[SUPPLEMENTARY MATERIAL]

Investigating the spatial organisation of Bronze and Iron Age fortress complexes in the South Caucasus

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Aerial drone survey

Ground control targets were laid out and mapped using a Leica TS-02 Total Station. Images were captured at regular intervals (80 per cent overlap) and then used to generate a georeferenced photogrammetric model with Agisoft Photoscan. The resulting 5 cm resolution orthoimage and digital elevation model (DEM) were used to create a number of DEM-derived products in ESRI's ArcGIS. These products were correlated with additional georeferenced survey data (such as walls visible at the surface) in order to determine which were most useful in identifying archaeological features.

Surface mapping and collection

Unlike some areas of the South Caucasus (e.g. the rain-drenched Black Sea coast and the highland plateaus of southern Georgia and northern Armenia), the landscape of lowland Kvemo Kartli is reasonably well-suited to systematic surface collection. The warmer, drier climate means that surface collections can provide a significant sampling of ceramics with which to assess the chronology and spatial extent of sites.

In 2013 and 2014, we tested a variety of systematic surface collection methodologies in order to determine the collections strategy that best matched the local landscape and our research goals (Erb-Satullo 2018). Surface collection within gridded squares proved a useful and flexible strategy for obtaining a significant yet manageable sample of surface materials. The size and distribution of these squares were adjusted based on the specific research questions and the quantities of materials exposed at the surface of each site.

With regard to hilltop sites, it is worth considering the effect that erosion may have had on the distribution of materials. Indeed, differential colluvial erosion has been documented on hilltop sites in this region (Erb-Satullo 2018). The specific environs of Kavakh Tepe and Mtsvane Gora were broadly similar but there were some differences that affected the surface exposure of ceramics. At Kavakh Tepe, vegetation cover and erosion patterns varied slightly, but did not affect the overall pattern; some of the highest densities of ceramics were found in areas with heavier vegetation. Importantly, the higher densities of ceramics seen in the lower settlement are situated on rising terrain separated from the main hill by a low valley. Thus, it is physically impossible for ceramics in this area to have derived from erosion off the main hill. Some colluvial erosion undoubtedly did take place in other areas of the site, but the key element of the distribution—a lower settlement somewhat removed from the main hill, cannot be accounted for by colluvial erosion.

At Mtsvane Gora, the south slope of the hill was noticeably warmer and drier, so colluvial erosion and exposure of ceramics and other materials were much more pronounced than on the north slope. In these circumstances, the extra-mural distribution of ceramics on the southeast slope of the hill is more likely the result of erosion and/or discard of materials down the slope.

In terms of ceramic terminology, the category of Late Bronze-Early Iron Age (LBA–EIA) ceramics included those dating from roughly the second half of the second and the first half of the first millennium BC, preceding the Achaemenid, Hellenistic and Roman periods (sometimes referred to collectively as the "Antique" period in local terminology). This differs slightly from other chronologies, where metal artefacts, whole vessels, and/or the presence of intrusive Urartian materials allows finer distinctions (see Abramishvili 1957; Smith *et al.* 2009: 68–93). For surface collections, we prefer this coarser set of chronological distinctions.

Broadly speaking, the LBA–EIA material culture groupings in modern day Eastern Georgia are far from settled (Sagona 2018: 380–82). While ceramics from this period (Figure S1) are distinguishable from earlier Middle Bronze Age and later Achaemenid-period ceramics, finer divisions are difficult to make, especially without whole vessels. Much discussion surrounds the geographical and chronological differentiation of assemblages such as the Samtavro and Lchashen-Tsitelgori Cultures (e.g. Akhvlediani 2005), the latter a Georgian variant of the Lchashen-Metsamor sequence discussed by Smith *et al*. (2009: 68-93). The source of this challenging chronological problem is rooted in a) the lack of major ceramic transformations within this period and b) the likelihood of significant geographical variation within this mountainous region (for additional explanations, see Sagona 2018: 382). Resolution of these issues must await the accumulation of a significant number of radiocarbon-dated ceramic assemblages (e.g. Bertram 2008).

