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Late Quaternary fluvial dynamics of the Algeti River in eastern Georgia

Spätquartäre fluviale Dynamik des Algetis in Ostgeorgien

Martin Menz [1], Hans von Suchodoletz [2,3] and Dominik Faust [2]

[1] Senckenberg Naturhistorische Sammlungen Dresden, Museum für Mineralogie und Geologie, Sektion Petrographie, Königsbrücker Landstraße 159, 01109 Dresden, Germany; martin.menz@senckenberg.de — [2] Technische Universität Dresden, Institut für Geographie, Helmholtzstraße 10, 01069 Dresden, Germany — [3] Universität Leipzig, Institut für Geographie, Johannisallee 19a, 04103 Leipzig, Germany

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Abstract

The 118 km long Algeti River originates in the northern Lesser Caucasus and is a right tributary of the Kura (Mtkvari) River, the main receiving stream of the eastern Transcaucasian Depression located between the Greater and the Lesser Caucasus. The meandering lower course of the Algeti River crosses the Marneuli Depression, a tectonic basin at the northern margin of the Lesser Caucasus filled with loose Cenozoic sediments. A system of morphological terrace levels, indicating several cycles of sedimentation and incision, is observed along the river channel. Geomorphological mapping based on DGPS-measurements enables a spatial differentiation of distinct terrace levels. Stratigraphic investigations of selected fluvial outcrops and radiocarbon (^{14}C) ages reveal the structures of these terraces formed during the last 7000 years. Furthermore, their chronological differentiation (Middle to Late Holocene) is possible using these analytical methods. Our investigations show intense fluvial dynamics of the lower Algeti River during that period. Triggering factors for these dynamics can only be supposed so far, but human influence as well as neotectonic activity and rapid climate changes come into consideration since this region was intensely used since the Neolithic Age and shows significant seismic activity.

Kurzfassung

Der 118 km lange Algeti entspringt im nördlichen Kleinen Kaukasus und ist ein rechter Nebenfluss der Kura (Mtkvari), des Hauptvorfluters der östlichen Transkaukasischen Depression zwischen Großem und Kleinem Kaukasus. Sein mäandrierender Unterlauf durchfließt die Marneulidepression, ein mit känozoischen Lockersedimenten gefülltes tektonisches Becken am Nordrand des Kleinen Kaukasus. Hier ist entlang des Flussbetts ein System morphologischer Terrassenniveaus entwickelt, welches mehrere Zyklen von Sedimentation und Einschneidung repräsentiert. Geomorphologische Kartierungen basierend auf DGPS-Messungen ermöglichen eine räumliche Differenzierung der verschiedenen Terrassenniveaus. Stratigraphische Aufnahmen von Sedimentprofilen und Radiokarbon (^{14}C)-Alter erlauben Einblicke in die Struktur der während der letzten 7000 Jahre gebildeten Terrassenniveaus. Weiterhin wird deren zeitliche Differenzierung (Mittel- bis Spätholozän) mittels dieser Analysemethoden möglich. Die Untersuchungen zeigen eine sehr starke fluviale Dynamik des unteren Algeti in diesem Zeitraum. Auslöser dieser Dynamik können bisher nur vermutet werden, jedoch kommen als Hauptursachen sowohl menschliche Tätigkeit als auch Neotektonik bzw. kurzfristige Klimaschwankungen in diesem seit dem Neolithikum intensiv genutzten und seismisch aktiven Gebiet in Frage.

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1. Introduction

Type and scale of sedimentary deposits characterizing geomorphological systems are mainly controlled by environmental influences. Therefore, sediments of different geomorphological settings often record palaeoenvironmental changes. Besides other kinds of continental palaeoenvironmental archives like e.g., lake sediments or loess-palaeosol sequences, also fluvial sedimentary archives have been used to reconstruct Late Quaternary palaeoenvironmental conditions during the last years (e.g., Faust et al. 2004, Houben et al. 2006, Zielhofer et al. 2010). However, in difference to the traditionally used palaeoenvironmental archives, fluvial archives often show large heterogeneities and thus are discontinuous. Furthermore, different factors can influence the fluvial dynamics of a river such as climate, tectonics and anthropogenic activity as well as the internal instability of a river causing a change of its sedimentation pattern without effect of any external driving mechanism (Charlton 2008). This multitude of potential triggers complicates the interpretation of fluvial sedimentary patterns. Thus, in order to identify precisely the triggers causing changes in the fluvial dynamics, it is necessary to study the phases of aggradation and incision during the past and to match these data with information from other palaeoenvironmental archives.

The southern Caucasian region is an area of strong tectonic activity (Adamia et al. 2010, Forte et al. 2010) and additionally, it is highly vulnerable to climatic changes (Keggenhoff et al. 2011). Nevertheless, only a limited number of palaeoenvironmental studies exists predominantly based on investigations of lacustrine deposits and peat bogs (e.g., Kvavadze & Connor 2005, Connor et al. 2007). In particular, apart from early Soviet works (Tsereteli 1966, Maruashvili 1971) there are only few studies about fluvial systems from that region (Arslanov et al. 2007, Ollivier et al. 2010).

