TECHNICAL COMMUNICATION

Coastal Geomorphological Applications of Ground-Penetrating Radar[1]

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ABSTRACT

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Ground-penetrating radar (GPR) is a recently-developed system for subsurface mapping of lithologically distinct sediments. This continuous subsurface profiling by impulse radar is now undertaken on a routine basis, and the costs are reasonable considering the amount of data that can be generated in a short period of time.

ADDITIONAL INDEX WORDS: *Subsurface profiler, impulse radar.*

INTRODUCTION

Coastal geomorphologists have invested considerable time and effort in subsurface studies of coastal areas, particularly barrier islands (*e.g.*, KRAFT, 1971; LEATHERMAN, 1985). The principal tools for three-dimensional geomorphic studies have been augering and coring. In recent years the on-land vibracorer has found much application (LANESKY *et al.*, 1979), but the penetration depth is severely limited in well sorted, clean sands. This vibracore methodology has meet with limited success on the south shore barriers of Long Island, N.Y., yielding penetrations of less than 2 meters (LEATHERMAN, 1985); it was even less successful along the medium to coarse-grained barriers of outer Cape Cod (LEATHERMAN, 1979). Land-based seismic surveying, while sometimes useful in locating the water-table or shallow bedrock, has found little application in coastal studies. This researcher as well as several others have tried single and multichannel seismic reflection/refraction surveying on barrier islands without success.

Ground penetrating radar (GPR) provides the means of acquiring subsurface information on barrier landforms to bridge the gap with seismic surveys undertaken on water (ocean and bay). Whereas bore-hole data only provide point-by-point sampling from which extrapolations must be made, the GPR procedure has the ability to produce continuous maps of subsurface features. This technique was largely developed to locate buried drums for toxic waste clean-up projects, but it has considerable potential for coastal barrier studies, which are only beginning to be realized and utilized.

DATA COLLECTION

An impulse radar system that provides continuous subsurface profile data has been in operational use since the early 1970's (MOREY and HARRINGTON, 1972). This system can be considered the electromagnetic equivalent of a seismic (acoustic) profiler used for marine sub-bottom investigations. The tool is an impulse radar that functions as an echo sounding system, sending and receiving short-time duration electromagnetic pulses through the ground from the same broadband antenna. When an impulse strikes an interface between two materials of differing electrical prop-

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perties (*e.g.*, soil-water table contact, sand-peat interface), a proportion of the impulse energy is reflected and displayed on a continuous strip-chart recorder. Travel times of the reflected pulses can be converted to interface depth by knowing the propagation velocity, which has been calculated for various earth materials. Because electromagnetic pulses of only a few nanoseconds duration are used, the system permits the measurement of depth of reflecting discontinuities in subsurface soils to within 10 cm (MOREY and HARRINGTON, 1972).

During a single day, 10 km of subsurface stratigraphic information in the vicinity of Watch Hill, Fire Island, New York was acquired using a Geophysical Survey System SIR 8 ground penetrating radar unit (Figure 1). The sled-mounted antenna was towed behind a four-wheel drive vehicle, carrying the DC power supply and related electronics and strip-chart recorder. The vehicle speed was maintained at about 3 mph in order to obtain the best resolution of subsurface reflectors. Shallow peat deposits at 3.5 meters were clearly evident on the continuous graphic record; presence of the peat layer was confirmed by sample recovery from cores.

Although the mapping of subsurface peat deposits on barrier islands has many geomorphological applications, the actual objective of this particular exercise was not achieved. Weston Consultants, operators of the GPR, estimated that the instrument has a penetrating range of approximately 15 to 20 meters in saturated barrier sands. Pleistocene material, if present on the records, is either sedimentologically similar to overlying Holocene sands so that no abrupt discontinuity is present or the Holocene-Pleistocene contact is located below this depth (PANAGEOTOU and LEATHERMAN, 1986). Recently, FITZGERALD (1986, pers. comm.) has utilized a similar impulse radar system to examine the barrier stratigraphy along Horseneck Beach in southeast Massachusetts. Excellent results were obtained as shown by backhoe excavation, revealing distinct layers of clean sand separated by gravel layers, the latter serving as a sharp stratigraphic reflector.

