

PALEOHYDROGRAPHIC EVOLUTION AND ITS INFLUENCE ON HUMAN SETTLEMENT IN THE KARTHALINY BASIN (GEORGIA)

Stefano Furlani^{1,2}, Giovanni Monegato³, Alberto Stinghen^{4,1}, Elena Roza⁵,
David Kuparadze⁶, Giovanni Boschian⁷, Matteo Massironi¹ & Aldino Bondesan¹

¹ Dipartimento di Geoscienze, Università degli Studi di Padova, Italy

² Dipartimento di Matematica e Geoscienze, Università degli Studi di Trieste, Italy

³ Istituto di Geoscienze e Georisorse, Consiglio Nazionale delle Ricerche, Torino, Italy

⁴ Museo Tridentino di Scienze Naturali, Trento, Italy

⁵ Dipartimento di Studi Umanistici, Università Ca' Foscari, Venezia, Italy

⁶ Caucasian Institute of Mineral Resources, Tbilisi, Georgia

⁷ Dipartimento di Biologia, Università di Pisa, Italy

Corresponding author: S. Furlani <sfurlani73@gmail.com>

ABSTRACT: Two Bronze Age human settlements of the Western Karthaliny Basin (Transcaucasia region, Georgia) were studied using a multidisciplinary approach. Satellite data (Corona, Landsat) and aerial images, as well as new archaeological data and a detailed field survey were applied to the study of the hydrographic evolution of the Kura (Mtkvari) River and of its tributaries; its influence on the archaeological sites scattered between the villages of Natsargora and Agara was also examined. Finally, four stratigraphic profiles were analysed; these are situated along the Kura river and on its tributaries flowing from the Greater Caucasus: the Western and the Eastern Prone.

Geoarchaeological analyses were carried out in the Bronze Age settlements: the first one -Natsargora- is situated on the top of a mound facing a valley, in an area of low hills, and it lies upon the Neogene bedrock. The position of the site indicates that the drainage system was already in a phase of deepening during the Early Bronze Age. The second one is located on a terrace of the Kura River and corresponds to the mound of Aradeti Orgora. The reconstruction of the palaeosurfaces and palaeochannels, and a radiocarbon date from the base of this site, allowed to outline the changes in fluvial style and drainage network.

Keywords: Geoarchaeology, geomorphology, late Holocene, Kura River, Georgia.

1. INTRODUCTION

In regions where early human settlements are well preserved, researchers studying the Holocene evolution of the landscape can take advantage of archaeological data, which represent specific markers, as well as useful chronological tools.

Usually, human settlements are closely related to the availability of water. In this perspective, river terraces were valuable locations, close to the river water, and also protected from natural hazards, like river floods. They represented ideal positions also from a strategic point of view, dominating the surroundings areas and improving the protection of the sites from enemies.

Human traces related to fluvial sediments or morphologies are the key to date alluvial events; they become crucial where river dynamics have changed the landscape through time.

This paper aims at outlining the palaeohydrographic evolution of the Kura River (Mtkvari in Georgian) and the related tributaries upstream of Gori, to the West of this town; the area lies between the archaeological sites of Natsargora and Aradeti Orgora, whose study explained the evolution of the drainage pattern.

2. STUDY AREA

The Karthaliny Basin is located in the Shida Kartli region of central Georgia. It consists of very wide basins and valleys confined between the Great Caucasus to the North and the Lesser Caucasus to the South (Fig. 1). From a geological point of view, the basin belongs to the system of Transcaucasian (*sensu* Khain, 1975) sedimentary basins related to the Alpine Orogenesis. The area is enclosed between two mountain ridges with opposite vergence, *i.e.* the North-verging Lesser Caucasus and the South-verging Greater Caucasus (Koçyiğit et al., 2001). The continental collision is still evolving, and it is testified by the high seismicity of the region (Adamia et al., 1977; Gamkrelidze, 1986; Triep et al., 1995; Reilinger et al., 2006; Tan and Taymaz, 2006).

The Karthaliny basin is 1.200 km² wide and its geometry is complicated by the internal ridge of the Kvernaqi Range. The area to the North of the ridge is dominated by alluvial deposition originating from the Greater Caucasus, while the Southern one consists of the middle valley of the Kura River. The Kura River is 1520 km long, with its upper catchment in eastern Turkey; then it crosses the whole Georgian territory from West to East, and flows into the Caspian Sea in Azerbaijan. The present level of the Caspian Sea is about -26 m below mean sea level, and it shows larger and

