Ground Penetrating Radar Detection of Subgrade Permafrost Along the Qinghai-Tibet Highway with Reverse Time Migration (Extended Abstract)

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Abstract

The distribution of the Qinghai-Tibet (QT) Plateau’s permafrost has dramatically changed, expressed as increasing permafrost degradation, thawing depth deepening and the disappearance of island permafrost. These changes have serious impact on the local ecological environment and the stability of engineering infrastructures. Ground penetrating radar (GPR) is used to detect permafrost active layer depth, the upper limit of permafrost and the thawing of permafrost with seasonal changes. Due to the influence of complex structure in the permafrost layer, it is difficult to effectively reflect the accurate structure within the permafrost on the radar profile. In order to get high resolution GPR profile along the QT highway, reverse time migration (RTM) imaging method is applied to GPR real data. The RTM algorithm is first validated through application to a synthetic data set generated from a groove model, then is applied to the real data acquired on the permafrost layer in the region of Beilu River along the QT highway. The results bear great significance for the study of complex structures and freezing and thawing process of permafrost.

Keywords: Qinghai-Tibet Highway, permafrost, ground-penetrating radar (GPR), reverse time migration (RTM)
MODELING THE GPR REFLECTIONS OF REINFORCED CONCRETE MASONRY WALLS

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Abstract

The ability to quickly and accurately assess the composition of existing concrete masonry walls has become a mounting concern to structural engineers, architects, and contractors. Minor destructive testing allows access to the structural components of the walls, but can be costly, causing further damage to the walls and project delays. The damage can be expensive to repair. Current nondestructive testing methods give an insufficient comprehension of the wall composition due to contrasting construction materials, voids, debris, moisture, and the overall complexity of reinforced masonry assemblies.

This research used Ground Penetrating (GPR) modeling software to model many wall types consisting of 156 different cell configurations of 200- and 305-mm thick concrete masonry walls. The various cell configurations modeled included different rebar sizes and placements, voids, construction debris, plumbing pipes, electrical conduits, fasteners, and other typical construction related materials. The research used two GPR modeling software packages: GPRSIM and GPRMAX. For verification purposes, the research team built a mockup 200-mm thick masonry wall with ten cell variations and performed GPR scans to validate the simulations.

After modeling the ten different cell configurations, the modeling results were statistically verified. The research directly compared the actual GPR scans of a physical mockup concrete masonry wall to the modeled GPR scans. Statistical results as to the models’ representing physical masonry cell configurations will be presented.

Keywords: Concrete masonry, GPR modeling, in-situ condition assessment, non-destructive testing, structural ev
HIGH-RESOLUTION INVESTIGATION OF THE CAPILLARY TRANSITION ZONE AND ITS INFLUENCE ON GPR SIGNATURES (Extended Abstract)

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Abstract

The boundary between unsaturated and saturated zone is commonly not characterised by a sharp interface, but, by a gradual increase of water content. The shape of this capillary transition zone (CTZ) depends on the pore-size distribution of the soil and has a strong influence on the signature of GPR reflections. This can be observed when mapping groundwater tables with GPR: high frequencies do not cause distinct reflections and the GPR groundwater table reflection appears higher than the groundwater table that is measured in observation wells and which is utilised by hydrologists. We present a technique that uses waveguides in shallow boreholes to deduce velocity-depth distributions. Numerical simulations and experiments showed that it is possible to measure dielectric permittivity and accordingly water content distributions around the borehole with a high vertical resolution of a few centimetres. We applied the technique at test sites with shallow groundwater tables and fit water retention functions to the data. The according permittivity distributions are used as input models for FDTD simulations and the wavelets reflected at the CTZ are analysed. The amplitude as well as the traveltime show strong dependence on the shape of the CTZ and the frequency of the source wavelet. Another observation is that the spectrum of the incident wave is shifted to lower frequencies when reflected at the CTZ. These findings are in accordance to observations in the field. The results of our investigation can be used to i) choose appropriate antennas for groundwater table mapping in different geologic environments and ii) to correct the traveltimes of GPR reflections so that the depths correspond to groundwater tables measured in observation wells.