In this paper, we present the results of geomorphological and sedimentological investigations from the lower Algeti River in the southeastern part of the Republic of Georgia, showing several phases of aggradation and incision during the Holocene.

2. Study area

The 118 km long Algeti River originates in the northern Lesser Caucasus and is a right tributary of the Kura (Mtkvari) River, the main receiving stream of the eastern part of the Transcaucasian Depression between the Greater and the Lesser Caucasus that finally flows into the Caspian Sea (Fig. 1). The meandering lower course of the Algeti River crosses the Marneuli Depression, a 25 km long and 10 km wide tectonic basin at the northern margin of the Lesser Caucasus. The Marneuli Depression is surrounded by folded Palaeogene and Neogene flysch and molasse sediments with intercalated volcanic deposits (Gamkrelidze 2003). The eastern boundary of the depression is marked by a steep escarpment of 20 m to 60 m at the western bank of the Kura River. The Marneuli Depression is filled with loose Cenozoic sediments reaching a thickness of up to 136 m (Tsereteli 1966, Maruashvili 1971). The flat, slightly eastward dipping surface of the depression is cut by the recent valleys of the Algeti, Khrami and Debeda rivers. The valleys of these rivers are incised into the surface by some meters showing several morphological terrace levels along their courses (Suchodoletz et al. 2011). North of the recent valley of the Algeti River a parallel dead valley exists. The study area comprises the last 17 km of the course of the Algeti River before its confluence with the Kura River, located between the villages of Azizkendi and Meore Kesalo (Fig. 2).

3. Methods

3.1. Spatial measurements of fluvial terrace levels

Along the last 17 km of the course of the Algeti River to its confluence with the Kura River, 239 relative heights (in relation to the riverbed) of fluvial terrace levels were measured by use of a differential GPS (Magellan ProMark3). Processing of the data was carried out using the software GNSS solutions 2.00.03. The vertical error of the relative heights between terrace level and riverbed is less than 10 cm (following manufacturer information).

3.2. Investigations of sedimentary sections

We investigated 16 naturally outcropped sedimentary sections along the lower part of the Algeti River with relative heights between 2.1 m and 13.0 m above the recent riverbed (Figs. 3, 4). However, often the basal parts of the profiles were not accessible for analyses, thus only the upper portions of the sections have been studied with regard to their structure, their carbonate content, the existence of carbonate concretions and other features of pedogenesis.

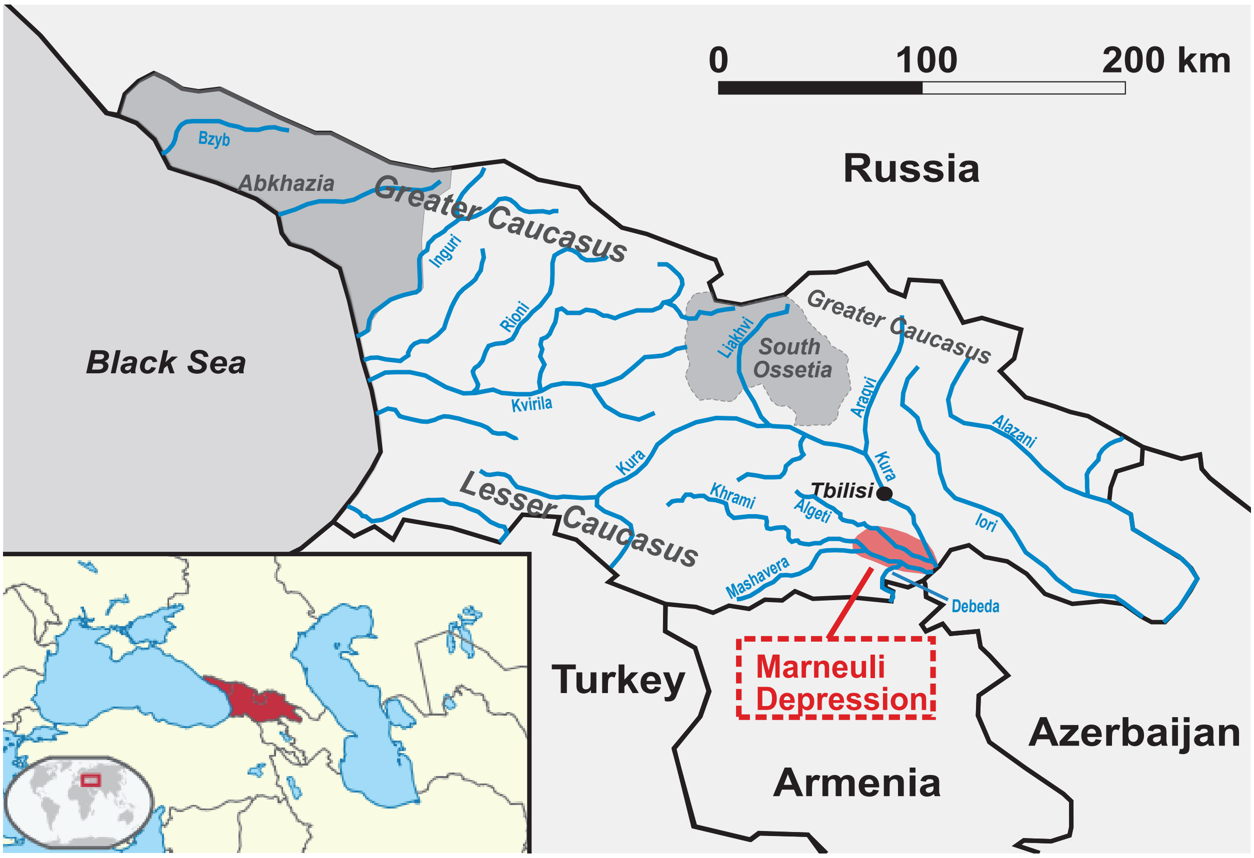

Fig. 1. Location of the Marneuli Depression in eastern Georgia (modified after Suchodoletz et al. 2011).

