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Raport

Hydroarchaeology program and surveying results using high resolution satellite imagery in the territorium of Tropaeum Traiani (Adamclisi, SE Romania)

Hydroarchaeology Program:

Initial research on the subterranean aqueducts at Şipote, 7 km from Adamclisi, were published by Al.-S. Ştefan in 1972. Ştefan had proposed that these aqueducts had supplied water to the Roman city of Tropaeum Traiani. Our research continues where Ştefan's work ended by investigating whether the subterranean remains of Roman aqueducts can be tracked through satellite imagery. The broader survey program has been investigating Roman-period aqueduct lines surrounding Tropaeum Traiani and documenting all known or suspected sites within a 25-km radius of this Roman city for the period during which Tropaeum Traiani was occupied (2nd-6th centuries AD).

The fourth (2005) season for the hydroarchaeological surveying program in the region (territorium) surrounding the Roman city of Tropaeum Traiani included:

- excavations of an aqueduct in the vicinity of the modern village of Adamclisi (L. Ellis)

- collection of GPS data throughout the territorium (P. Foschi)

- analysis of satellite imagery to locate archaeological features (P. Foschi)

- chemical analysis of water samples from local springs and functioning aqueduct lines (L. Ellis)

A major aim of this research is to enable identification of archaeological sites, utilizing satellite remote sensing, within the economic catchment zone (ca. 20-km radius) surrounding the Roman city of Tropaeum Traiani (2nd-6th centuries AD) in the region of Dobrudja, southeastern Romania. The 2005 season represents an initial data-gathering stage, as part of a larger research program, to create a knowledge base of surrounding rural settlements, natural water sources, and remains of buried aqueduct lines. The long-term research goals include understanding the ecological and economic roles of rural communities that supported Tropaeum Traiani for five centuries; study of the urban-rural interdependency during both the apex and decline of Roman imperial hegemony; tracking of underground aqueduct systems which not only supplied water to Tropaeum Traiani but possibly to Roman plantation-style farms; identification of the Roman road system integral to the functioning of urban-rural systems. Eventually, a resulting map of the region will provide a three-dimensional portrayal of a colonial economic system over the course of five centuries.

Excavations of Roman Aqueduct near Adamclisi:

In 2004, Mr. Ion Dan (Cadastral Supervisor for southern Constant¸ a County, Adamclisi Mayoral Office) provided locational information on a buried Roman aqueduct, in the middle of a fallow wheat field near Adamclisi. A small portion of the aqueduct had been exposed through erosion but this archaeological feature had never been recorded. In 2004, the area was cleared and eroded soil removed to uncover approximately one meter of the aqueduct. In 2005, our team excavated five meters of the aqueduct channel to evaluate the construction, capping method, and geometry.

The aqueduct was constructed out of local fossilferous limestone and covered with capstones that had been severely damaged by mechanized combines used in communist-era agriculture. The construction is 41 cm high; the U-shaped water channel is 26 cm high and 21 cm in top width; both sides of the channel measure 30-31 cm in top width. A hand-sized sample of the aqueduct construction material, which had naturally broken off, was taken to the U.S. for analysis. Dr. John Marshall, a planetary geologist at the SETI Institute (NASA), in Palo Alto, California, is currently analyzing the material, and the results will appear in a separate article.

Rescue excavations of an aqueduct pipe were also undertaken at Adamclisi-Nymphaeum. This Roman pipe was exposed and projecting out of the ground on a pathway used by herdsman. The ceramic pipe was significantly more deteriorated from 2004. Since hundreds of animals trample over the pipe every day, it was thought best to remove it altogether, repair it as much as feasible, and house it in the Adamclisi School to benefit historical pedagogy. Sections of the aqueduct system were also excavated and photographed with the pipe for documentation.

Analysis of Satellite Imagery:

In April 2005, P. Foschi obtained QuickBird digital satellite imagery from DigitalGlobe5. This imagery was preprocessed by DigitalGlobe to georeference the data to the UTM, zone 35, WGS84 datum and spheroid, projection. The imagery covers approximately 256 km2 and includes the Roman city of Tropaeum Traiani and its territorium. The satellite data was collected by the QuickBird satellite on 8 July 2002; the imagery contains a little cloud cover, but in general provides excellent visibility. QuickBird imagery has the highest spatial resolution currently available by civilian satellites; we acquired the imagery at full resolution: 0,6 meters for the panchromatic band (a blue-to-near-infrared broad band) and 2,4 meters for the four multispectral bands (blue, green, red, and near-infrared). The radiometric resolution of this imagery is 11-bit (2048 gray tones per band) which allows the discrimination of fine spectral differences. The near-infrared parts of the spectrum present in this imagery allow the detection of subtle changes in soil moisture and crop growth patterns that are often indicative of subsurface changes (e.g., buried structures, roads, and other archaeological features). Color composites made from the green, red, and near-infrared bands allow detailed image interpretation that is not possible with black-and-white or natural-color imagery.

