Evaluation of the ground penetrating radar (GPR) survey at TDCJ playa, Carson County

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Abstract

A ground penetrating radar (GPR) survey conducted at TDCJ playa, Carson County, imaged soil structures to depths of 2 to 4 m. Layering in soils, including the modern soils and several buried horizons, is parallel to the surface throughout the transect, which runs from the upland, down the slope of the playa lake basin, to the edge of the ephemeral playa lake. Little evidence of truncation of soil horizons is apparent on the images, suggesting that the playa basins are part of an accretionary rather than an incised landscape. Two trenches (1.9 to 2.5 m deep) and four boreholes near the GPR line confirm the horizontal structure of the soil and also document lateral changes not apparent on GPR. Interpretation of GPR is limited because of uncertainty in matching the GPR image to observed soil features, artificial changes in character of the GPR image at segment boundaries, and sloping features on GPR images that could not be recognized in trenches.

Methods

A ground penetrating radar (GPR) survey was conducted to investigate the feasibility of this technique for noninvasive description of shallow subsurface of playa basins. This study was conducted on property leased by the Texas Department of Criminal Justice (TDCJ), approximately 32 km (20 miles) northeast of Amarillo in Carson County, located off FM 1342 10 km (6.5 miles) east of its intersection with Highway 136 (fig. 1). The GPR transect is 790 m long and extends from the upland in the southeastern corner of the section, down the slope of the playa lake basin, to the eastern shore of the playa lake (fig. 2). The survey was conducted October 16, 1991, by Envirometrics, Inc. of Houston, Texas, using a GSSI SIR System-10 (Envirometrics, 1991). Both 300 and 120 MHz antennas were used to investigate the best combination of resolution and depth penetration. GPR responds to contrasts in the permittivity (dielectric constant) and electrical conductivity of the upper few meters of sediment and therefore can image moisture content variation or contrasts in soil mineralogy and texture (Annan and Cosway, 1992). Envirometrics (1991) estimates that the 300 MHz antenna penetrates about 2.1 m and the 120 MHz antenna penetrates about 4.2 m. The GPR data were collected in six segments along a surveyed line.

Two benched trenches were excavated near the GPR line to evaluate the geologic significance of the images. One trench was excavated May 11, 1993, on the gentle slope of the playa lake basin (fig. 2). It was 14 m long, 3.6 m wide, and 2.5 m deep, with the eastern end at approximately GPR station 57.5, which is 98 m west of a small drainage. The trench was located a few meters west of the concrete plug marking BEG borehole TDCJ No. 5. Ponding tests 1 and 2 (Xiang and others, 1993) were conducted at the slope trench. The second trench was sited across the "annulus" or diffuse shoreline on the east side of the lake a short distance north of the GPR survey line. This trench was excavated June 2, 1993, and was about 24 m long, 2 m wide, and a maximum of 1.9 m deep. The east end of the trench was placed at the 1992 high-water mark and the trench extended across a zone of rapid vegetative change into the nearly flat floor of the playa. Ponding tests 3 and 4 (Xiang and others, 1993) were conducted at this trench. Additional stratigraphic, grain-size, and moisture content data were obtained from four hollow-stem auger cores (TDCJ Nos. 1, 2, 3, and 5) collected near the GPR transect.

Results

The GPR survey imaged a number of features of potential geologic interest. All of the plots show horizons parallel to the surface defined by varying density of the GPR images (fig. 3). Gradual lateral changes in the apparent thickness and GPR character of these units can be seen. In addition, local anomalous features were observed on the GPR images.

In the upland setting, about 10 m above the playa high water line, the 120 MHz transect shows strong horizonation (fig. 3). Sediments collected in boreholes in this area have Pullman or Estacado soils at the surface overlying red-brown calcareous paleosoils of the Blackwater Draw Formation. The sharp break in the character of the GPR image may correspond to the top of the uppermost buried carbonate horizon (40% carbonate) found at about a 1-m depth in the TDCJ No. 1 borehole (fig. 4). Alternatively, the break may correspond to a decrease in gravimetric moisture content from 0.11 to 0.08 g H_2O/g soil at about the same depth (Scanlon, written communication, 1994). Layering in the lower part of the GPR image may correspond to zones of carbonate accumulation within buried soils of the Blackwater Draw Formation (fig. 4).

Sediments on the slope of the playa basin show similar strong horizonation (fig. 5). Changes in the character and processing of the GPR images between sections of the survey make lateral tracing of soil horizons uncertain, so that the relationships between upland and slope soils are indeterminate. Line 1-E (120 MHz antenna) imaged a feature resembling 5° dipping beds between markers 54 and 60 (fig. 5). A trench was excavated in this area, which is about 3.5 m above high water in the playa, to attempt to identify the geologic significance of the GPR images. The facies exposed in the trench are red-brown silty clay and clayey silt basin slope facies of the Blackwater Draw Formation. Major stratigraphic units observed were (1) the modern Estacado soil profile with a soil carbonate at the base, (2) a zone with evenly distributed soil carbonate nodules with an incised top and local weakly bedded channel deposits, and (3) a lower interval with two horizons of well developed but discontinuous soil carbonate (fig. 6). Some of the irregularity in the soil carbonate is related to a complex of infilled prairie dog burrows. Dissolution and reprecipitation of carbonate may also have occurred. The sharp break in the GPR image may correspond to the top of the uppermost soil carbonate. Soil moisture content decreased sharply below this horizon. The small channel is not evident on the GPR. No features corresponding to the 5° dipping structures imaged by the GPR survey were identified in the lower part of the trench. Other vertical anomalies on the GPR were not trenched.