Abb. 1. Lage der Marneulidepression in Ostgeorgien (verändert nach Suchodoletz et al. 2011).

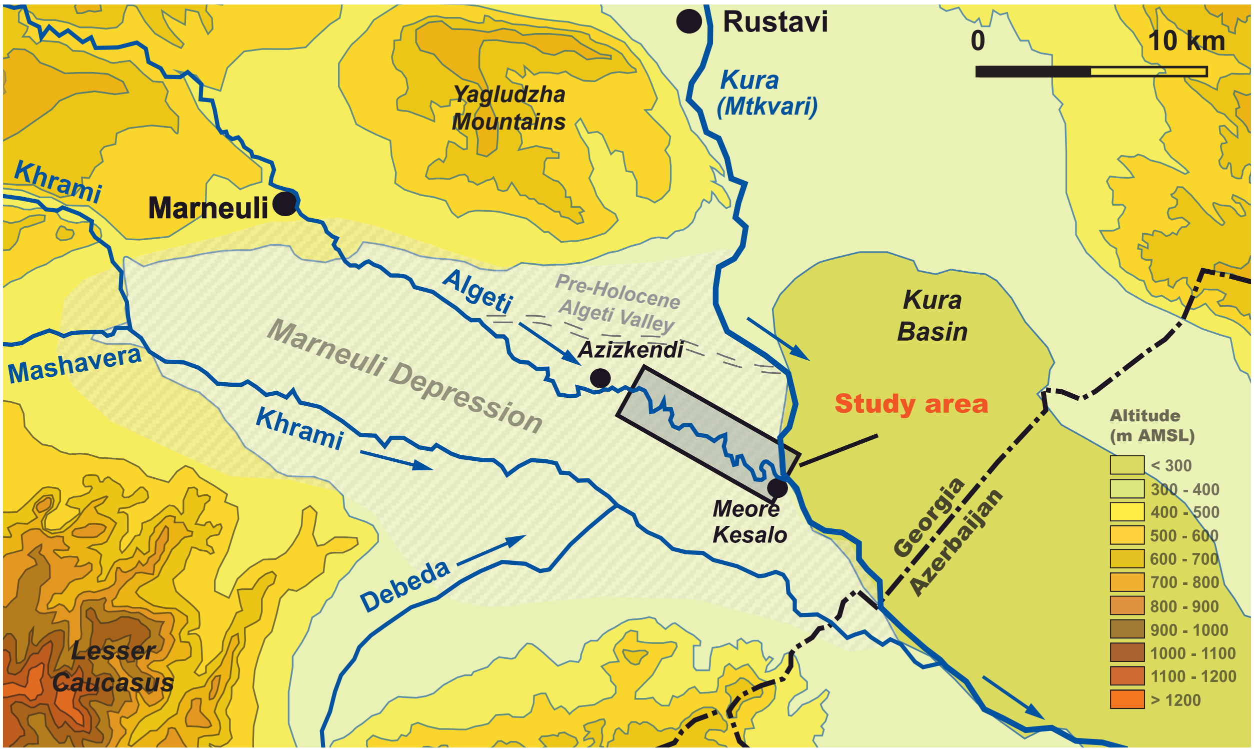

Fig. 2. Relief map of the Marneuli Depression. The study area is indicated with a shaded rectangle (modified after Suchodoletz et al. 2011).

Abb. 2. Höhenkarte der Marneulidepression. Das Untersuchungsgebiet ist durch ein schattiertes Rechteck gekennzeichnet (verändert nach Suchodoletz et al. 2011).

3.3. Dating

In order to develop a chronostratigraphical classification scheme for the fluvial sequences, 15 charcoal samples have been analyzed by radiocarbon dating in the Poznańskie Laboratorium Radiowęglowe in Poznan. Subsequently, radiocarbon ages have been calibrated using the program Cologne Radiocarbon Calibration & Palaeoclimate Research Package (www.calpal-online.de), the calibration program of the Universität zu Köln.

4. Results

Using differential GPS data and satellite images, we were able to construct a high-resolution relief map of the system of morphological terrace levels along the lower Algeti River. These terrace levels were differentiated by their relative heights above the recent riverbed (Fig. 3). The investigated course of the Algeti River has a medium channel slope of 0.238%. In detail, the channel slope of the last 1.5 km before its confluence with the Kura River is about 0.172%, whereas upstream the slope is about 0.243% showing only minor deviations.