During the summer of 2005, P. Foschi and S. Hall collected GPS locational data from known archaeological sites surrounding Tropaeum Traiani, as well as from exposed locations of linear features (aqueducts and walls). A Trimble GPS Pathfinder Pro XRS system was used to record X, Y, and Z directions of major points (e.g., current road intersections, modern buildings, Roman architecture) that are visible by satellite, and this GPS locational data was compared to corresponding latitude and longitude on the imagery. Because locational errors of 20-40 meters were found, additional GPS points were collected for the image subset containing Tropaeum Traiani; an initial polynomial geometric correction was performed using these points that improved locational placement to within 2 - 3 meters. Further geometric correction with GPS points already collected will be performed soon and is expected to yield imagery with locational errors of 0,5-1,5 meters (which is considered acceptable).

Initial image interpretations by P. Foschi were checked with ground surveys, and ground information was used to analyze potential information in the imagery. In this manner, an image analyst is able to “learn” the imagery for a particular location. Once the visual nature of known archaeological sites and buried features such as Roman aqueducts and roads have been identified, then the entirety of the satellite imagery can be searched and examined for additional archaeological features. Computer-assisted statistical methods may also be used to aid such searches and examinations.

One particularly fortuitous discovery was made during the ground surveys. An area on the imagery East of the village of Pietreni, visually interpreted by P. Foschi to be a partially buried wall with towers, was found to be completely buried on the ground and surrounding an old Turkish cemetery that contained reused Roman stones and columns. Permission to excavate at the outer corner of this site (over 30 meters from the gravestones) is being requested. This corner contains a patch of lush vegetation indicative of a water source that may be a cistern or aqueduct terminus.

Chemical Analysis of Water Sources:

Within the territorium of Tropaeum Traiani, there are numerous locations where subterranean aquifers (water-bearing formations) rise close enough to the surface that they were easily recognized and exploited in antiquity. In both the 2004 and 2005 seasons, we solicited information on communal wells and fountains known to have been used by local inhabitants and conducted surface surveys at each of these locations for any signs of archaeological remains. At the sites of Zorile, Abrud, Cucuruz, Şipote, and Adamclisi-Nymphaeum, substantial Roman-period remains have been found through surface surveys and/or prior excavations. Remains of Roman aqueducts have been found at Adamclisi-Nymphaeum, Şipote, and Abrud. At Abrud, water still flows through the Roman aqueduct and is used by local herdsmen for their animals. Most of these sources were also exploited during the Ottoman period, at which time fountains were built under Turkish administration of Dobrudja. In 2005, water samples were collected for chemical analysis from the seven above-named locations. Water was collected directly from the flow (not from basins) in sterile laboratory bottles. Only water flowing from 1) Roman aqueducts and 2) Turkish fountains with Roman pottery found in surface surveys were tested. Water from 20th-century piping and pumping systems and from historical fountains with no surface evidence of prior exploitation were not tested because it could not be readily verified whether these water sources were used in antiquity.

Six, preliminary chemical tests were performed: pH, total hardness, nitrite, total nitrate, chloride, and total alkalinity. The tests were done in the field with colorimetric water-quality test strips manufactured by Industrial Test Systems and WaterWorks, based on standards set by the U.S. Environmental Protection Agency (EPA). These results are semi-quantitative only (range values). The water samples were taken to the U.S. for more precise quantitative tests to be undertaken by L. Ellis at SFSU. Results and explanations for the preliminary chemical tests are below.

Explanation of Water Chemical Testing pH: The pH of water is a measure of the hydrogen ion (acid) concentration on a scale of 0 (very acidic) to 14 (very basic), with pH 7 being the neutral point. The pH value represents the instantaneous hydrogen ion activity rather than the buffering capacity or total reserve as in acidity or alkalinity tests. The pH of most natural waters ranges from 4 to 9 and is greatly influenced by the present of carbon dioxide, carbonates, bicarbonates, or acid rain. Waters with pH values of about 6.5 to 9 are considered safe for human and animal consumption, the ideal range being 7.5 to 8.5.

Total Hardness: Calcium and magnesium, from dissolved limestone and dolomite rock minerals, are the most abundant alkaline earth metals found in natural waters. Hardness is defined as the characteristic of water that represents the total concentration of calcium and magnesium expressed as their calcium carbonate equivalent. Other divalent ions also contribute to hardness, but their effects are usually negligible in natural waters. The ideal range for domestic purposes is 150-200 ppm.

Nitrite: Nitrite (NO2) occurs as an intermediate stage in the biological decomposition of compounds containing organic nitrogen. Nitrite is an unstable form of nitrogen and is not often found in surface waters because in aerobic conditions they are readily oxidized to nitrates. Levels of nitrites greater than natural residual amounts can be acutely toxic to humans and animals and water supplies containing more than 0.5 ppm require treatment. Sources of nitrites in rural areas are typically fertilizers and animal waste.

