HYDROARCHAEOLOGY PROGRAM IN THE *TERRITORIUM* OF *TROPAEUM TRAIANI*–ADAMCLISI. RESULTS OF MICROSCOPIC AND X-RAY DIFFRACTION ANALYSES OF CONSTRUCTION MATERIAL FROM THE ROMAN AQUEDUCT

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Abstract: The purpose of our research is, on the one hand, to continue the study of Roman aqueducts in the area of the city of *Tropaeum Traiani*, started by Alexandru Simion Ştefan, and, on the other hand, to document, within a radius of 25 km around the city, all known points (or not) containing traces of the Roman and Roman-Byzantine period. The methods used are varied: drilling, GPS data collection, archaeological surveys, soil analysis, water, using satellite photos. Most of the archaeological points of interest in the territory of the city of *Tropaeum Traiani*, as well as the watercourses or the surrounding settlements are already known. Dr. Linda Ellis (San Francisco State University) coordinates field research, including conducting archaeological surveys. Dr. John Marshall, a geologist at SETI Institute (NASA) in Palo Alto, California, deals with microscopic analysis and interpretation of their results. Dr. Don L. Williamson of the Colorado School of Mines analyzes X-ray samples of construction materials used for aqueducts. In 2004 and 2005 two aqueducts were investigated, the first on a length of 1 m and the second on 5 m. The archaeological surveys aimed to establish the construction technique, the depth and the direction of aqueducts. Three samples from the walls of the canal, the size of a fist, were taken to the USA for analysis. The results of the microscopic and X-ray analyses correspond to the already published results of the analyses of the Quaternary deposits from SE Romania.

Keywords: *Tropaeum Traiani*, *territorium*, aqueducts, microscopic analyses, X-ray analyses

ROMAN AQUEDUCTS

In AD 97, Julius Frontinus was appointed by Emperor Nerva to the post of water commissioner (*curator aquarum*) for the City of Rome and continued in this post when Emperor Trajan assumed power that same year. We are indeed fortunate that Frontinus left behind his substantial treatise, *De aquaeductu urbis Romae*[1], in which he not only outlines his duties as water commissioner, but also provides a history of aqueducts, technical details (*e.g.*, dimensions of aqueducts,

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[1] Rodgers 2004.

capacity), construction methods, hydraulics, water distribution systems, and even water quality. While this valuable work focuses exclusively on water engineering for ancient Rome, the Romans had constructed extensive aqueduct systems for many of their cities established throughout the Empire, on three continents. Spectacular Roman-era bridges, constructed exclusively to support aqueduct channels, are still remarkably intact in North Africa, Spain and France. And, while surviving feats of engineering, such as the bridge aqueducts at Segovia and Pont du Gard, capture most of the public awe and archaeological research interest, approximately 80% of known Roman aqueducts were constructed underground and thus not visible today. Roman subterranean aqueducts are critically important for two reasons. First, their enormous and collective extent means that these water diversion and control systems would have the greatest ecological and geomorphological implications and represent the most significant human alteration of the landscape since the beginnings of agriculture 10.000 years ago. Secondly, with the advent of 20th-century industrialized crop production, many if not most of these near-surface and subterranean aqueducts are at risk for damage or already have been destroyed.

ARCHAEOLOGICAL BACKGROUND AND HISTORICAL SIGNIFICANCE OF *TROPAEUM TRAIANI*

The Roman city of *Tropaeum Traiani*[2] is located 600 m from the modern village of Adamclisi in the region of southern Dobrudja (ancient late Roman province of Scythia), SE Romania. The city was occupied for five centuries (2nd–6th centuries AD) and covers an area of more than 10 ha. *Tropaeum Traiani* was a city founded together with a Roman military memorial complex (consisting of a 40-meter high triumphal monument, a mausoleum and altar) as a result of the battle, led by Emperor Trajan against the Dacians and their allies, who invaded the North the Roman province of Moesia Inferior after the first Daco-Roman war (101–102 AD).