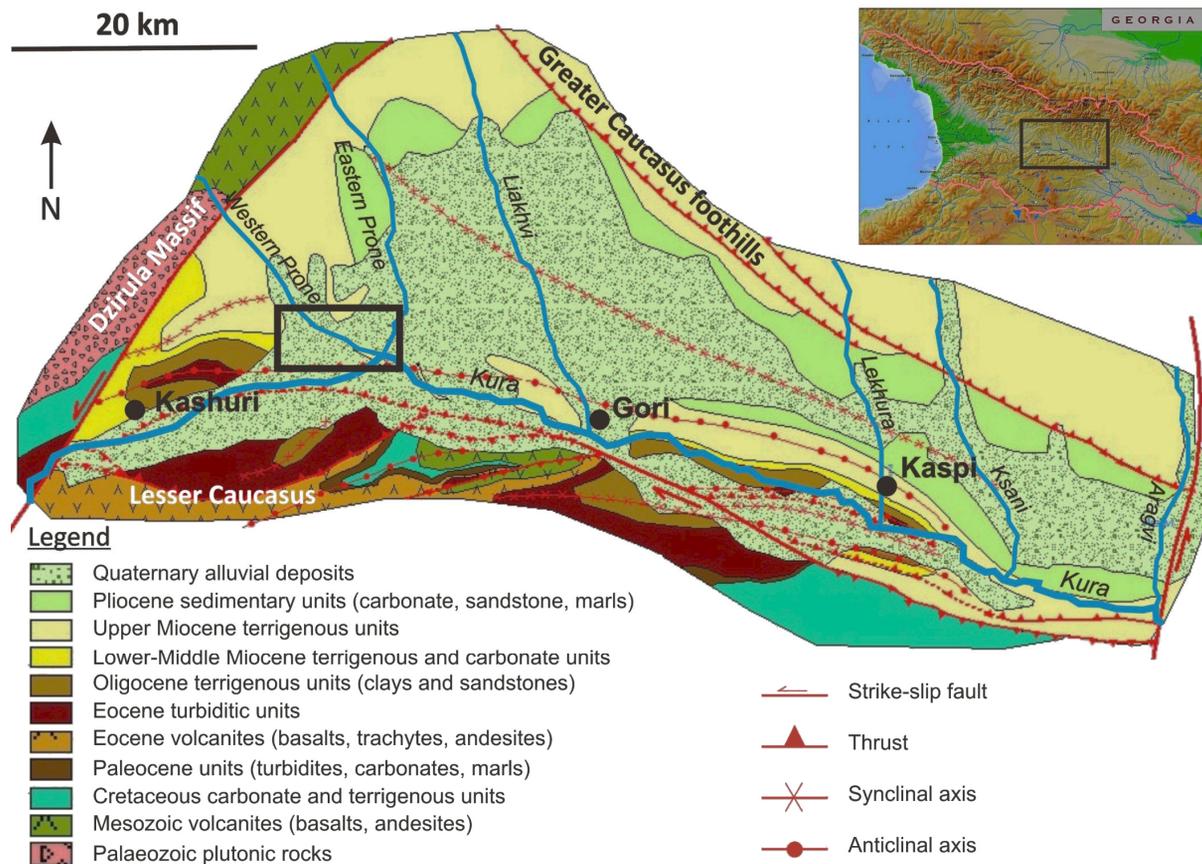


Fig. 1 - Sketched geological map of the Karthaliny Basin (modified after Gudjabadze, 2003). The Karthaliny Basin is located in the black frame in the geographical map of Georgia, while the study area is framed in black.

faster fluctuations compared to global sea level fluctuations (Karpitchev, 1993). The Caspian Sea is independent from the eustatic sea level of the world's oceans, thus creating an independent base level.

The basin is characterised by foreland basin sedimentary sequences of the Greater Caucasus, with a thickness of 2 km for the Middle Miocene – Quaternary time span (Ershov et al., 2003). The sequence starts with deposits ascribed to shallow-marine *facies* and shifts towards Quaternary continental deposits; these are mostly alluvial and are related to the Kura River system and -to the North- to rivers flowing from the Greater Caucasus, *i.e.* the Prone and the Liakhvi River (Gudjabadze, 2003). These Quaternary alluvial deposits mainly consist of sand, with subordinate gravel and clay. The latter is very important from an archaeological perspective, since it was exploited as raw material for bricks and pottery. The petrographic characteristics of the sediments indicate that the alluvial deposits originated from the mountain area of the Lesser Caucasus: the lithotypes coming from Tertiary magmatic rocks are abundant, together with gabbros deriving from the Permian magmatic series located westwards of the study area (Gudjabadze, 2003). Chert fragments originate from carbonate units located in the Southern as well as in the Northern zones of the basin. The Tertiary sedimentary fill of the Karthaliny basin is characterised by marls and chalky clays, with interbeddings of quartzitic and micaeous sandstones.

The climate of Georgia was divided into nine classes, as suggested by Davitaia (1970). Specifically, the climate of the Shida Kartli region is partially wet, with cold winters and long, warm summers. Maximum temperatures can reach 40°C in summer, while minimum temperatures, usually in January, can reach -16°C, but are usually around -5°C. Soil temperatures show similar variations. Annual rainfall is around 450-500 mm, with minima in winter (with 40-50 days of snow), and maxima in summer, with aspects of subtropical climate. Solar radiation is peculiarly intense in summer, since the days are mostly clear and with scarce cloud cover.

3. MATERIALS AND METHODS

This study was carried out following a multidisciplinary approach, with focus on published data and on new findings. It includes remote sensing and aerial photo analysis, archaeological survey in the area of two archaeological sites (Natsargora and Aradeti Orgora), and geological survey that was carried out during two research missions (2010, 2011). At Natsargora, archaeological excavations uncovered the anthropogenic features of the site and the thickness of the Quaternary sedimentary sequence. At Aradeti Orgora, which is located on the scarp of a river terrace, the sedimentary sequence and the lowest levels of the archaeological



Fig. 2 - The archaeological site of Natsargora. A) View from the Southern side. Early Bronze Age remains on the top of the site; B) view of the Natsargora mound toward South.

sequence were observed on outcrops along the river bank.

Remote sensing analysis was carried out on CORONA and ASTER images, upon which the position and the geometry of the major rivers and palaeochannels were reconstructed. The main morphometric features and hydrological elements of the studied area were traced on a Digital Terrain Model (DTM), produced using SRTM (Shuttle Radar Topography Mission) data with 90 m/pixel resolution (Farr et al., 2007). Fieldwork on the sedimentary cover was carried out contemporary to the archaeological survey, and several stratigraphic logs were sketched. A wood fragment from Aradetis Orgora was dated in the Radiocarbon Dating Laboratory of the Weizmann Institute of Science (Israel).

4. DATA

Field survey data and aerial photo analysis are reported in the following paragraphs. Fieldwork was focused on the study of the two Bronze Age archaeological sites, *i.e.* the Natsargora (Fig. 2) and Aradetis Orgora mounds (Fig. 3). An analysis of the relief in the study area and the related hydrographic network have been provided. Moreover, the stratigraphic sections of three outcropping profiles were described.

4.1. Relief analysis and hydrographic network

The Southeastern sector of the study area is crossed by the Kura River (Fig. 4), whose alluvial plain lies at an average altitude of about 630 m a.s.l., gently sloping towards Southeast. To the North, the plain is limited by an alluvial terrace extended throughout the study area, from the Eastern to the Western side (Fig. 4, 5c, d); its average elevation is about 650 m a.s.l., and it slopes gently southwards (Fig. 6). It is also incised by the Western and Eastern Prone, which are two left-side tributaries of the Kura (Fig. 1, 4).

Conversely, the Northwestern sector is characterised by a hilly morphology shaped in Miocene sedimentary units. These hills are the southernmost fringe of the Dzirula Massif, and consist of low, rounded ridges, ranging from 600 to 900 m; these are interrupted by small valleys developed along the E-W direction. This relief is characterised by slopes with average gradients lower than 15° (Fig. 5a, b); the summits are elongated in a SSE/NNW direction and follow the main tectonic structures of the area, fold axes and faults, whose strike is SSE/NNW. The southernmost relief is connected to the alluvial terrace through a surface that was interpreted as an erosional glacis (Fig. 5b).

4.2. Stratigraphic sections in the study area

4.2.1 Section 1. Stratigraphic section along the Eastern Prone

WGS 84 coordinates: 43°53'11,46"E 42°3'56,083"N, elevation: 670 m a.s.l. (Fig. 7a). This 10 m high per 10 m wide section crops out on the slope of the Eastern Prone left bank, Northeast of Aradetis Orgora.

