FLUVIAL ARCHIVES GROUP

FLAG Biennial Meeting

20-21 September 2021

Evolution of fluvial systems at different time scales

ABSTRACTS

Edited by:
Pedro Cunha, Alessandro Fontana and Andrei Panin

Moscow
IGRAS
2021

Fluvial Archives Group (FLAG)
Institute of Geography RAS (IGRAS)
Russian Association of Geomorphologists (RuAG)
Russian Commission for Quaternary Research (RusQUA)

Evolution of fluvial systems at different time scales. Fluvial Archives Group (FLAG) Biennial online meeting, September 20-21, 2021. Abstracts. Eds: P.Cunha, A.Fontana and A.Panin. Moscow, IGRAS, 85 pp.

The FLAG Biennial meeting was planned to be held in September 2020 in Moscow at the Institute of Geography of the Russian Academy of Sciences, followed by a 7-day field excursion along the upper Volga River. Due to the COVID-19 pandemic, the meeting was postponed to 2021. As the restrictions continued through 2021, the meeting was held on September 20-21 in the format of an online conference hosted by IGRAS. This volume contains the abstracts of the online talks presented at the conference.

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ISBN 978-5-89658-070-6

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TECTONIC AND CLIMATIC IMPLICATIONS OF FLUVIAL ARCHIVES IN THE SOUTHEASTERN BRAZILIAN ATLANTIC PLATEAU

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The Quadrilátero Ferrífero (QF–'Iron Quadrangle') is a remarkable mountainous region in southeastern Brazil inserted in the Atlantic Plateau. Its morphology has carved itself into Archaean and Proterozoic rocks and can be defined as the result of the evolution of a highly deformed geological substrate, resulting from the Precambrian orogeneses. Cenozoic tectonic inputs led to intense dissection through drainage and the strong structural control induced the inversion of the relief (relatively topographically elevated synclines and lowered anticlines) during Neogene and Quaternary. Therefore, there has been a predominant role of fluvial work in shaping the landscape in the QF region.

In view of the importance of fluvial work and aiming to deepen understanding of regional geomorphology during the Late Cenozoic, several surveys on fluvial terraces and depositional successions have been undertaken in the QF, but they have been of a local nature and few of these works presented ages of the analysed fluvial deposits. The present paper intends to fill the gaps left by the many localized studies about the evolution of fluvial systems in the QF and synthesize them in a super-regional overview.

An extensive literature review was carried out in regard to fluvial archives in the QF. Then, study sites were identified and revisited to review and reinterpret the data in the field and in the context of their regional setting. In total, 13 river valleys were investigated, covering the main valleys in terms of preserved fluvial sedimentary records. In each valley, the predominant means of identifying different fluvial levels were the heights and characteristics of the sediments of which they were composed. Finally, the depositional levels (floodplains and terraces) of all valleys were divided into regional phases of fluvial evolution. This organisation was based on the relationship among data from the characterisation of the depositional successions (such as the presence of duricrusts), geomorphological context of each level in its respective valley (i.e. its relationship with older and younger levels), and sediment ages when available. The studies with absolute dating techniques in the region are still in a process of building up data resolution and data density. So, we present a first attempt to synthesise these data which can be re-evaluated in the future.

The regional fluvial archives indicate a dynamic and young fluvial landscape, sensitive to tectonic forces and climatic oscillations of the Late Quaternary. The framework of fluvial levels in each valley (Fig. 1) allow to propose seven regional phases of formation of fluvial depositional levels (terraces and floodplains) between ~83 ka and the present (Fig. 2).

A number of evidences can be highlighted regarding tectonic influence on the evolution of the river valleys, such as trapped tectonic sediments and deformation and failure of sedimentary deposits. The widespread presence of terrace staircases in the valleys of the QF can be considered a response to phases of greater fluvial incision. The consecutive formation of river bedrock terraces is commonly attributed to regional uplifts [1], [2]. However, each fluvial dissection phase is unlikely to correspond to a neotectonic pulse, as there is no evidence in the literature of such a large number of different pulses during the last ~100 ka. For this reason, the Late Cenozoic neotectonic activity is considered to have led to an intense process of fluvial incision in the QF; however, it would have occurred in phases, accelerated to a greater or lesser extent according to the variable conditions of sediment production and outflow in the river valleys.

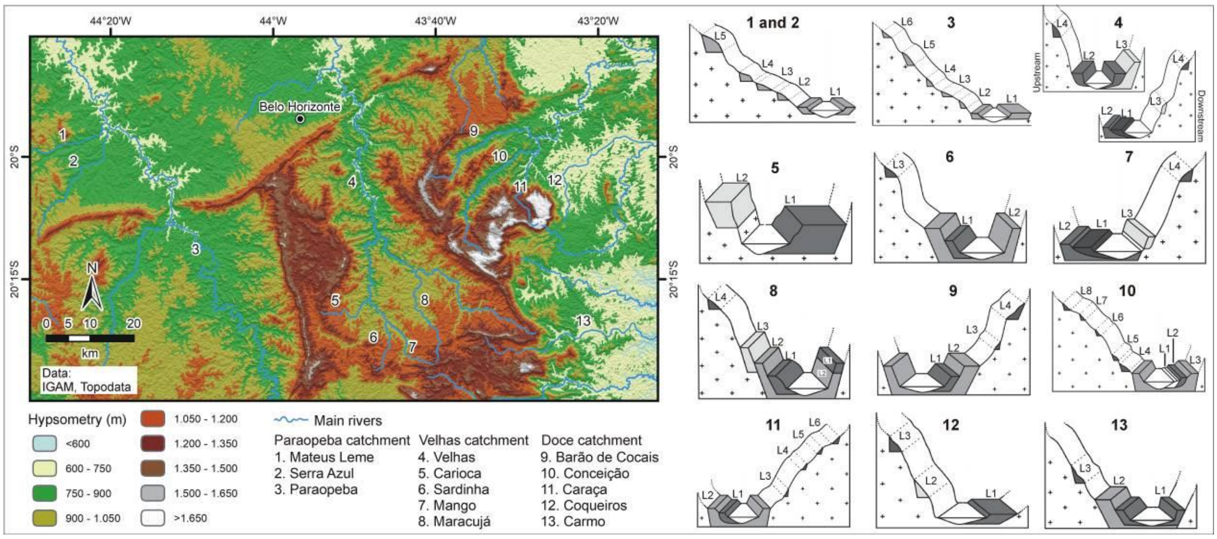

Figure 1. Topographic map of the QF and surroundings with the studied watercourses and the respective profiles of the depositional levels (without scale).

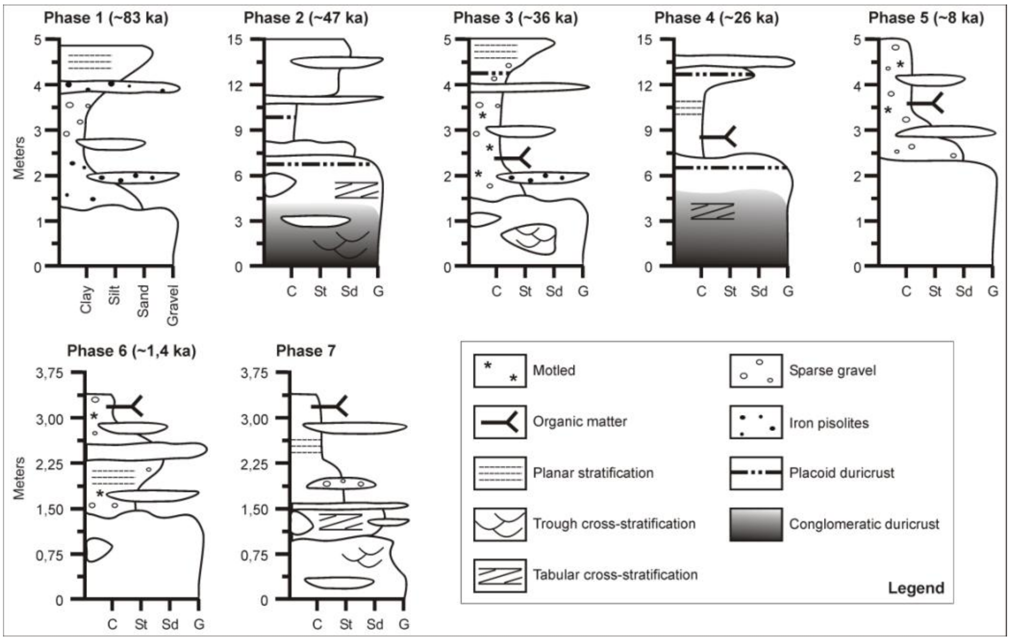

Figure 2. Stratigraphic profiles of synthesis relative to the evolutionary phases of the QF fluvial systems.

The data suggest that the Paraopeba catchment is draining a tectonic block that had greater uplifting during the Late Quaternary; hypothesis reinforced by the fact that in the Phase 2 and in similar deposits (Juatuba Formation), an E/SE tilting was registered with a dip of about 5º [3]. Still, in Phase 2 deposits, [4] described neotectonic faults, indicated by breaks in the gravel line. Likewise, the altimetric differences (about 20 m) between this deposit and those of the same terrace located downstream are indicative of a post-depositional tectonic uplift [4]. It is also noteworthy that excavations for a dam construction in the Serra Azul River revealed low angle planes, leading to the thrusting of Neoarchean schists over Quaternary alluvium [5]. Formation of the thick silt and clay packets in the upper-middle Paraopeba catchment (Phase 2) itself would probably have been conditioned by the movement of old faults or shear zones.

It is also noteworthy the high fluvial incision values found in the Holocene, with values close to those of orogenic environments [6]. However, it is crucial to point out that in no case was the outcrop of hard rocks observed to be below the river archives, and they were always on saprolite. Thus, it appears that the incision in the saprolite would explain the high river incision values, highlighting the importance of valley bottom weathering processes.

The occurrence of conglomeratic duricrusts in the riverbed can also influence incision rates. Phase 2 (~47 ka) records are at a height of 60–80 m (a.r.b.) in the Paraopeba valley, while in the Conceição valley, deposits are at 15–20 m (a.r.b.). In the former valley, there are basically no conglomeratic duricrusts, whereas in the later valley, they were formed recurrently. Duricrusts (Phase 4, ~26 ka) are also present in several other valley bottoms (Conceição, Caraça, Barão de Cocais, Mango and Maracujá) and may have prevented the waterways from experiencing a later fluvial incision phase.

Another important question to note is a clear alternation between fluvial phases developed under a moister and/or warmer climate and phases in drier and/or cooler periods according with literature data. The average interval between the moister/warmer phases is approximately 41 ka, while that between the drier/cooler phases varies between 21 and 18 ka. Thus, the interval between the moister/warmer phases approaches that of the earth's obliquity variation cycles, whereas those between the drier/cooler phases approach the earth's cycles of precession of the equinoxes. However, it would be reckless to invoke the mechanism of crustal 'loading' and 'unloading' [1] to explain the pattern of terraces observed, because the existence of several fluvial levels within the same 100 ka cycle is considered rare [1].

It seems that there may have been filling of valley bottoms in the dry phases (thicker successions) and formed duricrusts, i.e. the valleys would have filled and there would have been no river downcutting into bedrock. In the wet phases, there may have been a relatively quick fluvial incision, which would have occurred in the previously accumulated sediments, and, in the following context, in the saprolite, leaving staggered dry phase records. If fluvial incisions occurred in a certain balance with sedimentation, then fluvial successions during the wet phase would be accumulated. However, due to the permanence of the incision, there would be a migration of knickpoints and consequent abandonment of the wet phase records. Reinforcing a Pleistocene-Holocene neotectonic pulse [7], epirogenetic movements induced by the crustal mass balance in response to intense regional denudation may also have been responsible for that abandonment. The return of a dry phase would start a new cycle.

In the QF, only climatic oscillations—inducing hydrosedimentological changes in the river systems—could have caused abandonment and formation of fluvial levels in response to the new climatic conditions of the Holocene. Phase 4 fluvial archives are still present in the Mango, Maracujá, Conceição, Caraça and Barão de Cocais valleys, so that subsequent records are inset (Phases 6 and 7). Consequently, there is no fluvial downcutting. There are also no traces or evidence of large Holocene rearrangements in the river systems that would justify a change in the hydro-sedimentological regime through the loss of drainage areas.

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THE POTENTIAL OF LEAF WAX BIOMARKERS IN FLUVIAL SEDIMENT-PALEOSOL SEQUENCES – A CASE STUDY FROM THE UPPER ALAZANI RIVER, GEORGIA (CAUCASUS)

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Quantitative paleoclimatic and -environmental reconstructions are the key for a better understanding of how climate and environmental conditions have developed during the past and will develop in the future. In this context, biomarker analyses became a novel and innovative tool during the last decades. Long-chain *n*-alkanes ($>C_{25}$), for example, are leaf wax biomarkers that are produced by higher terrestrial plants and stay well preserved in sediment archives for millennia [1]. Their homologue pattern as well as their carbon and hydrogen isotopic composition can be used to reconstruct past changes in vegetation and paleohydrological conditions [2, 3]. While leaf wax biomarkers were successfully applied in lacustrine sediments and loess-paleosol sequences during the last years, no studies explored their potential for paleoenvironmental reconstructions in fluvial sediment-paleosol sequences so far. However, the latter kind of sediment archives are found ubiquitously in most regions of the world. Therefore, biomarker analyses in fluvial sediment-paleosol sequences have the potential to strongly enhance our knowledge of former climatic and environmental conditions in different landscapes and climate zones.

Here we present an explorative study that evaluates for the first time the potential of leaf wax biomarkers for paleoenvironmental reconstructions in fluvial sediment-paleosol sequences by studying a Holocene fluvial sediment sequence from the upper Alazani River in eastern Georgia (southern Caucasus). Since leaf wax biomarkers were not investigated in the Caucasus region so far, in a first step their regional applicability was evaluated on modern reference material from plants and topsoils prior to their application to the Holocene fluvial sediments. Subsequently, we carefully discussed potential archive-related limitations and investigated the age and origin of the leaf waxes in the fluvial sediments by compound-class ^{14}C-dating. Following those general considerations, we finally reconstructed the regional paleovegetation by leaf wax homologue patterns and paleoclimatic conditions by compound-specific $\delta^{13}C$ and $\delta^{2}H$ of those biomarkers.

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THE CONTRIBUTION OF ROB WESTAWAY TO THE STUDY OF FLUVIAL ARCHIVES

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Robert Westaway was a structural and hard-rock geologist who turned his attention to the study of Late Cenozoic fluvial archives, believing that the preservation of staircases of river terraces, particularly representing the Middle and Late Pleistocene, could only be explained in terms of crustal activity in response to surface processes, the latter affected by climatic change. His entry into this research area coincided with the realisation that such terrace sequences required surface or crustal uplift to have taken place over the time period represented. Workers were unable to explain this in terms of erosional isostasy, a process that could potentially have explained one-way crustal movement of the type observed. Westaway envisaged a mechanism by which mobile lower crust migrated to areas beneath uplifting areas, preventing their future subsidence. The mechanism requires complex mathematics to explain it, as well as lending itself to mathematical modelling of the process based on varying crustal properties and changes in the rates of surface processes in response to climatic fluctuation. Essentially the lower-crustal effect can be envisaged as a positive-feedback enhancement of erosional isostasy.

It became apparent that Westaway's theories could elucidate geomorphological and sedimentary fluvial archives that were otherwise difficult to explain. Mantle-based erosional isostasy could not explain terrace staircases, for example. Many of these occur in regions that are tectonically inactive, and so cannot be attributed to neotectonic activity. A game-changer in terms of persuading the wider community came from the recognition of crustally ultrastable regions in which progressive uplift has not occurred: Archaean cratons. Westway's lower-crustal flow would not be expected in such regions, which have cold, brittle and immobile crust to its full depth. Ancient fluvial deposits are found close to modern valley-floor levels in such areas. Regions showing intermediate situations were subsequently identified. Other particular dilemmas could be resolved, such as the 'back-tilting' of the early-Middle Pleistocene Bytham River in the English Midlands, caused by its drainage crossing crustal blocks with different properties. Although glacio-isostasy, mostly seen in the effects of post-LGM rebound, is largely accommodated in the mantle, and thus is reversed as a response to glacial loading and unloading, in areas of suitable crustal type there is evidently a small lower-crustal component that is not reversible.

Rob's important contribution has yet to be fully integrated into received wisdom in geomorphological and Quaternary circles, although much of it is now widely accepted and more will be explored and published in due course.

DISCUSSION OF THE TRANSITION OF ENDORHEIC TO EXOREIC DRAINAGE OF CENOZOIC BASINS IN GALICIA (NW OF IBERIA), THE DEVELOPMENT OF THE ANCESTRAL TRANSVERSE DRAINAGE TO THE ATLANTIC AND THE LATER STAGE OF FLUVIAL INCISION

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The drainage basin of the Atlantic Sil River is located in the central-eastern sector of Galicia (NW of Iberia) (Fig.1). The Sil and its tributaries, especially the rivers Xares, Bibei, Quiroga, Navea and Cabe, flow through a contrasting relief. Here, the transverse drainage is characterised by an alternance of tectonic depressions preserving Cenozoic sedimentary infills and incised meanders/canyons across montains of basement [1, 2]. The main tectonic depressions crossed by the Sill River are those of Valdeorras, Quiroga and Monforte (Fig.1). The mountains crossed by the river are mainly located the Ribeira Sacra sector. The Sil and tributaries mainly run cross basement areas, which mainly consists of Palaeozoic metamorphic rocks with minor granites, that are intensely faulted with main directions NNE-SSW, NO-SE and WNW-ESE.

In this work we present a characterization of the geomorphic and sedimentary units recording the geological evolution of the study area during the Cenozoic, under an intraplate compressive tectonic setting, leading to drainage re-organization, development of the Atlantic drainage and later stage of fluvial incision.

In the tectonic depressions, several sedimentary units are preserved: 1) two sucessive allostratigraphic units (unconformity bounded sequences; UBSs) of arkoses (Paleogene and Miocene); 2) two successive units of alluvial fan deposits, with endorheic drainage, probably recording the upper Tortonian to lower Zanclian (UBS11 and UBS12); 3) an uppermost unit of ocre heterometric alluvial fan deposits (UBS13), the first episode with exorheic drainage, tributary of an ancestral Atlantic river (the Sil River, conected with the Minho River) and with sedimentary record probably comprising the Upper Piacenzian to Lower Pleistocene (ca. 3.7 to 1.8 Ma) [2]; 4) a staircase of fluvial terraces (strath and sedimentary) produced during the later stage of fluvial incision (probably, the last ca. 1.8 Ma), recording the alternance of episodes of down-cutting, dynamic equilibrium and eventual sedimentary aggradation.

Regarding the NW of Iberia, our model for the transition of endorheic to exoreic drainage and the development of transcontinental drainage to the Atlantic Ocean is similar to the one proposed for the genesis of the Douro [3, 4] and the Tejo/Tajo (Tagus) [4, 5] rivers, involving as main mechanism an overspill induced by a major climatic change of increasing humidity by middle Pliocene.

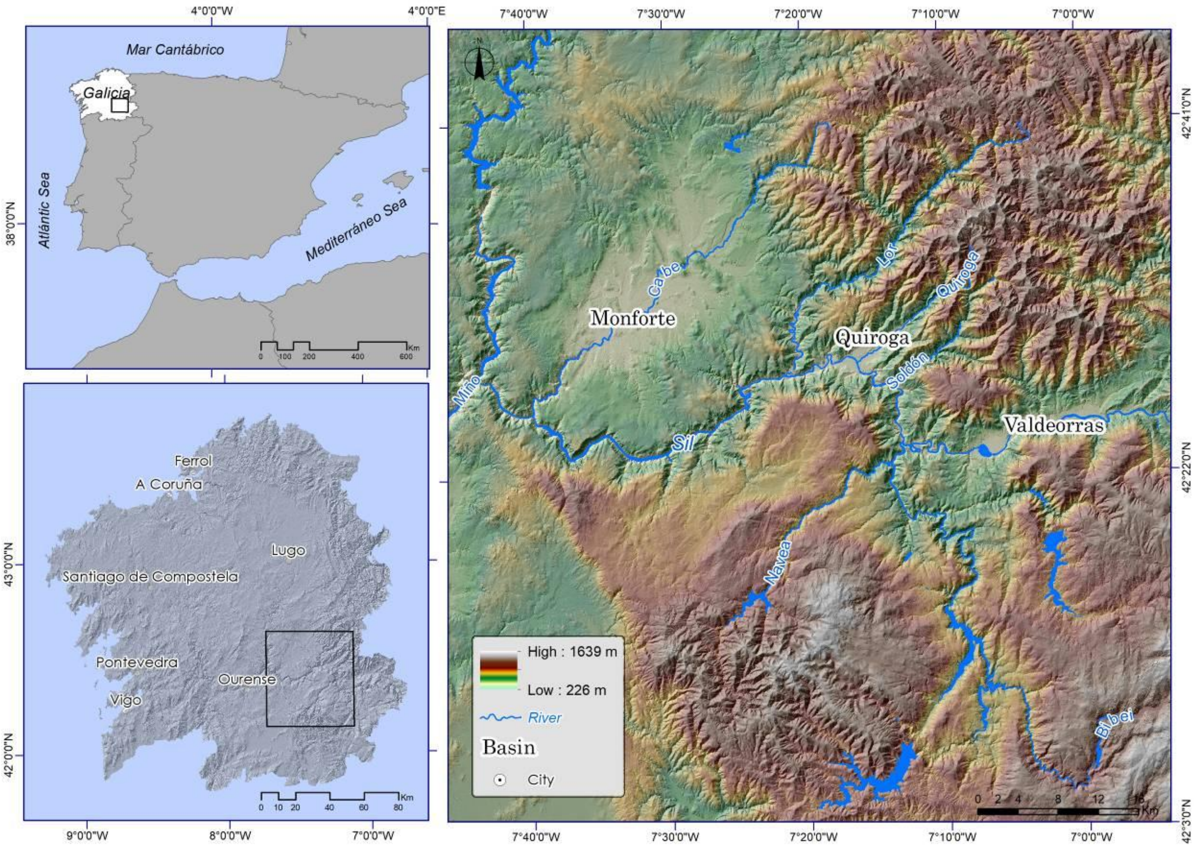

Figure 1. - Geographical setting and geological map of the study area in Galicia (NW of the Iberian Peninsula).

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TECTONIC REACTIVATION OF A PASSIVE MARGIN LANDSCAPE: INSIGHTS FROM QUATERNARY RIVER TERRACES (LOWER MONDEGO RIVER, WESTERN IBERIA)

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The Mondego River is the longest river with headwater in Portugal, flowing in an ENE-WSW direction, from the Estrela Mountain (Portuguese Central Range) until the Atlantic Ocean (Fig. 1). Along the upstream steep valley, the Mondego runs over basement rocks, but in the Lower Mondego Valley (LMV, the study area) it runs (~50 km) over Mesozoic (carbonates and siliciclastics) and Cenozoic (siliciclastics) sedimentary rocks. From upstream to downstream, the LMV can be subdivided in four main reaches (I to IV) limited by major faults and a gorge.

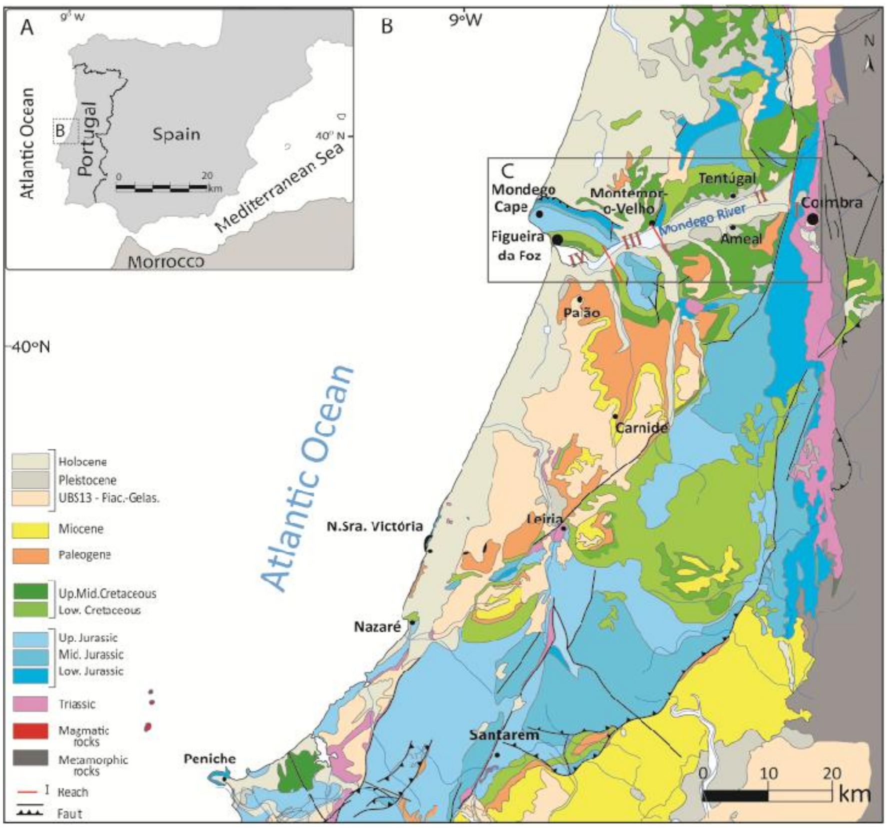

Figure 1. A – geographical setting within the Iberian Peninsula; B - geological map of central western mainland Portugal (modified from the Geological map of Portugal, 1/500000, LNEG); C – study area.

The study area has active tectonics and is located in the Western Iberian Margin, a passive margin under a compressive reactivation since ~80 Ma [1]. It is used for deciphering the long-term landscape evolution during the Quaternary and the control played by tectonics, eustasy and climate. The elaboration of a detailed geomorphological map allowed the establishment of the spatial and temporal distribution of the different geomorphological units and morphogenetic systems operating in the LMV. The culminant unit of the Mondego Cenozoic Basin (the allostratigraphic unit UBS13, recording an Atlantic fan-delta and adjacent shallow marine siliciclastic environments) [2, 3] and the terrace levels (fluvial and marine) are used as geomorphic markers to quantify the Lower Mondego River development and tectonic activity during the last ~3.7 Ma.

The main stages of geological evolution are: 1) by ~4 Ma, transition from endorheic to exorheic (Atlantic base level) drainage in the Mondego Cenozoic Basin; 2) by ca. 1.8 Ma, onset of the fluvial incision stage (valley entrenchment). Electron spin resonance (ESR) dating, integrated with previous OSL ages [4], is used to improve the chronological framework for the terrace staircases of the LMV and to decipher the response of the river to the regional uplift and other long-term controls (resistance of the substratum to erosion, eustasy and climate). Six river terrace levels (Tf1, the older, to Tf6, the younger) inset in the UBS13, were characterized and correlated with two terraces with marine deposits and with several wave-cut surfaces represented at the highly uplifted Mondego Cape [4]. The Tf1 (probably upper Calabrian) should correspond to the Middle Pleistocene Transition (MPT) cyclicity (Milankovicht cycles) and it seems that the glacio-climatic control strongly affects the terrace development after the MPT, during the 100 ka cyclicity. The fluctuating eustatic and climate controls are superimposed on a long-term crustal uplift. The data show marked compartmentalisation of fluvial system behaviour with changes in incision rates from east to west, creating distinctly different sectors. Differential uplift is deduced, between the valley sides and between the four main reaches in which the LMV is subdivided by major faults. Differential uplift is mainly related with regional fault systems, with trend: N-S to NNW-SSE; ENE-WSW; NNE-SSW and E-W to WNW-ESE. Using as geomorphic references the aggradation surfaces of the UBS13 and of the river terraces above the alluvial plain (UBS13 – 1.8 Ma, at +195 to +85 m; T1 – probably ~850 ka, at +128 to +72 m; T2 – ~670 ka, at +109 to +52 m; T3 – ~450 ka, +67 to +27 m; T4 – ~300 ka, +46 to 16 m; T5 – 100 ka, at +16 to +3 m), the estimated incision rates range from 0.08 m/ka to 0.34 m/ka, depending on the response of the lower Mondego River to coupled regional and differential uplift along the LMV. For each staircase, the average uplift rate ranges from 0.037 m/ka to 0.044 m/ka. Since the Early Pleistocene, the incision rates and uplift rates are increasing. This study demonstrates the applicability of river archives to access not just the timing of uplift on a regional scale, but also the relative uplift of individual tectonic smaller areas.

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PALEOHYDROLOGY AND GEOARCHAEOLOGY ALONG THE MUSONE RIVER (VENETIAN PLAIN, NE ITALY)

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One of the major issues in alluvial geomorphology and paleohydrological reconstructions is the possibility to assess the time interval intercurred for the formation of a channel morphology or the deposition of its sedimentary infill. Numerical geochronology is a key tool (e.g. Radiocarbon, OSL), but in some archaeological contexts the use of chronology supplied by cultural differentiation allow an even precise and detailed dates.

We present the case study of the Musone River, in the apical portion of the Venetian Plain, where the construction of the new highway road along the piedmont sector has allowed to describe long stratigraphic sections and to discover several new archaeological sites. One of the major finding corresponds to the Protostoric settlement located slightly east of the present river channel, north of the city of Riese. The ancient settlements were located along the active channels of the river and the new data allow to describe the interactions between the river changes and the settlement locations. In particular, at least 4 different channels of Musone dating between 1500 and 600 BC have been recognized. They display diverse characteristics, from meandering to braided typology. In some cases it is possible to follow the channel shifting with decadal precision.

The Musone is a minor stream fed by a catchment of 40 km^2 extending in the pede-Alpine area, where the bedrock consists of Tertiary siliciclastic formations prone to erosive processes. In the alluvial plain the Musone formed a narrow and elongated alluvial system along the interfluve between the alluvial megafan of Brenta River and the Montebelluna megafan, formed by Piave River before LGM. Since LGM the Musone aggraded of about 5 m over the aforementioned megafans and some buried soils testify significant depositional stasis. Musone River experienced an evolution that is strongly different from the depositional systems of the Alpine rivers, so, the study of this area supplies several data that are complementary to the ones collected in the rest of NE Italy for reconstructing the evolution of the Venetian Plain.