Emperor Trajan founded this major city in a good agricultural zone, but unnecessarily distant from a drinking source of water, distant from river transportation, distant from sea transportation – in other words, in the middle of nowhere. There are Roman cities along the Danube and along the Black Sea coastline, as well as inland cities with easy access to water and trade routes. The city of *Tropaeum Traiani* was not necessary from an economic, military or geographic point of view. Furthermore, when the Romans took over an area, they normally placed their cities on or near the foundations of other cities or other major settlements because there is usually a logical reason for that indigenous settlement being there – the Romans were pragmatists first and foremost.

However, since the battle between the Roman legions and the Dacian-Sarmatian-Germanic coalition on the Adamclisi plain was perhaps one of the Empire's

[2] Tocilescu, Benndorf, Niemann 1895; Barnea *et alii* 1979; Sâmpetru 1984.

bloodiest battles with the loss of thousands of lives, Emperor Trajan wanted to make sure that this place would be remembered. Hence, not only were a mausoleum, an altar, and a trophy monument constructed (the latter of which could be seen from the Danube), but a city was also founded, 1500 m from the military memorial. The city of *Tropaeum Traiani*, therefore, was Trajan's political statement to immigrants (barbarians) entering the empire via the Danube.

What is significant from an anthropological point of view is that this city, by being established on new land, was inadvertently a social and economic experiment that succeeded for five centuries. Most who built, lived, and worked in the city had to have come from somewhere else – first the multi-ethnic Roman army and war veterans, then the architects, engineers, political and religious leaders, business people, craftsmen, farmers, and slaves. *Tropaeum Traiani* was also a walled, heavily fortified city, which means that many people who provided the economic infrastructure actually lived outside the city. Obviously, the Romans recognized that the founding of cities, towns, and military bases needed a support zone surrounding a population center, which they themselves termed the *territorium*. Significantly then, both a new city and a new *territorium* were being created, from no pre-existing ecological support system.

The city itself was first investigated by the Romanian archaeologist and historian Grigore Tocilescu between 1891 and 1909. Tocilescu's monograph in 1895 for the first time revealed the identification and purpose of the monument to commemorate Emperor Trajan's wars against the Dacians and their allies in AD 101–102. Excavations continued by George Murnu, Paul Nicorescu and other Romanian archaeologists produced significant results on the architectural shape of the monument, the placement and historical significance of the figurative sculptures (metopes), and the dating of the construction. Later excavations would reveal that the trophy monument was actually part of a larger military memorial complex which also included a mausoleum for the incinerated remains of Roman officers and an altar dedicated to the soldiers[3]. More intense excavations of the nearby city of *Tropaeum Traiani* were conducted since the 1968 by Dr. Ion Barnea (d. 2004) and since the late 1980s by Dr. Alexandru Barnea and colleagues[4].

HYDROARCHAEOLOGY PROGRAM

Initial research and test pits on the subterranean aqueducts at Şipote, 7 km from Adamclisi, were published by Alexandru Simion Ştefan in 1972[5]. He had proposed that these aqueducts had supplied water to the Roman city of *Tropaeum Traiani*. This research was very important because Emperor Trajan emplaced a major city, purely for post-war political purposes, in an unlikely geomorphological zone, too distant

[3] Sâmpetru 1984.
[4] Barnea *et alii* 1979.
[5] Ştefan 1972.

from safe drinking water. Unfortunately, Ştefan's important research on the aqueducts never continued beyond his 1972 publication.

The aim of this research is to continue where Ştefan's work concluded by further 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 (2^{nd}–6^{th} centuries AD). We are utilizing a range of remote sensing and surveying techniques: archaeological field surveying, GPS data collection, test excavations, soil phosphate analyses, water chemistry, and satellite remote sensing, within the *territorium* of the Roman city. Currently, rural settlements, natural water sources, and remains of buried aqueduct lines surrounding *Tropaeum Traiani* are being mapped.