A 5 m-thick gravel body lies upon an erosional surface shaping the Tertiary sandstone bedrock. It is made up of roughly bedded, clast-supported and cemented sandy gravels; the clasts are rounded and comprise volcanic and sedimentary rocks. The top of this sedimentary body is an erosional surface, overlain by a 2 m-thick coarse gravel deposit. The pebbles are rounded, with an average size coarser than in the underlying body, and mainly made up of Tertiary volcanic rocks, suggesting a Lesser Caucasus provenance. The scarce matrix is sandy and the structure is clast-supported, with evident imbrications. This deposit is overlain by a 3 m-thick silty unit with gravel lenses occurring in the lower part, while the upper one is a massive reddish brown silt, on which a soil is developed. This includes an A horizon overlying a Bk petrocalcic horizon.

4.2.2 Section 2. Stratigraphic section along the Western Prone

WGS 84 coordinates: 43°47'23,528"E 42°3'58,119"N, elevation: 650 m a.s.l. This 3 m-high section crops out on the slope of the Western Prone right bank, Northwest of Aradetis Orgora, (Fig. 7b). A 0.50 m-thick layer of cemented gravel lies upon an erosional surface that cuts the bedrock, which is made up of Tertiary sandstone. These roughly bedded gravels are clast-supported, with rounded clasts made up of sedimentary rocks. The top of this unit is marked by an erosional surface overlain by 2 m of roughly bedded sandy gravel with rounded pebbles, made up of volcanic and sedimentary rocks, and abundant sandy matrix with matrix-supported structure. The section ends

up with about 0.5 m of massive silt, largely covered by vegetation.

4.2.3 Section 3. Stratigraphic section along the Western Prone, left side

WGS coordinates: 43°46'27,47"E 42°2'35,663"N, elevation: 650 m a.s.l. This 10 m-thick section (Fig. 7c) is located 2 km upstream of Aradetis Orgora, along the slope of the left bank of the Western Prone River. The bottom unit is a 6 m-thick plainly bedded sandy gravel layer with small cross-bedded lenses; the structure is clast-supported. The pebbles are rounded, with an average size of 50 mm, and made up of sedimentary and volcanic rocks. An erosional surface shapes the top of this unit, and is overlain by an about 4 m-thick coarse gravel body with clast-supported structure; the pebbles are rounded, with an average size of 10-30 mm, and mainly made up of volcanic rocks; the sandy matrix is abundant.

4.3 Archaeological data

4.3.1 Natsargora

The Natsargora archaeological site (Fig. 2a, b) is located in the Khashuri District, at the western border of the Shida Kartli province, close to the homonymous village (Bertoldi et al., in press), at the confluence of the Natsargorisghele and Pleula (Fig. 4) streams.

The site was excavated, between 1984 and 1992, by the Georgian archaeologist Alexander Ramishvili, and is presently investigated by a joint Georgian-Italian archaeological expedition (Rova et al., 2010; Puturidze & Rova, in press).

In the surroundings of the site, the relief is shaped into rather soft Miocene Molasses, and is characterised by smooth hills and valleys mostly developed along the E-W direction. Some small outcrops of sandstone and/or marl dipping towards the North can be observed in the surroundings of the site, mostly in spots affected by strong erosion.

Unfortunately, the topography of the whole area has been strongly reshaped in recent times for agricultural purposes: surfaces were smoothed mechanically, ditches were excavated, wide land extensions were reforested and then cleared again; therefore, it is now somewhat difficult to reconstruct the features of the original land- and soilscape.

At present, the area is mostly used for cattle grazing and crop growing, with sparse open wood areas and some scattered scrubby vegetation; the Eastern side of the archaeological site is partly covered by scrubs and few trees.

The archaeological site lies on the top of a small hill protruding from the side of the gently dipping ridge shaped by the two streams. This hill is about 50 m wide and 90 m long, with its major axis oriented NW-SE and

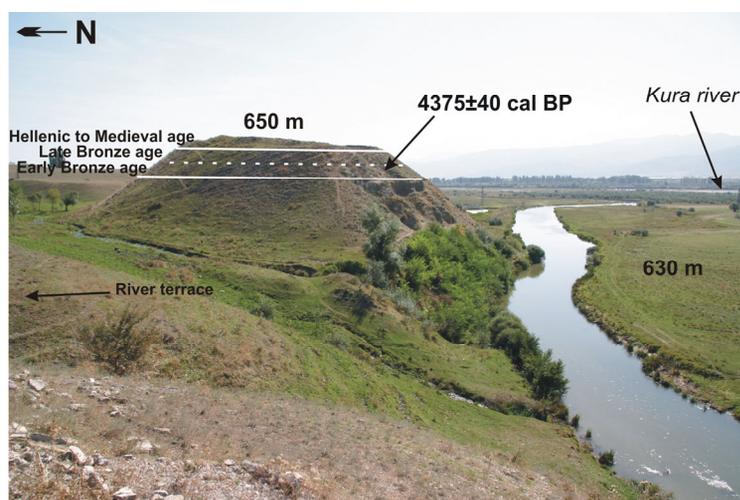
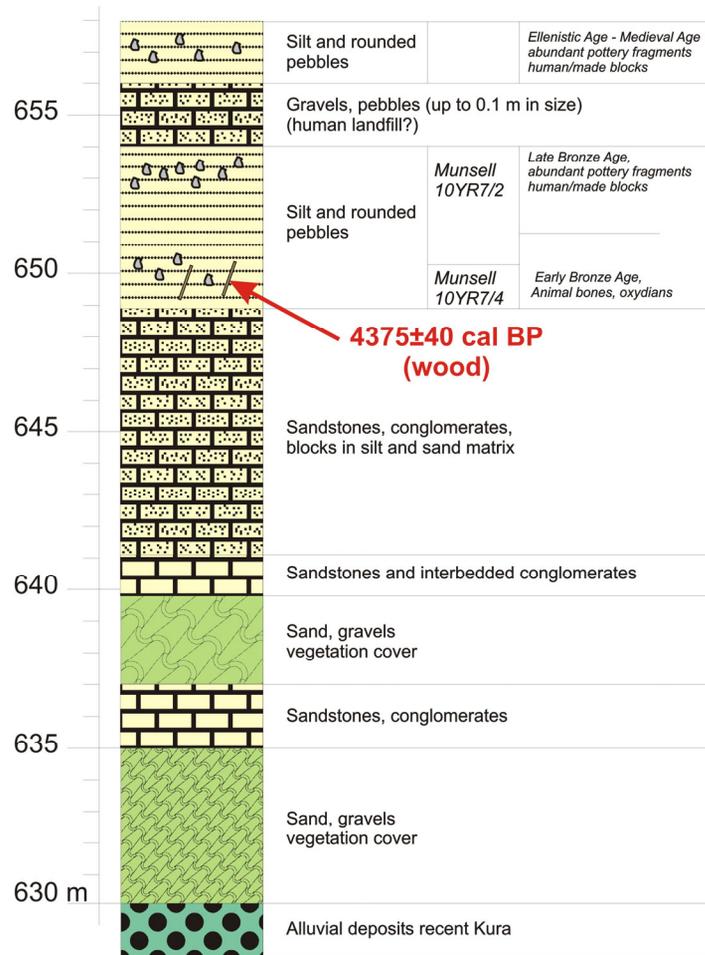


Fig. 3 - The archaeological site of Aradetis Orgora. A) Stratigraphic sequence of the Aradetis Orgora mound; B) View of the settlement of Aradetis Orgora built above the natural mound (terrace of the Kura).