15 out of the 16 investigated sections expose aggradational terraces displaying a very similar trend in their sedimentary record and development. In the basal parts of these sections mostly coarse-grained sands and gravels dominate, up-section, grading into fine-grained sandy and silty to slightly clayey materials. In many cases the sandy units show cross-bedding. A moderate to strong reaction to hydrochloric acid (10 % HCl) was observed along all measured sections demonstrating the presence of carbonate in the sediments. Apart from several findings at the recent surface, in two outcrops human artefacts occurred. At nine localities, layers with darker colouring, less carbonate content and stronger aggregation were classified as palaeosols. However, these palaeosols are not well differentiated and only show low thicknesses.

One of the investigated sections contains a peculiarity, since it consists of homogenously bleached fine-grained sediments that are totally different from those of the other 15 localities. Instead, this material strongly resembles Late Pleistocene fluvial and lacustrine deposits that build up the recent surface of the Marneuli Depression and are reported from several outcrops and drilling cores (own unpublished data, Tsereteli 1966, Maruashvili 1971). Due to the fact that the respective terrace level (no. 16 in Fig. 3) is higher than those of the other investigated localities, we assume that this level constitutes an erosional terrace.

All charcoal samples of the studied sections from aggradational terraces yielded Holocene ^{14}C ages, ranging from 6480 ± 115 to 142 ± 97 years cal. B.P.

5. Discussion

The Middle to Late Holocene radiocarbon ages of the sediments of the aggradational terraces implicate an incision of the lower Algeti River into its recent valley solely during the Holocene. This is in accordance with the theories of a southward shift of the Algeti River during the Quaternary discussed in older Soviet literature (Tsereteli 1966, Maruashvili 1971). Another evidence for this assumption is given by the existence of the dead valley north of the recent riverbed of the Algeti River with younger fluvial sediments overlying Late Pleistocene fluvial and lacustrine deposits. We assume that this southward shift was caused by uplift processes in the Yagludzha Mountains at the northern margin of the Marneuli Depression. Although the precise stratigraphic position of this stream diversion does not exist so far, the shift must have happened during a time interval represented by a gap in the sedimentary record formed between the underlying Late Pleistocene fluvial and lacustrine deposits both valleys are incised to, and the oldest known fluvial sediments in the present Algeti Valley (6.5 ka cal. B.P.).

The influence of tectonic processes on the fluvial systems marks a probable factor in an area of high tectonic activity as the Transcaucasian Depression (Forte et al. 2010, Suchodoletz et al. 2011). Likewise, the Kura Valley at the eastern margin of the Marneuli Depression shows an asymmetric cross-section with a steep western and a gentle eastern slope. Accordingly, Suchodoletz et al. (2011) assume a westward shift of the Kura River of several kilometers in Late Quaternary times. During this process, the Kura River laterally eroded the sediments of the Marneuli Depression thus forming a steep slope of up to 60 m at its western bank today. Similar to the situation at the Algeti River, this westward shift is triggered by tectonic uplift of the Kura fold-thrust belt (Forte et al. 2010). Furthermore, it caused base level lowering for the Algeti River resulting in different phases of fluvial incision. However, a detailed and quantitative evaluation of this influence requires more data.

According to Gregory & Schumm (1987) the mean channel slope of the lower Algeti River of 0.238% is a typical value for a meandering river system. The slighter channel slope along the last 1.5 km can easily be explained by the delayed river junction of the Algeti River with the Kura River. In contrast to other rivers of the Marneuli Depression (Maruashvili 1971, Suchodoletz et al. 2011), there are no continuous terrace levels recognized along the lower Algeti River. Nevertheless, a small-scale interlocked pattern of terrace levels of different heights was observed during our studies (Fig. 3). We assume that lateral migration of the meandering channel eroded at least parts of older terrace levels, so that terraces of different heights and ages are located very close to each other at present (Fig. 4).

A correlation of the investigated fluvial outcrops by means of stratigraphy and hence the compilation of a