Figure S1. Selected sherds from Kavakh Tepe surface collection showing typical LBA–EIA forms, as well as one example of mica-tempered pottery (lower right).

Magnetometry

Archaeological magnetic prospection maps surface and subsurface variations in the magnetic properties of deposits with the aim of distinguishing between natural and anthropogenic features. A magnetic gradiometer measures the local magnetic field at a given location. This measurement is of the sum of both induced and remanant magnetisations (Dalan 2005).

Remanent magnetism is the permanent magnetisation of a material that occurs during its compositional, thermal or depositional history (Heimmer & De Vore 1995). These materials remain magnetic in the absence of a magnetic field. Magnetometry surveys can be particularly successful in detecting anthropogenic activities that utilise or create materials with remanent magnetism. The success is partially due to the robust anomalies in magnetic data caused by thermoremanence. Thermoremanence occurs when soils, clays or rocks containing iron oxides are heated—most naturally contain 1 to 10 percent. The particles at first have no net magnetic properties, but when heated to the Curie point (about 600° C) the magnetisation is completely removed only to remagnetise at the time of cooling to the current geomagnetic field (Clark 2001). Many processes of heating were common in prehistoric and historic settlements including pottery production, cooking and perhaps the destruction of structures through burning (Kvamme 2006).

The earth's magnetic field produces a second type of magnetism known as induced magnetism. This type of magnetism only exists in the presence of a magnetic field. The potential of a material to become magnetised is known as its magnetic susceptibility, which is a function of the minerals in its composition that can become magnetised. Most soils and rocks contain such minerals and, in general, topsoils tend to be more magnetically susceptible than subsoil layers as well as the rocks they were produced from. This is the case for several reasons, including anthropogenic and naturally occurring fires as well as human refuse of organic and thermally altered materials during occupation. There is also a natural tendency for iron minerals to accumulate in topsoil due to their relative insolubility in comparison to less magnetic soil contents. Additionally, pedogenic enhancements such as low-heat chemical reactions as well as organic processes such as magnetotactic bacteria and other bacteria cause magnetic compounds to accumulate in topsoils (Dalan 2005; Kvamme 2006).

Slight anthropogenic alterations to topsoils are therefore detectable using sensitive instruments like magnetometers and magnetic susceptibility meters. The magnetic gradiometer has two sensors aligned vertically. The difference between the two measurements is called the "magnetic field gradient" (Kvamme 2001) and the unit of measurement for magnetic surveys is the nanotesla (nT). The use of the two sensors makes for a quick yet sensitive survey instrument. The distance of sensor separation determines the sensitivity of the instrument. The farther the sensors are apart, the closer it approaches the sensitivity of a total field measurement. However, there is a limit to how far apart the sensors can be with confidence that the operator can maintain vertical alignment while walking a straight line; a standard distance is 0.5 to 1m (Clark 2001).

A Bartington 601 Magnetic Gradiometer, consisting of a single axis magnetic field gradiometer system with two gradiometers mounted 1m apart on a horizontal bar, was employed in the survey. This instrument's configuration provides sensitivity of archaeological anomalies to an average depth of one meter. Surveys were conducted in parallel transects which were guided by fibreglass tapes laid precisely along the transect direction at 0.5m intervals with a 0.125m sampling separation along the walking direction.

The magnetic gradiometry data were downloaded and processed in ArchaeoFusion, a program developed by CAST. Magnetic data was processed using various processes depending on potential data issues. A zero median traverse (ZMT) was applied to the data of zig-zag survey grids to reduce striping effects caused by the directional changes of the survey direction and differences between sensors, although a majority of the survey was conducted in a unilateral transect pattern. A mean profile filter was applied which further assists in reducing striping effects, but it is often better at reducing stripes that are not the entire length of a profile. In some cases, destaggering was applied to reduce or remove data offsets caused by zig-zag survey. Grid matching was applied to reduce edge effects between survey grid blocks where necessary. A low pass spatial filter was applied to smooth data and reduce noise. The data were clipped to one or two standard deviations to enhance specific archaeological features. Additionally, data were resampled to 0.125 × 0.125m cells for visual appeal.

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