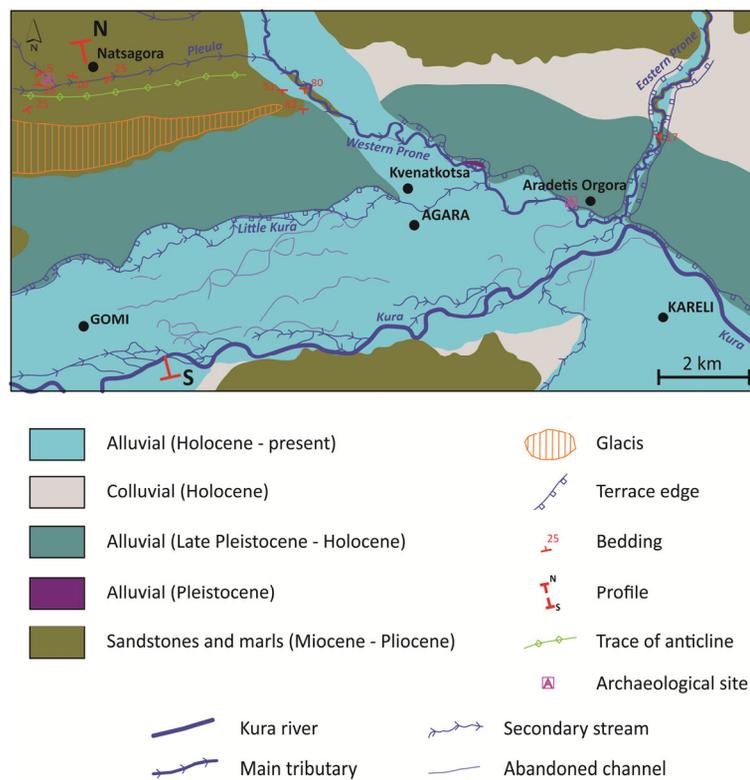


Fig. 4 - Geological and geomorphological sketch of the study area.

steep sides (up to 40°); the top is flat and almost horizontal, or very slightly dipping towards the SE, with a maximum height of 778 m a.s.l. The height of the top above the ridge side is about 10 m on the Northern side of the hill, and 25 m on the Southern one, because of the dip of the ridge itself. Summing up, the hill resembles a smooth cone with a flat top.

It must be pointed out that the shape of the hill was modified in the 1980s, during the archaeological excavations carried out by A. Ramishvili, who removed part of the original anthropogenic deposit from the top of the hill and dumped debris along its sides: it is likely that some narrow terraces occurring around the top resulted from these activities. The original total thickness of the anthropic accumulation can be estimated to about 3 m, considering that the A. Ramishvili's excavations removed about 2.5 m of sediment from the Northern part of the site, and about 0.5 m from the Southern one. Therefore, the maximum height of the hill was probably around 780.50 m a.s.l. before the beginning of the Georgian excavation.

At present, the archaeological deposit is rather thin or even absent to the Northwest of the hilltop, while it is at least 2.5 m thick to the Southeast; this implies that the erosion surface that shapes the marly/sandy bedrock dips towards the South more strongly than the present-day surface, although its precise shape is still unknown, since the Southern part of the site has not yet been excavated deeply enough. The natural surface of the mound may have been modified by humans during the first phases of the site use, and future excavations will be aimed to better highlight this aspect.

The archaeological deposit includes an Early Bronze Age level, overlain by a thick Late Bronze/Early Iron one; traces of Classical Antiquity frequentation are testified by sparse potsherds.

The sediments on the top of the hill are generally silty to loamy, with variable clay percentage and sparse stones; these may originate from the dismantling of complex anthropogenic features, like buildings or pebble pavements, that were also observed in various areas of the excavation. Cultural remains, like pottery, chipped stone, animal bones, and charcoal are extremely common.

The Early Bronze Age units were uncovered in small areas during the recent archaeological excavations, and their characteristics are still to be fully understood. Apparently, the main features are prepared floors made up of compacted yellowish silt, alternating with dark levels made up of poorly sorted fine material, rich in charcoal and generic domestic waste. Some other features are also present; these are shallow depressions (0.1 to 0.2 m deep) of roughly rectangular shape, 1.0-1.5 m wide, that are filled up with burned soil and daub, ash and some charcoal. In addition, poor remains of small circular huts were also unearthed.

Unfortunately, these deposits were intensely reworked and disrupted *ab antiquo* by the Late Bronze Age people, who excavated a very large number of sub-cylindrical pits, 0.5 to 1.5 m wide and up to 1 m deep; these often cut other previously refilled pits, so that the underlying sediments were almost completely destroyed throughout wide areas, where only few remains of the older features are preserved. This process has been particularly strong in the NW area of the excavation, where the archaeological deposit is also shallow; as a consequence, the Early Bronze Age levels are largely reworked here. Conversely, these levels are probably better preserved in the Southern area of the settlement, where some test trenches suggest the presence of thicker deposits.

The Late Bronze Age horizons are also characterised by prepared floors alternating with domestic refuse, similar to the Early Bronze ones; the pits are filled up by more or less homogeneous greyish silty loam, embedding mostly domestic refuse, like sparse stones, daub fragments, pottery sherds, animal bones, charcoal, etc.

Almost all traces of the post-settlement history were removed from the top of the hill during the Ramishvili's excavations. Colluvia occur all around the sides of the hill; they partly look rather fresh and made up of loose and fluffy sediments, so that it cannot be excluded that they are in fact recent (and more recently colluviated?) waste dumps of the previous excavations.