REFLECTION OF CLIMATE CHANGES IN SELECTED RIVER VALLEYS OF NE POLAND AND W BELARUS

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The main aim of this work is to present the results of geoarchaeological studies from the Biebrza and Narew river valleys (NE Poland) and Sporovsky Biological Reserve in Yasielda river valley (W Belarus). This area was occupied for a long time by the hunter-gatherer Mesolithic communities and later by the Niemen and Pripyat-Niemen cultures. These cultures only slightly changed the geographic environment in the Early and Middle Holocene. It makes it possible to trace the natural changes of geosystems during this period without the influence of an anthropogenic factor.

Relief of Upper Biebrza Basin was formed during Middle Polish (Saalian) Glaciation - Warta Cold Stage. During the next ice-sheet advance until the Pomeranian phase of last glaciation 15.5-15.0 ka BP [14], 16.2 ka BP [4] outflow from Naroch-Wilia and Skidel the dam lakes and river waters of the upper Neman river followed Łosośna river valley, its tributary Tatarka river breakthrough Pripilin-Nurki gap section to Biebrza and Narew river valleys [14], [19], [5]. Therefore, the Biebrza and Narew downstream of the confluence with Biebrza are underfit rivers with vast peat-bogs on their valley floors.

Results of studies from many archaeological sites in the Biebrza Basin [2], [17], [1], as well as from Sporovsky Reserve [13] indicate some periods of climatic changes and an increase of morphogenetic processes activity.

In the Late Glacial, the river systems were transformed and the channel development changed. The flows were concentrated and the Narew flowed in large meanders. Two generations of the Lateglacial macromeanders: older, probably from Bölling (11 780±100 BP; 11 851-11 461 cal. BC) and younger, probably from Alleröd and Younger Dryas (9900±90 BP; 9762-9231 cal. BC) occurred [17]. A less sinuous pattern of older generations reflects the first stage of transformation from braided to a meandering river, similar to Warta and Maas river valleys [15]. These changes have not been found in the Yasielda valley. At that time river formed a delta and flowed through many riverbeds to the Sporovskie Lake from the end of the Younger Pleniglacial. In the Early Holocene, this lake was much larger than in present-day [13] and carbonate gyttja sedimented in it [12], similar to other lakes from Polesie and Poozerie regions in Younger Dryas and Preboreal [9]. The formation of carbonate sediments poor in the organic matter in oligotrophic-mesotrophic lakes [18], [13] reflects an important stage of lake development connected with considerable climatic warming at the beginning of the Holocene [9]. In Sporovo the sandbanks separating the channels formed the elevations within the peat bog. Later (5th - 3th millennium BC) these forms were settled by the communities of the Pripyat-Neman and Neman Subeolithic cultures (Kokoritsa 4 archaeological site)[13], [12].

At the bottom of underfit river valleys (in the non-fluvial segments) starts accumulation of peats (e.g. Narew - in Wizna Basin : 10 135±90 BP; 10 143-9396 cal. BC) [17]. This phase was interrupted by short-term activation of aeolian processes that were recorded as inserts of sands in peats (Narew: after 8320±80 BP 7542-7141 cal. yr BC; Biebrza: between 9880±100 BP 9803-9182 cal. yr BC and 7350±110 BP 6425-6026 cal. yr BC [17], [3].

The beginning of the Atlantic period is very well known and recognized in many regions of Central Europe [5] (including Belarus - pollen diagrams [16], BO-3; 8400-7800 BP as well as from isotope curves 8300-8200 BP after [10]) as a climate cooling and humid phase [11]. There were very clear changes in river valleys, e.g. channel changes in Neman basin [6] and in Biebrza where the beginning of peat accumulation in the valley floor and meander cut-off was dated respectively at 8490±80 BP, 7658–7347 cal. yr BC and at 8330±120 BP, 7577–7083 cal. yr BC [1]. A phase of an increase of fluvial processes activity caused an increase in the rate of lateral migration and a rapid point bars increase [8], on which dunes could form, e.g. in the Narew valley [17]. At the same time, the increased fluvial accumulation could have contributed to the development of the Yasielda delta and the reduction of the Lake Sporovskie area - accumulation of peats on the lakustrine deposits (8190±90 BP, 7494-6866 cal. yr BC) [13] (Fig. 1).

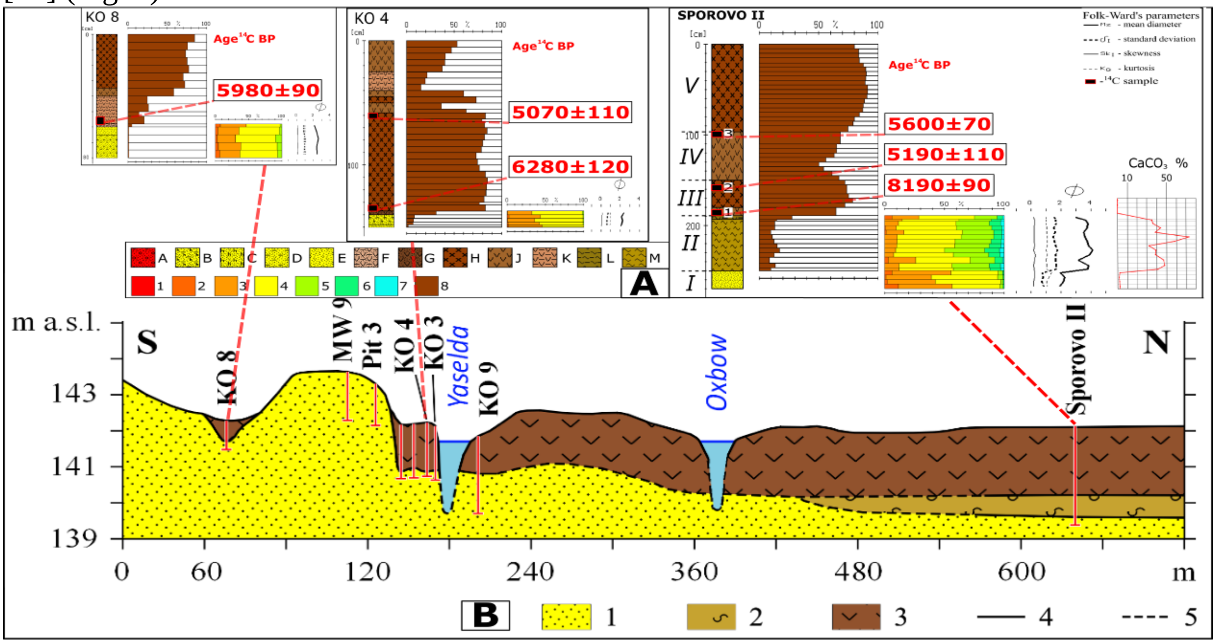

Fig. 1. Geological cross-section of the study area from Sporovo II to KO8 with lithological diagrams ([13] - supplemented), A: Lithology: A - sands with single gravels, B - humous silty sands, C - humous fine-grained sands, D - silty sands, E - fine-grained sands, F - sandy peaty silts, G - sandy peats, H - peats, J - silty peats, K - peaty silts, L - gyttja silts, M - gyttja; Fraction: 1 - medium and fine gravel (below -1ϕ), 2 - coarse sand (-1 to 1ϕ), 3 - medium sand (1-2ϕ), 4 - fine sand (2-4ϕ), 5 - coarse and medium silt (4-6ϕ), 6 - fine silts (6-8ϕ), 7 - clay (above 8ϕ), 8 - the content of organic matter B: 1 - sands, 2 - gyttja, 3 - peats; 4 - established limits, 5 - estimated limits

In the humid Atlantic period, the peat-bog in the Biebrza Valley expands covering the sands e.g. 7050±60 BP 6033-5789 cal. yr BC [3], 7020±70 BP cal. 6016-5746 BC [2]. In the Middle Atlantic (AT 2) groundwater rising in Neman floodplain caused death and tree fallen (6420±60 BP, 6100±80 BP) and an increase of fluvial activity channel caused changes its riverbed (6360±80 BP, 5480-5080 cal. yr BC)[6]. However, the floods during this period did not cover the entire fluvial segment of Narew in Wizna Basin. Therefore in its marginal parts, in the Lateglacial oxbow lake starts accumulation of peats (more than 80% of organic content)(6340±90 BP, 5481-5069 cal. yr BC) [17]. In this time groundwater rising caused peat accumulation in the Polesie region (6120±60 BP, 5260-4850 cal. yr BC)[15]. In Jasiołda valley peat accumulation starts from 6280±120 BP (MKL-5182) 5480-4953 cal. yr BC in the close vicinity of the archaeological site "Kakoryca-4" (Fig. 1). At a similar time (6170±80 BP, 5313–4911 cal BC) peat bog covers the oxbow lake at Lipowo in Biebrza valley and caused its disappearing in the relief [1]. The rising of the groundwater level must be very high if the peats started to growth in the depressions (KO8) on the sandy elevations in the Sporovo region since 5980±90 BP (MKL-5183) 5207-4621 cal. yr BC (Fig. 1). This corresponds very well with Usha river lateral migration and cut off about 5895±255 BP, 5500-4200 cal. yr BC

[6]. The next humid phase occurred at the end of the Atlantic period when trees were felled in the peat bog in the Biebrza valley at 5060±60 BP, cal. yr 3967-3712 BC. At this period trees couldn't grow on a peat-bog in the valley bottom [7] and occurred an increase in lateral migration of riverbeds in many valleys [6]. The changes in sedimentation observed in Sporovo do not have to be caused only by regional conditioning but may be related to the local situation and changes of the Yasielda riverbed. The palaeochannel of this river with water and preserved in morphology was still an active riverbed at the end of the Atlantic, located near the Sporovo II borehole up to 5600±70 BP. Later it was cut off and the river flow near the Kokoritsa archaeological site, which changed the type of sedimentation in the KO4 borehole after 5070±110 BP (MKL-5181) 4224-3642 cal. yr BC.

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ENDORHEIC – EXORHEIC TRANSITION: THE ATLANTIC DRAINING PARAÍBA DO SUL RIVER BASIN (BRAZIL)

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Present-day endorheic drainage systems are rare in tropical humid regions and / or close to the coast. During the late Cenozoic, under a humid tropical climate, the Paraíba do Sul River basin (SE Brazil) has developed along the South America passive margin (Fig. 1). This basin currently drains into the South Atlantic ocean, but it preserves landforms that are indicative of previous endorheic paleodrainage. This study examines the possibility that this region was endorheic for most of the Neogene, prior to the establishment of the present-day drainage to the Atlantic and discusses the transition from an endorheic to an exoreic system. Data was achieved through analysis of geomorphological features identified by remote-sensing techniques and verified in the field, as well as the interpretation of landscape evolution models elaborated by the Seppômen method. Five drainage convergence areas and possible endorheic paleobasins, previous to the Quaternary (or to the Pliocene) have been identified within the present-day Paraíba do Sul River basin (Fig. 2). Each area is associated with a Cenozoic graben and is separated by structural highs which would have formed paleo-drainage divides. The most probable mechanism for the transition endorheic-exorheic is overspill, leading to the progressive incorporation into the exorheic system and followed by headward erosion advancing inland from the gorge developed at each overspill area. Atlantic Ocean. Two processes often occur concomitantly and both contribute to the same result: the expansion of an exorheic basin by the incision of a permanent channel into the endorheic basin infill. The geological evolution ancestral Paraíba do Sul River, draining to the Atlantic, was later controlled by the very low sea levels during the Quaternary which determined the stage of fluvial incision. No numerical dating has been yet obtained for the proposed endorheic-exorheic transition; nonetheless, regional denudation rates suggest that this transition occurred sometime in the interval 8 to 4 Ma (end of the Miocene to mid-Pliocene), probably by 4 Ma. This transition was marked by a decrease in subsidence within the aforementioned grabens and by a much wetter climate that promoted the overspill and connection to the Atlantic. According to the interpretation of the evolution of headward erosion pulses in the Paraíba do Sul River basin, surfaces that dissected and sculpted the relief at different times during each tectonic and/or climatic event were interpreted (Figure 3).

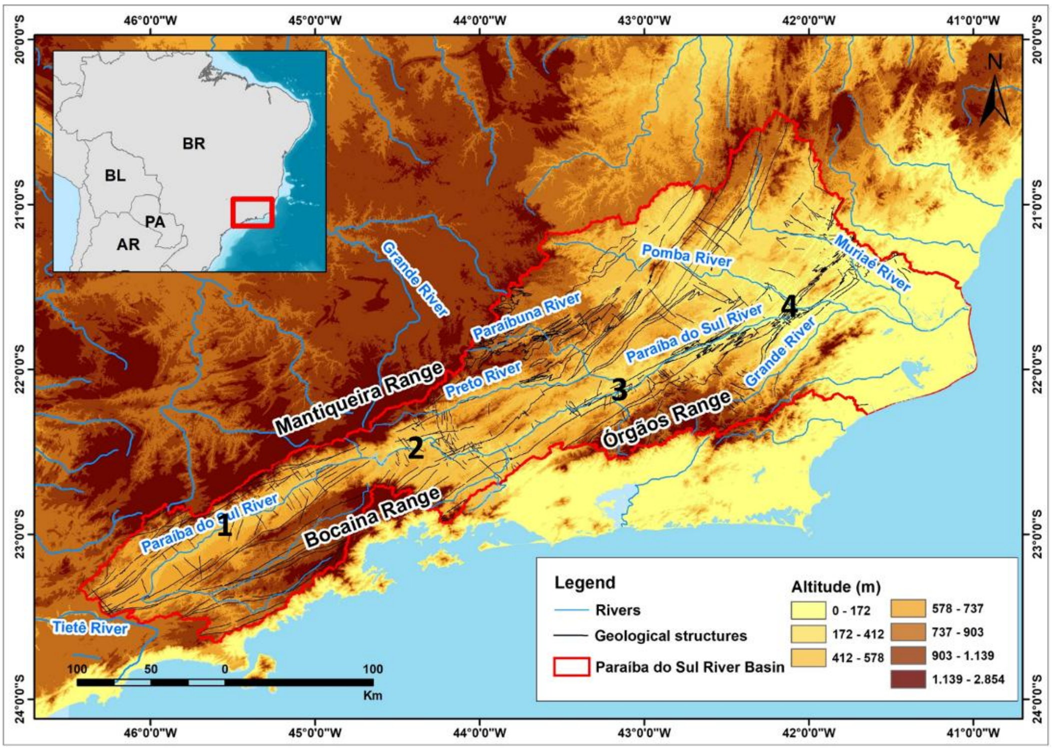

Figure 1: A) Digital elevation model of the region showing the location of Paraíba do Sul hydrographic basin. Grabens in the region: B) – Taubaté (1); C - Resende/Volta Redonda (2); D - Três Rios (3); E – Itaocara (4).

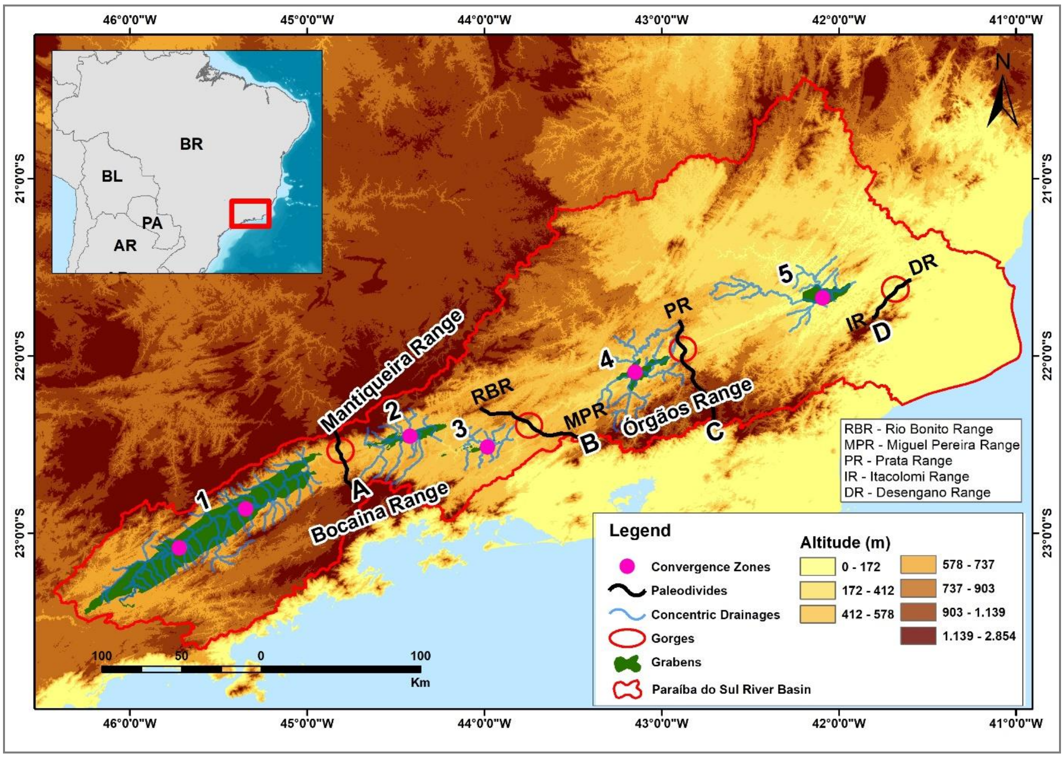

Figure 2: Hydrographic basin of the Paraíba do Sul River showing the location of areas with convergent drainage patterns, paleodivides and gorges. Convergent drainage areas: 1. Taubaté; 2. Resende; 3. Volta Redonda; 4. Três Rios; 5. Itaocara. Paleodivides with transversal topographic profiles given in Fig. 3: A - Queluz; B - Miguel Pereira; C - Sapucaia; D - Desengano.

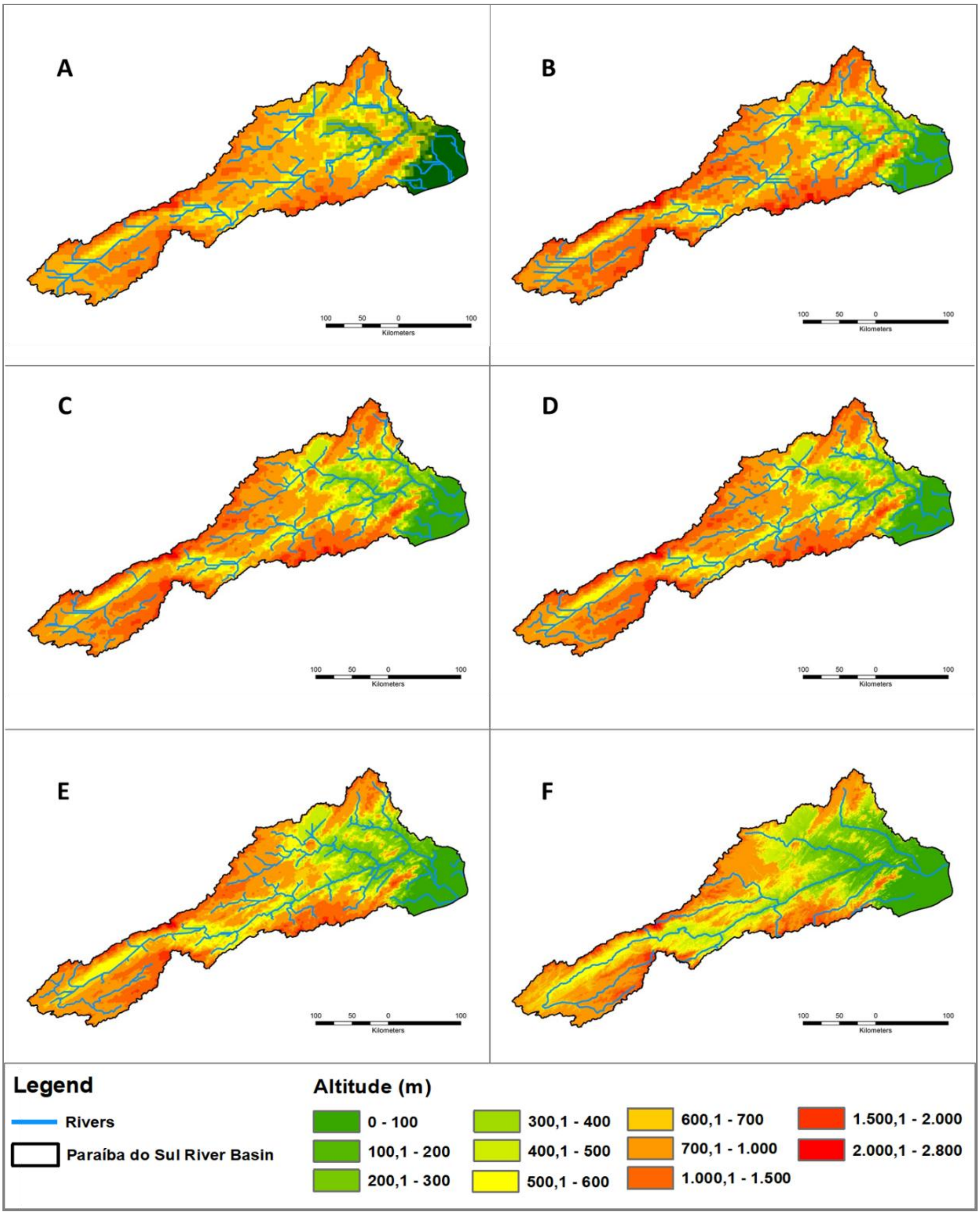

Figure 3: Paleotopographic (Seppômen) maps of the Paraíba do Sul River basin generated using varying cell sizes (km): A - 5x5; B - 4x4; C - 3x3; D - 2x2; E - 1x1; F -Present-day relief (DEM).

THE VOLGA AND DON RIVER RUNOFF IN WARM CLIMATE EPOCHS

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The features of the Volga and the Don River runoff changes during the Holocene Climatic Optimum and scenario conditions of global climate warming in the current century have been revealed. Paleoclimatic reconstructions based on data of spore and pollen analysis of fossil plants and results of calculations carried out on the ensemble of global climate models of PMIP-II program, as well as scenarios of climate warming, performed on an ensemble of global climate models of CMIP3 and CMIP5 programs, have been used. Hydrological changes have been evaluated on the basis of the monthly water balance model [Georgiadi & Milyukova, 2002]. Scenario air temperature in the Volga and Don basins, typical for the first third of the current century, was close to the temperature of the Holocene optimum reconstructed on the basis of palynological data. At the same time, the simulated annual runoff of the Volga and Don rivers was lower than the modern one. This result is consistent with the estimates of the water runoff obtained earlier for the Volga River on the basis of relations of annual flow with climate zonality, and with the results of the reconstruction of water runoff based on palaeomeander characteristics. At projected and the Holocene Optimum climatic conditions reconstructed by PMIP-II, annual runoff is above modern (in Volga) or almost does not differ from it (in Don). In the scenario projection for the first third and the middle of the current century, the annual runoff of Volga is likely to increase as the climate warms, while the runoff of Don is likely to remain unchanged. The most noticeable differences in the Volga and Don runoff in warm climate of the Holocene optimum, modern and scenario periods are manifested in changes in the intra-annual distribution of their water runoff.

Acknowledgements
These studies were carried out according to the theme of the State Assignment no. 0148-2019-0007/AAAA-A19-119021990093-8.

PATTERNS AND CONTROLS ON FLUVIAL INCISION IN THE LOWER DOURO RIVER (WESTERN IBERIA) FOLLOWING ENDORHEIC-EXHOREIC DRAINAGE REORGANIZATION

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The Douro River, is ~900 km long and has a drainage basin of ~97,600 km^2, crossing most of the Iberian Peninsula from east to west (Fig. 1). The study area of the present work comprises the Lower Douro River (LDR), limited upstream by a relevant hard basement knickzone known as the Arribas do Douro. This case study is an outstanding example of a transition from endorheic to exorheic drainage, expressed by a major continental-scale drainage reorganization, followed by the ongoing stage of fluvial incision.

By middle Cretaceous, the passive Western Iberian Margin started to be tectonically reactivated by an increasing N-S to NW-SE compression, leading to intraplate deformation. The deformation climax reached since ~ 9.5 Ma (middle Tortonian) lead to the differential uplift of crustal blocks [1, 2].

Until ~3.7 Ma (middle Pliocene) the regional drainage was towards east, to the endorheic Douro Cenozoic Basin (DCB) (Fig. 1). The cause for the transition was not a capture (fluvial piracy) due to a progressive upstream erosive evolution by a former small Atlantic river, cutting on the progressively high hard basement. Instead, the recently proposed mechanism is by overspill [3, 4]. Although the endorheic-exorheic reorganization leading to an Atlantic system, has recently been investigated [2, 3, 4, 5, 6], the fluvial incisional stage of the main river and tributaries is less understood along the LDR, which will be characterized and discussed here (Fig. 1).

Along the LDR, Douro cuts down through hard granitic and metamorphic rocks crossed by active fault zones, before reaching the Atlantic coast. The main valley comprehends a terrace staircase of 11 levels, being the upper ones straths and the 3 lower ones aggradational (with a thickness of deposits).

In this work, we characterize the transient landscape relief of four distinct sectors along the LDR (Figs. 4, 5, 6, 7), in terms of: with-valley floor ratio, degree and rates of incision, uplift rates, migration of the successive erosion waves and knickpoint propagation, preservation of old plateaus of the regional planation surface, influence of lithology on the relief evolution, and the staircase arrangement along the main course considering the presence/absence of aggradational levels. The four sectors are separated by two major NNE-ESE strike-slip fault zones, namely the Penacova-Régua-Vérin fault zone (PRVfz) and the Manteigas-Vilariça-Bragança fault zone (MVBfz), which are in general, associated to huge gorges along the uplifted blocks between pull-apart basins (e.g., Régua and Vilariça-Pocinho) where the aggradational terraces are well expressed.

The 4 sectors of the LDR are: I) from the river mouth till the confluence of the main northern tributary, the Tâmega River – adjacent to a wide littoral platform with inland hills (top less 500 m); II) from the Tâmega confluence till the tectonic corridor of Mesão Frio-Régua – uplifted reliefs of the Occidental Mountain Range; III) from Régua till the pull-apart basin of Pocinho-Vilariça – High Plateaus of Northern Portugal; IV) from Pocinho till the elbow that marks the DCB – the old erosion surface of the Iberian Meseta.

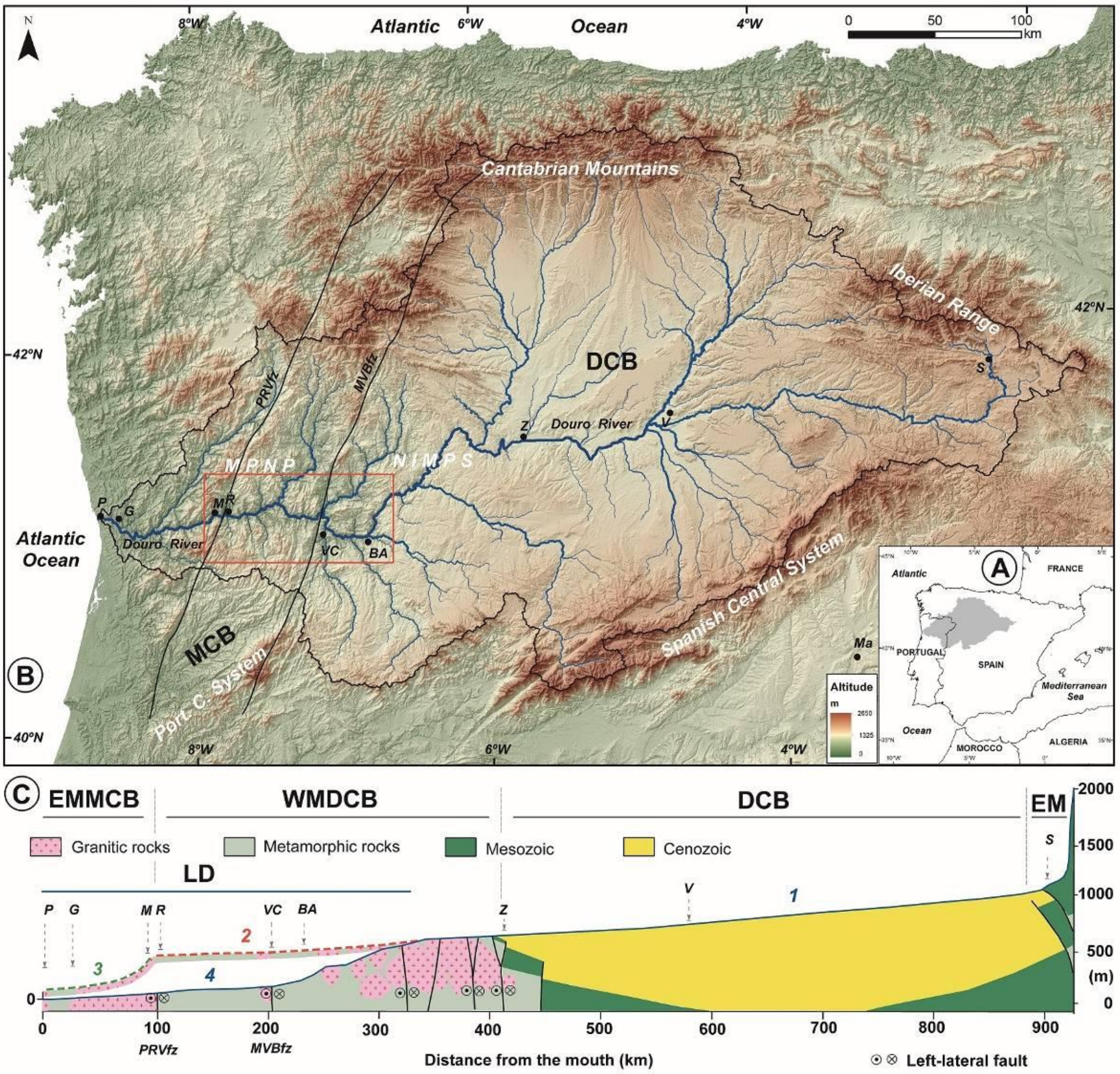

Fig. 1 - The Douro catchment (drainage divide=black line) and its drainage network (blue lines) (B), inset showing location in Iberia (A) and longitudinal profile (C) with bedrock geology. 1 - long profile of Douro River in the Douro Cenozoic Basin (DCB); 2 - long profile of the ancestral Douro in the study area; 3 - long profile of an ancestral coastal Atlantic river; 4 - long profile of the modern Douro downstream of the DCB; LD – Lower Douro.

