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Neolithic water management and flooding in the Lesser Caucasus (Georgia)

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ABSTRACT

River management is generally thought to have started at 5500 cal. BC within the development of eastern Neolithic societies. In the Lesser Caucasus, evidence of early river management has been discovered around the famous Neolithic sites of Shulaveri, Gadachrili Gora, and Imiris Gora in Georgia. Here we report a preliminary data set indicating that river management was set up at 5900 cal. BC leading to the flooding, destruction, and local abandonment of the hydraulic infrastructures of the Gadachrili village between 5750 and 5430 cal. BC. The hydraulic infrastructures were developed during a more humid period encompassing the 8200 cal. BP (6200 cal. BC) climatic event, probably to optimize agricultural yield. It potentially led to the first prehistoric engineering accident for which there is evidence, which may have been followed by the reorganisation of the occupation and/or to architectural modifications.

1. Introduction

Despite intensive surveys, fieldwork, and excavations conducted in the last decade by international teams, cross-research between archaeology and geomorphology is limited in the Lesser Caucasus, a mountainous region at the crossroads of Europe, Asia, and Africa. Excavations within the framework of a Caucasian-European joint project encompass some of the most important Neolithic sites of the Lesser Caucasus in Armenia (Badalyan et al., 2010; Chataigner et al., 2014), Azerbaijan (Lyonnet et al., 2012, 2017; Helwing and Aliyev, 2017) and Georgia (Hamon et al., 2016; Hansen and Mirtskhulava, 2017; Hansen and Ulrich, 2017). In the last decade, understanding of the Neolithisation of the Lesser Caucasus has grown. The dates of its emergence have been defined to the turn of the 6th millennium BC, with regional specificities identified (Badalyan et al., 2010; Guliyev and Nishiaki, 2010; Lyonnet et al., 2012; Hamon et al., 2016; Chataigner et al., 2014). The development of Neolithic societies in the Middle East and Central Asia was always closely linked to the management of water resources. This is illustrated by prehistoric water management in the Jordan Valley (Mithen, 2010; Fujii, 2007). There, the Neolithic is a key period of significant development, leading to the birth and prosperity of the first urban communities of the Early Bronze Age. The first hydraulic installations, intended, among other things, for the irrigation of cereal crops, appeared in the 6th millennium BC in Mesopotamia (Adams, 1974).

Defining clear prehistoric water management structures in the landscape and in stratigraphy is a difficult task due to their low archaeological visibility. In the Lesser Caucasus, signs of small artificial channel structures have been observed during the excavations of some Neolithic sites in Azerbaijan (Lyonnet et al., 2012, 2016; Ollivier et al., 2016) and Georgia (Hansen and Mirtskhulava, 2012), but their role has not been clearly defined as they have

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revealed limited evidence for runoff both through stratigraphy and sedimentology. With surface water management, channels vary widely in shape, size, and hydraulic characteristics (Bishop et al., 1967; Aurenche, 1982). They were frequently built to divert perennial and/or non-perennial river flows (Huckleberry et al., 2012; Huckleberry and Rittenour, 2014; Doolittle, 2011, Van Andel et al., 1990; among others). Their possible association with irrigation is also difficult to determine. The interplay between the need to respond to and to overcome certain natural constraints (climate, lithology …), and the diversity of cultural phenomena specific to different societies, makes the links between water management structures and the need for irrigation ambiguous (Staubwasser and Weiss, 2006; Coombes and Barber, 2005; Hassan, 2011; Cauvin, 1978).

Since the 1960s, some archaeological operations have been developed in Gadachrili Gora, a Georgian Neolithic site from the Southern Caucasus Shulaveri-Shomu culture (Hamon et al., 2016). In 2013, geomorphology research was developed in the framework of archaeological investigations in a joint project between the Georgian National Museum and the French National Centre for Scientific Research (Hamon et al., 2016). Gadachrili Gora is part of the Shulaveri group sites, located close to the modern village of Imiri in Kvemo-Kartli. It is close to the sites of Shulaveri, Imiris, and Dangreuli Gora that have provided the first chronology for the area as well as most of our knowledge on the first Neolithic culture and agriculture in Georgia (Kiguradze, 1986; Hamon, 2008).

We present here our results pertaining to the discovery of a series of channels linked to a probable Neolithic water management system discovered in the vicinity of Gadachrili Gora, diverting the flow of the Shulaveri Ghele, a tributary of the Khrami river. In support of this discovery, we also briefly present an example of a Neolithic channel under study in the archaeological site of Mentesh Tepe (Middle Kura Valley, Azerbaijan).