Our research program, which also serves as an archaeological field school for university students from the US, UK, and Australia, extends outside of the boundaries of *Tropaeum Traiani* to examine the rural support network, the "economic catchment zone", and attendant cultural landscape surrounding the Roman city. The long-term research goals include understanding the ecological and economic roles of rural communities that supported this city for five centuries; study of the urban-rural interdependency during both the apex and decline of Roman imperial hegemony; and tracking of underground aqueduct systems which not only supplied water to *Tropaeum Traiani* but possibly to Roman plantation-style farms.

In 2004, Mr. Ion Dan (Cadastral Supervisor for southern Constanţa County, Adamclisi Mayoral Office) provided valuable locational information on a subterranean 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 before been documented cartographically or archaeologically. In 2004, the area was cleared and eroded soil excavated to uncover approximately one meter of the aqueduct. In 2005, our team excavated five meters of the aqueduct channel to evaluate its construction, depth, and direction. The aqueduct construction is 41 cm high; the U-shaped water channel is 26 cm high and 21 cm in width at the top; both sides of the channel measure 30–31 cm in top width (fig. 1 and 3). The aqueduct was covered with capstones that had been severely damaged by mechanized combines used in socialist-era agriculture. Therefore, this was also a rescue excavation of the exposed portion of the aqueduct.

Dr. Linda Ellis (San Francisco State University) is conducting the surveying program and test excavations of the aqueducts and territory surrounding *Tropaeum Traiani*. Three hand-sized samples of the aqueduct construction were brought to the US for analysis. Dr. John Marshall, a planetary geologist at the SETI Institute (NASA), in Palo Alto, California, conducted microscopic analysis and interpretation of the construction material. Dr. Don L. Williamson, Colorado School of Mines, identified the mineralogical (crystallographic) composition of the construction materials by means of X-ray diffraction.

Microscopic analysis of aqueduct construction materials

Preparatory to X-ray diffraction analysis, samples were cleaned with water only, and observed in a wet state to enhance color differences. General observations:

1. The large stone examined is natural. It is a large piece of fossiliferous limestone as evident from: a) uniform calcite matrix, b) whole unfragmented fossils, c) classic arc-shaped cavities above each scallop. These were not loose shells or pieces of rock cemented together by human hand.

2. Attached to the limestone clast are thin patches of true man-made "cement" or "concrete" composed of a mixture of grit, a binding agent, and tiny red sandstone pebbles. This material is only millimeters thick and is superficially attached to the limestone and does not penetrate it (*i.e.*, the limestone is all one lump). The cement is very well bonded to the limestone.

3. The scale of the limestone clast, being 15 cm across, compared to the thickness of the aqueduct walls suggests, as in the accompanying figure, that the walls might have been made of stones cemented in place, rather like building a stone wall, then smoothing off the surface. This assumption rests on the caveat that the clast size is typical of materials at the site. Can the structure be defined as concrete or should it be defined as a cemented wall? Concrete might be defined as a 'matrix-supported' material where the stones are technically "embedded" and do not touch each other in general. The corollary definition of a "cemented wall" would be a "clast-supported" material where the stones support each other and the cavities between them are filled in with cement.

4. The small flakes of material examined are different again. These were from the inner wall face of the aqueduct. They appear similar in grain size to the cement, but they are more friable, they have no red pebbles, but they have white inclusions. This is not the same as the cement. In bulk, it has a vague pinkish color in certain light, but there is no evidence from microscopy that it has a separate top layer comprising the flat surface. The accompanying image shows an edge-on view. Various grain sizes and compositions are evident, but the composition is unknown at this time. This material may have been a capping on the cement, although it is extremely friable and appears unsuitable for the application. Presumably its chemical composition rendered it more susceptible to weathering than the cement.

5. There appears to be at least five types/sources of material: 1) fossiliferous limestone cobbles, 2) loose red sandstone fine gravel from a low-energy immature stream deposit (clasts indicate rudimentary rounding), 3) loose greywacke sandstone used in the cement, 4) similar material with white inclusions used in the capping, 5) binding materials, possibly calcareous/siliceous, used for cement and capping.