4.3.2 Aradeti Orgora

The Aradeti Orgora archaeological site hosts a settlement of Roman/Medieval Age, which was ex

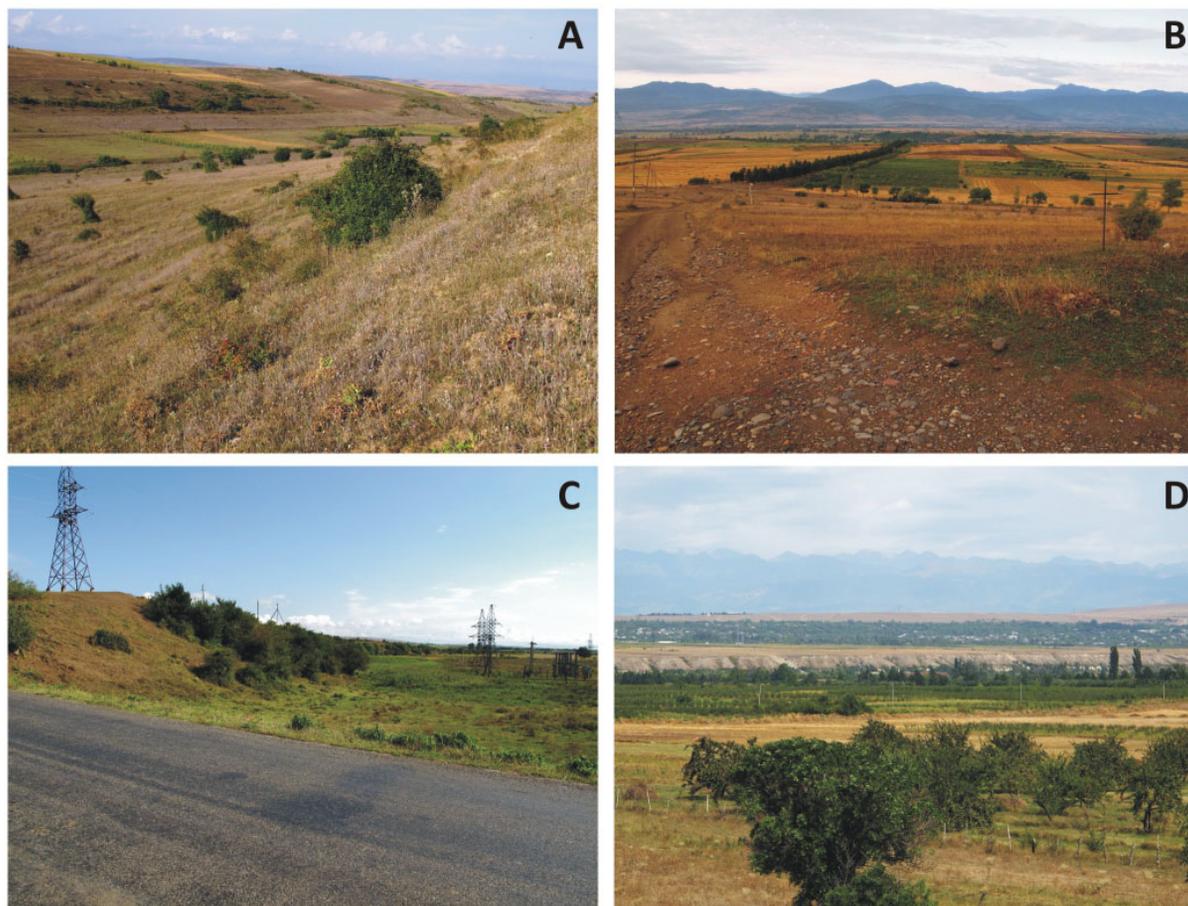


Fig. 5 - Views of the studied area: A) view of the valley of the Pleula river in Eastern direction. The valley is covered by 3 m of alluvial deposits and the river flows on the Tertiary bedrock. It merges with the Western Prone at Berzenauli; B) view of the glacis, the river terrace and the present-day alluvial deposits of the Kura river from Sajvare. In the distance the Lesser Caucasus; C) the terrace slope at Khidiskuri; D) view of the terrace slope from Samtsevisi in Northern direction.

cavated by Georgian archaeologists under the direction of prof. Iulon Gagoshidze (Fürtwängler et al., 2008). It is situated on the right side of the Kura River, on its terrace, a few hundred metres to the west of the confluence of the Eastern and Western Prone Rivers into the Kura, West of the village of Doghlauri.

The terrace escarpment faces SW and is oriented NW-SE; it cuts abruptly the site with a straight and very steep scarp, the foot of which dips almost directly into the Prone; this terrace is dissected by two secondary erosion features, *i.e.* two small valleys. One of these is a deep channel with steep sides, which runs East to West before flowing into the Prone; the other one is dry and oriented N-S, its sides are less steep, and it is wider and shorter than the former. The upper parts of these erosion features are connected, so that a sort of continuous channel separates a roughly conical hill with a flat top from the main terrace (Fig. 3, 8). The hilltop is 650 m a.s.l. high, and lies about 25 m above the level of the Prone River.

The stratigraphic observations were carried out on an exposed profile on the Southern side of the terrace scarp, where the archaeological levels are superimposed to the alluvial deposits of the Kura River and its tributaries (Furlani et al., 2011). The sequence exposed on the terrace scarp includes the following units, from bottom to top:

1. finely bedded coarse sandstone/fine gravel with crossed bedding. Thickness at least 3 m (the bottom was not observed).

2. well bedded and strongly cemented coarse polygenic conglomerate, with frequently imbricated rounded elements in sandy matrix. Thickness 7÷8 m.

3. medium to coarse polygenic conglomerate, somewhat chaotic, well cemented; finer levels (made up of well bedded fine gravel to sand, up to 0.5÷6 m thick, are common. Thickness 4÷5 m.

4. light yellowish sandy silt loam, homogeneous and without sedimentary features. Thickness about 1.5÷2 m.

5. light greyish to brownish silt loam, with well-developed coarse granular structure; the limit with the underlying level is diffuse. Poorly developed soil (Entisol), probably truncated at the top. Thickness ranges between 0.2÷0.4 m.

6. poorly cemented unsorted conglomerate in abundant silty loam matrix; the elements are angular to rounded, randomly scattered throughout the thickness of the unit. Thickness about 4 m. The unit is largely covered by recent colluvia, debris, and excavation dump, so that it is not easy to observe its characteristics throughout the thickness; apparently, the cultural remains that occur sparsely on the slope are probably reworked, and

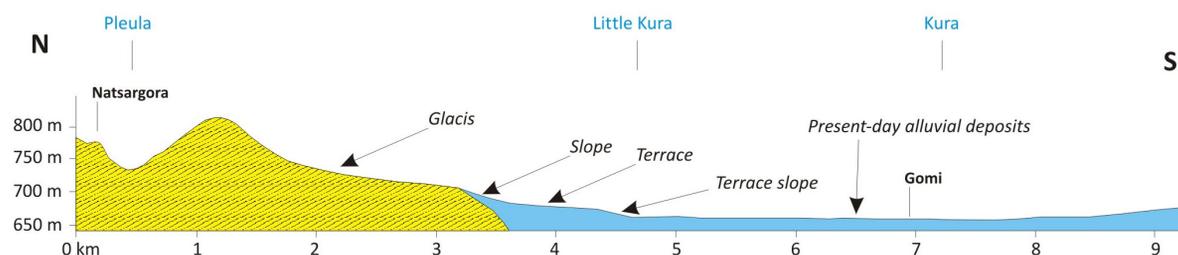


Fig. 6 - North-South topographic profile between Natsargora and the Kura. The profile highlights the presence of relieves at about 650 m a.s.l., a wide erosive glacis, the Quaternary terrace and the present-day alluvial course.

should be ascribed to the overlying archaeological deposit. A handaxe found in the same levels, some hundred metres from the site on the main terrace, may suggest a Middle Pleistocene age (I. Gagoshidze, personal communication, 2011).