Our results mainly raise the question of the links between climate, autocyclic phenomena, and development of water management structures in a region poorly known in this field, through a study integrating radiocarbon dating, geomorphology, archaeology, and palaeobotany of carpological remains. In spite of these different environmental, technological-typological, and topographical indicators, we carried out isotopic analyses on the seeds in order to characterise or not the occurrence of irrigation. Previous studies around the Mediterranean basin show that the carbon isotopic composition of cereal grain (mainly barley and wheat) can be used to evaluate the occurrence of irrigation practices, increasing aridity, or the impact of drought on Neolithic and Bronze Age societies (Araus et al., 1997a; b; Flohr et al., 2011; Wallace et al., 2013). In contrast, very little data of this type are available for the Lesser Caucasus where irrigation practices are not yet clearly identified for Prehistory.

Through this work we would like to highlight the possibility of the development in the Caucasus of the oldest known water management practices. In addition, we present an original focus on the potential effects of torrential palaeo-floods on Neolithic water management structures and riparian habitats.

2. Regional setting

2.1. Environmental context

Like the well-known Neolithic sites of Shulaveri Gora, Imiris Gora, and Aruchlo, Gadachrili Gora is located in the Kvemo-Kartli Plain dominating the Marneuli-Kura depression. The mountains surrounding the site show altitudes between 450 and 1080 masl and consist mainly of Cretaceous limestones, sandstones, and breccias, and of Upper Pliocene-Middle Quaternary basalts and andesites (Fig. 1). Present-day local climate is ranked, according to the Köppen classification (Peel et al., 2007), as warm-humid continental (Dfa). The average annual temperature is 13.4 °C and about 472 mm of precipitation fall annually (Climate-Data.org). This eastern part of Georgia has the driest climate of the country (Kvinikadze et al., 2006). The vegetation mainly consists of thornbush steppe type present on slopes areas, where plants develop in former forest areas. The dominant plants of this type of steppe vegetation are *Paliurus spina-christi* and steppe grain species (*Bothriochloa ischaemum, Festuca ovina, Stipa pulcherrima*). Here and there separate specimens of field maple and nettle tree (*Celtis caucasica*) can also be found (Nakhutsrishvili, 2012).

2.2. The Shulaveri and Khrami hydrosystem

This mountainous and steppic landscape is also cut across by a well-developed hydrosystem consisting of the Khrami river and its local tributary, the Shulaveri river (Fig. 1). The Khrami river is a right-hand side tributary to the Kura river (Fig. 1). It originates from a spring, located on the southern slope of the Trialeti range at an altitude of 2422 masl. With a length of 201 km and a watershed of 8340 km^2, the Khrami river has also two main tributaries, the Debeda and the Mashavera rivers. The hydrological regime is characterised by one significant spring flood. In other periods of the year, the water level is mostly low and occasionally disrupted by summer and autumn high waters. The annual discharge rates fluctuate from 7.02 to 51.7 m^3/s, depending on location (U.S. Agency for International Development & Development Alternatives Inc., 2002). The Shulaveri river originates from the joining of two springs on the northern slope of the Lokhi range at an altitude of 1190 masl and joins the Khrami from the right bank. The total length of the river is 38 km, with a catchment area of 117 km^2. Arriving in the plain, its average many-year discharge (0.44 m^3/sec) entirely runs to irrigation channels. The Shulaveri is not currently a permanent river. Both rivers, Khrami and Shulaveri, are generally fed by rain water (40–45% of annual discharge), snow water (20–25%), and ground waters (25–30%) (United Nations, 2011).

2.3. Archaeological setting

The site of Gadachrili Gora (363 m asl., 41°23′ N, 44°49′ E, Fig. 2) forms part of a series of Neolithic settlements (tell) in the Kvemo-Kartli Plain (Hamon et al., 2016), distributed along a non-perennial tributary of the Khrami river, the Shulaveris Ghele (Fig. 1). It occupies a more or less central position between the sites of Shulaveris Gora, Imiris Gora, and Dangreuli Gora (totally destroyed today). The excavation of the latter in the 1970s provided the first chronological frame and knowledge of the Neolithic Shulaveri-Shomu culture in Georgia (Kiguradze, 1986). The middle part of the site is actually incised by the river Shulaveris Ghele. As a result, two thirds of the former settlement has been completely destroyed. The south-eastern side of the site and a small quantity of cultural deposits on the right bank of the river have survived. The radiocarbon dating places the first levels of this tell between 5920 and 5720 cal BC (Hamon et al., 2016). The overall archaeological stratigraphy consists of two horizons showing different types of settlement organisation. Evidence from the deepest occupation levels suggests a high-density occupation in the settlement, with complex episodes of destruction and rebuilding. The coexistence of different building techniques in the two horizons has to be noted. The high number of storage structures and the discovery of organised built spaces dedicated to storage raise many questions about the status of the site, the organisation of agricultural practices, and the relationship of these populations to the hydrographic network within the area. In addition, the spatial distribution of the