Fig. 2 – Panoramic view of sector III from the Occidental Mountain Range (Alvão Mountain). High Plateau (MPNP) well preserved contrasting with the entrenched valley of Corgo River, a tributary of Douro of the right margin. Upstream of the minor bridge at left, there is the migration of the erosion wave and the transient knickpoint locate at the city of Vila Real.

Fig. 3 – Panoramic view of sector III upstream the village of Pinhão, where we observe the alternance of incision vs dynamic equilibrium marked by the staircase of strath terraces, highlighted by the location of the settlements and the bedrock terraces on the slopes.

Fig. 4 – Panoramic view of sector IV showing the transient landscape on the Côa River valley, a left margin tributary of Douro. On first plan, the spread of the incision upstream on the metamorphic soft basement, and the flattened erosion surface (NIMPS) that extends over the horizon to the residual quartzite relief of the Marofa Mountain (976 m).

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CORRELATION BETWEEN THE FLUVIAL TERRACE STAIRCASES OF THE LOWER TEJO RIVER AND THE MARINE TERRACE STAIRCASES ADJACENT TO THE RIVER MOUTH (WESTERNMOST IBERIA)

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This study provides new geomorphological and geochronological data (Electron spin resonance dating, ESR), allowing the characterization and correlation of the fluvial terrace (Tf) staircases of the Lower Tejo River (LTR) at reach IV with the marine terraces (Tm) adjacent to the river mouth, namely at the Raso and Espichel capes (western central Portugal) [2]. The terrace staircases are also correlated with the Marine Isotope States (MIS) and the control mechanisms that originated the marine and fluvial terraces are discussed.

Inland, the study area comprises the reach IV of the Lower Tejo River (Arripiado - Vila Franca de Xira), dominated by the Upper Pliocene – Lower culminant sedimentary unit of the Lower Tejo Cenozoic Basin (UBS13; the ancestral Tejo River before the stage of fluvial incision). The Middle to Upper Pleistocene is represented by fluvial terraces and an aeolian cover unit [4] [6]. Holocene sediments form an extensive alluvial plain, ca. 10 km wide in downstream part of the area.

Previous studies in reach IV, provided the characterization and dating (Qz-OSL, post-IRIR and ESR) of the six terraces levels present [1] [3] [7]. Using the terrace staircase of the left valley margin, several levels were identified: Tf1 at c.a 115 m (above mean sea level, a.s.l.) with a probable age of 950 - 850 Ka; Tf2 (82-72 m) with a probable age of 780-550 ka, Tf3, (60-50 m) is between 500 ka - 360 ka, Tf4 (38-20 m) has 335 - 155 ka, Tf5 (13-10 m) has 135-73 ka and Tf6 (-4 m) is between 62-30 ka. It was estimated an uplift rate of 0.10m/ka [3].

At Raso cape (Fig.1 A), four terraces below the culminant wave-cut platform (base of UBS13) at ~90 m a.s.l., 42-38 m (Tm1), 37-34 m (Tm2), 22-20 m (Tm3), 10-9 m (Tm4) were identified. The Tm2, comprising rolled boulders at the base, coarse to medium sands in the middle part and colluvium at the top, was dated by ESR (416±180 ka - Al; 437±67 ka - Ti). It was estimated an uplift rate of ca. 0.07 m/ka [2].

The Espichel cape (Fig.1 A, B) rises higher than the Raso cape, with the culminant wave-cut platform (base of UBS13) at 118 m and more. It has a marine terrace staircase composed by eleven terraces. In the western side of the cape, the marine terraces were identified as: Tm1 at 108 m a.s.l., 83m (Tm2), 74 m (Tm3), 68 m (Tm4), 53m (Tm5) and 45m (Tm6). The Tm7 at 33.6 m a.s.l., 25 m (Tm8), 18m (Tm9), 12m (Tm10) and the Tm11, at 8 m a.s.l. The Tm5 and the Tm7 were dated by ESR, (>343±10 ka and 417±40 ka (Al centre)), respectively. It was estimated an uplift rate of ca. 0.08 m/ka.

The ESR ages obtained in the study area were very important to propose a correlation between the marine and fluvial staircases and with MISs (Fig. 1C).

The higher number of marine terrace at Espichel cape in relation with Raso cape can be explained by the higher uplift rate.

The fluvial terraces, with larger thickness, could record longer intervals (probably related with more than one interglacial period). The sedimentation phase in the downstream river may be much longer in time than in a coastal stretch, controlled by the sediment supply and transport, the climatic oscillations, the source area uplift and the substrate present, while, the main driven mechanism that determines the accommodation space are the tectonics, glacial isostasy and the eustatic (base-level) changes.

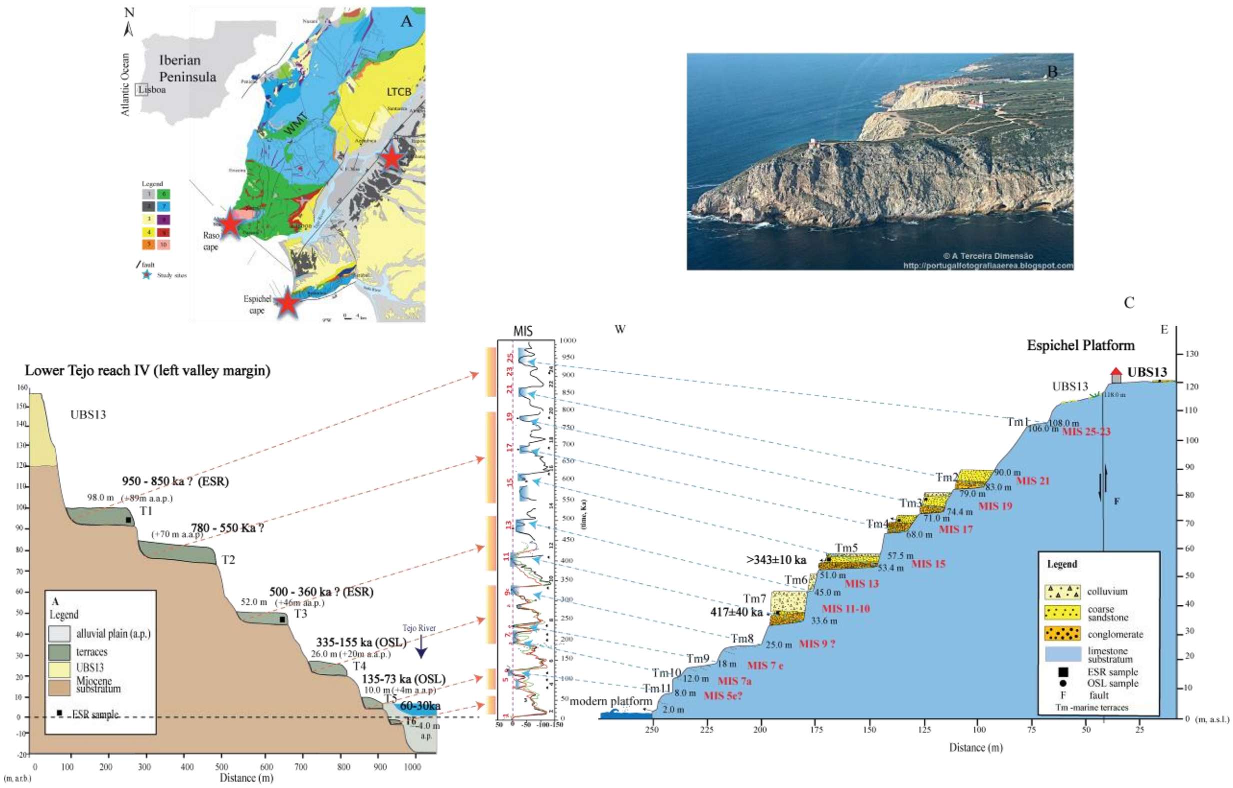

Figure 1. A- Geographical setting and geological map of the study area (adapted from Geological map of Portugal, 1/500 000, LNEG); B- Espichel Cape (photo from A Terceira Dimensão); D- Schematic terrace staircases of the Lower Tejo (reach IV) and Espichel Cape, with ESR and OSL ages; sea level estimates by[5]. Legend: WMT - Western Mesozoic Terrains; LTCB – Lower Tejo Cenozoic Basin. 1 - Holocene, 2 - Pleistocene, 3 - Pliocene, 4 - Miocene, 5 - Palaeogene; 6 - Cretaceous, 7 - Jurassic, 8 - Triassic, 9 - volcanic rocks, 10 - granite. The orange rectangles are the proposed aggradation intervals for the fluvial terraces.

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ENLIGHTENMENT OF LANDSCAPE DYNAMICS USING SG-PIRIR LUMINESCENCE SIGNAL OF FLUVIAL SEDIMENTS (RANGITIKEI RIVER, NZ)

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Feldspar single-grain post-infrared luminescence (SG-pIRIR) signals are increasingly used to date Quaternary deposits. It provides high-resolution equivalent dose (De) distributions, allowing age estimation through appropriate age models. For heterogeneously bleached fluvial deposits, we use the bootstrapped minimum age model [1]. Recent studies have shown that SG-pIRIR can also be used to reconstitute sediment pathways [2-4].

Our aim here was to use information from SG-pIRIR as a geomorphic tool to reconstitute the landscape evolution and better understand the origin of the grains that constitute the river sediment load. Investigations were carried out on the Rangitikei River (RR), New Zealand [4]. We found that RR last aggrading phase (17.4 ±1.9 ka to 11.6 ±1.5 ka) was followed by an incision in several steps. A dataset of 28 SG-pIRIR dates on terrace remnants along the river, indicates that rapid incision related to knickpoint retreat was followed by a phase of slower incision associated with widening of the RR canyon.

We also used the SG-pIRIR De distributions to investigate changes in sediment pathways over time. Towards this, we focused on the proxies provided by the fraction of saturated and well-bleached grains. We show that saturated grains were mostly sourced from bedrock and that their dominance in a sample is associated to high lateral input from valley flanks through landslides and related mass wasting processes during rapid incision and valley widening. In contrast, deposits formed during aggradational and slow incision phases contain a greater fraction of well-bleached grains. The De distributions also provide evidence that that a tributary, the Kawhatau River (KR), provides high sediment fluxes to the modern RR, a phenomenon that likely plays a major role in the widening dynamics on the downstream of the RR. Our results demonstrate that SG-pIRIR is well-suited to date fluvial terraces, reconstruct incision rates and reconstruct sediment sources. This makes is a versatile tool to study past and present river processes.

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PHASES OF ALLUVIATION AND COLLUVIATION
IN THE EZOUSAS RIVER VALLEY (SW CYPRUS)

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Cyprus is located in the eastern part of the Mediterranean Sea This area is characterized by high neotectonic activity with the uplift rate of Paphos region about 0.35-0.39 mm/year during the Upper Pleistocene [10]. The study area covers the Ezousas river basin. The spring of the river is located in the Troodos Mountains and the estuary in the Mediterranean Sea, some kilometers eastward from the Paphos city. The river cross two main geological units ranging from igneous rocks in its upper section (Troodos Terrane) to sedimentary rocks in its middle and lower sections (Circum Troodos Sedimentary Succession) [3].

The aim of study was to investigate the age and sediments of terraces and floodplains in Ezousas river valley [1, 4-8]. The geologic and geomorphologic mapping of various terrace and flood plain levels were carried out along the Ezousas river valley from the sea to the spring. Dating of alluvium by TL method was conducted in the Scientific-Didactic Laboratory of the Institute of Geography and Environmental Sciences of Jan Kochanowski University in Kielce.

Depending on the section, different terrace and floodplain levels can be distinguished. Erosion-accumulative terrace about 30.0 m above river level (a.r.l.) and floodplain 0.3 m a.r.l. occur in the upper section. It had been dated to 53.3±8 ka and to 19.7±2.9 ka, respectively. Characteristic feature of alluvium in this section is large part (up to 24%) of none-rounded grains (colluviums) transported from the rockwalls and steep slopes of the valley. In the middle section accumulative levels occurred [7]. The highest level of 2.6 m a.r.l was described as Holocene alluvia (Sequence EZG). The grading lower unit of this series with a sherd dated to 1300 AD was accumulated in 4 phases with variable velocity of the stream. The poorly sorted structure of the upper unit above was a result of a single flood event. After the flooding, the river deposited overbank sediments in the top of outcrop [2]. Colluvium 1.0 m a.r.l. has been dated to 63.2±9.5 ka. Alluvial plain 0.5 m a.r.l. has been dated to 13.6±2.0 ka. Subsequent four sites were situated on the same high 0.2 m a.r.l. and alluvium were dated to 63.1±9.5 ka, 42.6±6.4 ka, 37.0±5.6 ka and to 2.35±0.35 ka. Two dates occur from the lowest level about 0.1 m a.r.l. The remnant of older series exposed in the valley floor was dated to 406.0±61.0 ka [7]. The sample was under the boulder which fell down from the nearest rockwall probably during the earthquake was dating to 28.6±4.3 ka [6-8]. Alluvium in this section are finer almost without colluvium part [7]. In the lower section of the Ezousas river valley, the highest erosion–accumulative terrace on limestone monocline is 30.0 m a.r.l. Two alluvial series in superposition occurred here. The upper one, about 5 m thick, is dating to 18.9±2.8 ka very similar to landslide block at 25.0 m a.r.l. of this alluvium - 22.4±3.4 ka. The lower series at 26.5 m a.r.l. was dating to 57.4±8.6 ka. Next were located on accumulative levels. Terrace 11.0 m a.r.l. was dated to 57.9±8.7 ka and level about 2.5 m a.r.l. to 64.8±9.7 ka. Flood plain levels about 1.2 m a.r.l. and 0.2 m a.r.l. were dated to 22.3±3.3 ka and to 16.1±2.4 ka respectively. The thickness of the Pleistocene alluvium cut and fills is bigger than in the middle and upper reaches [7]. The. Holocene sediments (Sequence EZA) are also described in this section. Alluvium from the Roman period (1.5 m a.r.l.) were covered by Roman and Medieval colluvium 2.5 m thick [2].

In the Ezousas river valley there were very strong alluviation in the Pleistocene and small one in the Holocene [7]. Two main alluviation phases can be distinguish: 75-48 ka and

25-13 ka (Fig. 1). There is no geological data about increased neotectonic movements in these phases [10]. Therefore, an increased alluviation in Cyprus have been probably associated with climate change. Similar fact is also confirmed in the valleys of SE Poland [13]. In both phases the correctness of the increase in the number of dates along the course of the river occurred. This is caused by a clear intensification of the erosion process in the mountain section of the river, where few alluvial covers have been preserved and a distinct alluviation (accumulation) in the middle and lower sections.

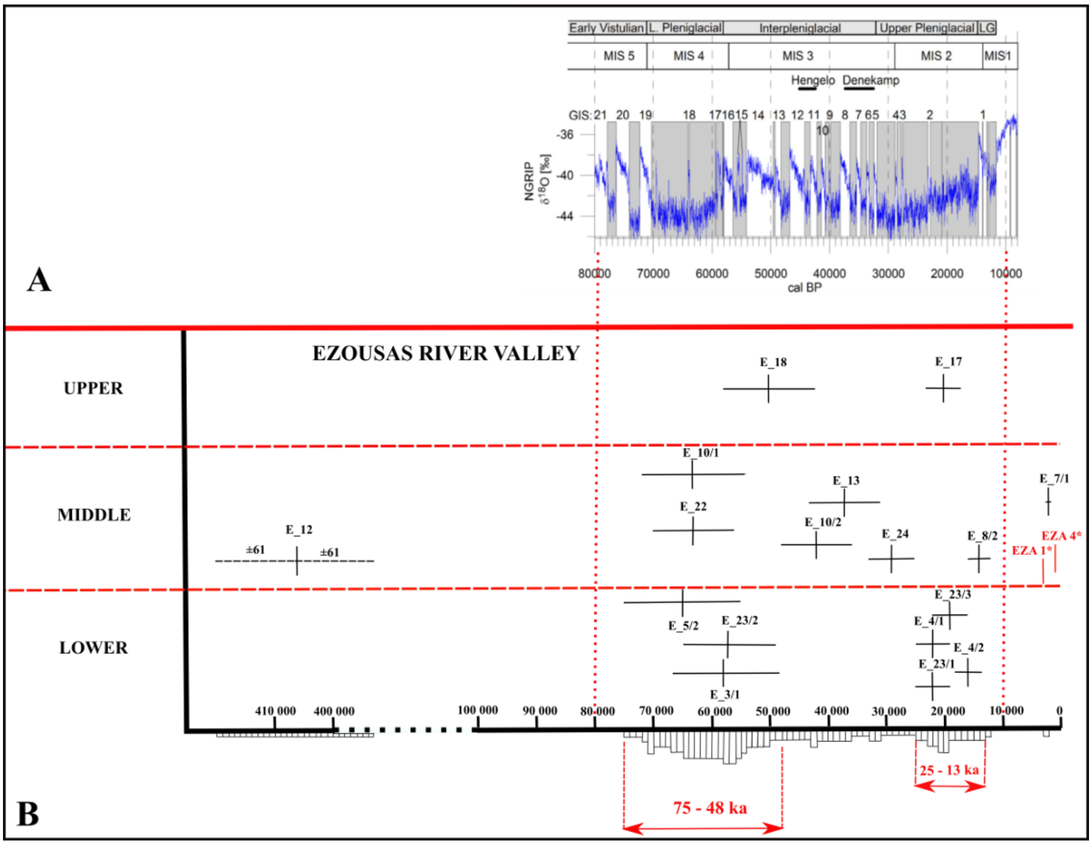

Figure 1. A: Greenland ice core records [9], **B:** TL records from Ezousas river valley

The results of mineralogical and petrographic analysis show compliance with the geological map units. Petrographic analysis of geological outcrops and gravels from alluvia made it possible to determine the place of alimentation of clusters in the riverbed [6, 7]. The maximum confirmed transport length in the Holocene was about 7 km. This confirms the small role of fluvial transport in the Holocene, which is consistent with data obtained from TL/OSL dating, hydrological data and measurements of present-day fluvial processes [4, 7].
Relief and the varied tectonic movements had a great impact on the Ezousas valley formation and alluvial features. The number of colluvium in alluvium decreases with the length of the river. The high rate of Cyprus uplift caused that in the upper, mountain section the rate of river incision in the period of 60-20 ka was about 30 m. However, in the wider, middle section located in front of the Troodos Mts. within the sedimentary margin of these mountains, the cut and fill of different age (400-2 ka) are located at almost one morphological level. Only the Medieval cut and fill is about 2 m higher, but the aggradation of this period probably did not cover the entire bottom of the valley, only a fragment of the alluvial braided plain. In the lower section, the river crosses the tectonic horst, which was uplifted about 30 m during the last 20 ka. Two alluvial series (57 ka and 22-19 ka) rest on it (Ezousas 23 site) in superposition. Uplift the lowest section of the valley crossing maritime terraces can be estimated at about 11 m during 60 ka. An accumulation of the great landslide in the dry

riverbed near Episkopi was probably triggered by earthquake, very frequent in Cyprus. It took place about 28.6 ka (Ezousas 24 site) [6-8].

Two phases of an increase of mass movement activity occurred [7]. First one, in the middle section was connected to the Interpleniglacial climate when the colluvium member was dated to 63.2 ka and was accumulated on alluvium. It is same period as older, alluviation phase. Second colluviation phase, only in the lower section was triggered by human impact and it was dated to the Roman period and Medieval time.

ACKNOWLEDGMENTS

The study is a part of Agora Paphos Project financed by The National Science Centre: grant NCN MAESTRO 2014/14/A/HS3/00283 "Agora oraz infrastruktura i aktywność gospodarcza Pafos, stolicy hellenistycznego i rzymskiego Cypru na podstawie badań interdyscyplinarnych"

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MACROMEANDERS IN CENTRAL EUROPE: A CASE STUDY FROM THE HOLY CROSS MOUNTAINS REGION (POLAND)

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One of the important issues in palaeogeographic research is the time of the macromeanders functioning. They were studied in Europe, i.a. in lowlands, uplands and structural basins near mountains [2-5, 7-9, 11-16, 18, 19]. Their formation was connected with environmental changes during the Late Vistulian [12]. The beginning of the macromeanders phase in individual valleys was not synchronous (Epe, Bølling, Allerød) due to local factors [5, 10, 17]. Most of these channels in Central Europe was cut off not earlier than in the Bølling and not later than in the Preboreal (between 13 and 9.3 ka BP). Organic sediments in bottoms of their fills were mostly dated at the younger part of Late Vistulian (Allerød-Younger Dryas) and the beginning of the Holocene [5, 12, 13].

So far, only the Czarna Nida macromeanders generation has been recognized in the Holy Cross Mountains region (Fig. 1). The bottom of the fill of one of them was palynological dated at the Allerød-Younger Dryas transition, and organic sediments above sandy overbank deposits of this fill were radiocarbon dated at 9670±45 BP [9]. These dating results are compatible with the timeframe of functioning and filling of macromeanders in Central Europe [5]. New data from Czarna Konecka river valley (Fig. 1-2) indicate an earlier development of large meanders in the north-west margin of the Holy Cross Mountains.

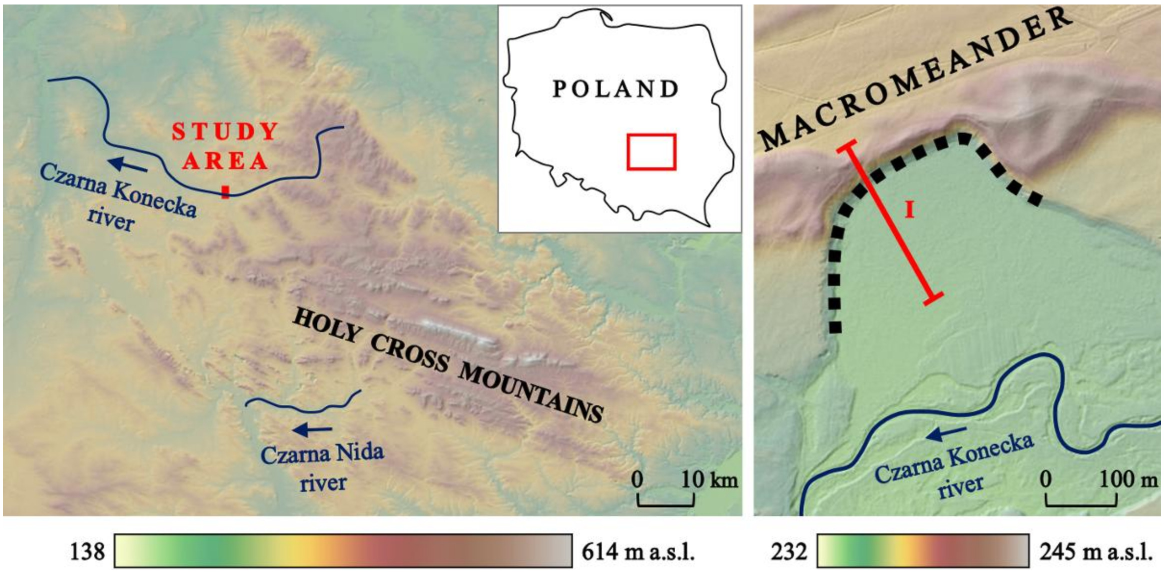

Fig. 1. Location of the study area and the cross-section line (I) (geoportal.gov.pl)

The macromeander undercutting Czarna Konecka terrace and dune (Fig. 1-2) was cut-off before the Late Vistulian. Fine-clastic overbank deposits, peaty silts, and after 14 100±120 BP (cal. 15 496-14 836 BC, MKL-5189) biogenic sediments were accumulated in the created oxbow-lake. Peats filled the entire palaeochannel, and later covered the sandy point bar. This led to create a peat bog plain. Silty peats at the top part of the 44A profile (next to the peat bog edge, see Fig. 2) could be connected with phase of increased fluvial activity, during which the entire valley floor was flooded many times, and flood waves transported the overbank deposits to the bottom of the deepest part of the oxbow-lake (from 1930±50 BP, cal. 39 BC-222 AD, MKL-5188).

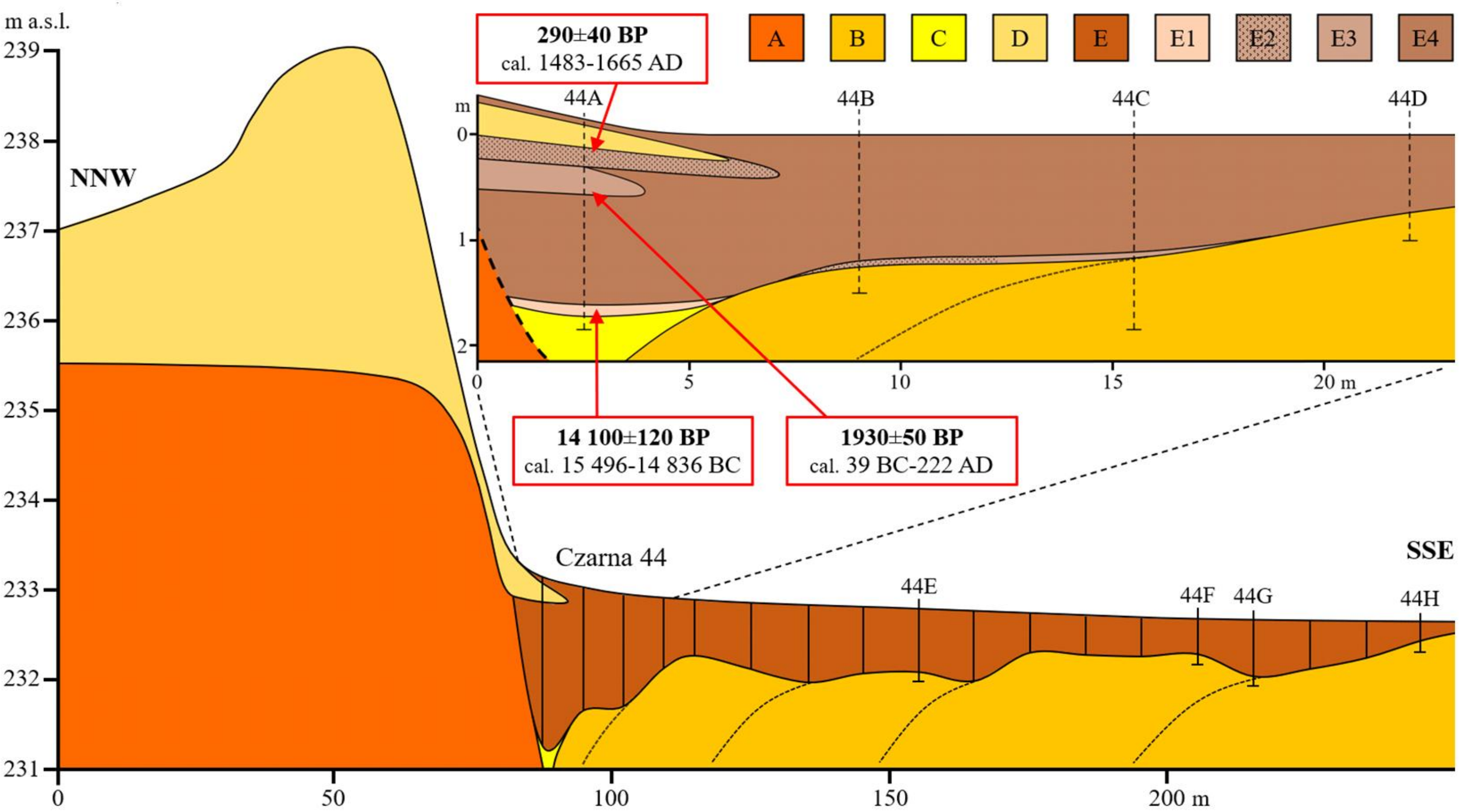

Fig. 2. Section across the macromeander in the Czarna Konecka river valley at Sielpia Mała (Czarna 44 site)
A – sandy alluvia of the terrace, B – sandy alluvia of the floodplain, C – fine-clastic sediments of the palaeomeander fill,
D – aeolian/colluvial sands, E – organic sediments (different types) of palaeomeander fill and peat bog on the floodplain
(E1 – peaty silts, E2 – sandy and silty peats, E3 – silty peats, E4 – peats/detritus)

The phase in this period is known from Central European valleys [5], also from the Czarna Konecka river valley, where the sedimentation type change (organic → clastic sediments) in the palaeochannel was analogically dated at 1930±60 BP [6]. Later deposition of mineral material and accumulation of colluvial sands on peats (after 290±40 BP, cal. 1483-1665 AD, MKL-5187) reflect the activation of aeolian processes on the dune and wash out on its steeper slope during the Little Ice Age. These were the effects of anthropogenic deforestation in order to obtain wood for metallurgical activities in the Old-Polish Industrial District (OPID). Collapse of the OPID contributed to growth of the forest on the dune and a decrease in the intensity of aeolian and slope processes. These environmental changes initiated the present-day accumulation of organic sediments in the edge part of the peat bog (Fig. 2).