7. thick sequence including a very large number of complexly interbedded lithologic units with highly variable characteristics, most of which are anthropogenic. Debris deriving from the collapse of walls and other archaeological features, pits filled up with unsorted domestic waste, etc. are common. The lowermost part is made up of finer sediments, mostly silty loam. Thickness up to 4÷5 m.

Within this last horizon, the Classical Antiquity archaeological levels overlay a long sequence of earlier levels, which date back at least to the late 4th millennium BC and constitute a large archaeological site that is still largely unexplored. Starting from the base, three main archaeological levels have been identified (Fig. 3):

1) an Early Bronze Age level characterised by a sequence of layers with abundant pottery and ceramics fragments of the Kura-Araxes and Bedeni periods (late 4th-mid 3rd millennium BC) in a muddy matrix. Radiocarbon dating of a wood fragment from the base of the sequence yielded an age of 4375 ± 40 ^{14}C BP (5050-4850 cal BP, 3100-2900 cal BC, 2σ , sample RTK-6134, Rehovot laboratory). This level is buried under a 1.5 m-thick coarse gravel body which apparently does not include cultural remains; though it may resemble fluvial gravel, its shape and position suggest that it is most probably anthropogenic. It must be pointed out that this body is exposed on a relatively small area, and that further observations should be carried out in order to infer its origin with reasonable confidence.

2) a Late Bronze Age level characterised by muddy matrix with abundant pottery fragments; a Roman Age and later level in the topmost part of the sequence, characterised by abundant pottery and brick fragments.

5. DISCUSSION

The studied human settlements are apparently located preferentially on terrace edges or on isolated high spots of the landscape. Even if the shape of the sites may often resemble the typical "tell" of the Near East and Levant, their mound-like shape is in fact for the most part natural, and not the result of continuous re-

building over previous features and products of their decay.

Regarding the Natsargora site, the original shape of the mound could be related to river erosion processes (e.g., Leopold et al., 1995; Mills & Mills, 2001).

In many cases, roughly conical hills were chosen for settling, and only their uppermost part is anthropogenic, as at Natsargora and Aradeti Orgora, and probably at other nearby sites. It is not unlikely that these hills were partly reshaped in order to fit the needs of the settlers, most probably by flattening their top; at Natsargora, the relative depth of the bedrock to the Northwestern and Southeastern ends of the area may suggest that the bedrock was also shaped in wide steps.

Conversely, it is much more difficult to show if also the sides of these hills were artificially shaped in order to improve their defensive power, as suggested by I. Gagoshidze (personal communication, 2011) with reference to the ravine that separates the Northern side of Aradeti Orgora from the adjacent terrace and by A. Ramishvili, in his unpublished excavation report, with reference to the depression which separated the Natsargora mound from the adjacent ridge. Unfortunately, these two sites were more or less extensively excavated in the last decades, so that no information about the late history of the sites -i.e. after their abandonment- is available.

The anthropogenic shaping of the mound top at Aradeti Orgora could be inferred by an accurate comparison of the elevation of the tops of the terrace and of the alluvial sediment lying below the archaeological sequence of the mound. Nonetheless, it must be observed that the limit between natural and anthropic sediments on the mound is largely covered by anthropogenic features and excavation waste dumps; good quality measurements will hopefully be carried out during future excavations. On the contrary, any intentional reshaping of the sides of the mounds cannot be distinguished from natural erosional processes.

Assuming that the deposits at the base of the terrace sequence are river sediments deposited by the Kura, field analyses indicate that the floodplain of the Kura River was much wider in the past, and it reached the hills to the North (Kvernaqi Range) and the toe of the glacis, South of Natsargora. The terrace is 30 m above the present thalweg of the Kura, and to its northern edge it is covered by alluvial fans and colluvia deposited by the Prone. The Kura conglomerates occurring in the lower 15 m of the sequence suggest that the floodplain

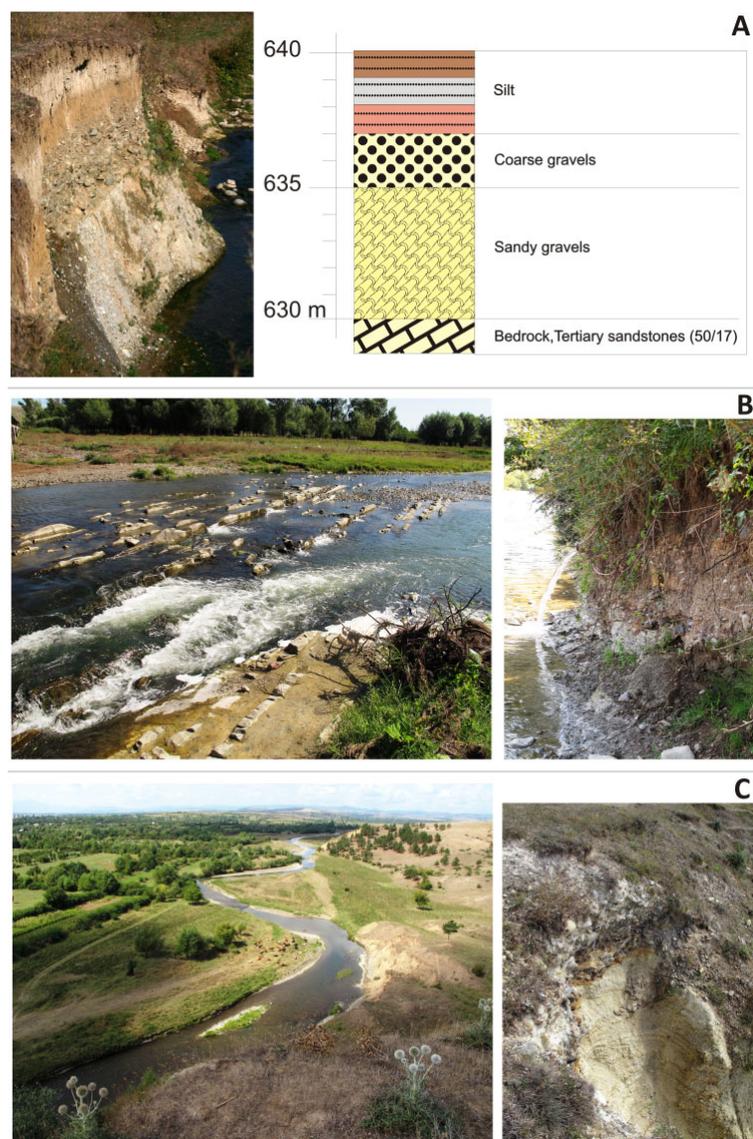


Fig. 7 - Localities of stratigraphic interest in the studied area. Section 1) stratigraphic sequence of an alluvial terrace along the Eastern Prone river. Section 2) a) the Western Prone flow on the bedrock which is composed by Tertiary sandstones; b) the river cuts a thin alluvial deposit; Section 3) a) view of the slope terrace along the southernmost sector of the Western Prone, near the site of Aradetis Orgora; b) detail of the alluvial deposits of the alluvial terrace.