Keywords: GPR, groundwater table, capillary transition zone, water retention function
Abstract

Detailed ground-penetrating radar (GPR) surveys were undertaken to locate unmarked burials at the historical Mueschke Cemetery, Houston, Texas. Extensive lateral clay boundary, age of burials, and lacking of previous GPR studies to locate burials in humid areas affect the GPR effectiveness. We demonstrated a technique that is applicable to Houston humid environment and acidic soil (pH = 5.1) to improve the GPR effectiveness in locating unmarked burials. Excavation near the cemetery reveals three soil strata with an increasing clay content as the depth increases. Soil samples collected at four depth intervals give the relative dielectric constant (2.5-10.3), moisture content (14.3%-21.4%) and the electrical conductivity (2.6-2.7) through laboratory measurements. Three methods were used to estimate the soil velocity: CMP, time-to-depth and hyperbola fitting. Time-to-depth conversion done by burying a rebar at 6 (0.25 m interval) measured depths. These methods yielded a soil velocity of about 0.06 m/ns. We established survey templates to characterize the shape of burials before and after 1940. Computer modeling of vaulted and non-vaulted burials match the field observation. The detection of burials before 1940 depend on the indication of the surface depression from the Light Detection and Ranging (Lidar) data, the settling of the surface soils above the coffin, the incision from the vertical shaft cut and the discontinuity of the reflector above the diffractions. Two new graves including the oldest grave were found.

Keywords: GPR, unmarked burials, historical graves, high-resolution geophysics, geoarcheology
CARBONATE GEOLOGY OF BONAIRE, NETHERLANDS ANTILLES: SUBSURFACE MAPPING USING GPR

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Abstract

The island of Bonaire lies in the Southern Caribbean as part of the Leeward Antilles islands. The geology of the island is comprised of volcanic basement overlain by successions of carbonate terraces. Recent geologic studies, conducted by J. Sulaica and JC. Laya in 2015, seek to build on historical investigations to better understand the clinoform geometries and depositional environments of the carbonate terraces as related to tectonic uplift and sea level change. In addition, as Bonaire is one of the few modern exposures of dolomitized beds, current studies seek to learn more about the complex processes of dolomite creation. Due to the arid island environment and low conductivity of the carbonate geology, Ground penetrating Radar (GPR) can be appropriately utilized on Bonaire to perform subsurface geologic mapping over relatively large scales. Depths of radar signal penetration can reach up to 10m and allow for investigation of geologic-scale features of interest. We present here the use of 2D common-offset GPR data to characterize the internal structure of carbonate terraces on the island. Simple and effective data acquisition techniques were used to collect multiple kilometers of continuous GPR data in a cross-island transect. The high resolution imaging provided by GPR results in the ability to identify near-surface features that cannot be detected by other geophysical methods. The results of this application of GPR to the geologic study of Bonaire show the method’s utility for investigation of carbonate geologies.

Keywords: GPR, Carbonate, Near-Surface, Geology
AVOIDING BIAS IN WATER CONTENT ESTIMATES FROM MULTI-OFFSET GPR

