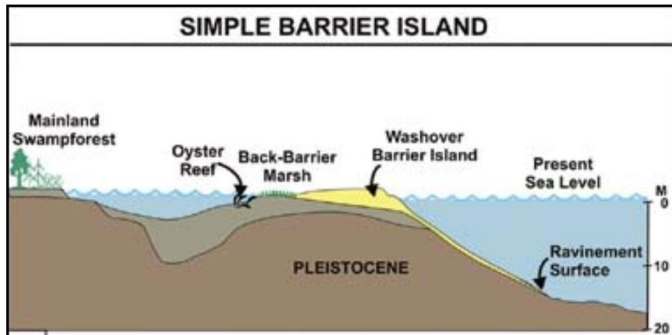
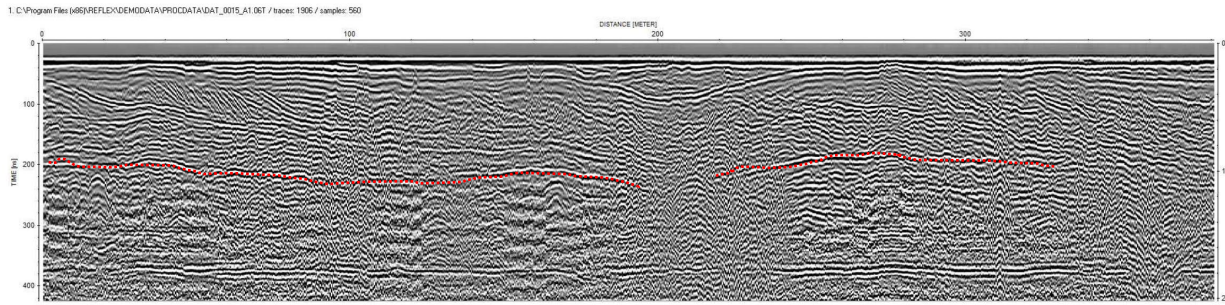


Figure 9. Diagram of a barrier island in North Carolina (S. R. riggs 2008)

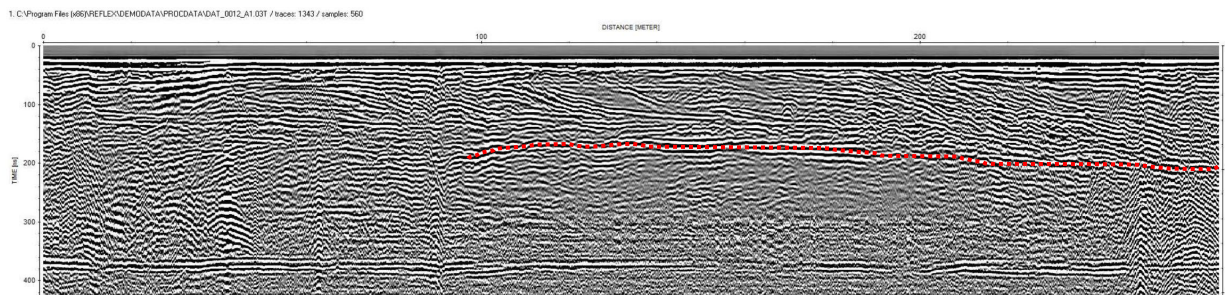
Additional GPR surveys (Figure 10.) of the area show a distinct reflector at the depth of 200 ns across adjacent radar images (Figure 11.). Each line was surveyed with 250 MHz and 100 MHz antenna. Higher frequency antennae show more detail but do not penetrate as deep, lower frequency results in a cruder image but has the potential for deeper imaging. Results from both frequencies are used in conjunction to describe the subsurface features in the area.



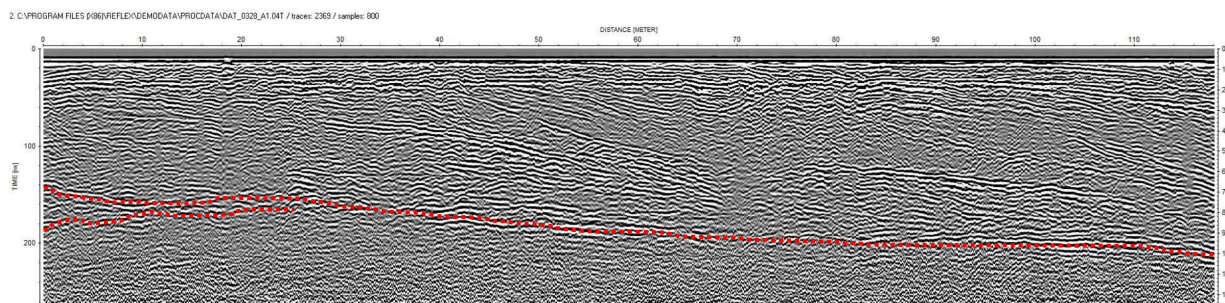
Figure 10. Google map showing GPR lines in Robert Moses State Park golf course and picnic area. The original GPR line and Geo-probe site are shown in yellow. Red lines show new GPR survey lines.



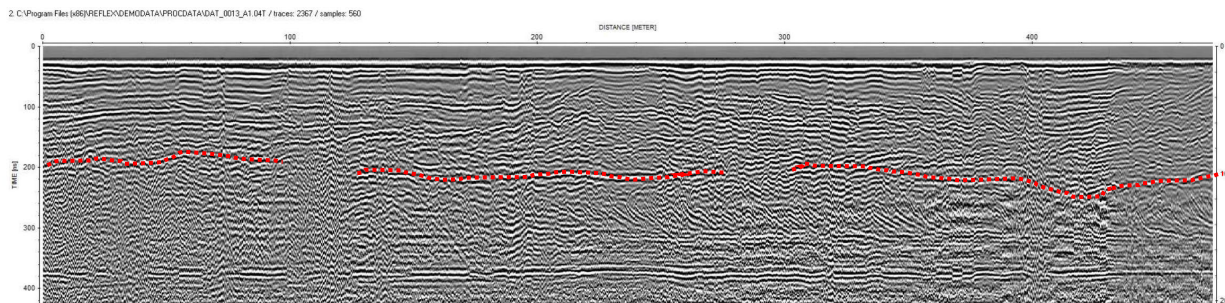
LINE 1 100MHz



LINE 2 100MHz



LINE 3 250 MHz



LINE 4 100MHz

Figure 11. Radar images of golf course and adjacent picnic area in Robert Moses State Park.

Results show high likelihood of a continuous layer under the present-day Fire Island in this area and possibility that the North Carolina barrier island model shown in Figure 9. is applicable to this study area.

SUMMARY

The behavior and evolution of the beach and barrier island environment in the past has been studied around the world. Some studies successfully showed the usefulness of combined use of Ground Penetrating Radar (GPR) for geomorphology and OSL dating for chronology (Havholm, Ames et al. 2004, Buynevich, FitzGerald et al. 2007, Mallinson, Burdette et al. 2008, Fruergaard, Moller et al. 2015). In North Carolina (Mallinson, Burdette et al. 2008) OSL ages were used to put constraints on paleo shorelines and relative sea level changes in the past ~80 ka years. Combined GPR and OSL were used to determine the change in storms frequency and intensity on the coast of Maine in the past 1500 years (Buynevich, FitzGerald et al. 2007). This GPR study of Robert Moses State Park shows that this area of Fire Island exhibits geological features which can be dated by OSL to give a more comprehensive description of development of a barrier island.

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