

Report of the 2004 Ziyaret Tepe Geomorphological Survey

During the 2004 field season, the geomorphological survey team was comprised of Dr Kathleen Nicoll (University of Oxford, UK) and Dr Timothy M. Demko (University of Minnesota Duluth), working with the general project leader Dr. Timothy Matney (University of Akron) and government representative Nurhan Turan (General Directorate, Ankara). The main goals of the continuing field survey were to (1) delineate the floodplain sediments associated with occupation of the tell at Ziyaret Tepe (ancient Tushan); (2) describe local landscape development through time; (3) test the utility of Ground-Penetrating Radar (i.e. GPR) methods for subsurface assessment of cultural contexts in the excavation area; and (4) characterize the properties of radar transmission, reflectance and attenuation within specific natural and cultural features along this reach of the Dicle (Tigris) River. The 2004 season involved vehicular, pedestrian, and geophysical survey, and acquired more than 1.6 km of Ground-Penetrating Radar (GPR) profiles from the tell and its environs.

Ground-Penetrating Radar (GPR) is a noninvasive methodology useful for imaging features preserved in sediments; details of the GPR technique are discussed by Conyers and Goodman (1997) and Bristow and Jol (2003). The GPR method operates by transmitting a series of short high frequency electromagnetic (EM) pulses into the ground using an antenna. The time it takes for signal transmission, reflection from subsurface stratigraphy and buried features and reception of the responding signal is measured. Readings are taken at intervals across the survey area, and at different depths depending on the frequency of the signal. The recorded signal is registered as amplitude and polarity versus two-way travel time (TWT). The signal is processed and displayed as a GPR profile, in which the vertical axis is expressed as two-way travel time in nanoseconds (ns, 1/1000 of a second), and the horizontal axis is a distance axis along the measured survey line in the field. The vertical axis can be converted to depth or elevation if the radar wave velocity in the penetrated material is determined. The raw data profiles are further processed for additional interpretation and correlation with the topographic profile.

The GPR acquisition system we used in our survey is a Sensors and Software, Inc. pulse EKKO 100 IV radar system with a 400 V transmitter and both 50 and 100 MHz antennae. Data were acquired in reflection survey mode using step separation of 0.25 m and antennae separation of 2 m or 1 m (respectively for the 50 and 100 MHz), with the antennae oriented perpendicular to the direction of movement along the survey line. Each trace was vertically stacked 128 times, with a sampling rate of 800 ps (picoseconds) over a time window of 300 ns (nanoseconds). Common Mid-Point (CMP) surveys were used to calculate the near-surface radar velocity for depth conversions and to determine signal penetration.

We commenced a pilot GPR survey in the lower town portion of the höyük in Operation K along trench 850-850 in order to test the suitability of the method and to ground-truth the GPR data with corresponding features apparent in the nearby excavation, which included building walls, cobble pavements, mudbrick city walls, roads, and cobble-gravel-fill. A N-S line approximately 47.5 m line was the test location for the initial reflection profiles and CMP surveys. Observed radar returns were calibrated with sediment features, and materials were sampled for further

analysis in the laboratory, including grain size, age determination, magnetic resistivity, and radar-specific properties including dielectric constant and attenuation. To this end, radar facies will be linked to specific sedimentary materials and cultural contexts. Additional lines acquired on the tell and adjacent floodplain were critical to determine the parameters for optimal subsurface imaging, and to develop strategies to avoid potential noise sources during the acquisition.

An initial evaluation of the materials we were surveying indicate that they have properties of high attenuation and low transmissivity at the frequencies used (50 and 100 MHz) and transmitter power (400 V). Signal penetration is somewhat low; only about 3-4 metres below ground surface can be imaged with the equipment used, although detection of large features may be possible. Velocities calculated from the CMP surveys range from 0.06 m/ns (clay) to 0.09 m/ns (silts and shales), which reflects the dominant sediment size of both natural landscape and cultural materials. From the raw data returns, certain archaeological features may be apparent as distinctive radar facies; mudbrick walls, baked clay tiles, set (inlaid) floors and cobble pavements can be recognized in the transects that have “ground-truth” in nearby excavation trenches. However, the signal-to-noise ratio is very low and it is important to insure the data quality. During our acquisition, we noticed artifacts contributed from local environmental factors such as surface metal objects (e.g. wheelbarrows, horse carts, pipelines, powerlines), military aircraft, buildings, plants (e.g. cultivated cotton plants), people and animals (e.g. site workers, shepherds and flocks). Within the excavation area, a wide (50 cm diameter) irrigation pipeline contributed returns on the profile at later TWTs. In local fields, ditches, crop furrows, and desiccation cracks contribute disruption to the airwave.

Although GPR studies are optimally conducted in sediments with low conductivities such as sand and gravels, we conclude that this method of subsurface investigation is a valuable contribution to the continuing studies at Ziyaret Tepe. Use of GPR in conjunction with surface geophysical surveying techniques (e.g. magnetic gradiometry and resistivity) has strong potential for imaging archaeological features in three dimensions prior to excavation. Future surveys should investigate the suitability of higher frequency antennae (to image smaller objects) and higher power radar transmitters (to overcome the high attenuation and the low transmissivity of the local materials).

References Cited

Conyers, L.B. and Goodman, D. 1997. *Ground Penetrating Radar: An Introduction for Archaeologists*. Altamira Press: Walnut Creek, CA 232 p.

Goodman, D. 1994. Ground Penetrating Radar simulation in engineering and archaeology. *Geophysics* vol 59: 224-232.

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