X-ray diffraction analysis of Roman aqueduct cement

The same samples examined microscopically (fig. 2) were also analyzed for their mineralogical composition with X-ray diffraction using a Siemens powder diffractometer. The four graphs show the XRD data. Figure 2/1 shows the entire data set while figures 2/2–4 show the data on expanded horizontal scales over three ranges: figure 2/2 from 7 to 33 degrees, figure 2/3 from 33 to 53 degrees, and figure 2/4 from 53 to 90 degrees.

All of the strongest peaks were identified with calcite > quartz > ankerite in intensity. The peaks labeled ankerite do not match the JCPDS file data exactly, but they lie closer to ankerite than dolomite so it is likely an intermediate solid solution closer to the ankerite composition used for the JCPDS file.

The weak phases are muscovite/illite (few %) and kaolinite (~1%) and perhaps anorthoclase (disordered) (~1%). There remain a few very small peaks (~1%) unidentified (*e.g.* at 9.8 degrees and at 11.4 degrees [likely some type of clay due to large d-spacings]).

CONCLUSIONS

The results of both microscopy and X-ray diffractometry correspond very well with published geological research on the Quaternary deposits in SE Romania. Southern Dobrudja, which includes all of the *territorium* surrounding *Tropaeum Traiani* (Adamclisi) has extensive eolian loess horizons, as well as outcrops of fossiliferous limestone and other fossiliferous deposits from incursions of the Black Sea. The uppermost loess layer in the region of Adamclisi has a very high content (20–27%) of lime (CaO)[6]. Analyzed profiles of the loess horizon also contain clay fractions which are predominantly illite and mica (muscovite) with lesser percentages of kaolinite and montmorillonite[7].

This geological history has implications on the safety of drinking water in the *territorium* of *Tropaeum Traiani* and will appear in a separate publication (L. Ellis) with chemical analyses of the water sources in use today and flowing water sources archaeologically attested to have been exploited during the Roman period.

Acknowledgements

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[6] Conea 1970, p. 56.
[7] Conea 1970, p. 58.

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REZULTATELE ANALIZELOR MICROSCOPICE ŞI CU RAZE X ALE MATERIALELOR DE CONSTRUCŢIE FOLOSITE LA APEDUCTELE DIN *TERRITORIUM*-UL ORAŞULUI ROMAN *TROPAEUM TRAIANI* (ADAMCLISI, JUD. CONSTANŢA)

REZUMAT

Scopul cercetării este, pe de o parte, acela de a continua studiul apeductelor romane din zona oraşului *Tropaeum Traiani*, început de Alexandru Simion Ştefan şi, pe de altă parte, de a documenta, pe o rază de 25 km, în jurul oraşului, toate punctele cunoscute (sau încă nu) conţinând urme din perioada romană şi romano-bizantină. Metodele utilizate sunt variate: periegheză, adunarea de date pentru o bază GPS, sondaje arheologice, analize de sol şi apă, folosirea fotografiilor satelitare. Cele mai multe puncte de interes arheologic din teritoriul oraşului *Tropaeum Traiani*, precum şi cursurile de apă sau aşezările din jur sunt deja cunoscute.

Dr. Linda Ellis (San Francisco State University) a coordonat cercetarea de teren, inclusiv efectuarea sondajelor arheologice. Dr. John Marshall, geolog de la Institutul SETI (NASA), din Palo Alto, California, s-a ocupat de analizele microscopice şi de interpretarea rezultatelor acestora. Dr. Don L. Williamson, de la Colorado School of Mines, a analizat cu raze X probele din materialele de construcţie folosite pentru apeducte.

În anii 2004–2005 au fost cercetate două apeducte, primul pe o lungime de 1 m, iar al doilea pe 5 m. Sondajele arheologice au avut ca scop stabilirea tehnicii constructive, adâncimea şi direcţia. Trei probe din pereţii canalului apeductelor, de mărimea unui pumn, au fost duse în SUA pentru analize.

Rezultatele analizelor microscopice şi cu raze X corespund rezultatelor deja publicate ale analizelor depozitelor din Quaternar din sud-estul României.