Nitrate: Nitrate refers to the univalent radical NO3 or a compound containing it, especially calcium nitrate, sodium nitrate or potassium nitrate in fertilizer. Nearly all metal nitrates are soluble in water. Therefore, nitrates are the most frequent groundwater pollutants in rural areas. The origin of nitrate in groundwater is primarily from fertilizers and manure spreading operations. Fertilizer nitrogen not taken up by plants, volatilized, or carried away by surface runoff ends up in the groundwater in the form of nitrate. The US federal standard for nitrate in drinking water is 10 ppm nitrate-N; specific recommendations are as follows:

- recommended level: less than 50 ppm nitrate-N

- acceptable level: 50-100 ppm nitrate-N

- not recommended and water treatment required: more than 100 ppm nitrate-N

Chloride: Chloride is a salt compound resulting from the combination of chlorine and a metal. Some common chlorides include sodium chloride (NaCl), potassium chloride (KCl), calcium chloride (CaCl2), and magnesium chloride (MgCl2). Sodium chloride may impart a salty taste in water at 250 ppm; however, calcium or magnesium chloride are not usually detected by taste until levels of 1000 ppm are reached. EPA recommends chloride levels of 250 ppm or less. Chlorides present in water may result from agricultural runoff or rocks containing chlorides that have dissloved in the aquifer.

Total Alkalinity: Alkalinity is the capacity to neutralize acid and refers to the amount of bases in water. The presence of carbonates, bicarbonates, and hydroxides is the most common cause of alkalinity in natural waters. Total alkalinity includes all carbonate, bicarbonate, and hydroxide alkalinity. Sources producing alkalinity are primarily dissolved limestone or dolomite minerals (carbonates and bicarbonates) from soil or rock minerals. Alkalinity and hardness are usually similar in values because they derive from the same dissolved minerals. If alkalinity is much higher than total hardness, then the water is also naturally high in sodium. If alkalinity is much lower than total hardness, then the water may be contaminated with chlorides, nitrates, and sulfates.

Six of the most common chemical tests were performed in order to obtain a comprehensive profile of each source, even though some of the tests are not relevant to the ecosystem of the Roman period. Total nitrate level, for instance, is the result of mechanized agricultural practices in communist-era Romania. Nitrates, from continuous use of industrial fertilizers, migrate through the soils and contaminate subterranean aquifers. In the Adamclisi area, the nitrate content of the historical water sources was so high that it was beyond the colorimetric scale of our tests. However, total hardness and total alkalinity are independent of modern interference with the landscape and result from groundwater in contact with the limestone/dolomitic rock formations. The zone surrounding Adamclisi and indeed all of western Dobrudja, flanking the right bank of the Danube, is situated on a loess horizon with the highest percentage of carbonates (20-27%) in comparison with the rest of the province6.

Of particular concern to this research were the levels (bi-)carbonates and dissolved minerals in the water sources during antiquity. Therefore, the results for total hardness and total alkalinity are the most significant. Of all the chemical contaminants in water, only the (bi-)carbonates could have been easily recognized by ancient peoples. High levels of carbonates and minerals make it very difficult to wash oneself and one’s clothing, stunt the growth of chemically-sensitive fruits and vegetables, and in very high quantities may cause human and animal sickness.

Adamclisi-Nymphaeum, the water source closest to the ancient city of Tropaeum Traiani, has two Turkish fountain basins and an exposed pipe, all of which have water flowing and are used by herds of livestock. Test results show extraordinarily high values for total hardness of all the sources tested. This high mineral content was undoubtedly recognized by inhabitants during the Roman period. It is for this reason that we believe that the Roman administration created extensive aqueducts in the territorium.

Zorile, Abrud, and Şipote show moderately high levels of dissolved carbonate minerals, just above the ideal range for human consumption and domestic uses. However, these three sources also have total alkalinity levels higher than total hardness. It is surmised here that this discrepancy between alkalinity and hardness is a result of chlorides in the rock formations of the aquifers. The lower level of dissolved carbonate minerals at Abrud and S¸ ipote most likely induced the Romans to construct an extensive aqueduct from Şipote to Tropaeum Traiani (Ştefan 1972) and another aqueduct at Abrud (to a currently unknown destination). The slightly elevated pH levels (above neutral 7) at all sources result from dissolved carbonates.

However, the most interesting water source is at Cucuruz, a village whose population was forceably removed and relocated during the early years of the communist era—hence, the lowest level of nitrates in the water as a result of village abandonment and lack of industrialized farming. The most important natural characteristic of this water is the lowest level of dissolved minerals (total hardness), which makes this source (of those tested) the safest drinking water in the region. The high alkalinity level may very likely result from sodium natural to the rock formations. It is for this reason that Cucuruz deserves some serious archaeological exploration. Since Roman-period remains were found during a surface survey in 2004, it is surmised that this good source of water was exploited heavily in antiquity.

Both soil phosphate analysis of suspected and known sites (2002-2004) and chemical testing of water sources (2005) have proven invaluable for identification and appraisal of known and possible Roman-period archaeological sites in the rural territorium of Tropaeum Traiani.

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Note

- 5. DigitalGlobe, the company that owns QuickBird, owns the copyright to all satellite images; therefore, this intellectual property cannot be published. However, publication of image-derived maps is permitted and publication of limited image data may be possible upon permission from DigitalGlobe.

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