was first interested by strong braided channel stream development; conversely, the upper 3 m-thick silty-sand body points to overbank episodes; this *facies* change can be ascribed to the evolution of the fluvial system from braided to an increase of sinuosity, with the formation of meanders. These river processes filled up a large part of the valley up to a level of about 18 m above the present-day valley bottom. After the deposition of the silty levels, the depositional processes stopped for a probably short time, allowing the formation of an Entisol.

Later on, alluvial fans started developing from the North to the South, because of the Eastern Prone activity; the soil and the underlying sediments were covered by about 4-5 m of rather chaotic coarse gravel, and the Kura River bed was pushed to the South (left side of the course) by the developing fan (or fans). In this case, the

biface found on the terrace surface should be considered just as a *terminus post quem*, as it may have been transported by the Prone from elsewhere in its basin.

In a final phase, the Kura changed its aggradational trend into deepening, and the formation of the terrace and of the entrenched meander started. The Western and Eastern Prone were flowing 30 m above the present level, and followed the Kura base level starting the incision of the terrace edge just at the beginning of its formation.

Regarding the deepening processes of this phase, it can be observed that the bottom of the trough encircling the Northern side of the Aradetis Orgora site is suspended above the present-day Kura floodplain, and that the two short valleys that compose it end towards the Kura with evident steps. Therefore, it can be inferred that this shape is in fact an abandoned meander, entrenched in the sediments lying below the surface of the terrace.

Part of these processes may be related to Late Pleistocene climate changes, but the intense seismicity characterising the area (Philip et al., 1989; Triep et al., 1995) suggests also some tectonic contribution to the uplift of the area. In this perspective, the early development of the Prone rivers alluvial fans, as well as of the glacia, could have been triggered by the uplift of the Kvernaqi Range. The development of the wide Kura floodplain may be ascribed to an increase of river flow connected to the end of the last ice age (18-15 ka), while the incision of the drainage network would have been triggered by the uplift of the Kvernaqi Range coupled to erosion processes connected with the Late Pleistocene - early Holocene climate instability. Later on, according to Connor and Sagona (2007), the period between 6 and 4 ka BP (roughly corresponding to the expansion of the "Kura-Araxes" communities) was characterised by a

climatic improvement, with high rainfall and mild temperatures; this environmental situation would have favoured the development of the wood cover and a general stabilisation of the hillslopes, but it must also be considered that the Kura-Araxes groups may have contrasted this process starting deforestation processes because of strong wood exploitation for metal processing.

In this perspective, if the entrenched meander developed before -or even during- the prehistoric frequentation, then the gravel layer covering the Early Bronze Age levels (Fig. 3, 8) found atop the Aradetis Orgora hill (*cf. supra*, point 1 of the archaeological sequence) cannot be other than anthropogenic. Subsequently, the deepening of the Kura riverbed and its southward migration, coupled with the energy increase of the local

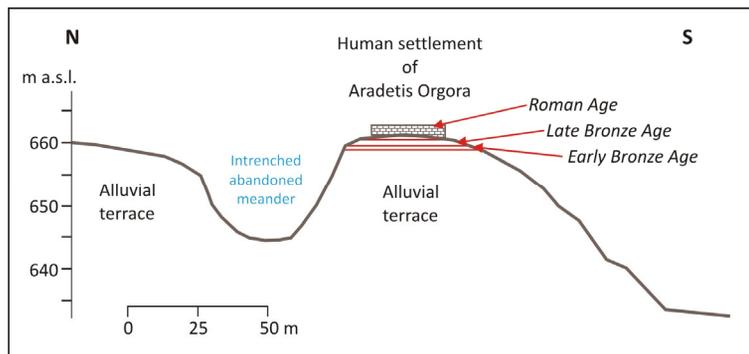


Fig. 8 - Profile of the terrace and the archaeological settlement of Aradetis Orgora.

streams due to deforestation may have reshaped the intrenched meander changing it into the two small incisions surrounding the site. Conversely, if the shape was not identified as an intrenched meander, a late development of the incisions would not be in accordance with the generalised behaviour of the Copper-Bronze Age groups, who apparently preferred naturally isolated hilltops for settling.

6. CONCLUSIONS

Fluvial systems react to natural agents like tectonics, climate or sea-level changes (e.g., Schumm, 1977; Jones et al., 1999) as well as to human modifications, such as agricultural, mining and urban activities. On the other hand, humans and their settlements react to, and adapt themselves to natural environment. In this perspective, the Transcaucasian region represents a good case study to assess the relative importance and the overlapping of these factors; here, the interaction of natural and anthropogenic modifications started at least in the Middle Holocene, when the spread of production economies triggered strong human interference on the environment.

Detailed archaeological investigations at Natsargora and the analysis of the exposed section of Aradetis Orgora were integrated with identification and analysis of the geomorphological and sedimentary features of the Karthaliny Basin. The result of this work are a reconstruction of landscape evolution and an outline of the interactions between human settlements and palaeohydrographic setting of the area, since the Early Bronze Age. This research was mainly based on a multidisciplinary fieldwork approach, involving archaeologists, geomorphologists and geologists, and merging together different disciplines to reconstruct a complex landscape evolution.

Data from satellite images, new and published archaeological data and a detailed field survey allowed to better outline the hydrographic evolution of the Kura River and its influence on the archaeological sites, which are distributed between the Natsargora and Agara villages.

Geoarchaeological analysis was carried out in two archaeological sites: the first one, at Natsargora, was built on the top of a small relief separated from the terrace. The second one, which corresponds to the mound of Aradetis Orgora, is located on an intrenched abandoned meander of the Kura River. In both cases, rela-

tively strong intentional modification of the topography was apparently carried out by the settlers, in order to adapt the areas to the settlement needs.