The very early development of Czarna Konecka macromeanders can be connected with the warming after the Poznań phase of the Vistulian (epe), which Dzieduszyńska and Forysiak [1] date for Central Poland at about 18-17 cal. BP (the Kamion phase). This untimely change in the river pattern (from braided to meandering) could also be a consequence of the influence of local conditions.

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GEOLOGICAL STRUCTURE OF ŚWIŚLINA RIVER VALLEY NEAR DOŁY BISKUPIE (HOLY CROSS MOUNTAINS REGION, POLAND)

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The site is located in the Świślina River valley at Doły Biskupie, downstream from the "Wióry" water reservoir. It is the north-eastern part of the Mesozoic margin of the Holy Cross Mountains, where the Triassic sandstones and shell limestones, marls and clay mudstones are covered with a thick layer of the Pleistocene loess. The relief is dominated by a flat plain (Palaeogene peneplain) that cuts down the age-different structural elements - the Palaeozoic, steep Godów fold, and the highly disturbed Triassic and Jurassic rocks. It is deeply cut by river valleys with terraced bottom, i.e. Świślina river. In its basin, loess areas developed a dense network of gullies and hollow way (Fig. 1).

The Świślina River basin is located in an area where the Prehistoric metallurgy developed (bloomerys), and later, in the Middle Ages and modern times, in the Old Polish Industrial District area. Metallurgy activity was concentrated along many rivers in the Holy Cross Mountains region, including Świślina river, which is confirmed by historical data.

In the studied section, the valley has steep slopes. A two steps are marked in the valley bottom as narrow 4.5-5.5 m high flood plain and a wider terrace raised 9-11 m above the river level (a.r.l) (Fig. 1). Both levels are build of fine-fraction sediments (anthropogenic muds), grain size similar to loess, in which numerous traces of metallurgical activity in the form of slags with a diameter of up to 25 cm were found. These traces indicate very young age and anthropogenic genesis of these sediments accumulation, related to the metallurgy development [5].

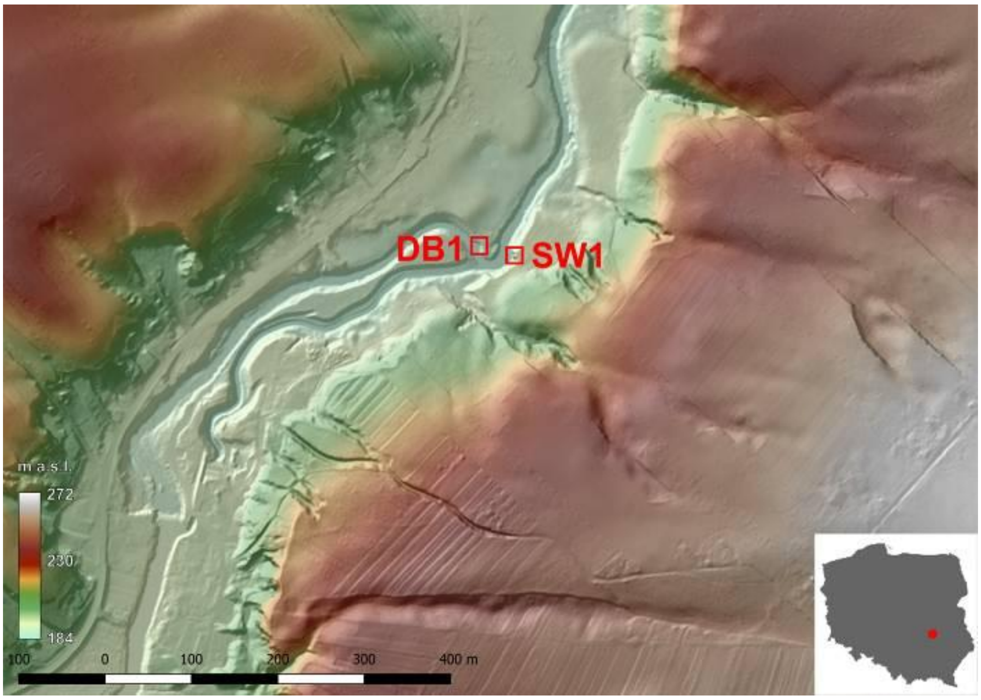

Fig. 1: The location of the study area (DB1 and SW1 profiles) in the DEM map (by K. Żurek) [2]

In 2014 and 2020, a sediment study was undertaken on the site in the left-bank of the flood plain and using specialist mountaineering equipment, in the five-meter exposure of loess on the right slope of the valley undercut by the river (Fig. 2). In addition to the standard grain size analysis by sieve and laser diffraction, the coarsest material was measured using the planimetric method. The geochemical analyzes of the flood plain alluvia were performed on the content of heavy metals such as Fe, as well as the Magnetic Spherule Separation from overbank sediments.

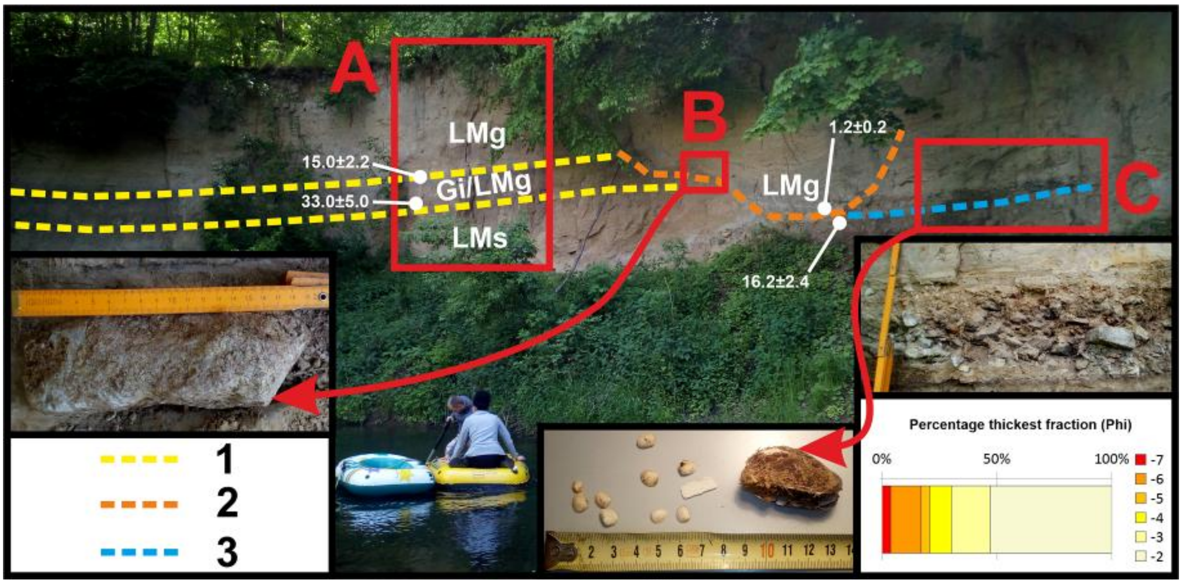

Fig. 2: The SW1 profile (photo P. Przepióra 2020) in right-bank of the river with OSL dates (in ka)
1 - buried soil complex (A) 2 - buried gully filled with loess and limestone boulder in the bottom (B); 3 - lens of non-rounded limestone fragments and malacofauna (C)

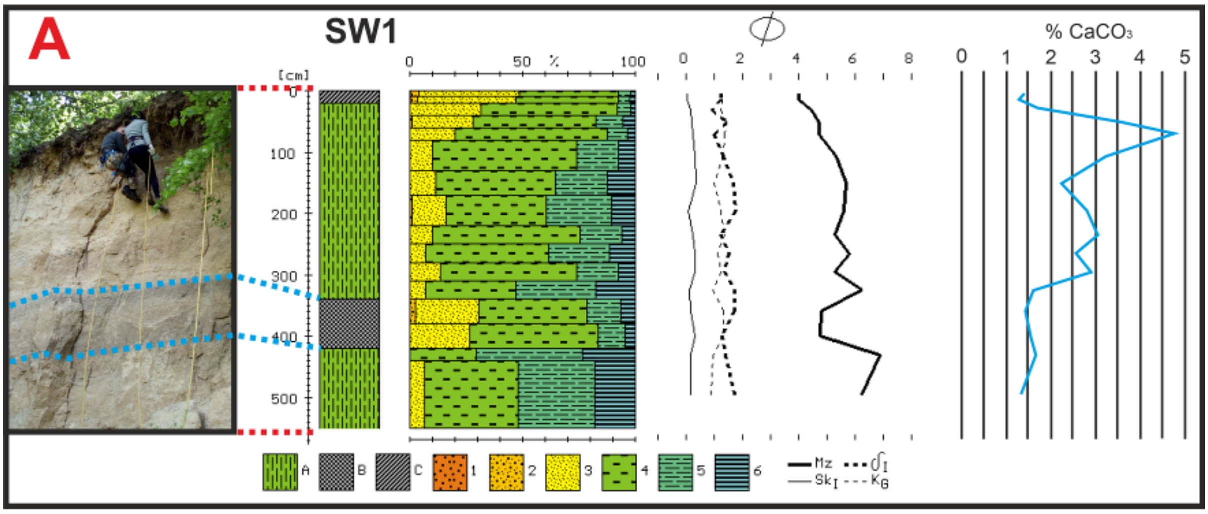

Fig. 3: The SW1 profile (photo P. Przepióra 2020) with the grain size and $CaCO_3$ concentration
Lithology: A – loess, B –buried soil complex, C – A-horizon of present-day soil; Fractions: 1 – gravel (below -1φ); 2 – coarse sand (-1–1φ), 3 – medium sand (1–2φ), 4 – fine sand (2–4φ), 5 – coarse and medium silt (4–6φ), 6 – fine silt (6–8φ), 7 – clay (above 8φ); Folk-Ward's grain size distribution parameters: Mz – mean size, δ_I – standard deviation, Sk_I – skewness, K_G – kurtosis

The loess outcrop is several meters wide. To the left is a complex of two buried soils (GI/LMg)(33.0±5.0 ka; UJK-OSL-132) with a low organic content separating the two loess series (LMs and LMg). The older one, directly below the buried soil, is finer and decarbonated, which may be related to the development of soil formation processes. The upper series (15.0±2.2 ka; UJK-OSL-131) is more sandy, slightly carbonate, and the carbonate content varies significantly from 0 to 5%. The graining and fluctuations in carbonate content may indicate that this is a sediment series redeposited from the plateau (Fig. 3).

On the right side of the outcrop, a buried gully filled with a series of upper loess (16.2±2.4 ka; UJK-OSL-130) is visible. At the bottom of its filling, there is a sharp-edged 20 cm diameter limestone boulder. In the most extreme, right-site part of the outcrop, at a height of approx. 2 m a.r.l. the lens of non-rounded limestone fragments with a maximum diameter of 10 cm is preserved (1.2±0.2 ka; UJK-OSL-129). This layer is about 25 cm thick, and in its highest part, there are undamaged shells of *Unio* and other species of malacofauna (Fig. 2). The coarse sediments are remnants of catastrophic flows (flash flood) with short redeposition of the material lead to accumulation of i.a. malacofauna shells between the rocks. This layer may be related to the Medieval catastrophic event in the past triggered by basin deforestation during the time of metallurgical activity. It could be connected also with catastrophic flash floods after dam failures are also known from other Holy Cross Mountains river valleys and accumulated very coarse cut and fill alluvial bodies [3], [4] and similar to modern flood that occurred after the „Wióry" water reservoir dam failure in 2001 [1].

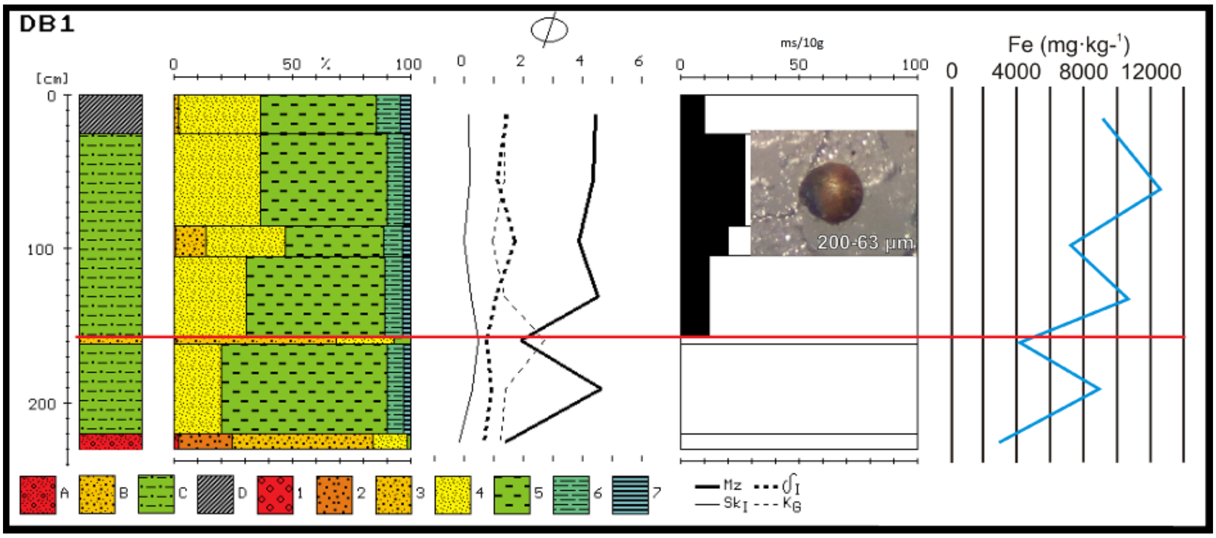

Fig. 4: The DB1 profile with the microslags (iron spherules) concentration (ms/10g - magnetic spherule per 10 g of material). The red box marks the flood layer location
Lithology: A – sands with single gravel, B – medium sands, C – sandy silts, D – soil; Fractions: 1 – gravel (below -1φ); 2 – coarse sand (-1–1φ), 3 – medium sand (1–2φ), 4 – fine sand (2–4φ), 5 – coarse and medium silt (4–6φ), 6 – fine silt (6–8φ), 7 – clay (above 8φ); Folk-Ward's grain size distribution parameters: Mz – mean size, δ_I – standard deviation, Sk_I – skewness, K_G – kurtosis

In the DB1 profile of the floodplain, on the lag deposits (poorly rounded gravels) there are overbank sediments, silts with an admixture of sands where the numerous microscopic iron balls (spherules) was found (Fig. 4). They occur only in the upper and middle part of the profile, above the distinct sandy flood layer. This confirming that the sediments above were redeposited from the upper part of the catchment where only the Prehistoric and Medieval metallurgical activity was confirmed i.a. large slags in the sediments in the site area [5]. The geochemical analysis of the sediments in this profile showed an increase in the content of elements towards the surface, with the maximum concentration at 25-105 cm depth. This tendency, in particular in the case of iron (Fig. 4) clearly correlates with the presence of microslags, the markers of the Prehistoric and historical industry influence in this area. Increased geochemical accumulation can also be connected with a large share of the fine-grained fraction, influencing the sorption properties of the sediments, and with the reaction determining the migration of individual elements in the profile. Moreover, an inverse relationship was found between the content of the studied metals and the concentration of carbonates. The geochemical changes and microslags are an excellent marker of metallurgical activity and are helpful in the interpretation of the processes, genesis and age of alluvia at the studied site.

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MACRO- AND MICROSCOPIC SLAGS AS A MARKER OF THE METALLURGICAL ACTIVITY IN THE HOLY CROSS MOUNTAINS, POLAND

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All over Europe, there are areas that have been used for hundreds of years for the metallurgical activity. These industrial areas depended on the abundance of local natural resources such as iron ore and forests, which are the basis of the charcoal production. The most common metallurgical plants were, i.a. medieval and modern forges, often driven by a water wheel on small streams. Technological developments lead to shutdown the outdated metallurgical plants. In their place, water mills were built. Sometimes the area was simply abandoned and the progressive renaturalization processes blurred all traces of the old industrial activity.

The method used so far in Western Europe, consisting in the separation of microscopic remnants of the metallurgical activity lying in the alluvia, allows for the verification of the location of former metallurgical plants. Appropriate use of the results allows to estimate the rate of sediment accumulation in the floodplain, as well as the level of anthropogenic changes in the river section. Used since the 1970s [11] i.a. in Wallonia [3, 4]. shows the great potential of this relatively simple method, where the main research tool is a magnet. Currently, the method of Magnetic Spherule Separation (MSS), which has proved successful in the Ardenas area, is now being used in the Old Polish Industrial District (Central Europe) [5, 9] (Fig. 1).

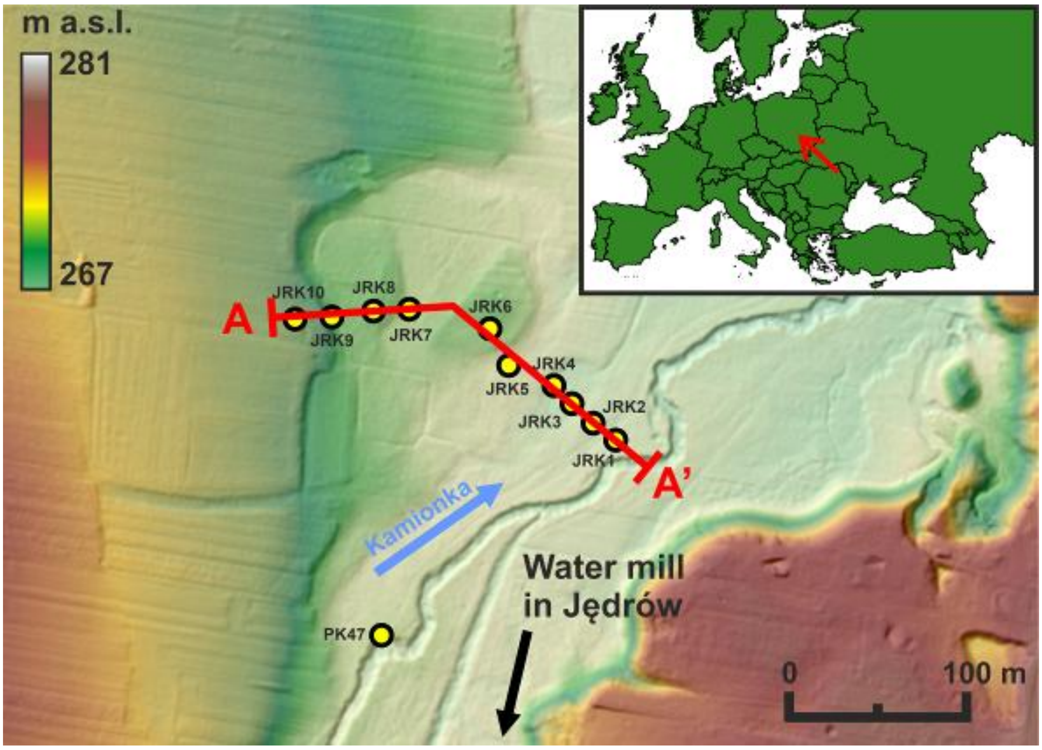

Fig. 1. DEM [2] of the study site at the Jędrów water mill in the Kamionka River with boreholes and cross-section and cross-section

The ferromagnetic properties of the slag had previously been used to separate larger fragments from sediments. The smaller, microscopic elements from the furnaces and forges activity not searched before, esecpecialy in areas where the macroscopic traces were not found or they not formed a clear sedimentation level. The Old Polish Industrial District is an interesting research area, as metallurgical activity developed here from Prehistoric times to the first half of the 20th c. [7, 10], intensely transform many catchment areas [6].

The aim of this study is to present a preliminary interpretation of the first results from several selected sites in the Old Polish Industrial District, i.a on Czarna Konecka, Kamienna, Kamionka and Świślina River.

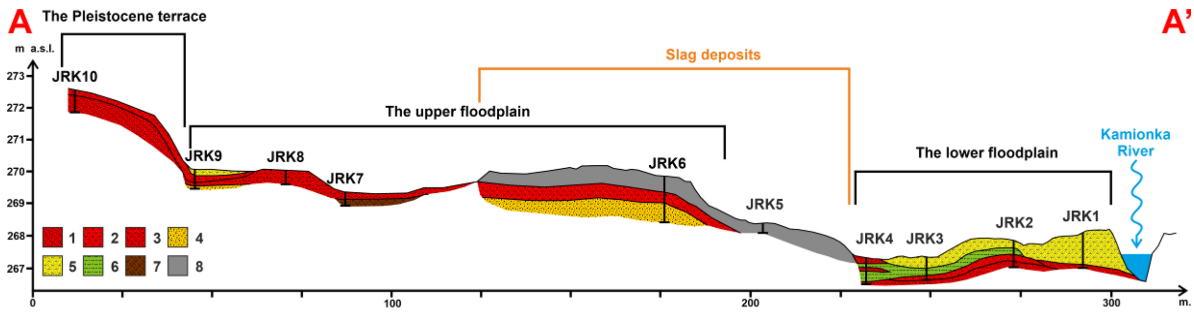

Fig. 2. Lithological section across A-A' the Jędrów site. Lithology: 1 – sand with gravels, 2 – sand with single gravels, 3 – silty sand with gravels, 4 – medium sand, 5 – silty sand, 6 – sandy silt, 7 – clayey peat, 8 – embankment

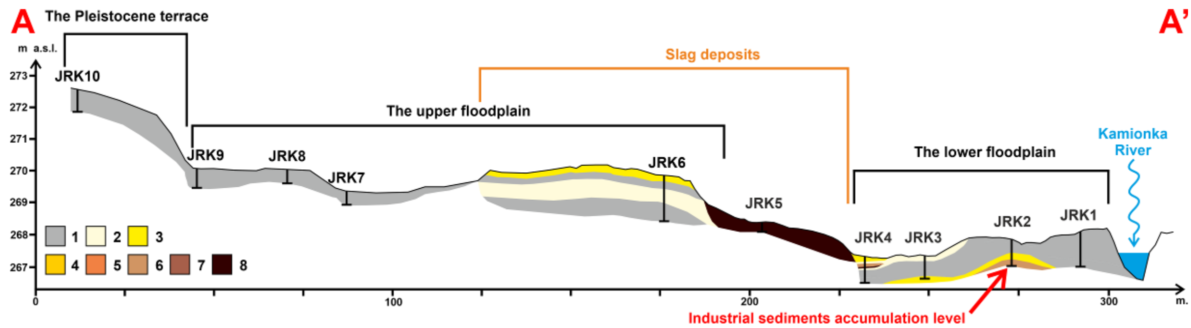

Fig. 3. Slag concentration (%) section across A-A' the Jędrów site: 1 – no slags, 2 – 1-5, 3 – 6-10, 4 – 11-15, 5 – 16-20, 6 – 21-25, 7 – 26-30, 8 – >30

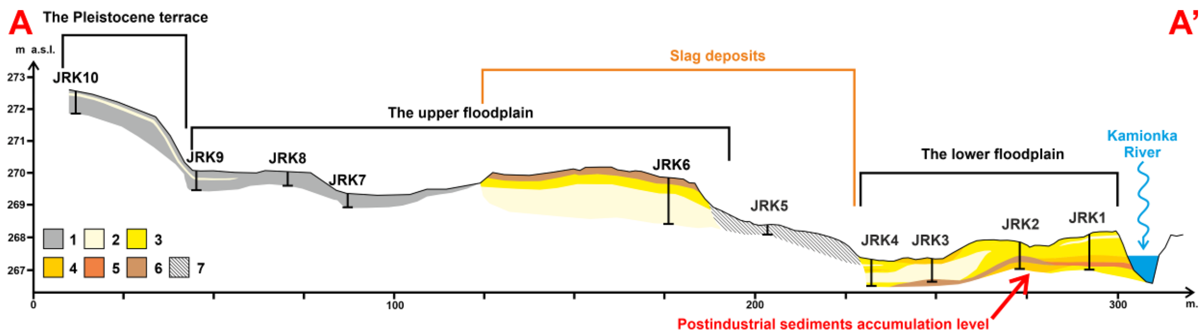

Fig. 4. Microslag (magnetic spherules) section across A-A'in the Jędrów site. Magnetic spherules per 1 gram of material (ms/1g): 1 – 0, 2 – 1-5, 3 – 6-10, 4 – 11-15, 5 – 16-20, 6 – >20, 7 – macroscopic slag deposits (no spherules)

The MSS method enables the detection of particles with a size of 200-63 μm, or even smaller sizes, depending on the apparatre. Distinguishing from the background of natural quartz grains or rocks, perfectly spherical objects were created during the smelting and forging of iron [1]. Small particles were transported by the wind and accumulated up to 10 km from their source. Also, fluvial processes within the flood plain led to a further redeposition of these elements, often creating clear clusters of iron balls within a specific post-industrial layer, e.g. on the Kamionka floodplain near the water mill in Jędrów (Fig. 1, 2, 3, 4). This site is an excellent example of the deposition of numerous slag fragments in the sandy alluvia of a small river floodplain (Fig. 2). The slags forming a clear layer, most likely created during the nearby forge activity (Fig. 3). Where no traces of slag have been detected, there is a high concentration of microscopic iron spherules, which are a secondary remnant of the forge activity. On the example of the Kamionka River site, they form a clear post-industrial layer, analogous to those detected in Wallonia [4] or other rivers in the Holy Cross Mts. region, e.g. Czarna Konecka or Świślina. These layers are probably formed during the modern forge's activity, or shortly after its shutdown (fluvial redeposition) (Fig. 4). Post-industrial layers are sometimes well readable in sediments and they also contain numerous charcoals, the age of which confirms the period of metallurgical activity of the study site (Fig. 5).

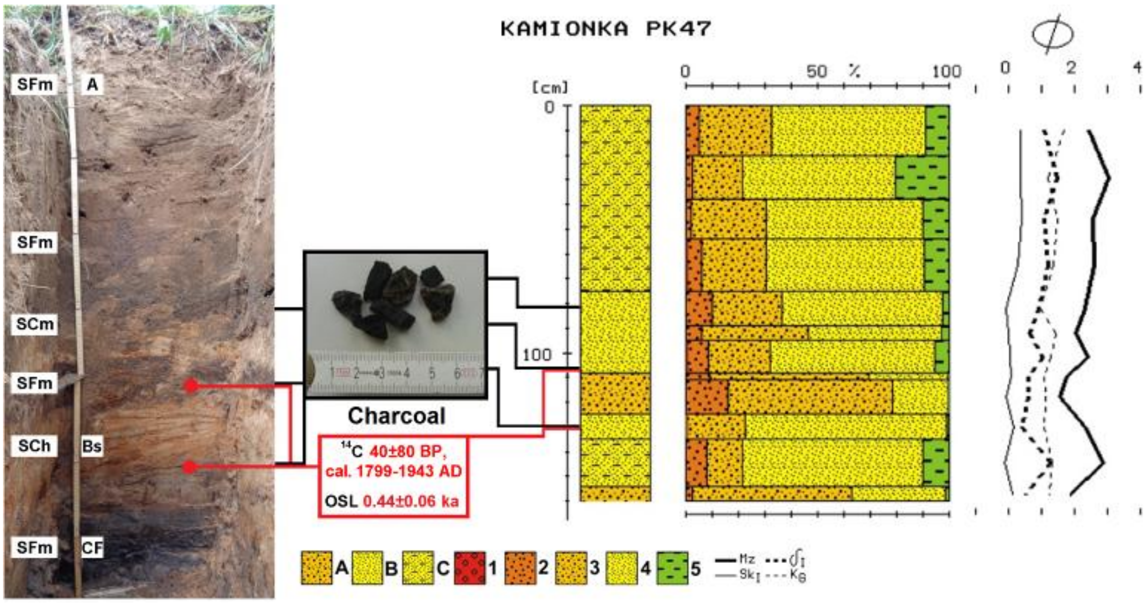

Fig. 5. PK47 profile in Kamionka River site with two visable postindustrial layers with charcoal inserts. Lithology: A – medium sands, B – fine sands, C – silty sands; Grainsize: 1 – gravel, 2 – coarse sand, 3 – medium sand, 4 – fine sand, 5 – silt and clay; Folk-Ward's distribution parameters: Mz – mean size, δ_I – standard deviation, Sk_I – skewness, K_G – kurtosis; Lithofacial codes: SFm – silt/clay sands, massive structure, SCm – fine-coarse sands with charcoals, massive structure, SCh – fine-coarse sands, charcoals, horizontal lamina1tion; Lithogenetic codes: CF – channel fill; Soil horizons: A – humus horizon, Bs – iluvial-irony horizon [8]

The MSS method in the case of the Old Polish Industrial District is perfect for determining the rate of floodplain sediment accumulation and the state of the anthropogenic sedimentation environmental changes. Also, an appropriate combination of the results enables the dating of these sediments and the verification of historical and cartographic materials on the metallurgical activity in the studied areas.

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LUMINESCENCE DATING OF SUKHAYA MECHETKA MIDDLE PALEOLITHIC SITE (PRELIMINARY RESULTS)

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The Middle Paleolithic site Sukhaya Mechëtka is located on the right bank of the Lower Volga river in the Volgograd city. The exposed sediments show a sequence of mainly silt-rich fluvial deposits and intercalated, partly organic-rich palaeosols, reflecting various cycles of fluvial deposition and interruptions in fluvial aggradation. Not only being an important palaeoenvironmental archive, the site has attracted the attention of Paleolithic researchers since its discovery in 1951 by geologists A.I. Koptev and M.N. Grishchenko [1, 3, 5, 7-9, 12]. The data of the site – both assemblages and chronostratigraphic information – can be considered as reference for open air paleolithic sites of Central and Eastern Europe. The site acquired this significance largely as a result of the presence of only one perfectly preserved cultural layer, which lies in clear stratigraphic conditions [12]. The cultural layer is overlain by more than 23 m of mainly silt-rich fluvial deposits and is therefore well preserved and remained almost unaffected by post-depositional cryoturbation/ reworking processes within the last glacial cycle [7, 9, 12]. Flint and quartzite tools assemblages and field documentation archives created by M.Z. Panichkina and S.N. Zamyatnin, allow a reconstruction of the life of the settlement of Middle Paleolithic hunters for a limited time interval, which is confirmed by preliminary results of planigraphic and technological analysis using refitting: Sukhaya Mechëtka is interpreted to be a practically unchanged cast of the life of an individual Neanderthal community [3]. There are some descriptions of the assemblages according to traditional schemes [1, 3, 9, 12] which indicate that the typological features of Sukhaya Mechetka assemblages deal with Micoquian (or Keilmessergruppen) morphological and technological patterns. However, the chronological framework of site still remains unclear and is until now based on partly controversy radiocarbon ages and stratigraphical information [7, 9]. To get more precise insights into the chronology of Sukhaya Mechëtka, we now used pIR225 luminescence dating on polymineral fine-grains. The preliminary results point to a deposition of the sediments bracketing the cultural layer at the transition from MIS 4 to MIS 3 and/ or during early MIS 3. As the cultural layer is also connected to a paleosol, the luminescence age estimates provide first insights into the period of site occupation as well as the timing of climatic shifts and potentially sea level fluctuations of the nearby Caspian Sea [2, 4, 6, 9-12].

