# Aqueduct construction in the late-antique east: an agent-based modeling and geoarchaeological approach to building evidence for the Water Supply of Constantinople.

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## INTRODUCTION

The result of recent research (Snyder, 2013 – PhD thesis) on construction materials and workforce has shown that the Water Supply of Constantinople was one of the largest construction projects undertaken in the ancient world, requiring as much stone as the Great Pyramid of Giza and five times more manpower than of the Baths of Caracalla in Rome. However, with lacking archaeological and textual evidence, many vital questions remain about macro-level outcomes of this massive undertaking and the organisation of the labourers involved. This project provides the unique opportunity to explore one of the most under-appreciated aspects of modern classical scholarship: the spectrum of large-scale construction from the role of the individual to the function of the empire in the late antiquity.

The construction process in the eastern Roman provinces is an important topic that has seen little inclusion into modern scholarship, especially compared to Imperial Rome and the west. Often, this is based on the perpetuated and antiquated idea that the decline and fall of Rome signalled the end of an administrative ability to produce long-lasting monumental architecture. This research project will address this knowledge gap by investigating details of the large-scale building operations that led to these important infrastructural successes in the hinterland of Constantinople and beyond, many of which are under threat from modern development projects. In order to accomplish this, an original interdisciplinary approach will be taken that includes the application of new methods such as social simulation and geospatial analysis.

## AIMS AND METHODOLOGY

Agent-based modelling (ABM) is an emerging technique for analysing social behaviour and organization in an archaeological context. Important studies include Kohler's (1995) "Agent-based modelling of Anasazi village formation in the northern American Southwest", Graham's (2006) "Networks, Agent-Based Models and the Antonine Itineraries: Implications for Roman Archaeology", and Maas and Ruths' (2012) "Road Connectivity and the Structure of Ancient Empires: A Case Study from Late Antiquity". Applying GIS and ABM to the study of construction processes of the Water Supply of Constantinople will allow for the systematic exploration of assumptions made due to the lack of physical and textual evidence.

How many people could build at the same time? What role did the terrain play in the location of the construction site? Would composite building materials be prepared closer to the raw material source or the construction site? What would have been the most efficient combination of workmen compared to the available stream of material resources? This innovative computer-based simulation will provide a means of experimenting with 'what-if' scenarios based on important variables such as topography, bedrock geology, workforce interaction, and climate to answer these questions. Applying agent-based modelling to this project will allow us to approach a quantitative subject of manpower and required construction materials with new and unique qualitative results— something that was previously impossible.

- PART I: QUARRIES, PRODUCTION SITES, AND SUPPLY NETWORKS

With no evidence of quarries, little has been said with confidence about the specific regional sources of stone (facing, core rubble, water channel masonry) and sand (mortar aggregate) materials for the Water Supply of Constantinople. Through previous research, it has been shown that vast amounts of these materials were needed and consequently, a massive workforce for their extraction and implementation.

- **Aim**: Identify likely areas of stone and sand sources used in the building of the water supply and long wall. By identifying any geographical relationship between building sites and these raw material sources, a system of supply networks will be built using GIS and tested through ABM analysis (discussed in part II).
- **Methods**: Detailed geological bedrock data for the Thracian Peninsula will be used to identify possible areas of raw material procurement in proximity to the water supply and long wall. This information will be integrated with data from the Anastasian Wall Project to build a terrain model which will be the basis for this project such as developing scenarios for material transportation by least-cost path GIS analysis as well as for the agent-based computer simulations in Part II of this project.

- PART II: WORKFORCE ORGANISATION AND BUILDING LOGISTICS

Again, with almost no information available from the textual or archaeological record, little is known about the size of the workforce, how the work was organized, or the time it took to construct them. Janet DeLaine (1997) developed methodology to explore large-scale construction scheduling and organization using analogous studies of historical construction prior to mechanization in her work on the Baths of Caracalla. This work has been very important for our understanding of monumental construction in Roman Italy but the methods cannot be directly transferred, due in part to the scant evidence for construction organization in the east.

- **Aim**: Explore scheduling and worksite organization in order to build timeframes of construction as well as identify aspects of the workforce that built the Water Supply of Constantinople and the Anastasian Wall.
- **Methods**: Using the terrain model of Thrace from Part I as the cornerstone, agent-based modelling (NetLogo) will be applied to test scenarios of construction logistics. These 'what-if?' scenarios, derived from analogous information from earlier large-scale construction projects in the Roman west (i.e. Eifel Aqueduct, Hadrian's Wall, Baths of Caracalla), can "generate answers 'organically'" (Graham, 2006: 60) with limited archaeological and textual evidence (Maas and Ruths, 2012). Additionally, the transportation network from Part I will be simulated to test and compare the usefulness of GIS analytical techniques.

This paper will discuss the historical framework, the project to date, and the preliminary design of this new project phase. This is part of a larger project on the archaeology and engineering of the Water Supply of Constantinople to be undertaken at the University of Edinburgh starting in the fall of 2014 under the direction of Prof. James Crow.