Cuvinte-cheie: *Tropaeum Traiani*, *territorium*, apeducte, analize microscopice, analize cu raze X

EXPLICAȚIA FIGURILOR

Fig. 1. Adamclisi. Apeduct cercetat în 2005.
Fig. 2. Adamclisi. Probe din canalul apeductului.
Fig. 3. Adamclisi. Probele analizate la microscop.

Fig. 1. Adamclisi. Aqueduct excavated in 2005.

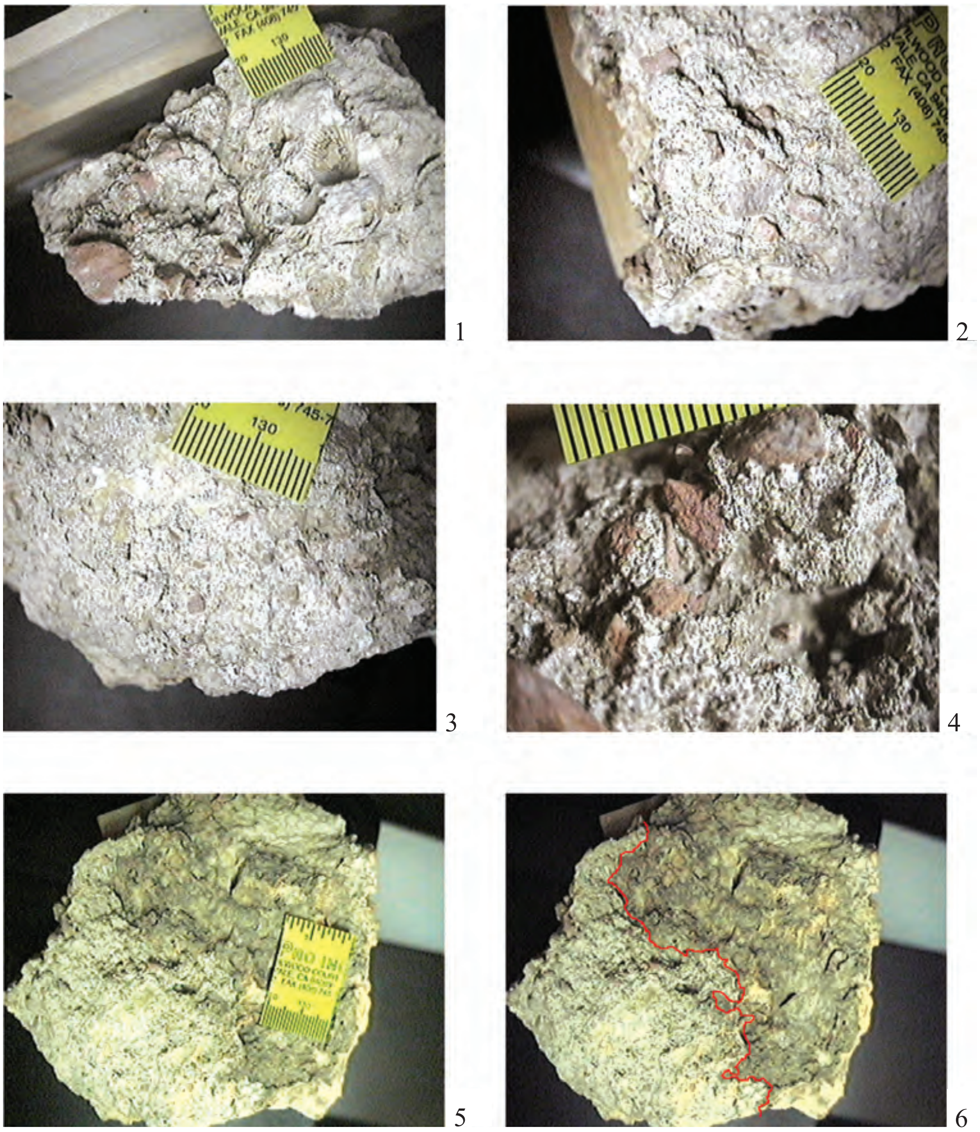

Fig. 2. Adamclisi. Samples of the aqueduct construction.