Future work will concentrate on collecting highly resolved sedimentological and also additional chronological data from the section to better understand the site formation and to connect the interplay between climatic shifts, the response of the sedimentological system and presence and absence of Neanderthals.

Acknowledgements

Many thanks go to Dr. Marcel Weiβ for his helpful management. This work was carried out within the framework of the Program of Fundamental Scientific Research of the State Academies of Sciences, State Assignment № 0184-2019-0001(Middle Paleolithic of Russian Plain: environment, chronology, culture features); geoarchaeological investigations were supported by Russian Science Foundation (Project No. 21-18-00552).

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ALLUVIAL FAN ARCHIVES – UNLOCKING DEEPER TIME PERSPECTIVES IN FLUVIAL LANDSCAPES

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Alluvial fans are but one landform element that comprises part of an alluvial fan landform system within fluvial landscapes. Unlocking the information contained within these underused fluvial archives will substantially benefit our understanding of fluvial landscape development. The net-depositional, distributive fluvial landform element of the fan system (the actual fan) is the element most likely to be preserved over Quaternary time-scales and beyond (i.e. deeper time, Fig. 1) and is the dominant landscape portion (>80%) of modern depositional basins observable on the Earth surface [1].

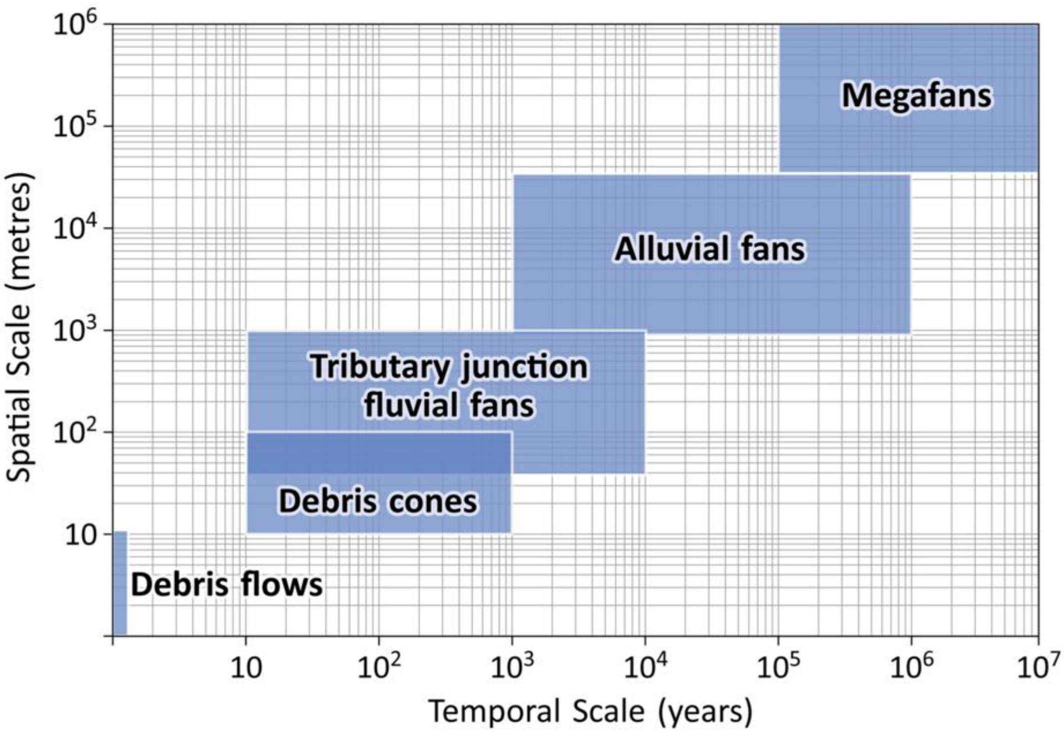

Fig. 1 Distributive fluvial system landform elements – typical spatial and temporal scales covered [2]

In contrast the net-erosional, contributive fluvial landform element of the system (the catchment area that supplies the water and sediment to the fan) dominates the adjacent upland mountain landscape areas, but has minimal preservation potential over these longer time-scales. As a result geomorphological studies focusing on landscape development have mainly concentrated on what we can learn from the morphology of both catchment and fan elements [3], whilst geological studies have focused largely on the sedimentology and stratigraphic architecture of the fan [1,2]. To add complication to these often disparate views on 'fan systems' the fan and the catchment may be additionally linked by a third landscape element –

a transportation dominated zone (an incised river system) where alluvial fan systems bridge growing tectonic structures [4] and 'telescope' out, for example along a mountain front where the orogen is actively growing and thus widening (Fig. 2).

Alluvial fan systems in their entirety are therefore composed of both contributive and distributive fluvial elements that can be driven by 'top-down' (catchment area) and bottom-up (base-level) drivers (Fig. 3). These can occur over a variety of spatial and temporal scales within fluvial landscape contexts. Alluvial fan systems are consequently potentially invaluable records of longer-term landscape change and yet their full potential has yet to be realized within this context.

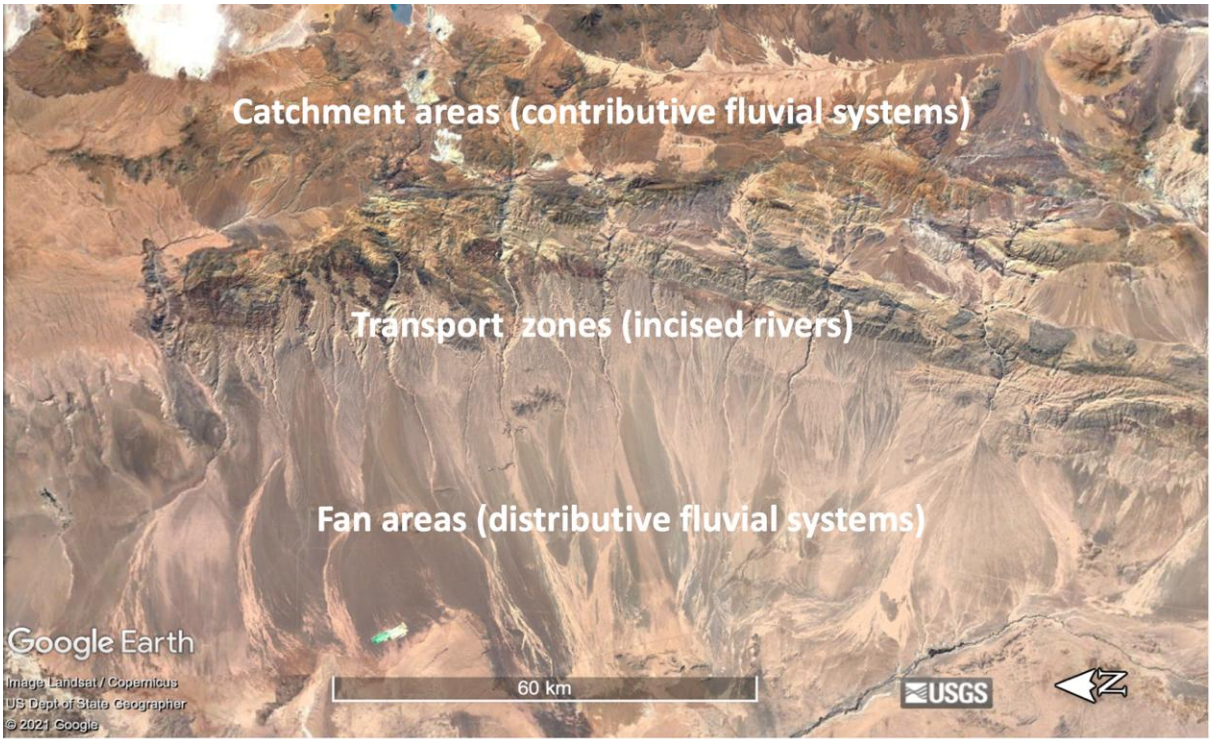

Fig 2. A Satellite view (courtesy of Google Earth, 2021) showing large fan systems comprising contributive elements (catchment areas), transport dominated zones (incising river systems) and distributive elements (fans). These fan systems have their catchments located within the Precordillera of the western central Andes. At this point the Precordillera is growing higher and wider, leading to the westward 'telescoping' of the fans and the development of net 'transport' zones between the catchment areas and the fans which form part of the regional Pacific Palaeo-surface of Peru/Chile - [4].

This presentation aims to examine how we can develop the potential of alluvial fan archives by utilizing and integrating the lessons from geomorphological and geological based alluvial fan system research approaches. In so doing we will address how this knowledge can be used to further our understanding of fluvial landscape development over deeper time-scales. This will be achieved via a range of predominantly dryland case studies which apply novel approaches to alluvial fan system analysis combining both geological and geomorphological concepts. We will then use these data to address what the fan can tell us (qualitatively and quantitatively) about the fluvial landscape development e.g. river capture, geomaterials, landscape processes, palaeohydrology, vegetation and the likely external driving factors (climate, tectonics, base-level).

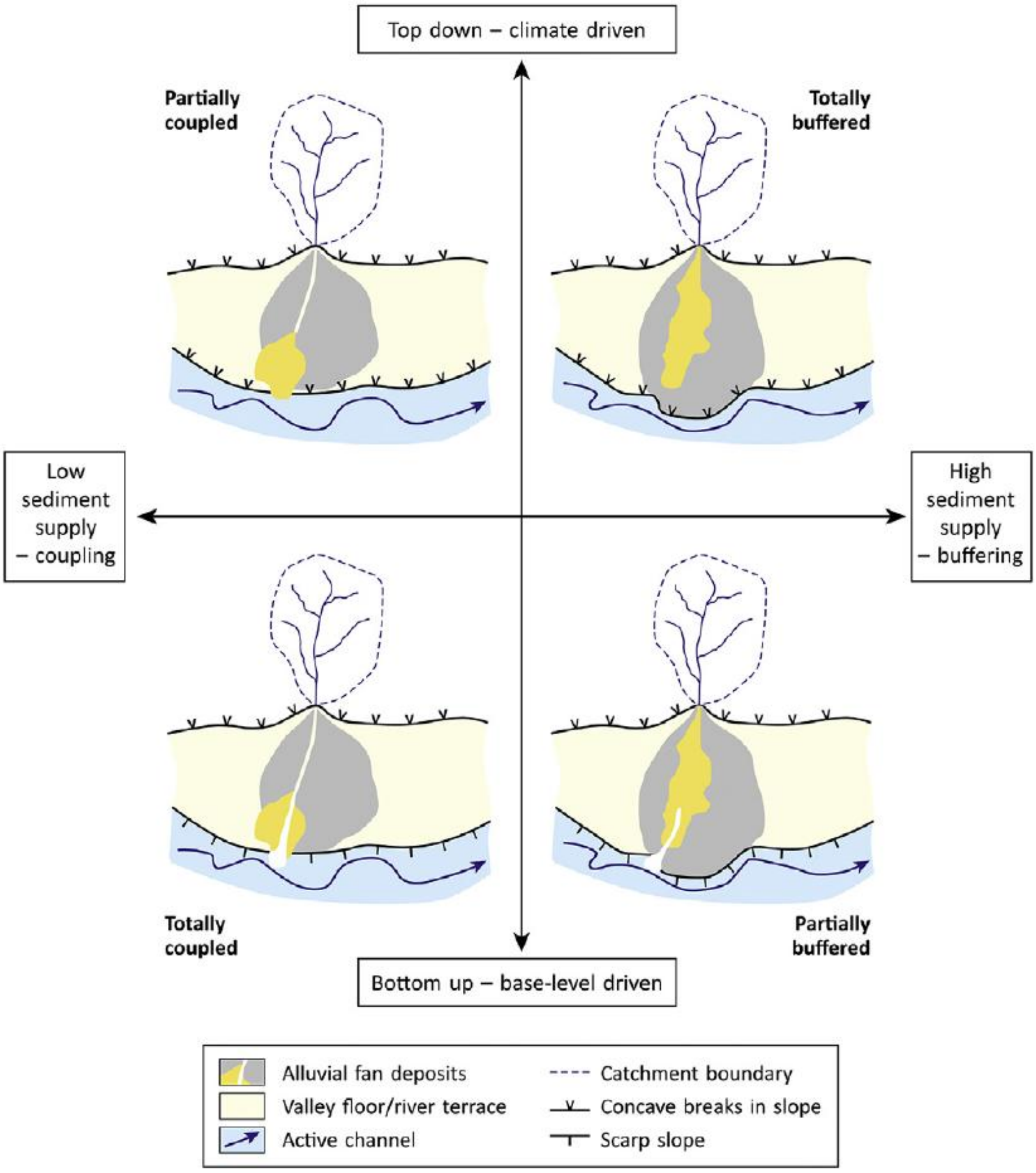

Fig. 3. *A conceptual model of tributary fan system interaction with adjacent fluvial systems and the key drivers of connectivity between the river and fan systems [2]*

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THE HISTORY OF THE MOKSHA RIVER VALLEY DEVELOPMENT IN THE LATE PLEISTOCENE

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The Moksha River valley was studied in its lower part between the Tsna River confluence and the mouth of the Moksha River. Moksha is a meandering channel. On the key site the Moksha River has wide floodplain with large and small paleochannels on its surface (Fig. 1). Small paleochannels have the same parameters as the modern river channel: their width is about 100-150 m, wavelength is between 300-400 and 600-700 m. Large paleochannels' parameters are few times bigger: their width is about 250-300 m, wavelength is about 1500-2000 m. These large paleochannels (macromeanders) are the signs of Late Pleistocene high flood activity epochs.

We studied both large and small paleochannels to reconstruct palaeohydrology and history of the Moksha River valley development in Late Pleistocene. Large paleochannels correspond to the time of high river runoff. The oldest ones of small paleochannels were studied to know the time of lowering of the river runoff.

Wide floodplain and two levels of terraces are presented on the studied part of the Moksha River valley. The height of the floodplain is from 1 to 6 m, of the first terrace – about 9-11 m, of the second terrace – 18-22 m. The width of the valley in the study area is about 14-16 km, but sometimes it can reach 20-22 km and more. The width of the floodplain is about 12-14 km.

The main aims of our study were reconstruction of Late Pleistocene history of the Moksha River valley development and establishing the absolute chronology of paleochannels' formation.

In our study we used field and laboratory methods. Boreholes in large and small paleochannels were made during fieldwork in August-September 2019 and September 2020. Organic material from alluvium of the river valley bottom was sampled to make radiocarbon (AMS) dating to find the time of river incision and aggradation, paleochannels' formation and infilling. Radiocarbon (AMS) dating was done in the Laboratory of Radiocarbon Dating and Electronic Microscopy of the Institute of Geography (Russian Academy of Sciences, Moscow). Radiocarbon dates were calibrated (IntCal20) using the online version of OxCal 4.4 program [1]. Also, we made the reconstructions of paleo-discharges of the Moksha River based on big paleochannels' parameters. For quantitative estimates of paleo-discharges we used the method developed by Alexey Sidorchuk [2].

Data analysis shows the following results and conclusions. In the interval between 40-30 ka BP, the river incised deeper than the present level, due to the increase of the river runoff associated with climatic changes. Then the incision was replaced by the filling of the valley caused by the drying up of the climate and a lowering of the river runoff, that was more significant on the period of the last glacial maximum (LGM, 23-20 ka BP). In the Late Glacial starting from 18.5 ka BP there was again a significant increase in river runoff, which led to the formation of macromeanders and widening of the valley bottom. Modern wide high floodplain was formed at that time. The Holocene was characterized by a decrease in runoff and channel parameters and narrowing of the meandering belt of the river.

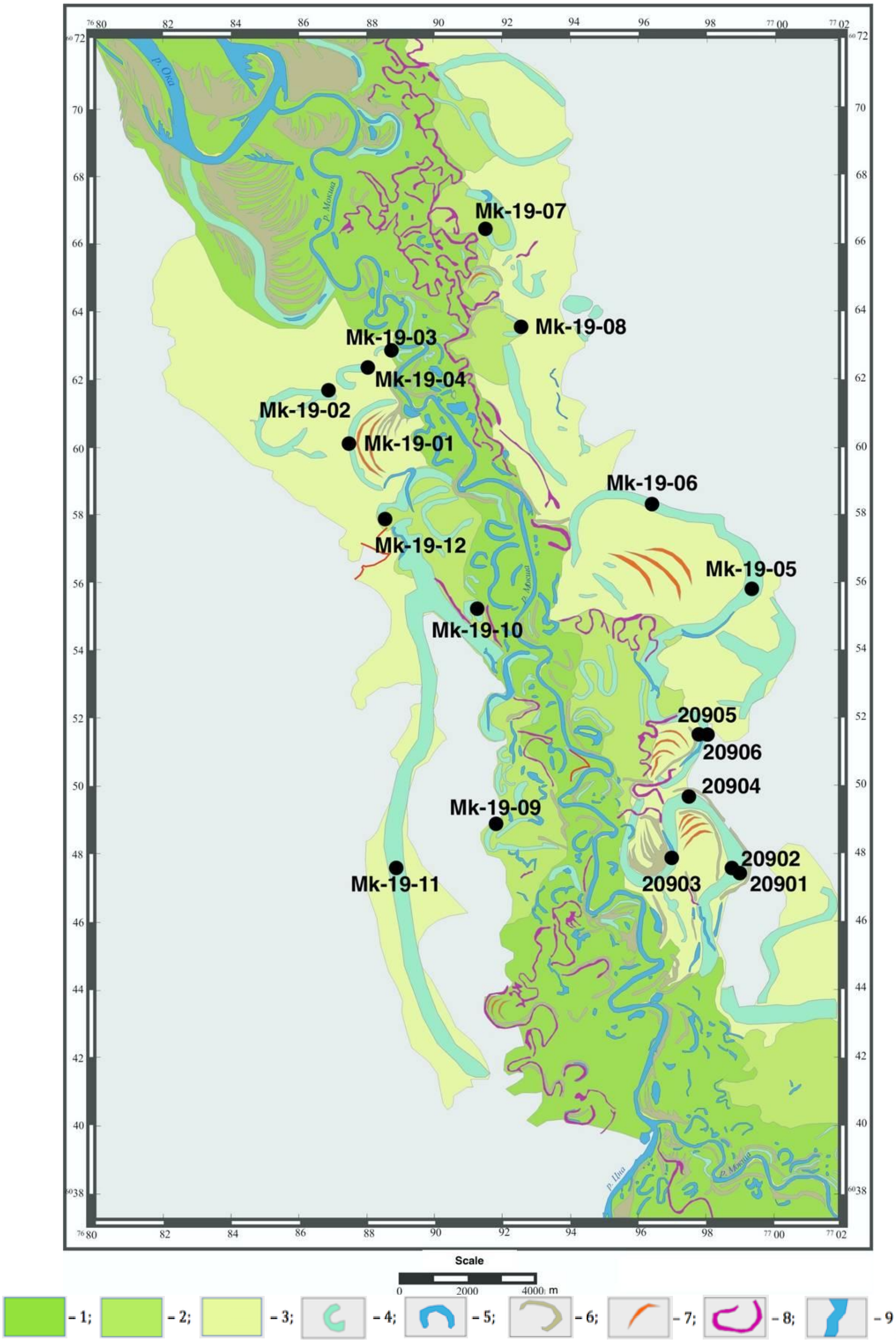

Fig. 1. Geomorphological map of the Moksha River floodplain.
Symbols: 1 – Late Holocene floodplain; 2 – Early Holocene floodplain; 3 – Late Pleistocene high floodplain; 4 – palaeochannels; 5 – oxbow lakes; 6 – levees; 7 – scroll bars; 8 – floodplain channels; 9 – modern river channel.

Acknowledgments. This study is supported by Russian Science Foundation (Project № 19-17-00215 “Research and modeling of possible scenarios for the formation of extreme paleohydrological phenomena in the Caspian basin after the Last Glacial Maximum”). Field data processing was performed under the facilities of the Institute of Geography RAS, taskforce 0148-2019-0005, and the Department of Geomorphology and Paleogeography of Moscow State University, taskforce 121040100323-5.

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LANDSLIDE-RIVER INTERACTIONS DURING QUATERNARY IN THE MOLDAVIAN PLATEAU (ROMANIA)

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Bahluieț Valley at Costești village, Northeastern Romania, is a site with geomorphological importance for the Quaternary of Eastern Europe. Here, the interactions between landslides and rivers [1], in the context of a monoclinic geologic setting [2], have shaped a morphology (Figure 1) that was considered by [3,4] to have geoheritage value. The Late Pleistocene age of the landslide was inferred for the fossil landslide [5, 6], being later confirmed [7,8]: the organic matter from the terrace deposits that cover the Costești fossil landslide returned 45 920-43 985 cal BP (Beta Analytics ID 518575), while the OSL dating of the same deposit in the area of Costești-Cier archaeological site returned 15.59 and 21.55 ky. These results imply that fossil landslide was triggered before MIS3. The age of the 3.5-4 m thick floodplain deposits that sit over the landslide deposits is Late Pleniglacial, the other landslide reactivations having Holocene age.

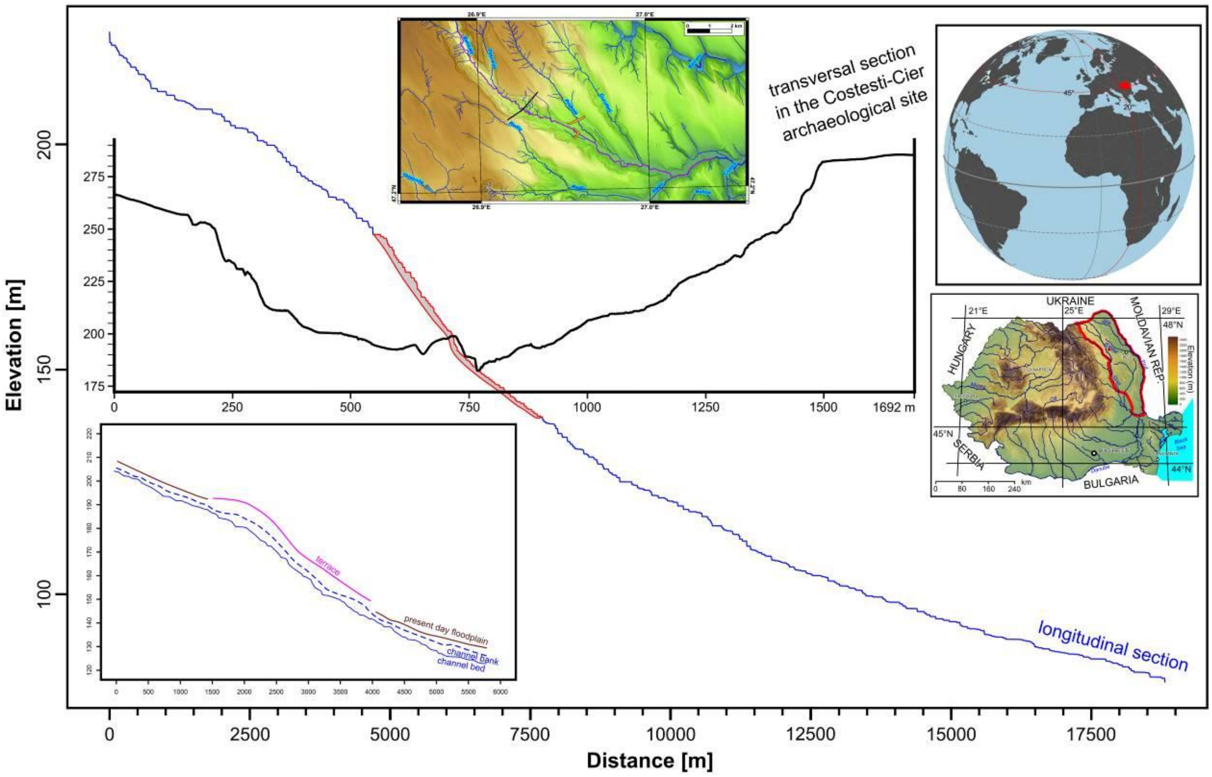

Figure 1 The topographic setting of the Bahluieț Valley at Costești village.

At the current geomorphologic research stage, the Late Pleistocene age of the fossil landslide is it well constrained, without the possibility to say the precise timing of the triggering, but only upper bounds [8]. These bounds imply that multiple events generated the fossil landslide deposit [8]. The landslide retrogressional reactivation continued during the Holocene, generating a complex landslide that affects the entire hillslope [9].

The river incision in the floodplain and fossil landslide deposit is Holocene, with an increased rate in the last centuries [8]. Supplementary OSL dating of the terrace deposits (Figure 3) indicates a major incision period after the Neolithic period [7], Cucuteni-Trypillia culture ceramics being found in the deposits.

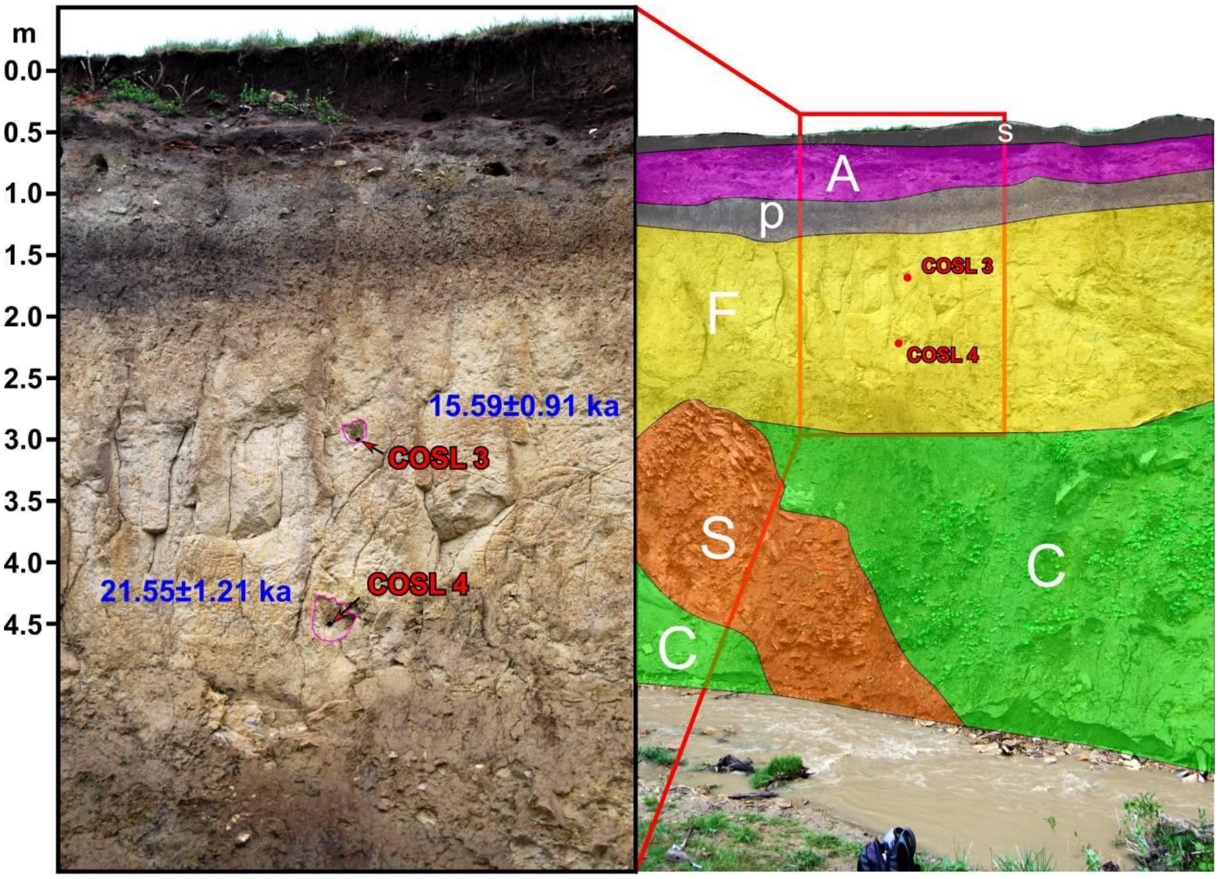

Figure 2 The OSL dating results in the Costeti-Cier archaeological site section: s – soil, A – arcaheological deposit, p – paleosoil, F – terrace deposit, C+S – slided landslide body of geological deposits with sandstones (S) and mudstone (C).