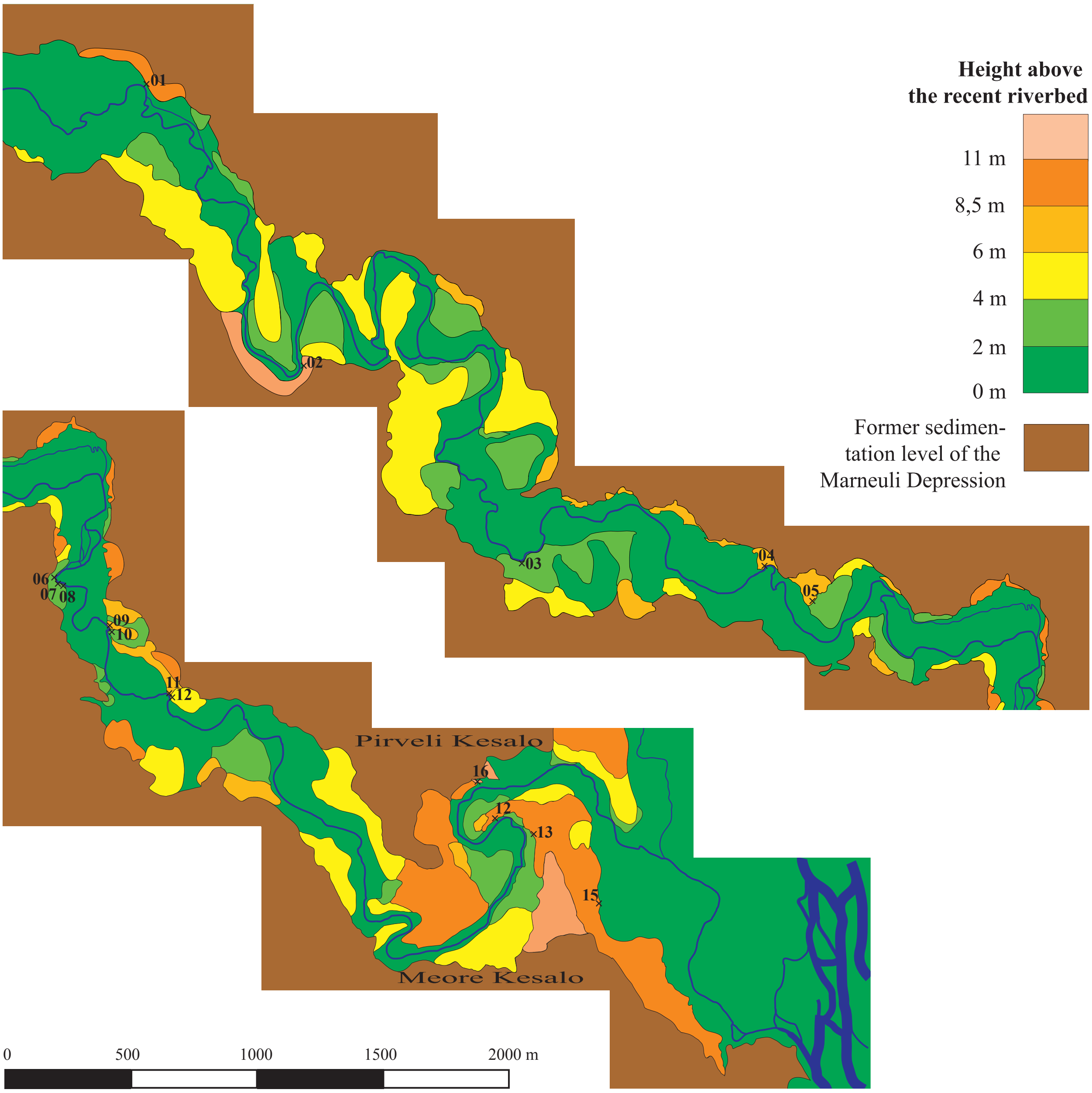

Fig. 3. Relief map of the lower Algeti River. The altimetric data refer to the height of the terrace levels above the riverbed. The numbering follows Fig. 5.

Abb. 3. Höhenkarte des unteren Algetis. Die Angaben beziehen sich auf die Höhen der Terrassenniveaus über dem Flussbett. Die Nummerierung folgt der in Abb. 5.

stratigraphic scheme for the lower Algeti River is a fairly complex task especially due to the mentioned discontinuity of terrace levels. Furthermore, although structure can be used to classify the sediments genetically, it does not give information about their stratigraphic position in a broader context. Generally, point bar sediments are characterized by sandy-gravelly units and in contrast, overbank and channel deposits are dominated by silty-clayey material, but these features can neither help to assign them to a certain period of the geologic time scale, nor to put them into a stratigraphic framework (Charlton 2008). Moreover, ^{14}C ages are mostly determined from the upper portions of the sections, whereas there are hardly ages from the lower parts. Due to the sparseness of archaeological artefacts there is no further chronological information about the fluvial depsosits available. Though, merging all existing data and the radiocarbon ages, it was possible to reconstruct several fluvial phases of the Algeti River during the Late Quaternary. For this interpretation, palaeosols were of special importance since they indicate stages of stable conditions with reduced fluvial activity and/or periods of incision. However, they are not sufficiently differentiated to laterally correlate specific intervals of pedogenesis based on differences in their pedogenic intensities (Faust et al. 2000; Fig. 5). In total, we were able to identify nine phases of