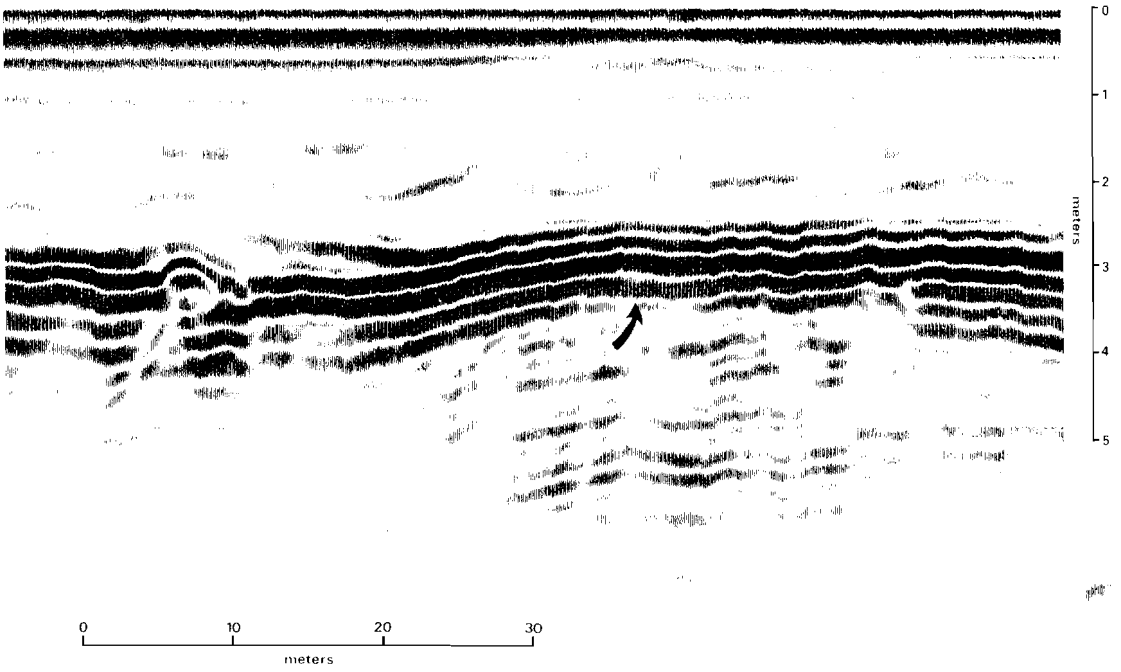

Figure 1. Ground-penetrating radar (GPR) record, indicating shallow peat deposit at 3.5 meters below the surface at Watch Hill on Fire Island, New York. Peaty deposits result in a broken or confused record as compared to the strong, distinct radar signal return from sandy barrier sediments. The chart paper is calibrated in nanoseconds of time, which can be converted to depth according to the travel time for different lithologies as delineated here by vibracoring.

CONCLUSIONS

The advent of ground penetrating radar represents a new technology for application in 3-D geomorphic investigations. While conventional seismic surveying has been found to be useless on barrier islands and detailed stratigraphic correlations are difficult based on bore hole data (LEATHERMAN, 1985), GPR can provide a continuous record to a depth of at least 15 meters in most conditions. A penetration of over 20 meters was achieved in a glacial delta in Massachusetts, composed of water-saturated sands; elsewhere penetration depths to 30 meters in dry sand have been reported (MOREY and HARRINGTON, 1972). Due to the dielectric properties of sea water, the signal is rapidly attenuated so that impulse radar is virtually useless under these conditions. For coastal barrier research, peat deposits and alternating layers of sand and gravel have been shown to have clear signatures on the continuous trace of this echo sounding system. The return signal can also be recorded on magnetic tape, and computer processing is now being used to improve the signal to noise ratio. This capability does not obligate the considerable value of obtaining real-time profile data in the field as graphically displayed on a strip-chart recorder. The full potential of the GPR technique will only be realized by cooperative efforts between coastal geomorphologists and the instrument developers.

ACKNOWLEDGMENTS

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□ RESUMEN □

El radar de penetración en suelo (GPR) es un sistema de reciente desarollo, que permite obtener la topografia subsuperficial de los sedimentos de litologia diversa. La obtención del perfil de la subsuperficie se está realizando en la actualidad de forma rutinaria a un coste razonable, sobre todo si se tiene en cuenta la cantidad de datos se generan en un corto intervalo de tiempo.--*Miguel A. Losada, Universidad de Cantabria, Santander, Spain*

□ ZUSAMMENFASSUNG □

Das Boden-durchdringende-Radar (GPR) ist ein neues System, wofür Unteroberflächenkartenaufnahme der lithologisch besonderen Sedimente entwickelt wurde. Diese beständige Grundlage-Profilierung durch das Impuls-Radar wird üblich unternommen, da sind die Kosten heute vernünftig, besonders wenn man betrifft, dass eine grosse Menge Daten in einer kurzen Zeit eingezogen werden kann.--*Stephen A. Murdock, CERF, Charlottesville, Virginia, USA*