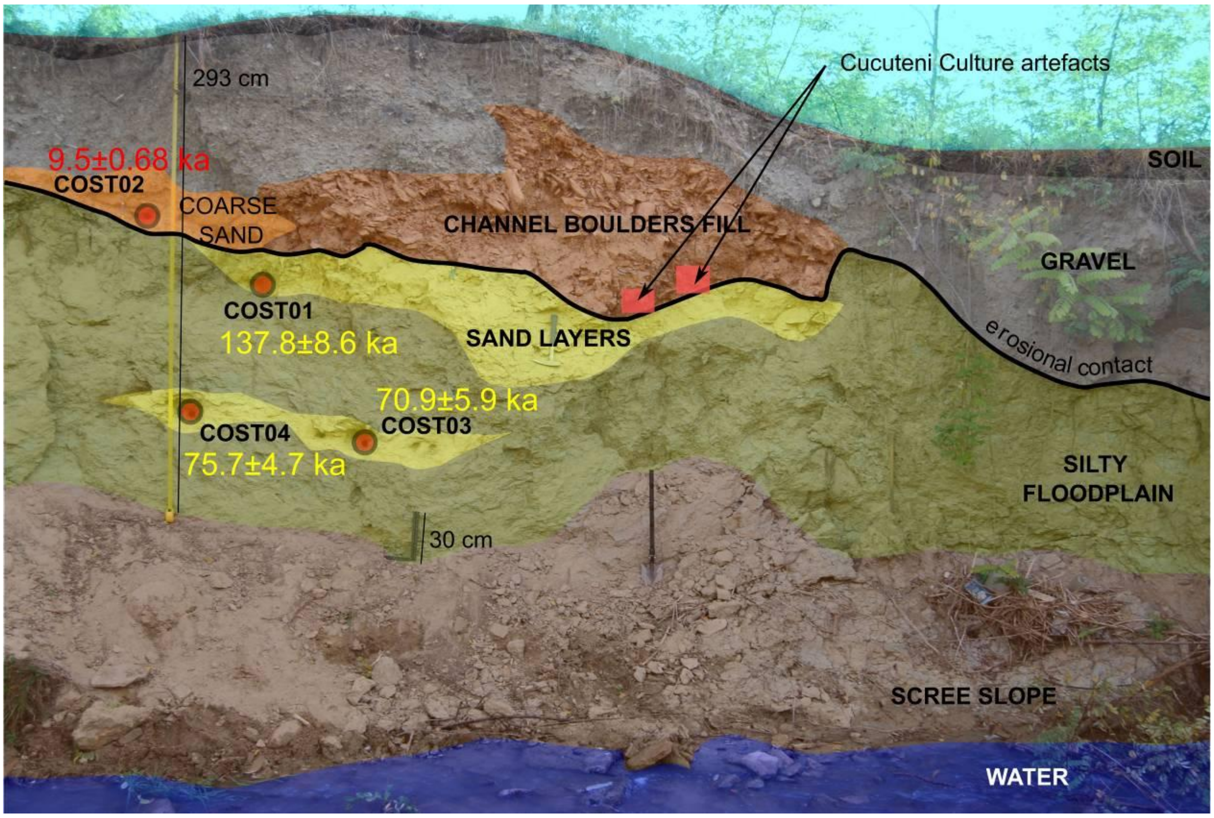

Figure 3 The supplementary dating of an erosional contact of the terrace deposits.

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THE UPPER VOLGA RIVER IN MIS 2 - EARLY HOLOCENE: RESPONSE TO CLIMATE CHANGES AND ICE SHEET IMPACT

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The source of the Volga River is located in the marginal zone of the last, Valdai glaciation in the northwest of the East European Plain (Fig. 1). The age of the upper Volga terraces is a controversial issue. Some researchers [4] believed that the upper Volga is a young river formed after the drainage of the system of proglacial lakes at the end of the last Ice Age and, therefore, its upper terrace belongs to MIS 2. Others [7] believed that the Volga valley was formed immediately after the Moscow (MIS 6) glaciation and dated the upper terrace to MIS 5–4. Until recently, the only data on absolute geochronology from the Volga valley were Holocene radiocarbon dates for the floodplain alluvium. Alluvium of older terraces does not contain organic remains, and no direct dates have been obtained on the terraces so far.

To clarify the question of the age and history of the development of the valley, we carried out luminescence (OSL) dating of the alluvium of the terrace staircase on two profiles at the Bolshaya Kosha village and at the Rzhev town, located at a distance of 80 km along the river from each other (Fig. 1). The structure of the river valley in both locations is similar: alluvial levels are represented by floodplain up to 4 - 4.5 m high and four to five steps of above-floodplain terraces, of which the highest terrace is the widest on both profiles. On both profiles, it has the same height of 15 - 17 m and is separated from the lower terraces by a 5 - 7 m high step. 20 OSL dates from terrace deposits were produced in the GADAM Centre, Silesian University of Technology.

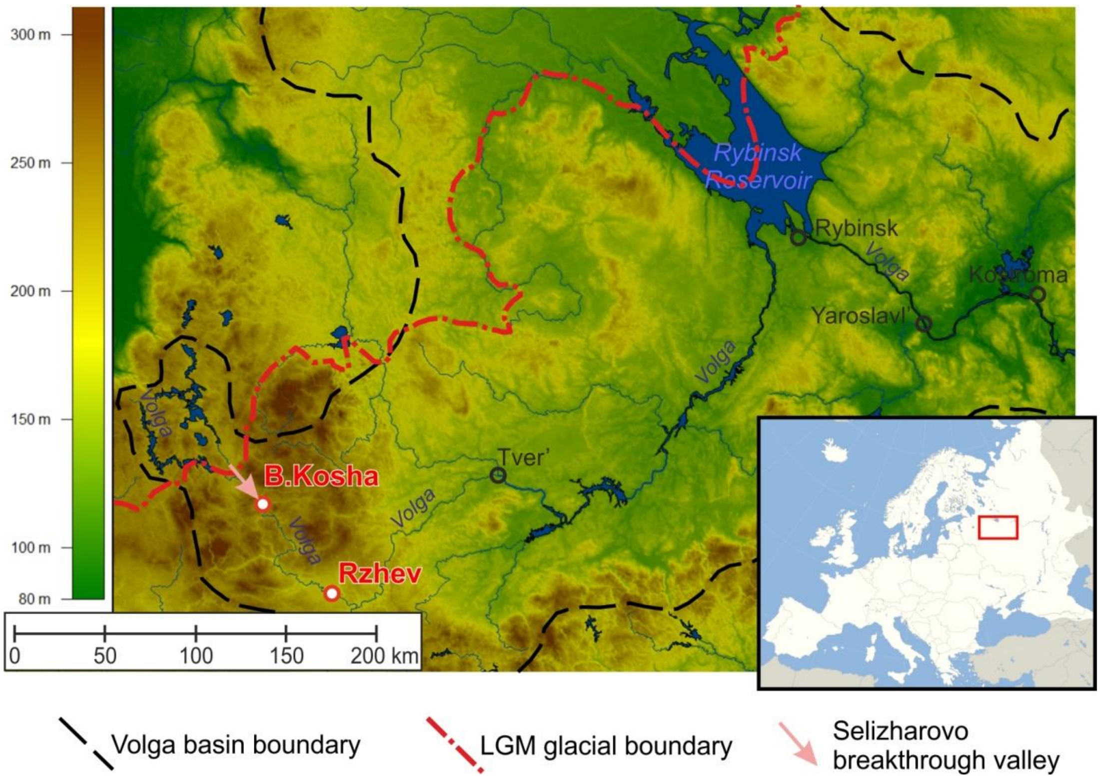

Fig. 1. *Upper Volga River catchment, study area and the last glacial boundary*

The similarity of the terrace staircases at both sites gives grounds to combine the obtained dates for statistical processing into a single array. In contrast to the traditional age-depth models, we have constructed an age-height model using the rBacon software [2]. The analogy between terrace height and depth in a geological section is incomplete, since the age of the terraces grows from bottom to top, and the age of alluvium in each individual section grows from top to bottom. Therefore, the modeling was carried out in two versions. In the first, the height above the river of each individual sample was taken (Fig.2A), in the second, for all samples from one terrace, a single height is taken - the height of this terrace (Fig.2B).

Both models gave similar results. The modeled age of the 15-17-m terrace in the first case is 23±3 ka, in the second - 21±2.5 ka. Age about 19 ka was modeled for the lower 12-13-m terrace. Taking into account the scatter of dates, it cannot be excluded that both terraces are about 19-20 thousand years old. This does not contradict the existing geochronological data on the dynamics of the southeastern edge of the Scandinavian ice sheet: according to [3], the ice sheet entered the upper reaches of the Volga basin about 20 ka BP, reached its maximum at about 19 ka BP and left this part of the Volga basin no later than 18 ka BP. This gives the basis to associate the formation of both highest terraces and the beginning of the incision of the river with the runoff of glacial melt waters through the Volga valley. Judging by the ^{14}C dates from the floodplain, the incision stopped in the middle of the Holocene. The total depth of incision was 12 m, the average rate – 1.2-1.5 m per ka.

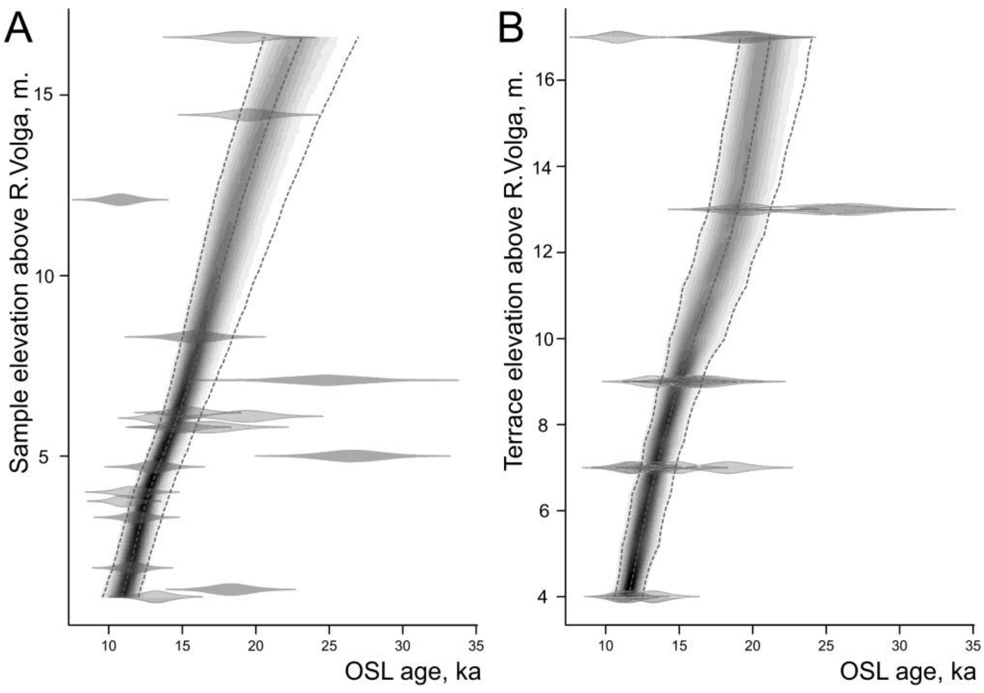

Fig. 2. *Age-Elevation models for alluvial OSL ages from R.Volga terraces (A – elevation of terraces, B – elevation of individual samples).*

Below we discuss three possible reasons for the river incision.

1. Postglacial deformations of the earth's crust as a result of glacioisostatic adjustment (GIA). To estimate the magnitude of deformations of the topographic surface, we used the realization of the ICE-5G Global Glacial Isostasy model [7]. The constructed map of deformations shows that the earth surface sank in a strip 250-300 km wide along the edge of the ice sheet. The magnitude of subsidence at the edge of the glacier was about 150 m. At a distance of 300-800 km from the glacier, there was a glacial forebulge 10-15 m high. All these deformations influenced the longitudinal profile of the upper Volga (Fig. 3).

2. Climatically driven increase in river runoff in the period 18-13 thousand years ago, established earlier for the center and south of the Russian Plain [6].

3. Increase in the Volga runoff due to an increase in the basin area. It is assumed that before the last glaciations, the source of the Volga was the river B. Kosha. A breakthrough valley was formed around the LGM between the Selizharovo town and the B.Kosha village (Fig. 1). This led to the capture by the Volga basin of the entire modern region of the Upper Volga lakes. The increase in the basin area led to an increase in runoff and river incision until a new equilibrium longitudinal profile was formed.

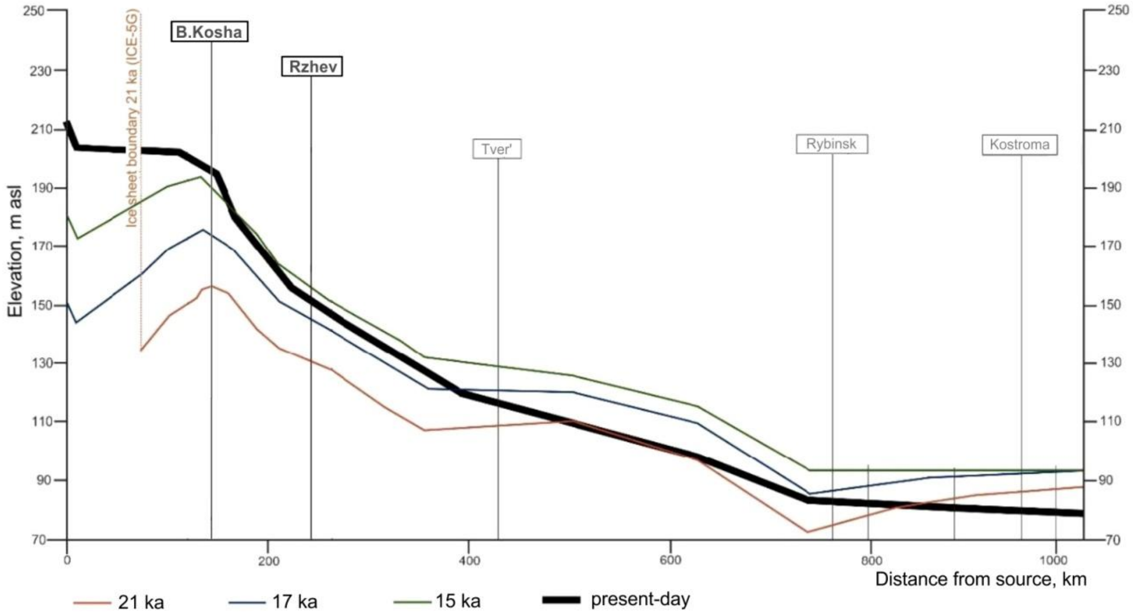

Fig. 3. *Transformation of R.Volga long profile due to glacio-isostatic adjustment, according to the ICE-5G GIA model [7]*

Acknowledgment

The research was carried out with the financial support of the Russian Science Foundation (project No. 17-17-01289).

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MACRO- AND MICROSLAGS DELTA DEPOSITION IN THE POSTINDUSTRIAL WATER RESERVOIR IN SIELPIA (HOLY CROSS MTS., POLAND)

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The Sielpia Reservoir (Holy Cross Mountains, Poland) (Fig. 1) is one of the former post-industrial ponds, the functions of which were changed during economic transformations in the Old Polish Industrial District region [11]. The reservoir is located about 30 km NW from Kielce and belongs to the anthropogenic small-scale water retention system (ASWRS) [7]. On Czarna Konecka, many similar ponds were built as the part of the forges and other ironworks hydrotechnical infrastructure. Currently, many of these ponds have been abandoned, and some of them, just like in Sielpia, have changed their purpose for tourism and recreation. However, traces of historical metallurgical activity are still visible in the forms, but also in the lacustrine deposits. Today, sediments has been intensively transported and accumulated from the upper sections of Czarna Konecka, which in last years has formed a distinct inland delta in the reservoir bottom [3]. Before starting the hydrotechnical works in 2018, the reservoir in Sielpia in 1974 had an area of 60 ha. As a result of intensive silting, this area decreased to 55 ha in 2015 [1], [9].

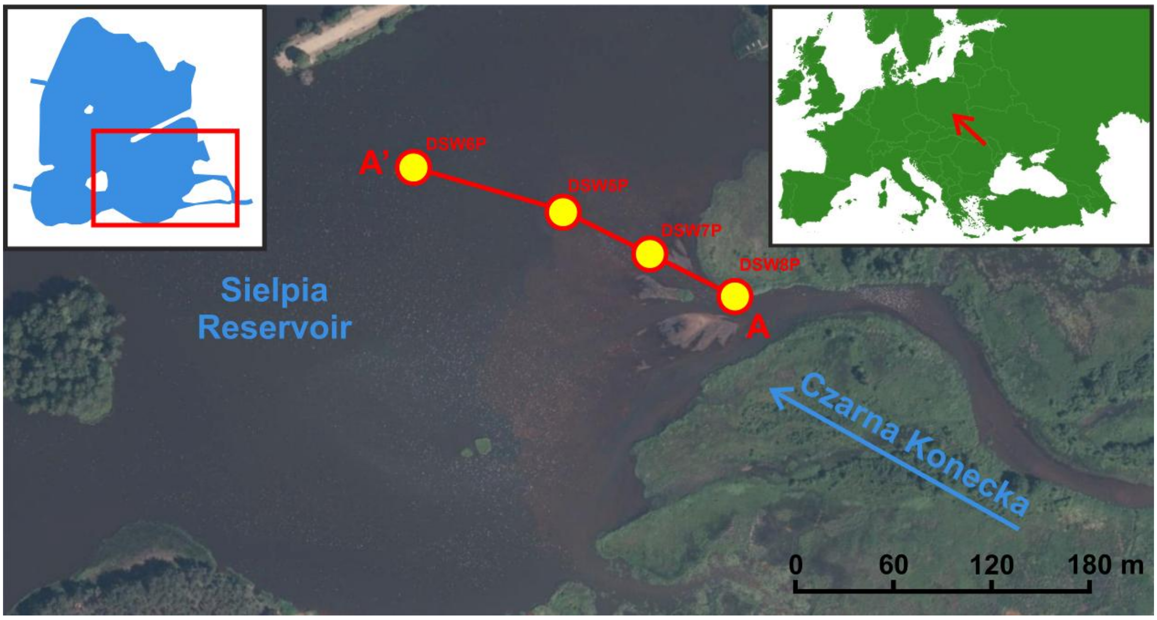

Fig. 1. Location of the study area, and orthophoto map [4] from 2019 of the inland delta in Sielpia Reservoir with profiles and longitudinal section

During the hydrotechnical works the field research were carried out in 2019-2020 on the reservoir and inland delta area. Profiles were excavated along the delta (Fig. 1) from which the material for grain-size analyzes was obtained and the Magnetic Spherule Separation (MSS) was performed [12]. A field inspection of the site was also carried out and photographic documentation was made.

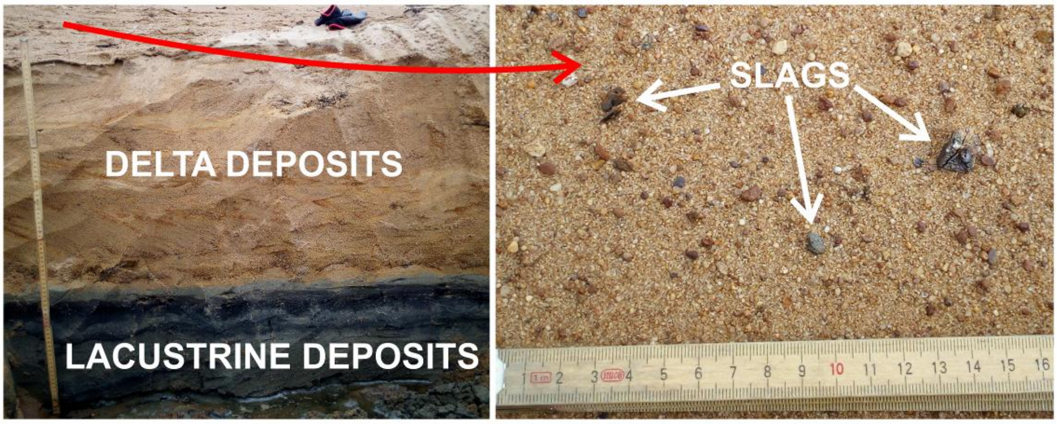

Fig. 2. DSW6P profile in the front of delta with visible dark layer of lacustrine deposits and bright inland delta deposits (left) with many small slags creating deflation pavement on the top of alluvium (right) (Photo P. Przepióra 2019, 2020)

The delta is build of sand and gravel sediments covering a darker layer of finer deposits with visible detritus inserts (Fig. 2). Among the coarse-clastic sediments there are numerous slag fragments redeposited from the upper section of the river. They also create a distinct deflation pavement on the delta surface, which shows the scale of the amount of metallurgical material deposition. Grain size analysis allowed to create a lithological delta longitudinal section, which shows 3 phases of sediment accumulation with one lacustrine sediment (I) and two phases of delta accumulation (II, III) (Fig. 3).

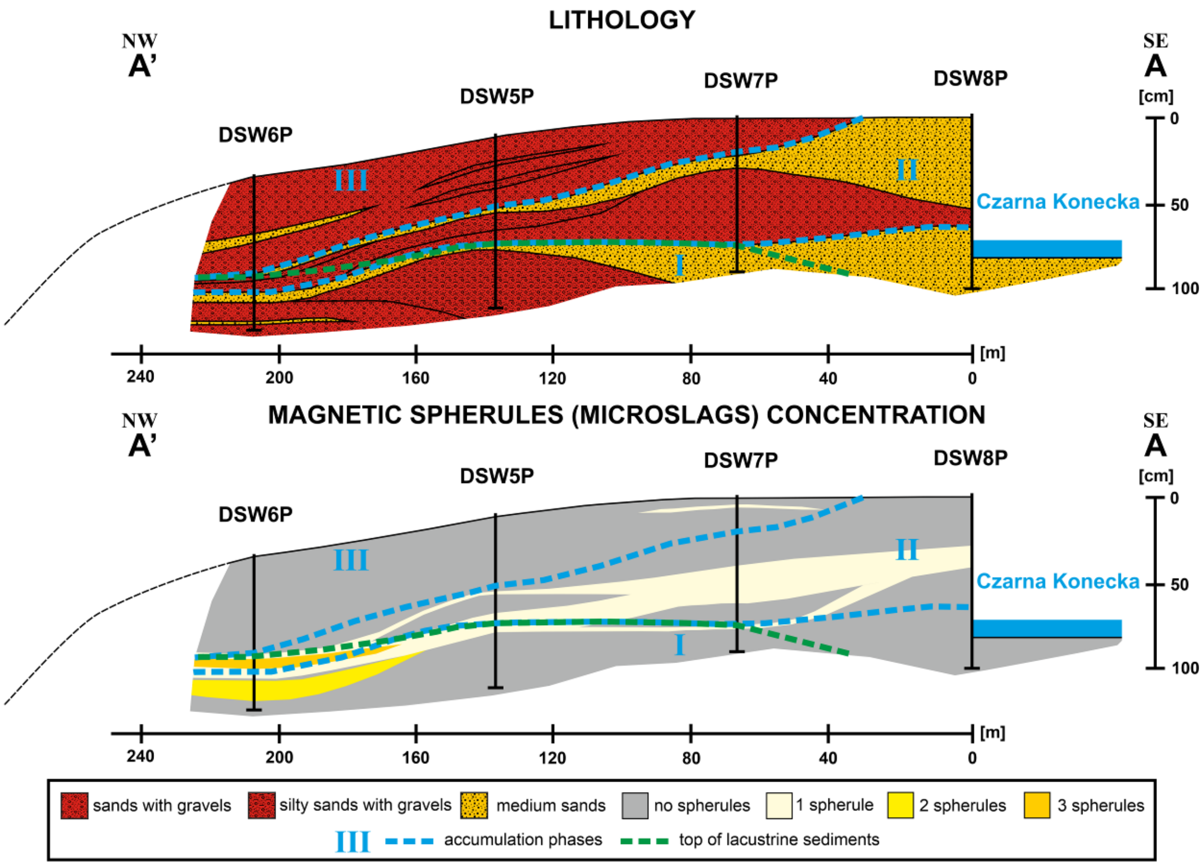

Fig. 3. Longitudinal section of inland delta with the lithology, accumulation phases and magnetic spherules (microslags) concentration (by P. Przepióra)

The MSS method was used on samples obtained from four profiles made on the inland delta (Fig. 1). Only a small amount of iron spherules in several samples of 10-20 g weight was found. They are traces of metallurgical activity of the forges in this area [2]. The small number of the spherules however was able to made an inland delta longitudinal section with a concentration of magnetic iron spherules (Fig. 3). A visible level of microslags deposition coincides mainly with the lithological accumulation phase II and some in phase I. The greatest number of iron spherules was detected in the top of lacustrine deposits and in the bottom of delta sediments (Fig. 2, 3). Just like the macroscopic slag fragments, the iron spherules occurring in the delta sediments were redeposited from the upper part of the Czarna Konecka. This material was transported during fluvial processes, which might suggest their small number in the sediments (flushed out).

Iron spherules detected in the delta sediments of Sielpia Reservoir can be mainly connected with their secondary accumulation (II). The macro- and microslags preserved in the delta's sediments was flushed out from the upper section of Czarna Konecka, where many forges were operating with similar industrial ponds (ASWRS) [11], [7]. Over time, these reservoirs were abandoned and destroyed during floods. The formed layer of iron spherules may indicate the accumulation of these sediments during one of such catastrophic events on the river during 21st c. The obtained results indicate that the MSS method has been used so far mainly in flood plains [5], [6], [10], [8] it can also be effectively used in sediments filling the bottom of former industrial ponds, including young inland deltas.

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THE MULTILAYERED EVOLUTION OF THE FLUVIAL SYSTEMS IN THE GULF OF TRIESTE (ADRIATIC SEA) SINCE THE LGM

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The Isonzo (Soča in Slovenian) is the easternmost large river of the southern Alps, with a catchment of 3400 km2 extending between Slovenia and Italy. This fluvial system is been bounded to the east by the carbonate bedrock of the Karst and by northern Istria, thus, it represents the limit of the large alluvial environments that characterize northern Italy, as the Po and Venetian-Friulian plains.

Through the analysis of a dense network of CHIRP profiles, multibeam DTMs and sediment cores collected in Adriatic seabed, both in the Italian and Slovenian sides of the Gulf of Trieste, this work reconstructs the evolution of the Isonzo River fluvial system at the scale of the entire gulf. Thanks to the recent geological map of Quaternary of Friuli Venezia Giulia Region [1], it is also possible to relate the submerged areas to the present alluvial plain. Thus, the megafan of Isonzo can be considered on its whole extent.

In particular, among the different ancient channel belts recognized in this work, we reconstructed the planform and the stratigraphic architecture of a paleo Isonzo over a length of almost 50 km, when this stream passed almost along the present coast, flowing near Trieste, Koper and Piran.

Alluvial systems are highly susceptible to environmental changes, such as variations in water and sediment discharge and in the position of the base level, making them natural data loggers capable of recording the various dynamics and forcing active at different scales over a certain time span. However, only extensive and detailed surveys allow to unwind the complex set of information stored in the alluvial stratigraphic record as documented in other alluvial systems of northern Italy [2, 3].

The fairly well-known boundary conditions in terms of structural, geological and recent climatic-related configuration of the Isonzo basin allow to understand the timing and style evolution of the Isonzo systems starting from the Last Glacial Maximum (LGM) up to the Early Holocene, when the area was flooded by the Adriatic.

Due to its position, along the late Quaternary the Trieste Gulf has been directly influenced by the water and sediment discharge supplied by the Alpine glaciers during the LGM and it after experienced the constrain of the post-LGM rising sea level. In describing the evolution of the Trieste Gulf, this work provides therefore a potential analogue for a wide variety of areas scattered over the world, from paraglacial environments to distal megafan areas and continental shelves with gentle slope, now submerged.

Our reconstruction also provides an ideal case study for the prediction of the impact of sea-level rise on natural systems, which is of paramount importance in the perspective of the ongoing global warming and the predicted loss of continental ice.

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LARGE-SCALE PRODUCTION OF CHARCOAL FOR THE HISTORICAL METALLURGY IN THE MAŁA PANEW RIVER BASIN (SILESIAN LOWLAND, CENTRAL EUROPE).

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Until the 19th century, the primary fuel in metallurgy was charcoal [1]. Large amounts of charcoal for the needs of water-powered metallurgical centers were obtained through a controlled process of dry distillation of wood in charcoal hearths. A charcoal hearth is understood as compact, most often round piles of wood, often made of straight and relatively thin logs, branches and sometimes split trunks. The construction was covered with turf, with the air supply controlled through holes in the hearth [2]. The wood for charcoal burning was obtained from trees growing in the river valleys and adjacent areas. The landforms left over charcoal burning are almost invisible in the field and have survived today where drainage, forestry or agricultural treatments are not carried out.

The aim of this study was to identify the charcoal hearth remains (CHRs) (digital analysis) and to determine their number. An additional goal was to determine the age of the studied forms (radiocarbon dating) and thus to determine the time of charcoal production. Another goal was to determine which tree species were used to produce charcoal (palaeobotanical analysis). An additional goal was to identify the potential environmental effects of charcoal production.

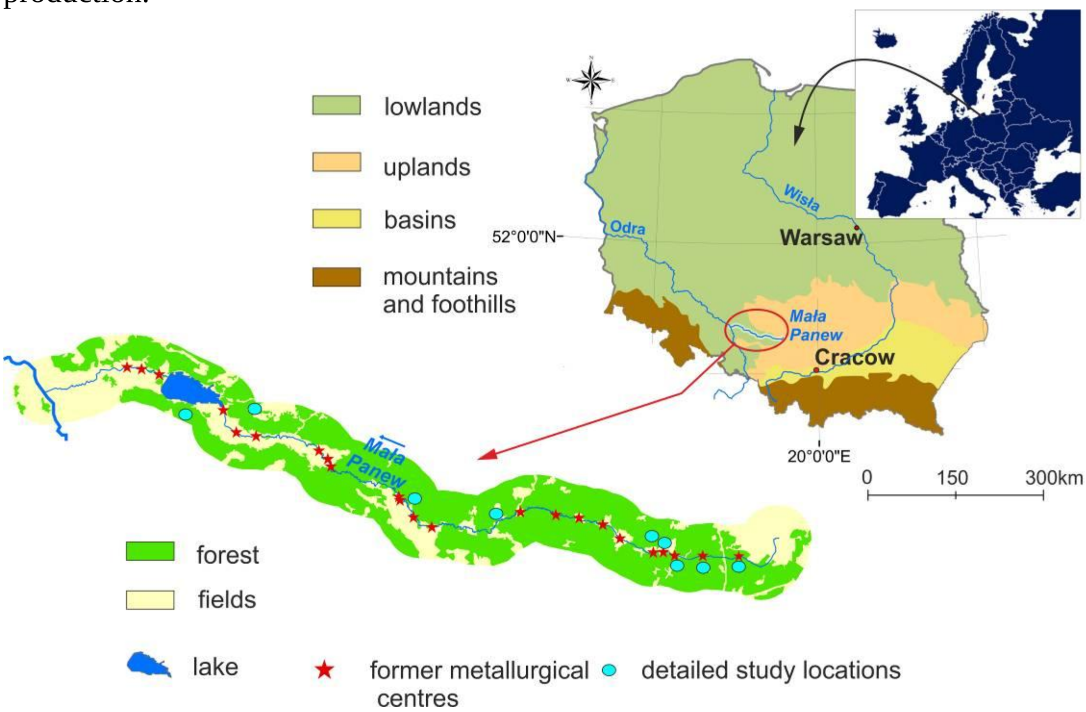

Fig.1 Study area.