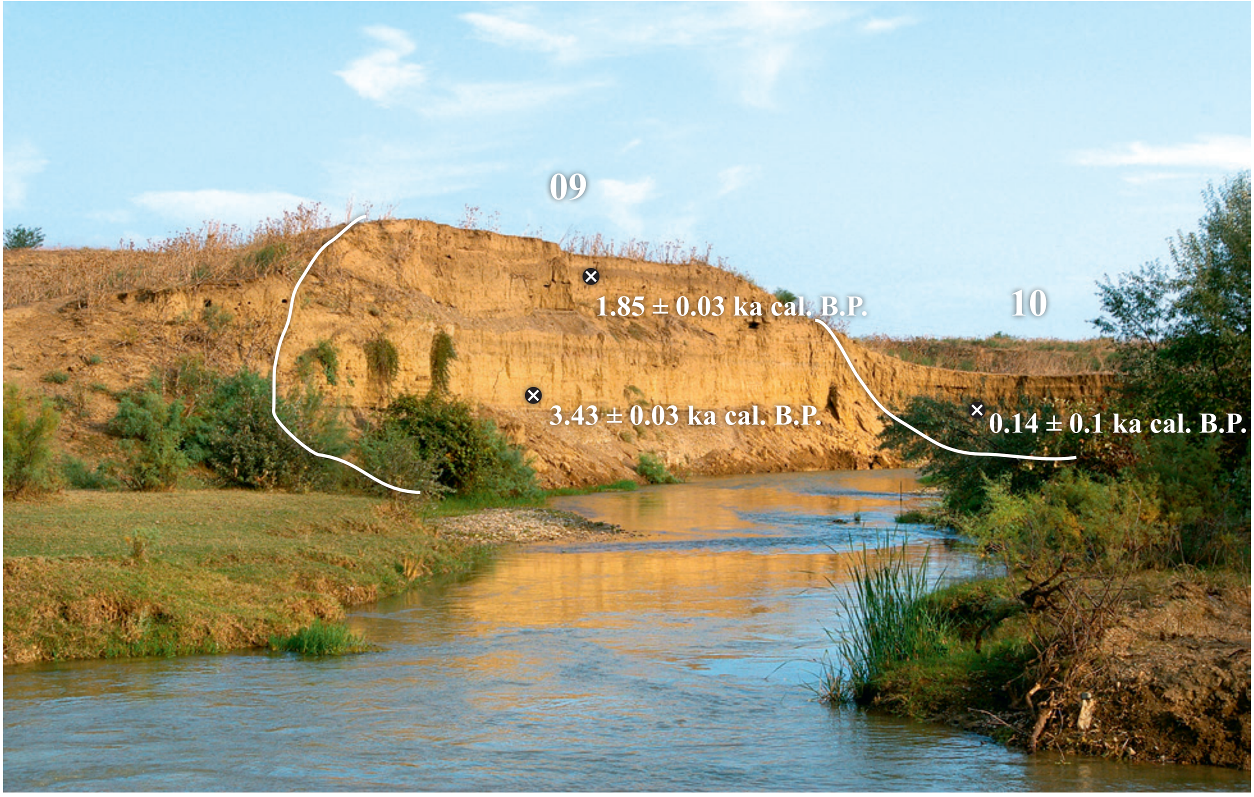

Fig. 4. Natural exposures at the left bank of the lower Algeti River (outcrops 09 and 10 of Figs. 3 and 5). The older terrace in the center was cut by a meander loop, which is conserved in a younger terrace level at the right.

Abb. 4. Natürliche Aufschlüsse am linken Ufer des unteren Algetis (Aufschlüsse 09 und 10 in Abb. 3 und 5). Die ältere Terrasse im Zentrum wurde von einem Mäanderbogen zerschnitten, welcher im jüngeren Terrassenniveau rechts erhalten ist.

fluvial development of the Algeti River during the Late Quaternary (Fig. 6).

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Phase 1: During the Late Pleistocene or Early Holocene, the Algeti River shifted from the northern dead valley southward to its recent position. This shift was presumably connected with uplift processes in the northern Yagludzha Mountains.

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Phase 2: The Algeti River incised into its present valley by 7–6 ka cal. B.P. at the latest. A short hold-up of this cutting process generated erosional terraces (site 16 in Figs. 3, 5) close to the confluence with the Kura River.

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Phase 3: Fluvial material aggraded in the new Algeti Valley. Gravelly units older than 6.48 ka cal. B.P. are located 8 m above the recent riverbed. At point bar positions fluvial deposits reached the former sedimentation level of the Marneuli Depression. At the end of this phase reduced fluvial activity and/or subsequent incision allowed the development of soils (age of the palaeosol at site 01 ca. 6.5 ka cal. B.P.).

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Phase 4: The largest part of the aggraded material was eroded by strong incision.

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Phase 5: Probably from 3.4 ka ca. B.P., at the latest from 2.7–1.85 ka cal. B.P., the river aggraded fluvial material again. At site 09 gravel layers from this period can be observed up to 5.5 m above the recent riverbed.

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Phase 6: During this phase, fluvial deposits were partly washed off by incision and lateral migration of the river. At higher terrace levels, soils developed until 0.8 ka cal. B.P. (e.g., sites 04, 11, 14).

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Phase 7: From 0.8–0.7 ka cal. B.P. a new phase of aggradation followed. In contrast to previous sedimentation phases, only fine overbank deposits were recognized (e.g., sites 06, 08). This indicates a phase of strong fluvial activity with high floods but without aggradation and thus heightening of the riverbed.

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Phase 8: The period from 0.7–0.2 ka cal. B.P. was dominated by stable conditions, indicated by soil formation (e.g., sites 05 and 11). Locally, fluvial material was eroded by lateral migration of the river. A minor incision phase can not be excluded.

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Phase 9: Since 0.2 ka cal. B.P. fine overbank sediments have been aggraded anew. According to local farmers, in rare cases the Algeti River inundates terrace levels up to 5 m above the riverbed. Furthermore, abandoned river channels have been filled with fine sediments (e.g., site 10).

