Using Ground Penetrating Radar to Characterize Geological Environments of the Shallow Subsurface on Long Island, New York

Francis D. Winslow III, Elliot C. Klein, Dan M. Davis
Department of Geosciences
SUNY Stony Brook

Ongoing ground penetrating radar (GPR) surveys conducted on Long Island have demonstrated that fine to large scale sedimentary and glaciotectonic structures can be resolved, allowing the geological environment to be determined. A typical GPR system consists of a transmitting antenna, receiving antenna, and a control unit to coordinate the transmitting and receiving of radar signals and to store the collected data. Many units now include a separate computer for recording and displaying the data. The resolution of the instrument will vary with the frequency of the antenna and the velocity of the medium being surveyed. The system used in these studies is comprised of five antennas, with frequencies of 25, 50, 100, 200, and 400 MHz. At 100 mm/ns, which is a typical radar velocity for glacial sediments cited in the literature and observed in our own surveys, the wavelengths of the 400, 200, 100, 50, and 25 MHz antennas are 25 cm, 50 cm, 1 m, 2 m and 4 m respectively. The actual resolution, however, is ¼ the wavelength, so the resolution of these antennas range from as small as 6 cm to about 1 m. As the antenna frequency increases, however, the penetration of the radar energy decreases. By utilizing a suite of antennas, it is possible to discern targets as small as 6 cm while imaging bedding and structures spanning hundreds of meters.

Boulders, cobbles and other similarly sized objects will generate hyperbolic reflectors on a raw radargram, whereas targets large relative to the antenna wavelength will generate line, or surface reflectors. Glacial diamict, a poorly sorted sediment and a major component of glacial sediments on Long Island, tends to scatter radar energy and generate chaotic radargrams because of the wide range of target sizes. The first in a series of surveys was conducted on the Stony Brook campus to establish characteristic radar signatures of known subsurface environments. Maps of the physical plant on campus provided the location of tunnels and pipes, which were used to identify anthropogenic targets and to distinguish them from small boulders and cobbles. The campus maps also provided the depths of pipes, which were used to calculate radar velocities for anthropogenically disturbed sediments. If sediments are disturbed by construction or bioturbation, then they will exhibit faster radar velocities, causing "pull-up". This "pull-up" will make objects appear shallower than they actually are. Additional surveys conducted on campus revealed the occurrence of several reflectors. It was observed that the signal from the shallowest of the reflectors varied with antenna frequency. The 400 MHz antenna resolved a layer of hyperbolas, while the 200 MHz antenna recorded a solid reflector. Based on average radar velocities for glacial moraine sediments from the literature, and confirmed by analysis of the radar data, this was interpreted to suggest a glacial diamict containing cobbles of up to 6 to 10 cm in diameter at a depth of approximately 4 meters. Drill cores later confirmed the existence of a cobble-rich layer at that depth. Surveys were then conducted in areas of Long Island where the topography suggested complex geologic histories.

Based on previous seismic and stratigraphic investigations that indicated a glaciotectonic origin, Hither Hills State Park was chosen as the first area to survey. The survey was conducted along a power line clear-cut in the southern region of the park. A suite of antennas, with frequencies of 400 to 50 MHz, was used to resolve structures in the subsurface over as wide a depth range as possible. The GPR was able to resolve the same structures seen in data from the previous seismic survey, but in greater detail and over a greater depth range. The radar data revealed numerous shallow layers, structures, such as antiforms, and small boulders. Many of the shallower antiforms are arranged in overlapping vertical packets, with relatively well-defined limbs dipping to the north, but truncated or missing limbs dipping to the south. These structures, which in the seismic surveys appeared as piggybacked antiforms, more closely resemble a complex and poorly ordered imbricate-stacked thrust system in the more detailed radar data. In some cases, it was possible to follow the structures imaged by the GPR to the point where they were expressed at the surface in the power line clear-cut. One plausible explanation for these structures would be episodes of compression due to successive, periodic glacial advances during a period of overall retreat.

Another area surveyed was the Grandifolia Sand Hills, located in Baiting Hollow on the north shore of Long Island, New York. Again, a suite of antennas, with frequencies of 400 to 50 MHz was used. The survey revealed numerous, roughly parallel reflectors, dipping » 20º in a southeasterly direction. These reflectors extend down through the first 10-12 meters of the profile. At that depth there is a strong reflector which appears to be a bounding layer between different depositional environments. The characteristic "push-moraine" radargrams, with chaotic, hyperbolic reflectors are not seen above the bounding layer in this study area. Initial processing of the data using migration indicates a radar velocity in the top 10-12 m of » 130 mm/ns, which is significantly higher than glacial moraine radar velocities cited in the literature and observed in our surveys. Both the 400 MHz and the 200 MHz antennas record the reflectors as surfaces, not hyperbolas. This places an upper bound on the grain size of the sediments of about 8 cm. Based on radar data from the literature and GPR data collected in other study areas on Long Island, the results of this survey are interpreted to be eolian sediments deposited on the underlying Harbor Hill Moraine.