The research was carried out for a specific area of the Mała Panew river basin (Fig.1). Preliminary identification of the CHRs allowed to establish that their greatest concentrations are located relatively close to the riverbed and in modern forested areas. On this basis, a research area was designated up to 4 km from the river bed on both banks, along its entire length, which gives the research area of 902 km^2 of the Mała Panew river basin. Then, relief models covering selected areas were created using the Sky View Factor tool in the Relief Visualization Toolbox – RVT [3]. On the basis of SVF images, the charcoal hearth remains were counted manually. Detailed field studies were carried out in the vicinity of the former metallurgical centers in the study area. They consisted in the field verification of CHRs, previously identified on digital images. Exposures were made in the selected CHRs. Charcoals were collected from the exposures for further laboratory analysis. In total, several hundred test ditches were made in order to verify the origin of landforms. For the selected area of the Mała Panew river basin, an extensive sampling of charcoal samples from the CHRs was carried out, as well as a broad identification of the tree species used for charcoal burning. A total of 45 charcoal hearth remains were tested on 9 sites, 45 of which were charcoal fragments subjected for radiocarbon dating. A total of 1,412 charcoal fragments from 45 CHRs were submitted for palaeobotanical analysis.

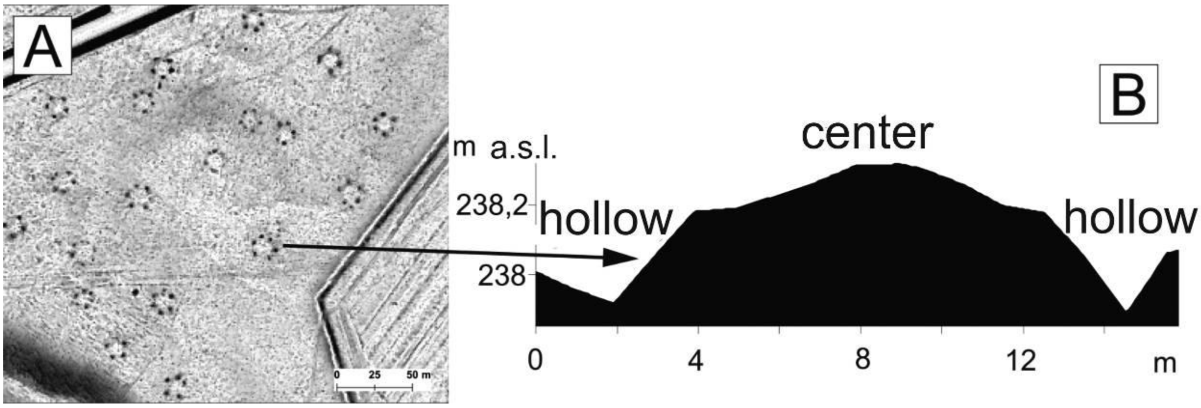

Fig.2 A-CHRs identified on the basis of SVF image; B-terrain profile trough the single CHR.

Based on the generated SVF (Sky View Factor) images in the studied area of the Mała Panew river basin, 166 356 CHRs were found on an area of 902 km^2, so on average there are as many as 184 CHRs per 1 km^2. Measurement of randomly selected CHRs showed that they were characterized by the following parameters: height 0.2 - 0.5 m in the central part of the landform, diameter from 11 to 20 meters. The elevations in the central part of the object were surrounded by pits 10 to 20 cm deep and 2 to 3 m in diameter (Fig.2). Depending on the size of the object, the number of pits ranged from 4 to 9. Charcoal fragments and coal dust mixed with sand were detected in all tested landforms, which confirms the genesis of the studied forms related to charcoal burning. Charcoal fragments and ash mixed with sand constituted a dark layer with a thickness of several to 25 cm, lying directly on the loose sands. The layer of ash and charcoal was covered with a layer of the forest litter. The charcoal fragments ranged in size from a few millimeters to several dozen centimeters. The profile depth depended on the depth of the layer of charcoal and ash. Outcrops of sediments made in the hollows of CHRs showed that they were filled with a mixture of gray sands and ash with small fragments of charcoal, while at the bottom of the hollow there were usually large fragments of charcoal, several or several centimeters high. Radiocarbon dating indicates that the oldest CHRs come from the 12^{th} / 13^{th} (two datings), the 13^{th} / 16^{th} (one dating) and the 15^{th} / 17^{th} century (two datings). Other forms were dated for the period between the 17^{th} and 20^{th} centuries. The results of the palaeobotanical analysis allowed to establish that both coniferous and deciduous tree species were used to burn charcoal in the study area. Coniferous species predominate, mainly Scots pine (Pinus sylvestris) - 1310 fragments (93% of the total), which proves the deliberate choice of this species for charcoal burning or the high availability of this species in the past. In addition, the following taxa were identified: alder (Alnus sp.), Birch (Betula sp.), Oak (Quercus sp.), Norwegian spruce/larch (Picea abies / Larix sp.), Silver fir (cf. Abies alba) and European ash (Fraxinus excelsior). Over-exploitation of forests could cause negative environmental effects, such as: transformation / modification of forest species composition, significant deforestation of exploited areas or complete disappearance of forests, intensification of floods, or launching of aeolian sands transport.

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IMPACT OF THE MID-PLEISTOCENE TRANSITION ON MEUSE RIVER TERRACES IN THE SOUTHERN NETHERLANDS

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River terrace deposits are excellent archives of paleoenvironmental conditions. The Meuse river terraces are an example thereof. In the region of South Limburg, in the Netherlands, the flight of terraces carved by the Meuse, a major tributary of the Rhine, is well preserved and, for decades, has been intensely investigated. This study aims to find in these terraces sedimentary and depositional trends resulting from the Mid-Pleistocene climate transition (MPT). More specifically, the trends are identified according to different groups of terraces: East Meuse, Higher, Middle and Lower terraces. The groups are, then, assessed regarding whether they were formed before or after the MPT. Accordingly, a comparison between the different sedimentary and depositional trends will be made in order to clarify to what extent these trends are a product of climate change and/or tectonic forcing. For example, the transition from Higher to Middle terraces is topographically represented by steep escarpments formed during the main uplift-driven incision phase of the Meuse river (ca. 700 – 780 ka). This observation is well accepted among peers to be a product of tectonic forcing (e.g., [1], [2]). However, what is the role of the climate in this transition? Is the MPT somehow related to the onset of this main incision phase? It is expected that the sedimentary and depositional trends can provide new insights on how the MPT might have contributed to changes in the incision rates. Even more relevant, it is also expected that the analysis of these trends will point out how the Meuse river system responded to the MPT.

To achieve the proposed goals, this study updates the Meuse terrace maps for the Netherlands, and integrates it with the maps for the adjacent regions in Germany and Belgium that also encompass remnants of the Meuse terraces. For that, this study relies on existing maps [3–6], a high resolution DEM, and a dense borehole database together with sediment core archives provided by the Geological Survey of the Netherlands (TNO). Using the DEM, the flat surfaces representing terrace fragments are mapped with the support of the TerEx tool, a GIS application that semi-automates the identification of potential terrace surfaces according to user-defined parameters [7]. The data generated by this tool is then complemented by TNO's borehole and sedimentary core databases, which allows for the identification of the top and base of specific terrace levels. Once mapped, sedimentary parameters of specific terrace groups can be compared, for instance, terrace thickness, gravel content, gravel size, lithology and heavy mineral content. Furthermore, as part of the development plan of this study, isochron burial dating will be applied at a later stage in order to build a robust age control on the terraces that mark the MPT. The results of this dating method will allow for the estimation of paleodenudation rates and, consequently, the paleo sediment fluxes of the Meuse catchment in periods pre- and post-MPT.

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ALLUVIAL FANS AS RECORDERS OF AFRICAN HUMID PERIOD FLOOD HYDROLOGY

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Alluvial fans are cone-shaped depositional landforms that commonly build along mountain fronts, valley sides or at tributary junction settings in uplands or along the margins of uplands. Their sedimentology and geomorphology provide important archives of long-term Quaternary landscape development driven by interplay between tectonics, climate, and rock strength controls. Within this study, we explore the use of alluvial fans as important but overlooked recorders of long-term climate-related Quaternary fluvial landscape development, an issue first highlighted to the FLAG community by Mather et al [1].

Within an alluvial fan, as part of the broader fluvial system, climate controls 1) weathering and erosion processes, influencing sediment supply to the fan, and 2) flood hydrology to and within the fan, driving sediment transport and deposition. Past changes in flood hydrology (palaeohydrology) can be derived from the sedimentology (size and flow depth) and geomorphology (surface slope and channel cross-sectional area) of dated deposits, an approach often applied to river terrace sequences [2]. However, river terraces typically reflect long temporal and large spatial scale integration of palaeofloods and their fluvial sediment. In contrast, alluvial fans offer a more localized, almost in situ, hydrological perspective of climate-related precipitation and flood discharge due to small transport distances over shorter temporal scales. Despite the climate-landscape response insight offered by alluvial fans, palaeohydrological perspectives and their climate relationship are lacking from Quaternary alluvial fan (fluvial) archive research.

In this study, we explore the application of palaeohydrological analysis to a large alluvial fan that has built along the flanks of a volcanic island, Santo Antao. This is the most north westerly positioned island of the Cape Verde archipelago (east-central Atlantic Ocean), some 850 km offshore West Africa. The study location is excellent for alluvial fan palaeohydrological analysis. 1) The island is tectonically quiescent during the Upper Quaternary (stationary oceanic plate setting and marine terrace evidence), meaning fan building is unaffected by uplift. 2) The volcanic island setting provides a clear and simple geological framework for the fan catchment (dipping layered lava flows, cross-cut by dykes) and its depositional area (volcano flank, akin to a mountain front setting). The volcanic bedrock and some minor volcanic events during the Upper Quaternary provide chronological insight into fan building (i.e. dated and spatially extensive volcanic markers and dateable fan material). 3) The coastal setting of the fan means that well constrained eustatic base-level variation is a key control on fan building space, driving fan progradation (falling sea level and lowstands) and shortening / incision (rising sea level and highstands) in concert with global climate changes. 4) The fan has built under a dryland climatic setting, with Cape Verde considered an offshore extension of the Sahara Desert. The dry climate means an easily observable landscape devoid of vegetation, with excellent preservation of fan depositional lobes and their fluvial bar form and channel networks. The Cape Verde location (offshore west Africa) and the Quaternary context of the Sahara Desert is especially interesting since the Quaternary African climate is strongly influenced by precession-related climate changes called 'African Humid Periods' (AHPs). AHP events are driven by wobbling of the Earth's axial spin, which alters atmospheric circulation patterns every ~20 ka, repeatedly bringing elevated hydrological conditions (~5ka duration) to low-mid latitudes of continental Africa, and offshore areas such as Cape Verde.

The study fan (Fig. 1) is located on the SW flank of Santo Antão Island. The fan is ~6 km long with an area of ~11 km^2, fed by a main catchment with an area of ~28 km^2 and relief of 1300 m. A modern active fan lobe occupies a small portion of the distal coastal area of the fan (0.4 km^2), activated annually during late summer / early autumn storms. This active lobe is fed by a deeply incised channel that cuts down through an expansive abandoned relict fan surface. In proximal fan areas the channel is incised by up to 120 m below the surface, forming a narrow (10’s of meters wide) slot canyon. Incision decreases to around 10 m in distal fan areas with the canyon widening to several hundreds of meters into distal fan areas. Along the coast, a 10 m high coastal cliff is being cut into the distal most part of the fan. Small streams originating from the coastal cliff cut back into distal and mid parts of the fan as a series deep and narrow at a scale of meters to 10’s of meters. The deeply incised channels reveal a fan sediment sequence of up to 100 m thick. Contacts with basalt basement bedrock are only observed in proximal fan areas. A lava flow (not dated) and a 200 ka Ar-Ar dated tephra unit are interbedded with the fan sediments and can be observed across proximal-mid-distal fan settings in various locations. In the most proximal fan areas the fan surface is mantled with a 100 ka tephra.

Fig. 1. Oblique drone imagery of A) relict fan surface, noting fluvial bars and channels and B) modern active lobe with recent flow evidence.

The fan surface forms the focus of our palaeohydrological investigations. The surface appears to comprise a single level, lacking in any altitudinally separated surface levels often observed on alluvial fans subject to base-level changes (e.g. tectonics). This surface comprises a network of low relief (<3.5 m) distributive cobble-boulder fluvial bars and channels. Mapping of the channels using satellite imagery reveals that the surface forms 3 lobes, a proximal lobe and two adjacent mid-distal fan lobes. Field survey along transects across the fan surface confirms the separate lobes with lobate convex surface forms being enhanced by deep channel / stream incision in the topographic lows around the separate lobe margins. Preliminary ^{3}He cosmogenic exposure dating of bar form boulders sampled in different locations across the fan surface suggests lobes are associated with different AHP periods. The proximal lobe appears to have formed between 10-20 ka (AHP1), with the mid-distal fan lobes forming between 50-60 ka (AHP 2) and 80-90 ka (AHP3). This is chronology and AHP climate association is currently being refined with additional sampling and dating.

For palaeohydrological analysis we use a competence based palaeoflood discharge quantification approach developed by Clarke [3] called the 'maximum boulder size' method. The approach calculates the minimum force needed to move a boulder. It requires field and remote sensing data inputs: triaxial boulder dimensions; relict flow width, slope, and roughness; and the lithology (density) of the clasts. Force is partly a function of the channel slope. To apply the method, we selected a range of proximal-distal fan surface locations, most of which coincide with our ^{3}He sampling sites and incorporate the x3 AHP-related lobes. At each location, we used a drone to image a 200x200 m area from which we used Agisoft/Metashape structure from motion software to build a 3D digital surface model (Fig. 2A). This mapping provided a high-resolution topography from which we could obtain multiple slope and width measurements from different channel and barform morphologies for palaeohydrological modelling data inputs. Within the drone surveyed areas we collected clast size data, measuring the a, b, c axes of the 10 visibly largest boulders across a given unit barform (Fig. 2B). Boulders were all basalt lithologies, so we used an average density value of 2.9 g/cm^3. We also hand surveyed the area for field-based slope and width measurements.

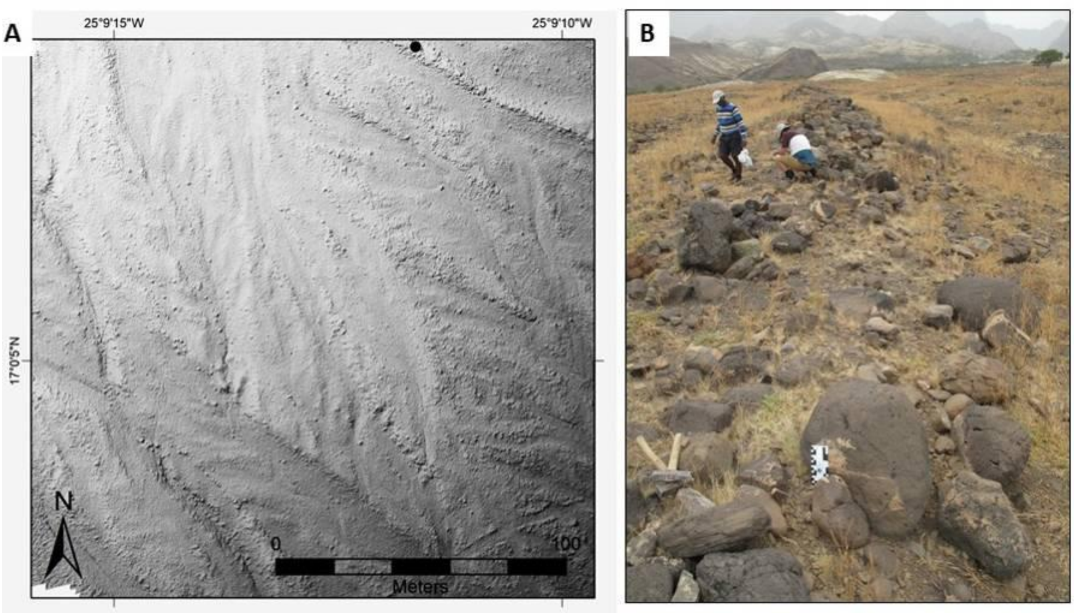

Fig. 2. A) Drone surveyed surface example. B) Boulder measurements from bar form.

Within our presentation we will discuss 1) the challenges of applying competence palaehydrological analysis to alluvial fan settings and 2) make some preliminary interpretation and discussion points concerning the palaeoflood discharge results and their relevance to wider AHP hydrological understanding and research.

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THE FLUVIAL ARCHITECTURE OF BURIED FLOODPLAIN SEDIMENTS OF THE WEIßE ELSTER RIVER (GERMANY) REVEALED BY A COMBINATION OF CORE DRILLINGS WITH 2D AND 3D GEOPHYSICAL MEASUREMENTS

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The fluvial dynamics of a river are generally complex and non-linear, showing repeated periods of sediment erosion and re-deposition in different parts of the floodplain. Therefore, understanding the fluvial architecture of a floodplain, i.e. the three-dimensional spatial arrangement and genetic interconnectedness of different types of fluvial sediments, is fundamental to obtain well-based information about natural or human factors controlling the fluvial dynamics from fluvial sediment archives. Whereas the fluvial architecture can relatively easily be studied in recently incised river systems with large natural outcrops, this is challenging in currently buried floodplain deposits. Within the frame of a multi-disciplinary geoarchaeological project, we investigated the fluvial architecture of the middle and upper Weiße Elster floodplain in Central Germany that offers an extraordinary long-standing archive of Holocene flooding patterns and landscape changes in sensitive loess-covered Central European landscapes. At three sites we did a combined interpretation of 2D transects of Electrical Resistivity Measurements (ERT) and closely spaced core drillings with 3D measurements of Electromagnetic Induction (EMI) of larger floodplain areas. The aim was to decipher the fluvial architecture for larger areas at these sites with high resolution and to reconstruct the main steps of their former fluvial dynamics. Our novel systematic approach allows for time and cost-efficient core drilling based on the preceding ERT measurements, and enables a spatial up-scaling of the main elements of the fluvial architecture from the 2D floodplain transects to their surroundings. Doing so, it was possible to (i) extrapolate the distribution of thick fine-grained silt-clay overbank deposits to larger floodplain areas, and (ii) follow currently buried palaeochannel structures in these areas what allowed to reconstruct former channel patterns. It turned out that fine -grained sandy and silty-clayey overbank deposits overlying basal gravels in the middle and upper Weiße Elster floodplain were deposited during several periods that were separated from each other by geomorphologically stable periods with soil formation. These deposits were affected by strong lateral erosion during two main periods probably linked with strong meandering or possibly even braiding. Brick and pottery fragments in the corresponding sediments indicate that the last phase of lateral erosion and fine-grained sedimentation must have occurred during the Little Ice Age. This study demonstrates that our novel systematic method combination is a promising and cost-effective approach for future studies of buried floodplain sediments.

BOTTOM SEDIMENTS AS AN ARCHIVE OF ANTHROPOPRESSURE – CASE STUDY (KIELCE UPLAND, POLAND)

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Accumulation of bottom sediments is a process characteristic of all types of water reservoirs. The course of this phenomenon, and thus the composition of the bottom sediments, depends on many factors, including: the geological structure of the catchment area, the type of soil cover, the morphology of the basin and the size of the reservoir, hydrological and climatic conditions, and the degree of the catchment development [14]. Regardless of the type of source of origin, trace metals migrating to waters are deposited mainly in sediments, which, due to their ability to absorb and adsorb pollutants, are often referred to as geosorbents [1]. Bottom sediments accumulate contaminants that enter the reservoir over a long period of time. It can be argued that sediments are the ecological condition indicator of not only reservoirs, but also their catchment area. These deposits playing the role of a specific integral indicator of the level of anthropopressure. The analysis of the chemical composition of bottom sediments allows to determine the condition of the water ecosystem, as well as the degree of its degradation [1-4, 6-9, 11-13].

The aim of this study is to present a preliminary interpretation of the first results of the physical and chemical properties of bottom sediments from 3 selected water reservoirs located in the Kielce Upland.

Study area and methods

The investigations concerned three water reservoirs: Borków, Wilków and Rejów located in the Kielce Upland (Fig. 1, Fig. 2).

Fig. 1. Study site areas: 1 – Borków Reservoir, 2 – Wilków Reservoir, 3 – Rejów Reservoir.

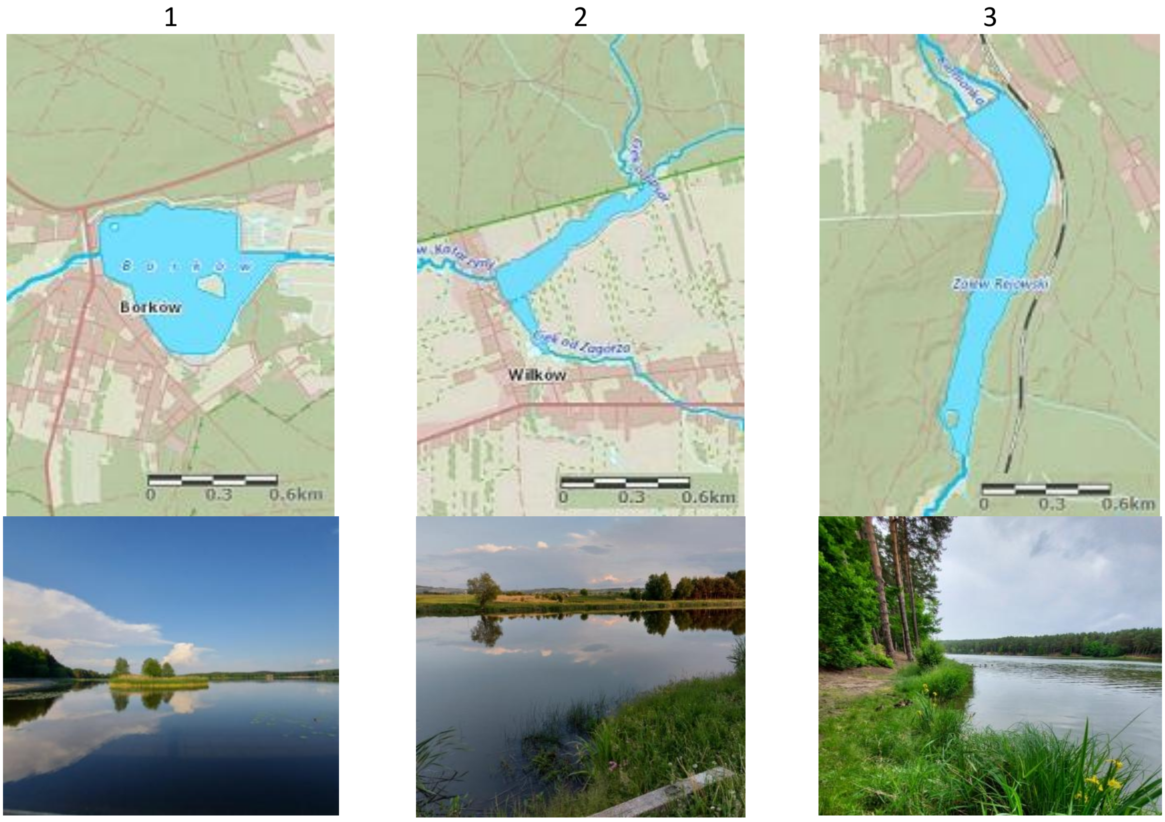

Fig. 2. Investigated water reservoirs 1 – Borków Reservoir, 2 – Wilków Reservoir, 3 – Rejów Reservoir [5, photos: I. Tomczyk-Wydrych, 2021].

The studied water reservoirs differ in age, size and the way of the catchment development. They are multi-purpose and their basic functions are: retention and tourist-recreational [3, 10, 11] (Table 1).

Table 1. Characteristic of the reservoirs and their catchments.

Reservoirs	Location	Construction year	Area [ha]	Catchment	Use	Type of reservoir / river	Forms of nature protection
Borków	50°46'22.7"N 20°45'21.8"E	1976	36	Czarna Nida od Stokowej do Pierzchnianki	forest area, built-up areas	flow tank, Belnianka	Cisowko-Orłowiński Protected Landscape Area
Wilków	50°55'11.3"N 20°50'58.0"E	2004	10.4	Lubrzanka do Zalewu Cedzyna	forest area agricultural	flow tank, Dopływ ze Św. Katarzyny	Świętokrzyski Protected Landscape Area, the buffer zone of the Świętokrzyski National Park, borders the Natura 2000 area (Łysogóry)
Rejów	51°04'56.1"N 20°51'17.5"E	rebuilt in 1939	30	Kamionka	forest area agricultural	flow tank, Kamionka	none

Samples of bottom sediments from the studied water bodies were collected in the summer of 2021 at designated test points from the 0-5 cm thick top layer using a tubular bucket. Five samples were taken at each test site and placed in sterile polyethylene containers. In laboratory conditions, the collected material was dried at room temperature, and then the concentration of trace metals was determined.

Bottom sediments are an excellent indicator of the influence of the catchment area on the geosystem of the reservoir, and also reflect its ecological condition. The selected water reservoirs differ from each other, among others age, area and the way of managing the catchment area. This suggests that the content of trace metals in bottom sediments will vary, which may be the result of anthropogenic pressure caused the impact of industry, agricultural activities, sanitary sewage discharge from sewage treatment plants and runoff from road infrastructure.

Therefore, this study focuses not only on the comparison of the chemical composition of bottom sediments, but also on determining the factors that may affect the content of trace metals in bottom sediments. The research results can be used to determine the current state of the environment and the nature, intensity and scale of the impact of natural and anthropogenic factors on the ecosystem. It is particularly important from the perspective of environmental monitoring, especially issues related to water protection and protection against pollution.

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A CUMULATIVE PROBABILITY DENSITY FUNCTION OF DATED LOWER MEUSE RIVER DEPOSITS

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Over the last decades the Lower Meuse River (the Netherlands) has been the focus of a growing number of earth-scientific and (geo)archaeological studies. Of particular interest for fluvial geomorphologists are the changes that occurred in the Late Glacial landscape, with shifts between braided and meandering river planforms, the formation of fluvial terraces by phases of channel entrenchment, and the mobilisation and redeposition of local fluvial sediments by aeolian transport. Targeted case studies have laid the groundwork for a broad understanding of fluvial responses during glacial-interglacial cycles and climatic anomalies such as the Younger Dryas [1, 2].

The Lower Meuse has also been a hotspot for geoarchaeological studies, as the catchment was home to the early agriculturalists, and it was an intensively cultivated area afterwards, particularly during the Iron Age and Roman Periods [3].

Studies from both fields of research have caused a steady growth in the data set of dating information derived from the fluvial environment, often from well-studied local settings that are supported with detailed sedimentary and palynological information.

In the current study we performed a Cumulative Probability Density Function (CPDF) on the currently available data set of c. 250 radiocarbon and OSL (Optically Stimulated Luminescence) dates that were collected within a fluvial context. A first analysis of the CPDF suggests that the clustering of dated units since the Weichselian Late Glacial coincides with; (i) changes in channel planform, (ii) phasing of the Lower Meuse flooding regime and the occurrence of extreme flood events during the Holocene, and (iii) human influence. A hitherto not deployed application of CPDF analysis in fluvial environments was to study major changes in channel planform; first occurring during the Bølling-Allerød interstadial with a shift to meandering, a return to a (semi-)braided style during the cold Younger Dryas, and a final transformation into meandering during the early Holocene. Peaks in the CPDF based on radiocarbon dates alone related to the formation and preservation of organic deposits in permanently wet residual channel zones of meandering rivers, whereas OSL dates clustered over cold periods when the sandy deposits of braided rivers formed. Moreover, a two-stage Younger Dryas climate event was inferred from the CPDF results, with increasingly dry conditions during the later part, marked by the clustering of OSL-dated aeolian deposits at that time and a sharp reduction in the formation/preservation of organic deposits. Whereas this division was previously suggested based on local observations in the Lower Meuse Valley [4], the current CPDF demonstrates its existence over a larger region, and thus further supports the significance of such climate-induced changes on fluvial behaviour.

Following the more standard application of CPDF-analysis, we used the clustering of change (activity) dates that marked lithological transitions versus those of stability dates to reconstruct phased changes in the Lower Meuse flooding regime. Intervals of increased and reduced dating information were compared with similar results from NW-European river catchments [5] and other hydroclimatic proxy records in order to infer a regional coherence in flood regime changes and to identify the dominant climatic forcings for these to have occurred.