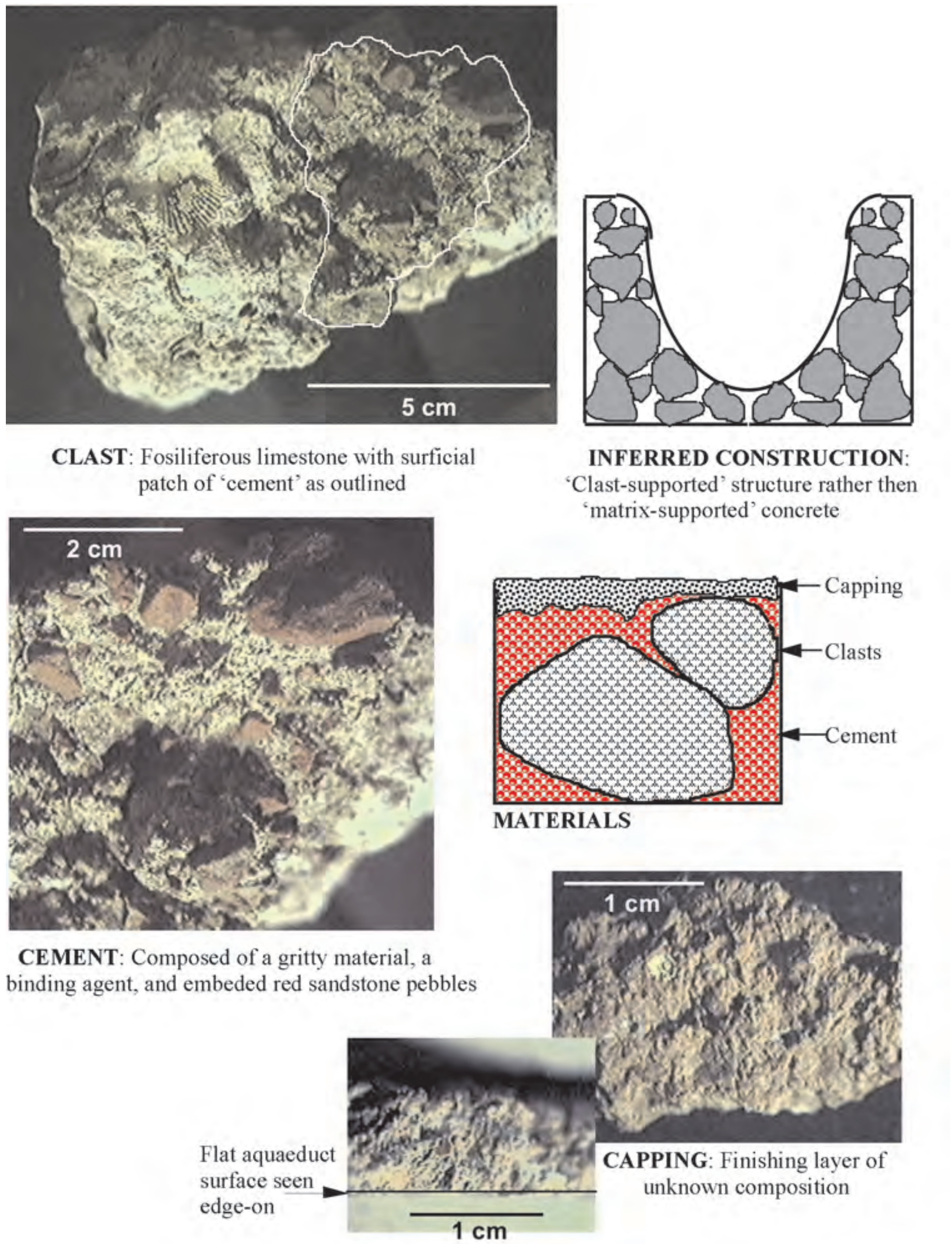

Fig. 3. Adamclisi. Samples on microscop.