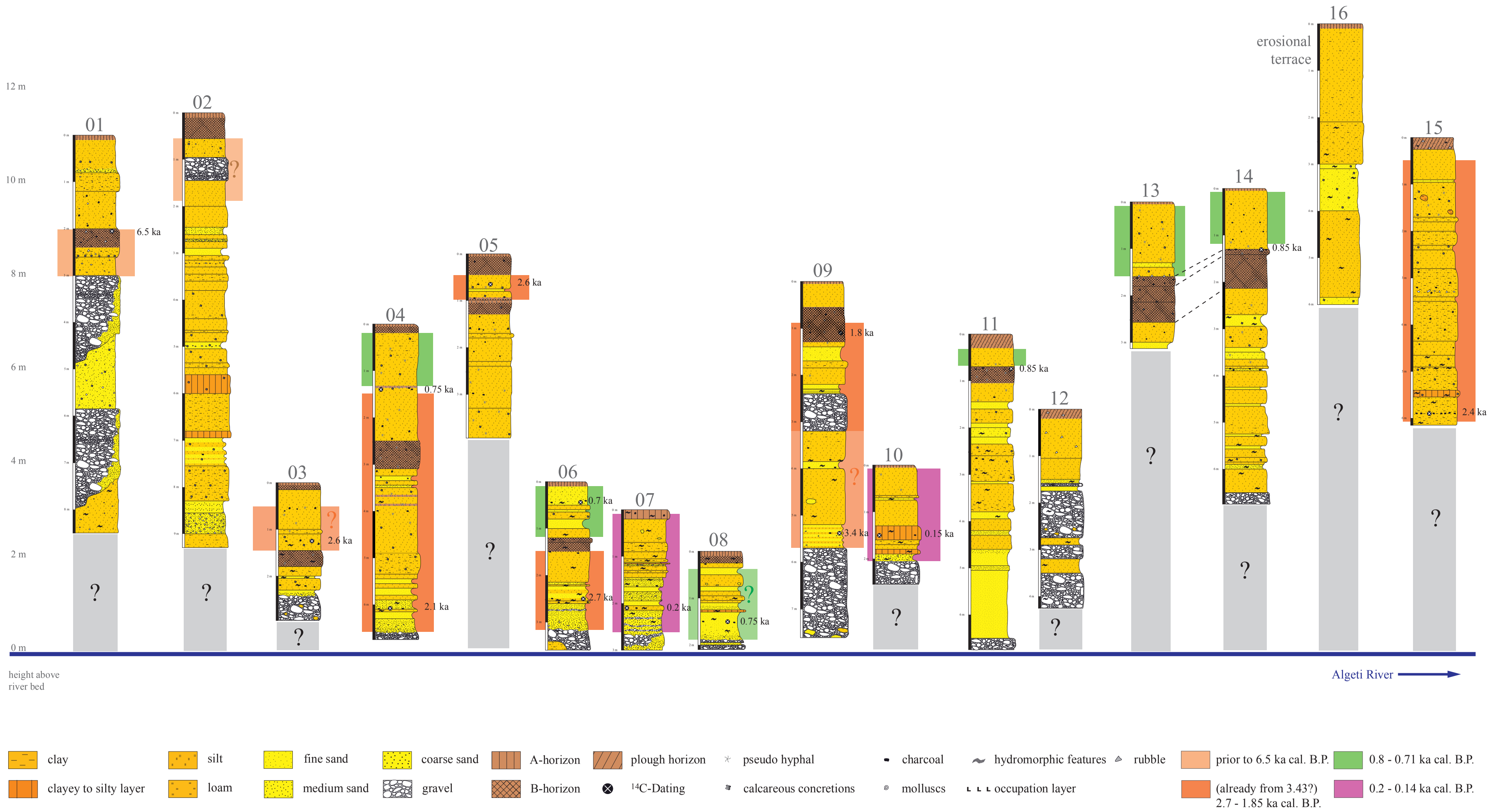
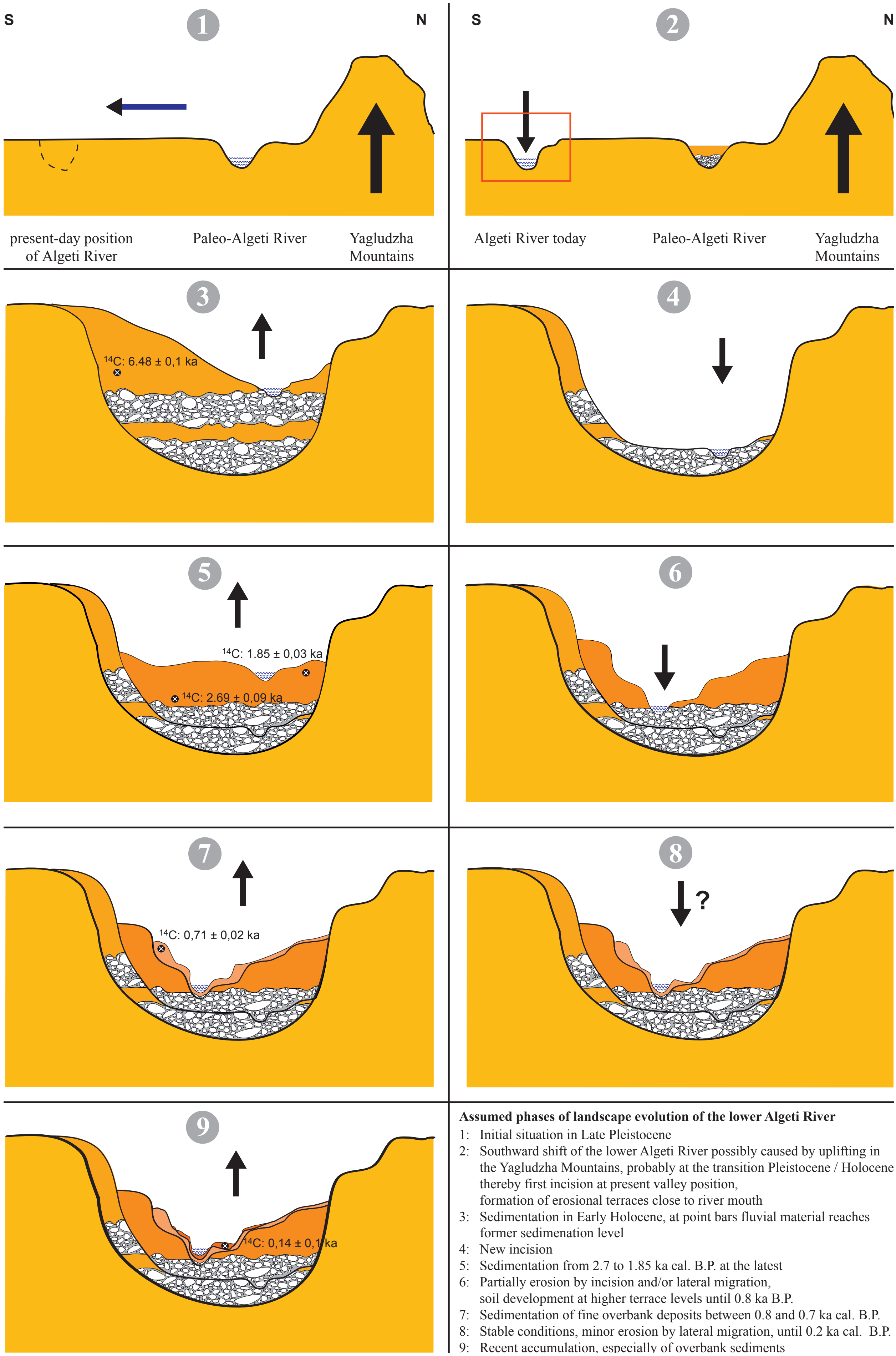