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FLUVIAL TERRACE FORMATION ON THE PERUVIAN COAST CONTROLLED BY PRECESSIONAL FORCING AND LOWER CRUSTAL FLOW

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The ~2200 km-long Peruvian coast is characterised by large river systems that originate in the high Andes mountains and that flow towards the Pacific Ocean thereby traversing the Western Cordillera and the forearc plain. The fluvial terrace sequences of those river systems have hardly been investigated, despite that the region experiences short-term and long-term climate variability that is registered in the terrace record [1, 2, 3]. The coastal areas also experience intense tectonic deformation [4], especially in southern Peru where subduction of the Nazca Ridge has uplifted the coast and formed well-developed marine terraces [5]. No attention has been paid so far to fluvial terraces as recorders of these crustal movements. In order to fill this knowledge gap we present the preliminary results of a study on the fluvial terrace record of the Cañete River, located at 14° S latitude. The terraces were mapped along an 80-km-long transect that traverses the entire terrestrial forearc and part of the Western Cordillera. Three terrace levels were mapped at ~5 m (T1), ~15 m (T2) and ~30 m (T3) above floodplain level (+FP). InfraRed Stimulated Luminescence (IRSL) and post IR IRSL (pIR IRSL) dating of nine terrace sediment samples was carried out to evaluate the behaviour of five different signals ($IRSL_{50}$, $IRSL_{110}$, $IRSL_{180}$, $IRSL_{225}$ and pIR $IRSL_{290}$). The results showed that the $IRSL_{50}$ and the $IRSL_{225}$ signals often overestimated the age. The $IRSL_{110}$ and $IRSL_{180}$ signals, and in five samples also the $IRSL_{50}$ signal, gave coherent ages. Terrace ages of ~0.9 ka were obtained for the current floodplain (FP); ages of ~11-14 ka for T1; ages of ~22-31 ka for T2 and T3 was estimated to have formed ~30-47 ka ago. The ages of the FP, T2 and T3 are in agreement with the last three positive, or transitions between positive and negative, phases of the precession cycle, whereas T1 coincides with the last negative phase of the precession cycle. It has been shown that positive phases of the precession cycle result in increased precipitation in the Andes and rising lake levels [6] resulting in an estimated five-fold increase in fluvial discharge [2]. Fluvial sedimentation may therefore be climate-controlled as in other parts of the Peruvian Andes [7]. The number of terraces, their ages and the inferred climate control agree with published data from the nearby Pisco River [1].

Based on terrace surface elevation and age, uplift rates were estimated at ~0.4-0.7 mm a^{-1}. These rates are much higher than the highest, reported uplift rates for the southern Peruvian coast, which are < 0.5 mm a^{-1} maximally at the location of the subducting Nazca Ridge [5, 8] and < 0.2 mm a^{-1} away from the Nazca Ridge [5]. The Cañete River is situated north of the area that is being uplifted by the Nazca Ridge and ridge subduction can therefore not be directly responsible for the high uplift rates in the Cañete River valley. The forearc is currently subsiding and in transtension, which should pose unfavorable conditions for terrace formation [4]. The Western Cordillera obtained most of its current elevation during the late Miocene [9], so subduction of the Nazca plate is most likely not responsible for the anomalous uplift rates either. Instead, exhumation ages based on apatite fission-track and (U-Th)/He analysis shows increasingly younger ages when going from the Nazca Ridge axis northward towards the Cañete River basin [10]. Seismic recordings of the lower crust and upper mantle show that at the location of the Cañete River valley the Moho is situated ~10-20 km higher than in other parts of the southern Peruvian coast where ridge subduction occurs [11]. This was explained through a possible mechanism where Nazca Ridge subduction creates lower crustal flow towards its flanks [11]. We therefore hypothesize that the rapid uplift in the Cañete River valley may be related to lower crustal flow.

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THE RELATIONSHIP BETWEEN INTERNAL SEDIMENTARY ARCHITECTURE AND MEANDER EVOLUTION WITHIN THE STUIVENBERG DELTAIC CHANNEL BELT.

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Meandering rivers function in a variety of environments and geological settings [1 - 4]. Important distinction can be made between meandering systems within deltaic respectively valley settings. In the latter, fluvial activity is often laterally constrained (narrow floodplain, channel in incised position), meaning that the river self-reworks its channel belt over long periods of time. In contrast, in major delta plains individual meander belts tend to function for relatively short time only, because of repeated repositioning of channel activity (i.e. avulsions) across the wide delta plain and aggradational setting. The short 'lifespan' and favorable preservation of deltaic channel-belt makes them well suitable to study the architectural products of steady meander evolution,without complications of repeated bend cutoffs, and of abandonment deposits induced by avulsions.

Our main research question is how stage wise meander belt evolution (initial activity, maturation, abandonment) governed the eventual sedimentary architecture in deltaic meander belts. We studied this in detail for the classic Stuivenberg channel-belt (StvCB) in the Rhine-Meuse delta. Using traditional coring based methods (>4000 boreholes in the StvCB) as well as high resolution LiDAR data the channel belt boundaries and the top and thickness of channel, overbank and residual channel deposits were mapped. We developed a procedure to separate 'main activity' from 'abandonment stage' sandy facies in our cross-sectional and planform architecture mapping. Using empirical hydraulic geometry relationships [5, 6] in combination with cross-sectional observations a first order approximation of ~100m is chosen to represent a uniform width of the paleochannel (Fig. 1). The reconstruction of ridge swale morphology made use of borehole- and LiDAR datasets.

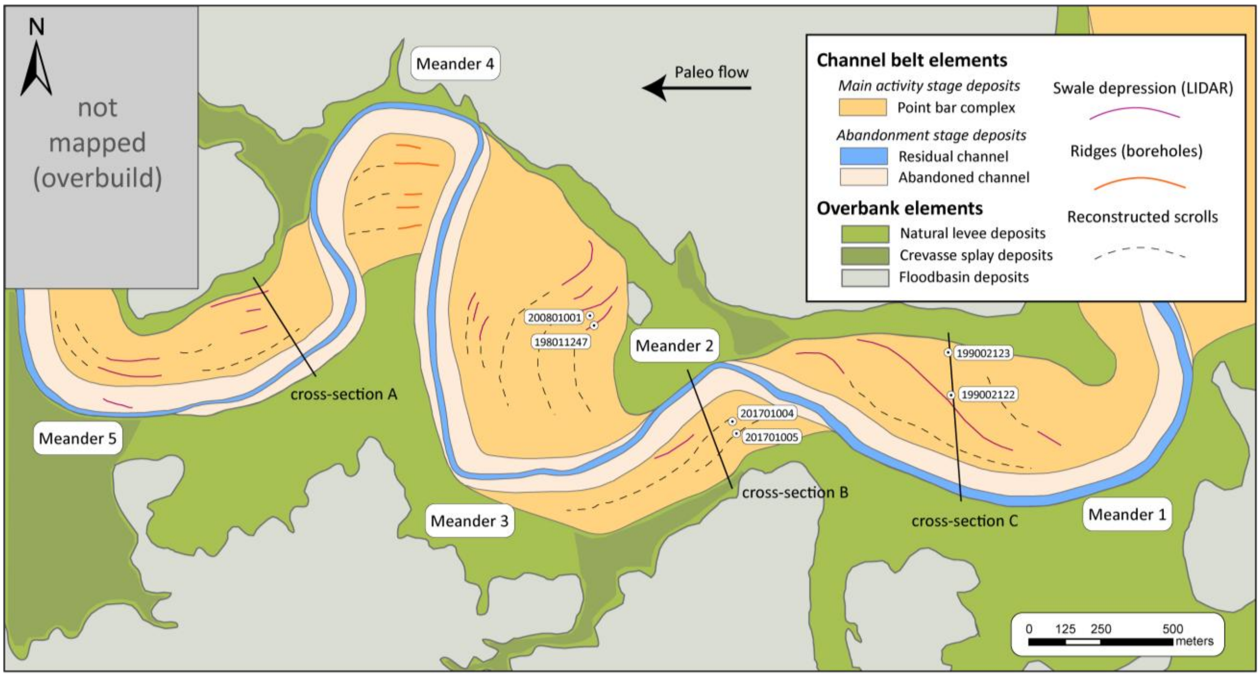

Fig. 1 Planform reconstructions of the main activity and abandonment stages of the StvCB

Our reconstructions show that abandonment stage deposits turn out to comprise roughly 1/3 of the width, while ridge-and-swale scroll complexes cover the other 2/3 of the Stuivenberg meander belt. Combining ridge-swale curvature and channel belt width mapping allows trace meander migration history and to classify the trajectories of individual meanders (e.g. translation, expansion and rotation). Strategically positioned cross-sections (Fig. 1-2), allows to explore relationships between the lithological composition of the StvCB meander belt sands and the stage-wise meander evolution. Sands laid down during the StvCB's main activity stage, show a clear difference between convex and concave zones. Where convex accretion occurred, lower bar deposits lack vertical sorting trends, whereas upper bar deposits express great variability in such sorting trends (with both FU and CU sequences occurring locally Fig. 2). Lower bar deposits identified to be deposited in initial stages of StvCB activity, are finer grained than those trapped in later stages (Fig. 2). Where concave accretion and downstream translation of meanders occurred, the sedimentary architecture is more complex and the lithology finer (including non-sand accretionary units). The lithology of the abandoned channel zone, is found to be only modestly finer grained compared (and their top only subtly lower elevated) compared to neighboring deposits from the main activity stage. Our results show that the architectural subdivision of the deposits into 'abandoned channel zone', 'active phase: convex point bar' and 'active phase: concave accretion' turned out functional in analyzing grainsize variation in heterolithic deposits of the StvCB.

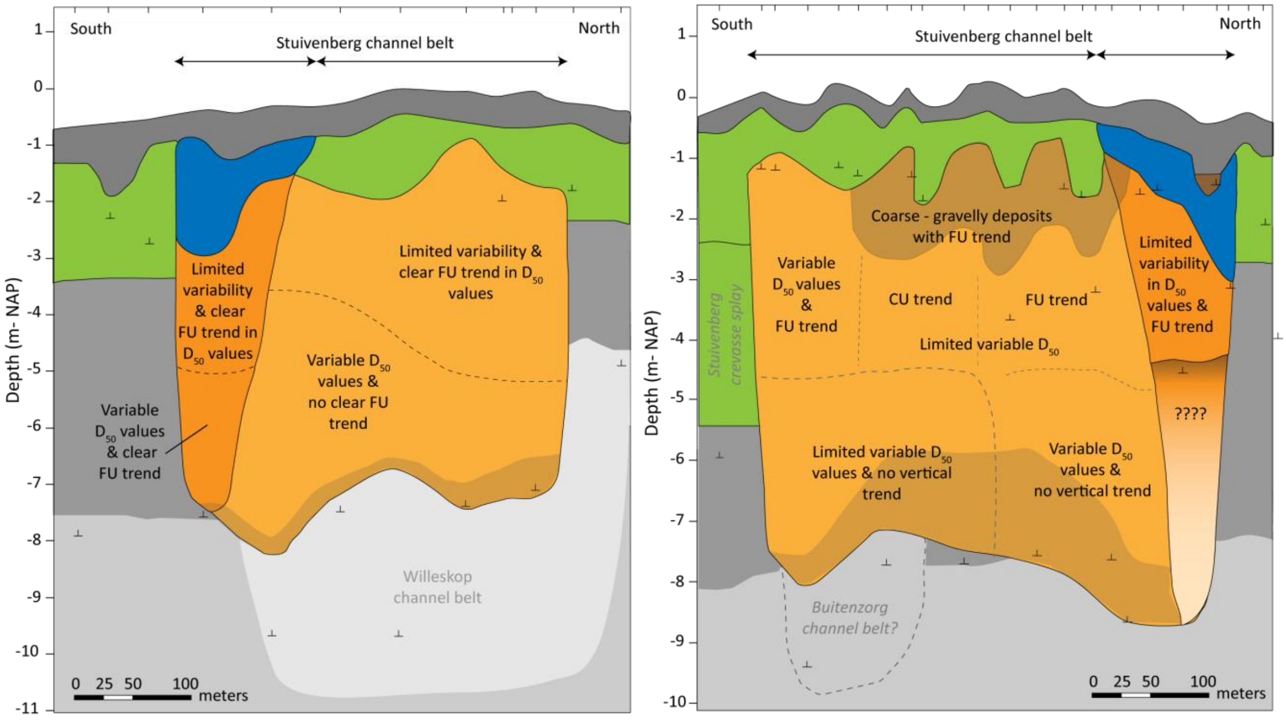

Fig. 2 Lithological cross-sections A (left) and B (right) over the StvCB.

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A PUNCTUATED RIVER INCISION MODEL FOR QUATERNARY STRATH TERRACE FORMATION

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We define a conceptual model of punctuated incision for strath terrace formation, with implications for deriving river incision and rock uplift rates. To illustrate this model, we present a detailed ~200 kyr history of strath terrace formation spanning two stratigraphic levels in the High Atlas Mountains (NW Africa). Extensive preservation and exposure of strath-top gravels, and the post-orogenic setting unaffected by eustatic sea level, allow us to derive a rate of base-level fall, integrated over periods of strath-top deposition, metastable equilibrium, and incision, which is consistent with an independently constrained regional rock uplift rate [1]. In addition, we find limited correlation of strath-top deposition with climatic shifts, and variable lengths of time between terrace incision across stratigraphic levels and downstream locations. Combining our conceptual model with our well-constrained terrace formation history allows us to demonstrate how often-used assumptions about Quaternary river incision and deposition can lead to the problematic Sadler Effect [2, 3]: an apparent dependence of incision rates on measured time interval. Subsequently, reinterpreting previously published data [4, 5] we demonstrate that the punctuated incision model, even when combined with limited terrace age data, leads to more consistent and parsimonious conclusions about rates of river incision, rock uplift and base-level lowering.

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THE BRZOZÓWKA RIVER VALLEY DEVELOPMENT BASED ON PALAEOGEOGRAPHIC AND GEOGRAPHICAL METHODS

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The main aim of this presentation is to present the results of palaeographic research on the Brzozówka River (NE Poland) and its left-bank tributary, the Biebła River. In particular, environmental changes occurring within the river valley bottoms will be recognized, as well as the phases of the dynamics of fluvial processes and the phases of peatland initiation, as well as the natural and / or anthropogenic causes of these changes.

In prehistory, this area became an ecumen of the community of Lusatian Urn Fields, with which the settlement in Jatwieź Duża should be associated [6], [8]. This archaeological culture from the Bronze Age, functioning in the Subboreal period, was the first to use the nearby natural environment on a large scale for its needs, and traces of its activity are recorded in the area of the Brzozówka and Biebła valleys.

The relief of this area was shaped during the last two glaciations. The Middle Polish glaciation in the Warta Cold Stage gave the main relief [4], [5]. During the next glacial advance (Vistula glaciation), this landscape was remodeled in periglacial conditions (Fig. 1).

During this period the Pleistocene relief of the bed of the Brzozówka valley, probably of melt-out origin [4], underwent evolution under the influence of two factors. The first of these was meltwater from the melting ice sheet, which flowed down to the south and entered the valley floor to form a series of fluvioglacial terraces (sandur plains) [1]. The second factor was probably the intrusion of a part of flood waters from the outflow of the Narocz-Vilno and Skidel lakes into the Brzozówka depression. This current followed the valley of the Łososna River and the Pripilin-Nurki. It reached the Biebrza and Narew valleys [2]. This event occurred around 15.5-15.0 ka, [3] or 16.2 ka [2]. During this period, the river had a stream development (Fig. 1).

The Pleistocene relief of the Brzozówka river valley was transformed during the late glacial and Holocene periods. The flow direction was reversed and the river was flowing in the N direction into the Biebrza. The reason for this may have been the decreased erosion base after the undercutting of the Biebrza River at the end of the younger Pleniglacial.

At present, the river in the surveyed section has a meandering character.

The Brzozówka depression is filled with peats which started to develop from 9770±110 BP (MKL-5082), which considering probability at 95,4% gives intervals 9457 - 8805 BC (91, 3%), 9551 - 9481 BC (2.4%) and 9657 - 9605 BC (1.7%) and a probability of 68.3% determines the interval 9371 - 9123 BC (57.4%), 8997 - 8997 BC (10.5%) and 8884 - 8880 BC (0.4%) (Fig. 2).

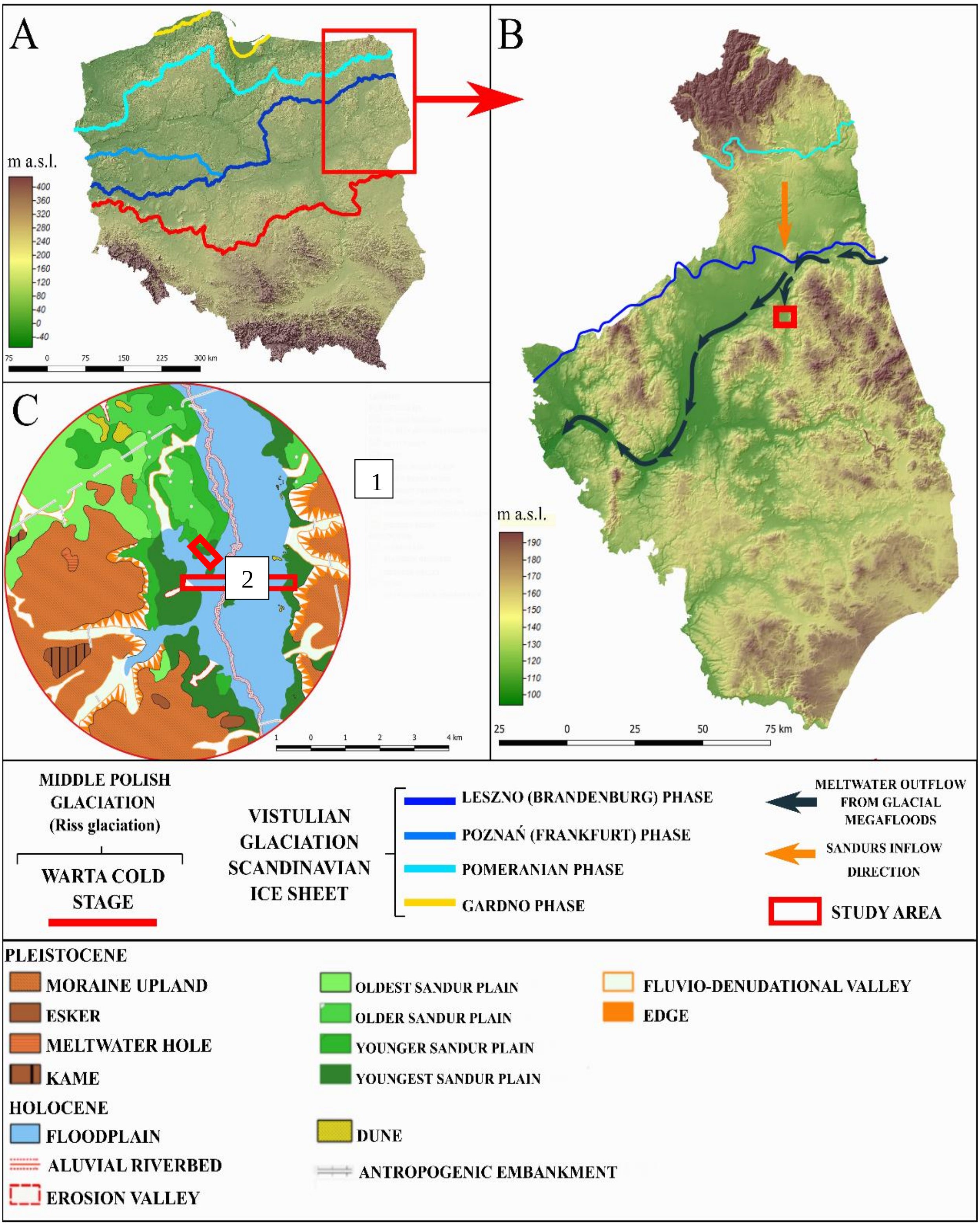

Fig. 1. Location of the study. A – Hypsometric map of Poland with glaciation ranges (compiled after [5]); B – Hypsometric Map of Podlasie Voivodeship (compiled after [7]); C – Geomorphological map of the study area (by M. Frączek, T. Kalicki); 1- Brzozówka cross-section profile, 2 - Biebła cross-section profile.

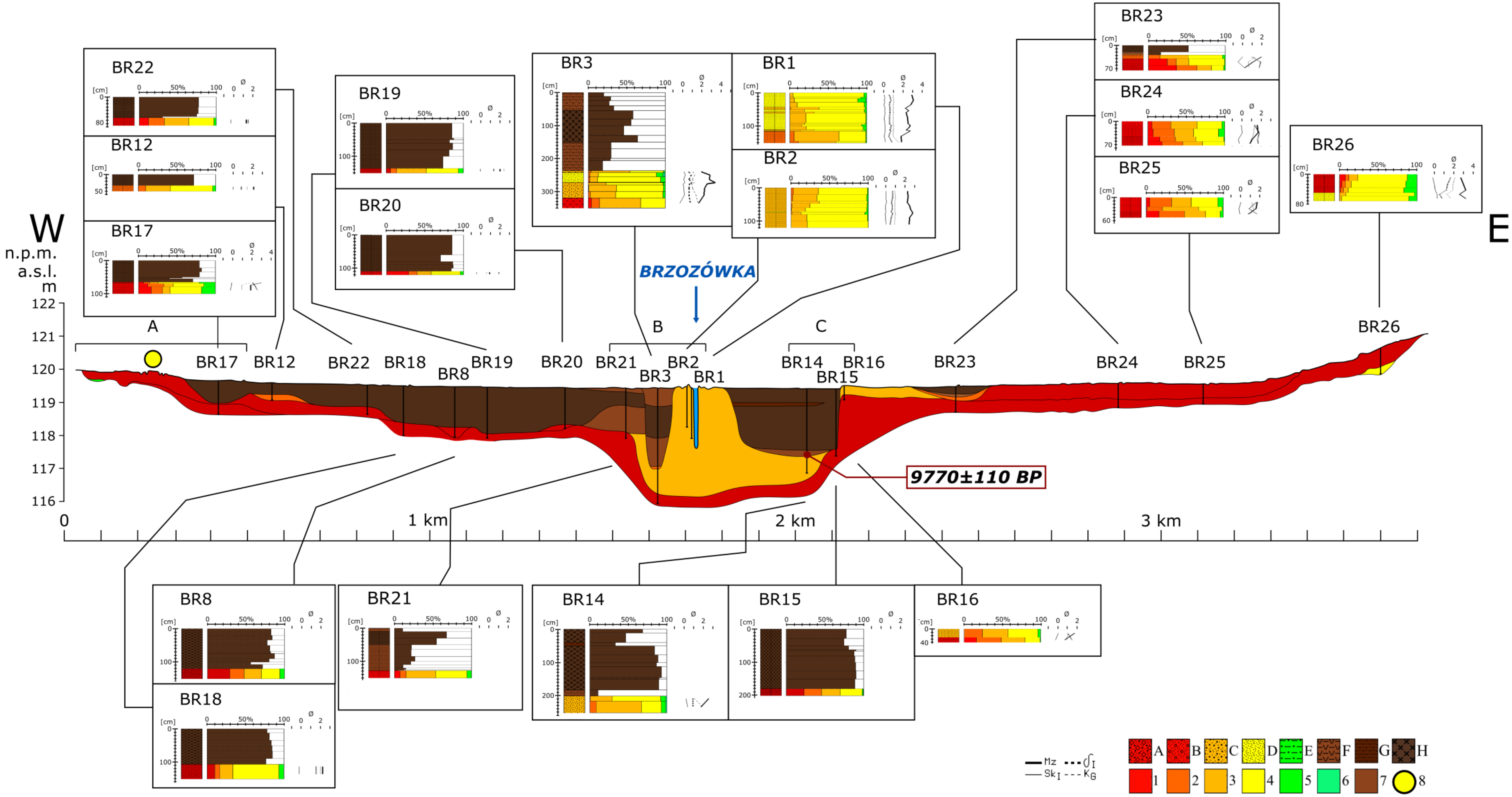

Fig. 2. Schematic geological cross-section of the Brzozówka valley. Lithology: A - sand with gravels, B - sands with single gravels, C - medium-grained sands, D - fine-grained sands, E - silts and clays, F – peaty silt, G - silty peats, H – peats; Fractions: 1 – gravel, 2 - coarse sand, 3 - medium sand, 4 - fine sand, 5 - silt and clay, 6 - clay, 7 - the content of organic matter; Folk-Ward's distribution parameters: Mz - mean diameter, δ_I - standard deviation (sorting), Sk_I - skewness, K_G -kurtosis

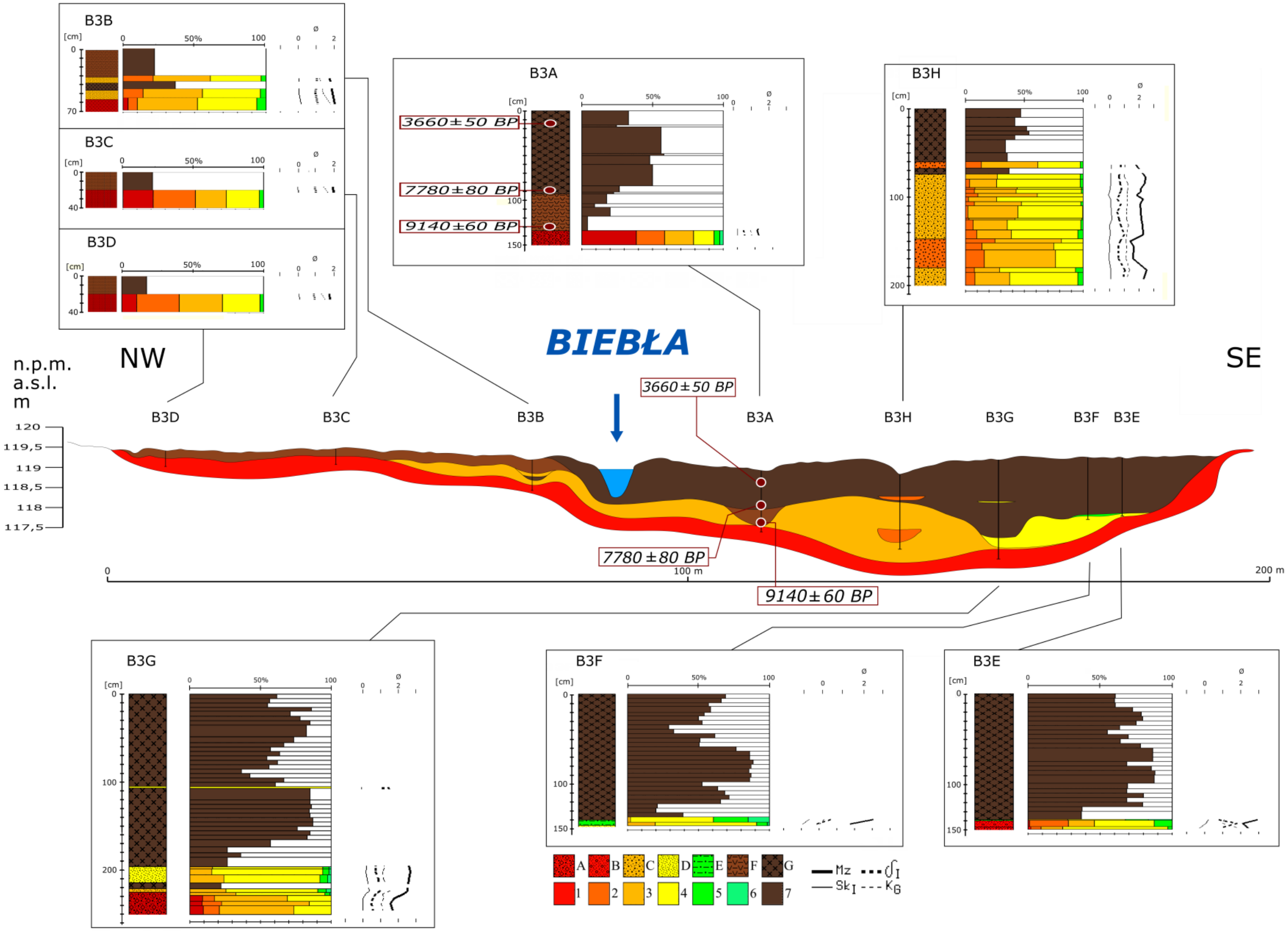

Fig. 3. Schematic geological cross-section of the Biebła valley. Lithology: A - sand with gravels, B - sands with single gravels, C - medium-grained sands, D - fine-grained sands, E - silts and clays, F – peaty silt, G – peats; Fractions: 1 – gravel, 2 - coarse sand, 3 - medium sand, 4 - fine sand, 5 - silt and clay, 6 - clay, 7 - the content of organic matter; Folk-Ward's distribution parameters: Mz - mean diameter, δ_I - standard deviation (sorting), Sk_I - skewness, K_G -kurtosis

Recognition of geological structure of the bottom of the Brzozówka valley (fig. 2) made it possible to differentiate three segments of the valley of different age and structure:

a. sand terrace of the valley built of sand and gravel deposits,

b. peat plain of 0.5 to 2 m thickness, which started to grow from the beginning of the Holocene on uneven mineral substrate, which may be a remnant of an old system of rivers,

c. alluvia accompanying the modern river bed, made up of well-sorted sands of the meander drainage (fig. 2).

Reorganisation of the fluvial environment of this area is better visible in the Biebła valley bottom (fig. 3), which is a left-sided tributary of the Brzozówka River. The results of the research made it possible to distinguish several phases in the evolution of the valley:

a. erosion phase, which took place after the Warta cold stage. During which two levels of sand and gravel series were formed in the bottom of the Biebła valley,

b. the gradual concentration of flows and the establishment of a single-channel system. This may have occurred at the turn of the Late Glacial and Holocene, as organic sediments in the bottom of the shallow palaeochannel have been dated to 9100 BP,

c. development of valley floor peatlands during the period of full Atlantic forestation (from 7780 BP),

d. Holocene period of meandering rivers where the development of valley bottom peatlands began during the period of full Atlantic afforestation (from 7780 BP),

e. Subboreal period - during this period intensive human activity takes place in the catchment area. From 3660±50 PB, cal. 2147-1897 BC (B3A) a marked decline in the organic matter content of the peats is observed. This probably indicates deforestation of the catchment.

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