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Abstract

Multi-offset ground penetrating radar measurements are frequently used to estimate subsurface wave velocity, relative dielectric permittivity, and volumetric water content. Analysis of subsurface structure with more than one reflector is frequently done using the Dix relationship for calculating interval velocities. As has been long recognized in seismic acquisition, this simple conversion method can produce large errors under some conditions. The GPR community often avoids this pitfall by making assumptions about structure and geometry. However, these assumptions are routinely violated and the transformation from wave velocity or relative dielectric permittivity to volumetric water content may suffer from a strong bias. For example, within thin layers, errors >100% are expected and non-physical velocities or water contents may be calculated. Similar errors in layer thickness may be encountered. Notably, under certain thin-layer conditions, the Dix relationship fails altogether. Here we illustrate the bias explicitly in term of volumetric water content, and demonstrate an alternative to the Dix conversion based on ray-tracing inversion. Through synthetic and measured examples, we demonstrate how this ray-tracing inversion effectively eliminates bias in interval velocity and interval calculated volumetric water content. The inversion approach is capable of correctly resolving layer thickness and water content at any geometry, even below the instrument resolution limit. We also demonstrate a simple scheme for estimating uncertainty on the resulting water content estimates. We find that the bias in water content estimates from GPR using Dix relationship data is not negligible and must be accounted for to ensure reliably reported values. By highlighting the weaknesses of the common multi-offset data analysis scheme, we hope to convince the GPR community to broadly adopt a more robust approach for estimating water content.

Keywords: GPR, water content
EVALUATING THE EFFECTIVENESS OF HYPERSTACKING FOR GPR SURVEYS (Extended Abstract)

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Abstract

Although some benefits of Real-Time Sampling (RTS) for Ground Penetrating Radar (GPR) have been known for decades, the cost of high-speed samplers has only recently lowered enough to make them commercially viable. Signal to Noise improvements of more than 30 dB can be realized with RTS systems compared to the traditional Equivalent Time Sampling (ETS) methods, especially when implemented properly. One such implementation called “HyperStacking” (HS) is achieved by a method of averaging (i.e. stacking) the results of many individual scans. This new technique solves several issues associated with RTS which include 1) dynamic range limitations, 2) regulatory compliance issues, 3) sampler core offset error and 4) timing errors. The timing of HS pulses is randomly or pseudo-randomly dithered, and the phase of the interpolation is shuffled in order to avoid producing discrete spectral lines in the radiated RADAR signal. This ensures that FCC restrictions are optimally met, with no sacrifice in collection rates.

The goal of this study was to examine the field performance benefits of HS compared ETS under various soil conditions.

In low loss soils the signal to noise ratios (SNR) increased significantly, improving the penetration depths in some cases up to twice the range of an ETS system with the same antenna geometry. The resolution of shallower targets is also visibly improved.

However, in high loss soils like clays and peats the benefits of HS were marginal at best, compared to an equivalent ETS system. The SNR is similar, and the depth penetration is only slightly improved. As in low-loss soils, resolution improvements are noticeable in shallow targets.

Perhaps the main benefit of HS is demonstrated in high noise environments. Surveys performed near cell towers, for example, show significant noise immunity compared to ETS systems.

Keywords: HyperStacking, Noise Immunity, lossy conditions
COVERED KARST INVESTIGATIONS USING GPR AND ELECTRICAL IMAGING

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Abstract

Connections between surface water and groundwater occur in the Withlacoochee River valley of south Georgia through karst conduits within the Miocene Hawthorn Group. We are employing both our MALA 100 MHz GPR system and an AGI Supersting R8 system to identify the dimensions and depth of the karst features through which surface water and groundwater interact. Both techniques have already identified conduits beneath the floor of a large surface depression called "Shadrick Pond." Transects with the 100 MHz GPR antenna were spaced two meters apart running from south to north (18 profiles) on November 11, 2010. Transects were then run on November 15, 2010 from east to west across the same area. A three-dimensional model developed from the S-N data identified a "pipe" conduit approximately four meters in diameter. Large depressions on the top-of-rock surface were more difficult to identify, however, and attenuation of signal due to a rise in the water table particularly affected the mapping based upon the E-W data. Both three-dimensional and two-dimensional imaging of these same areas using DC Resistivity data from our AGI Supersting R8 system identify relationships between some of these larger depressions and fractures evident at the surface along the south and east margins of the large surface depression. Sandy surface sediments at the surface, however, resulted in high contact resistance making the GPR a better tool for mapping the conduits in detail.

Keywords: GPR, Electrical Imaging, Karst, Groundwater, Inversion, 2D, 3D