GPR section F imaged the lower slope of the playa basin to the lake shore. The thickness of the upper layer on the GPR image increases gradually toward the playa lake shore (fig. 7). Comparing the lakeward end of GPR section F (fig. 7) with the core from TDCJ borehole No. 3 (fig. 8) shows that the well-defined layer in the GPR image may be the base of the Randall clay soil at 1.4 m. Lower layers may correspond to coarser grained and slightly more calcareous slope soils beneath the lake clays. The upper layer at the shore of the playa lake thins by about 15 percent away from the shoreline and appears to be gradational into the Estacado soils on the slope of the playa basin. The character of the GPR image changes abruptly between sections E and F on the 120 MHz survey. The character does not change correspondingly on the 300 MHz survey, indicating that the change may be an artifact of data collection or processing. No change in character that might correspond to increased moisture content at or near the playa lake shore is identified in either survey.

A trench through the annulus on the eastern edge of the playa was sited north of the line of the GPR survey where the annulus was well defined (fig. 9). In this area, the surficial Randall clay soil thinned and gradually changed character from the lake floor to the high-water line. The soil became dryer, with better developed peds and more roots, and more silt toward the upper part of the annulus. The base of the Randall clay soil was marked by a gradational color change at 0.6 m below the surface. Dark materials appear to have been translocated downward along elongate features, imparting a darker color to the sediment. These dark stained areas may be the natural equivalent of the planar features in the Randall clay soil, which were dyed blue in the ponding experiments (Xiang and others, 1993). These planar features may be areas of preferential flow where pigments carried by downward-moving water accumulate. The GPR survey was run at the margin of a small delta at the mouth of the two drainages entering the playa from the southeast. Infilling of a broad, wide valley by Randall clay and delta sediments may explain the greater thickness of clay in this area.

Discussion

Several different acquisition and display techniques were tried during this pilot study of GPR in playa basins. GPR images made using a 120 MHz antenna show several buried soils beneath the modern soil; those made with the less deeply penetrating 300 MHz antenna show more horizonation within the modern soils. Differences in display parameters and possibly data collection techniques between segments of the survey contribute to difficulty in interpreting the results; these could be eliminated in future studies. The significance of intensity changes on both color and black-and-white images varied from line to line, which obscured any interpretable trends. This GPR line was collected when the playa lake was full of water. Additional GPR collected across the floor of a dry playa lake might be useful in imaging sand within the lake sequences. At TDCJ playa the sand layers in the center of the playa are 5 m below surface, below the depth of GPR imaging. Shallower sand layers at Sevenmile Basin might have been imageable.

Boreholes show that the pattern seen in the annulus trench and borehole TDCJ No. 3 of red-brown silty soils overlain by dark Randall clay soils continues all around the southern margin of the playa. Toward the center of the floor of the ephemeral playa lake, the redder slope soils pinch out into lake marginal and lacustrine clays. The present playa lake is larger and extends farther to the south than it did in the past. The base of the Randall clay soil does not appear to cross cut horizonation in older soils. This suggests that the enlargement of the lake is mostly a result of higher water level in the lake, and erosion and incision of the lake into older sediments is minimal. On a larger scale, the same can be said of the playa basin. Land-surface parallel structures on the GPR within the slope of the playa basin indicate that the basin has not been cut into an originally flat landscape. Instead, aggradation of the land surface has taken place in approximate equilibrium, with accumulation of sediments in upland, slope, and playa environments at approximately equal rates. The older soil horizons in the playa basin slope appear to be parallel to land surface and to the modern soils rather than being truncated. Therefore, the gentle slope of the playa basin existed during previous episodes of sediment accumulation and soil formation. This observation of the shallow subsurface fits well with cross sections made using core (Hovorka, 1993) and seismic data (Paine, 1993) that playa basins have had a long history during which the geometry of the basin was maintained as sediment accumulated.

Conclusions

GPR images at TDCJ playa best show the modern soil or moisture profile associated with the modern soil. Older soil horizons are visible, but it is difficult to determine exactly what features were imaged. Angular features shown by the GPR could not be seen in trench exposures. Small-scale features such as small channels and prairie dog burrows seen in the trench were not imaged by GPR.

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Figure 1. Location of TDCJ playa.

Figure 2. Locations of the GPR survey line, trenches, and boreholes at TDCJ playa.

Figure 3. Segment A of the GPR survey, 120 MHz, depth approximately 4 m. Survey station numbers at 5-m spacing provide horizontal scale. Reproduced from Envirometrics (1991).

Figure 4. Lithologic log of hollow stem auger core from TDCJ 1 and offset 1B boreholes.

Figure 5. Segment E of the GPR survey, 120 MHz, depth approximately 4 m. Survey station numbers at 5-m spacing provide horizontal scale. Reproduced from Envirometrics (1991).

Figure 6. Drawing of segment of the trench in the slope setting, showing typical stratigraphy near station 56.

Figure 7. Segment F of the GPR survey, 120 MHz, depth approximately 4 m. Survey station numbers at 5-m spacing provide horizontal scale. Reproduced from Envirometrics (1991).

Figure 8. Lithologic log of hollow stem auger core from TDCJ 3 borehole.

Figure 9. Drawing of segment of the trench in the annulus setting, showing typical stratigraphy from the high-water mark down into the playa.