Fig. 5. Stratigraphic correlation of the investigated natural exposures along the lower Algeti River. Identically coloured parts represent corresponding ages. For location of the sections, see Fig. 3.

Abb. 5. Stratigraphische Korrelation der untersuchten natürlichen Aufschlüsse entlang des unteren Algetis. Gleichgefärbte Partien repräsentieren korrspondierende Alter. Zur Lage der Aufschlüsse siehe Abb. 3.



Assumed phases of landscape evolution of the lower Algeti River

1: Initial situation in Late Pleistocene
2: Southward shift of the lower Algeti River possibly caused by uplifting in the Yagludzha Mountains, probably at the transition Pleistocene / Holocene thereby first incision at present valley position, formation of erosional terraces close to river mouth
3: Sedimentation in Early Holocene, at point bars fluvial material reaches former sedimentation level
4: New incision
5: Sedimentation from 2.7 to 1.85 ka cal. B.P. at the latest
6: Partially erosion by incision and/or lateral migration, soil development at higher terrace levels until 0.8 ka B.P.
7: Sedimentation of fine overbank deposits between 0.8 and 0.7 ka cal. B.P.
8: Stable conditions, minor erosion by lateral migration, until 0.2 ka cal. B.P.
9: Recent accumulation, especially of overbank sediments

6. Conclusions and further studies

The recent lower course of the Algeti River is accompanied by several morphological terrace levels consisting of Middle to Late Holocene sediments. It is paralleled by a former riverbed some kilometers to the north. By investigating this fluvial palaeoenvironmental archive, we revealed a multiphase landscape development during the Late Quaternary (Fig. 6). Neighbouring terraces of different origin and age point to fluvial incisions, which indicate highly dynamic conditions during the investigated period.

Processes controlling this aggradation and incision along the river can only be assumed so far and include tectonics (the westward shift of the Kura River, the base level lowering of the Algeti River) aswell as a shift of the ratio between sediment load and river transport capacity caused by anthropogenic activities (e.g., modifications of land use), climate (e.g., higher precipitation during the Little Ice Age; Maruashvili 1971) or tectonic changes (e.g., damming of river courses). In order to verify these hypotheses and to integrate the results into a large-scale regional context of fluvial activity in eastern Georgia, it is necessary to extend our detailed stratigraphic investigations to obtain more numerical datings. Moreover, a comparison between the fluvial dynamics of the Algeti River and that of other rivers in the Marneuli Depression as well as with rivers from neighbuoring regions is necessary.

7. Acknowledgements

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Fig. 6. Assumed model of landscape development based on the investigation of 16 sections along the lower Algeti River.

Abb. 6. Angenommenes Modell der Landschaftsentwicklung, basierend auf Untersuchungen von 16 Profilen entlang des unteren Algetis.

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