The position of the sites suggests that the drainage system, dominated by the Kura River base level, was already in a phase of deepening during the Bronze Age in the whole Karthaliny Basin, as also suggested by the incised pattern of the two Prones. These data, along with the reconstruction of the palaeosurfaces and palaeochannels, and together with a radiocarbon date from the base of the Aradetis Orgora site, point to rapid changes in fluvial styles and drainage

network, and to fast erosion processes during the Late Pleistocene and Early Holocene.

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REFERENCES

- Adamia Sh.A., Lordkipanidze M.B., Zakariadze G.S. (1977) - Evolution of an active continental margin as exemplified by the Alpine history of the Caucasus. *Tectonophysics*, 40, 183-199.
- Bertoldi L., Stingham A., Bondesan A., Furlani S., Massironi M., Monegato G. (in press) - Geology and Geomorphology of the Natsargora Archaeological Site. In M. Puturidze & E. Rova (eds.), *Khshuri Natsargora: The Early Bronze Age Graves (Publications of the Georgian-Italian Shida Kartli Archaeological Project I)* (Subartu 30), Turnhout: Brepols Publishers, 3-5.
- Connor S., Sagona A. (2007) - Environment and Society in the Late Prehistory of Southern Georgia, Caucasus. In: B. Lyonnet (éd.), *Les cultures du Caucase (VIe-IIIe millénaires avant notre ère): leurs relations avec le Proche-Orient*. Paris. CNRS Editions / Editions Recherche sur les civilisations. 21-36.
- Davitaia F. (1970) - Landscape Map of Georgia. Tbilisi, Metsnierebe.

- Ershov A.V., Brunet M.F., Nikishin A.M., Bolotov S.N., Nazarevich B.P., Korotaev M.V. (2003) - Northern Caucasus basin: thermal history and synthesis of subsidence models. *Sedimentary Geology*, 15, 95-118.
- Farr T.G., Rosen P.A., Caro E., Crippen R., Duren R., Hensley S., Kobrick M., Paller M., Rodriguez E., Roth L., Seal D., Shaffer S., Shimanda J., Umland J., Werner M., Oskin M., Burbank D., Alsdorf D. (2007) - The Shuttle Radar Topography Mission. *Rev. Geophys.*, 45, RG2004, 33 pp, DOI: 10.1029/2005RG000183.
- Furlani S., Stingen A., Bertoldi L., Boaretto E., Bondesan A., Kuparadze D., Massironi M., Monegato G., Rova E. (2011) - Integrating archeological and geomorphological data to evaluate the late-Holocene behavior of the Kartalini Basin (Georgia). *Il Quaternario – Italian Journal of Quaternary Science*, special number, 24, 186-188.
- Fürtwängler A., Gagoshidze I., Lohr H., Ludwig N. (2008) - Iberia and Rome. The Excavations of the Palace at Dedoplis Gora and the Roman Influence in the Caucasian Kingdom of Iberia. *Langenweissbach 2008*.
- Gamkrelidze I.P. (1986) - Geodynamic evolution of the Caucasus and adjacent areas in Alpine time. *Tectonophysics*, 127, 261-277.
- Gobejishvili R. (2004) - Late Pleistocene (Wurmian) glaciation of the Caucasus. In J. Ehlers & P.L. Gibbard (Ed.) *Quaternary Glaciations – Extent and Chronology*, Amsterdam, 129-134.
- Gudjabadze G.E. (2003) - Geological Map of Georgia, 1:500.000. Georgian State Department of Geology and National Oil Company "Saqnavtobi".
- Jones S., Frostick L.E., Astin T.H. (1999) - Climatic and tectonic controls on fluvial incision and aggradation in the Spanish Pyrenees. *Journal of the Geological Society of London*, 156, 761-769.
- Karpytchev Y.A. (1993) - Reconstruction of Caspian sea-level fluctuations: radiocarbon dating coastal and bottom deposits. *Radiocarbon*, 35, 409-420.
- Khain V.Y. (1975) - Structure and main stages in the tectonomagmatic development of the Caucasus: An attempt at geodynamic interpretation. *American Journal of Science*, 275(A), 131-156.
- Koçyiğit A., Yılmaz A., Adamia S., Kuloshvili S. (2001) - Neotectonics of East Anatolia Plateau (Turkey) and Lesser Caucasus: Implication for transition from thrusting to strike-slip faulting. *Geodinamica Acta*, 14, 177-195.
- Leopold L.B., Wolman M.G., Miller J.P. (1995) - *Fluvial processes in geomorphology*. Dover Publications, 522 pp.
- Mills H.H., Mills R.T. (2001) - Evolution of undercut slopes on abandoned incised meanders in the Eastern Highland Rim of Tennessee, USA. *Geomorphology*, 38, 317-336
- Philip H., Cisternas A., Gvishiani A., Gorshkov A. (1989) - The Caucasus: an actual example of the initial stages of continental collision. *Tectonophysics*, 161, 1-21.
- Puturidze M., Rova E. (in press) - Khashuri Natsargora: The Early Bronze Age Graves (Publications of the Georgian-Italian Shida Kartli Archaeological Project I) (Subartu 30). Turnhout: Brepols Publishers.
- Reilinger R., McClusky S., Vernant P., Lawrence S., Ergintav S., Cakmak R., Ozener H., Kadirov F., Guliev I., Stepanyan R., Nadariya M., Hahubia G., Mahmoud S., Sakr K., ArRajehi A., Paradissis D., Al-Aydrus A., Prilepin M., Guseva T., Evren E., Dmitrova A., Filikov S. V., Gomez F., Al-Ghazzi R., Karam G. (2006) - GPS constraints on continental deformation in the Africa-Arabia-Eurasia continental collision zone and implications for the dynamics of plate interactions. *Journal of Geophysical Research*, 111(B05411), doi: 10.1029/2005JB004051.
- Rova E., Puturidze M., Makharadze Z. (2010) - The Georgian-Italian Shida Kartli Archaeological Project: A Report on the First Two Field Seasons 2009 and 2010. *Rivista di Archeologia*, 34, 5-30.
- Schumm S.A. (1977) - *The Fluvial System*. Wiley, New York, 338 pp.
- Tan O., Taymaz T. (2006) - Active tectonics of the Caucasus: Earthquake source mechanisms and rupture histories obtained from inversion of teleseismic body waveforms. In Y. Dilek & S. Pavlides (Eds.) *Postcollisional Tectonics and Magmatism of the Mediterranean Region and Asia*. Geological Society of America Special Paper, 531-578.
- Triep E.G., Abers G.A., Lemer-Lam A.L., Mishatkin V., Zakharchenko N., Starovoi O. (1995) - Active thrust front of the Greater Caucasus: The April 29, 1991, Racha earthquake sequence and its tectonic implications. *Journal of Geophysical Research*, 100(B3), p. 4011-4033, doi: 10.1029/94JB 02597.

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