

Phases of gully erosion recorded in alluvial fans (Lublin Upland, E Poland)

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Abstract: The study was focused on the alluvial fans formed in the bottom of the Bystra river valley. A detailed analysis of four fans allowed to distinguish several phases of gully erosion related to human activity. The gullies started to develop in the Neolithic times, the subsequent phases of gully erosion could be dated to: Bronze Age, Middle Ages. In modern times, most of the sediments have been retained within the extensive gully systems.

Keywords: alluvial fans, historical gully erosion, loess areas, E Poland

Introduction

In the case of loess areas, which are particularly susceptible to human impact, alluvial fans built from material washed away from gullies play a significant role in the relief of river valley bottoms. Additionally, fans are of great significance when the study of past morphodynamic processes is concerned. This is mainly because the type, structure and texture of sediments constituting the fans comprise a record of climate changes and other processes occurring in catchments (Ballantyne 1991, Chiverrell 2007). In many cases the covers of proluvial sediments cover the entire width of the valley bottom. The fans are composed of material washed away from slope systems and accumulated in the bottom of the valley shaped by fluvial processes. Therefore, these forms function as a link between two geomorphological systems.

The study was aimed at reconstructing the phases of gully erosion, strongly influenced by human activity and reflected in fan sediments of the Bystra river. Determinants, structure and age of the sediments were also studied. A significant number of gully systems occur within its loess catchment and vast alluvial fans are formed there. Four fans were chosen for more detailed study. Special attention was paid to the impact of human settlement and agriculture on the formation of fans (i.e. intensity of gully erosion). The development of human communities in the area of study was analysed based on archaeological mate-

rials, and detailed measurements of the topography of the fans were carried out (by means of differential GPS). In order to examine the structure of the fans, 66 drillings were made (total length of approx. 300 m). Additionally, sediments filling contemporary gullies were examined. Samples were also taken for OSL and carbon dating as well as for a detailed sedimentological analysis.

Area of study

The area of study is located within a Nałęczów Plateau, a loess meso-region of the Lublin Upland. This area is drained by a small tributary of the Vistula, the Bystra River that has an average flow of 1 m s^{-1} . The floor of the valleys, both of the Vistula and the Bystra, constitutes the base level of erosion for the network of gullies with an average density of 2.5 km km^{-2} that, however, locally exceeds 10 km km^{-2} . The main gully systems cut not only through the loess cover, but also through the glaciogenic sediments and sometimes the lime silicate bedrock.

The study was carried out in the vicinity of Celejów village where, on a stretch of 2 kilometres, three big gully systems (catchment area of $0.5\text{--}1.0 \text{ km}^2$) as well as three smaller gully systems discharge into the valley of the Bystra river (Fig. 1). The gully density ranges from 5 to 10 km km^{-2} . Gullies are in-

cised into the bottoms and slopes of dry erosion-denudation valley, and fragmentarily even into the loess plateau. A number of alluvial fans of different sizes occur at the mouths of the gully systems.

Results and discussion

The sediments of the alluvial fans consist of four main series: 1) upper silts, 2) sands and gravels, 3) silts and sands and 4) lower silts. The sediments have a different stratigraphic position and structure in the particular alluvial fans. In a fan located near the left slope of the valley, there are no lower silts, only the other three series are present. In the upper and middle section of the fan, a series of sands and gravels covers the alluvial fan from the Vistulian glaciation. In its distal part it lies on peat and peaty aggregate mud. In the axis of the fan the sediments form a dome while in the distal part they have a palmate pattern. The gravel-sand sediments are covered completely by sands and silts. The upper sediments of the alluvial fan are made up of upper silt and present-day soil (Fig. 2).

Two alluvial fans that can be found at the mouth of gully systems cutting into the right slope of the valley are built in a different way and cover different

sediments. The floor series of these fans are lower gley silts that transform into silts of flood plain in the direction of the axis of the valley. The sediments border laterally and vertically with lithologically diverse sediments of the meander belt of the Bystra river – sands, sandy-silts, sandy gravels and silts. Sediments of alluvial fans and flood deposits together with the bed material lie entirely on a 2.5 meter thick layer of peat that was probably deposited from the Late Glacial Period to the early Neolithic Age.

The analysis of stratigraphy and structure of all sediments of the Bystra river bottom as well as material deposited in gullies point to the fact that 5–6 gully erosion phases could have occurred in this part of the Nałęczów Plateau.

The beginning of the Holocene erosion was probably linked to the settlement of the Neolithic people, their farming and animal husbandry activity. In the Celejów area, Neolithic settlements were concentrated mainly north of the Bystra valley on flat areas of the loess plateau in the upper parts of dry valley catchments. The settlements are represented by two Neolithic agricultural cultures (the Volhynia-Lublin Painted Ware culture and the Funnel Beaker culture) and campgrounds of the Eneolithic nomadic and pastoral Globular Amphora culture. People of those cultures were active in the 4th and first half of

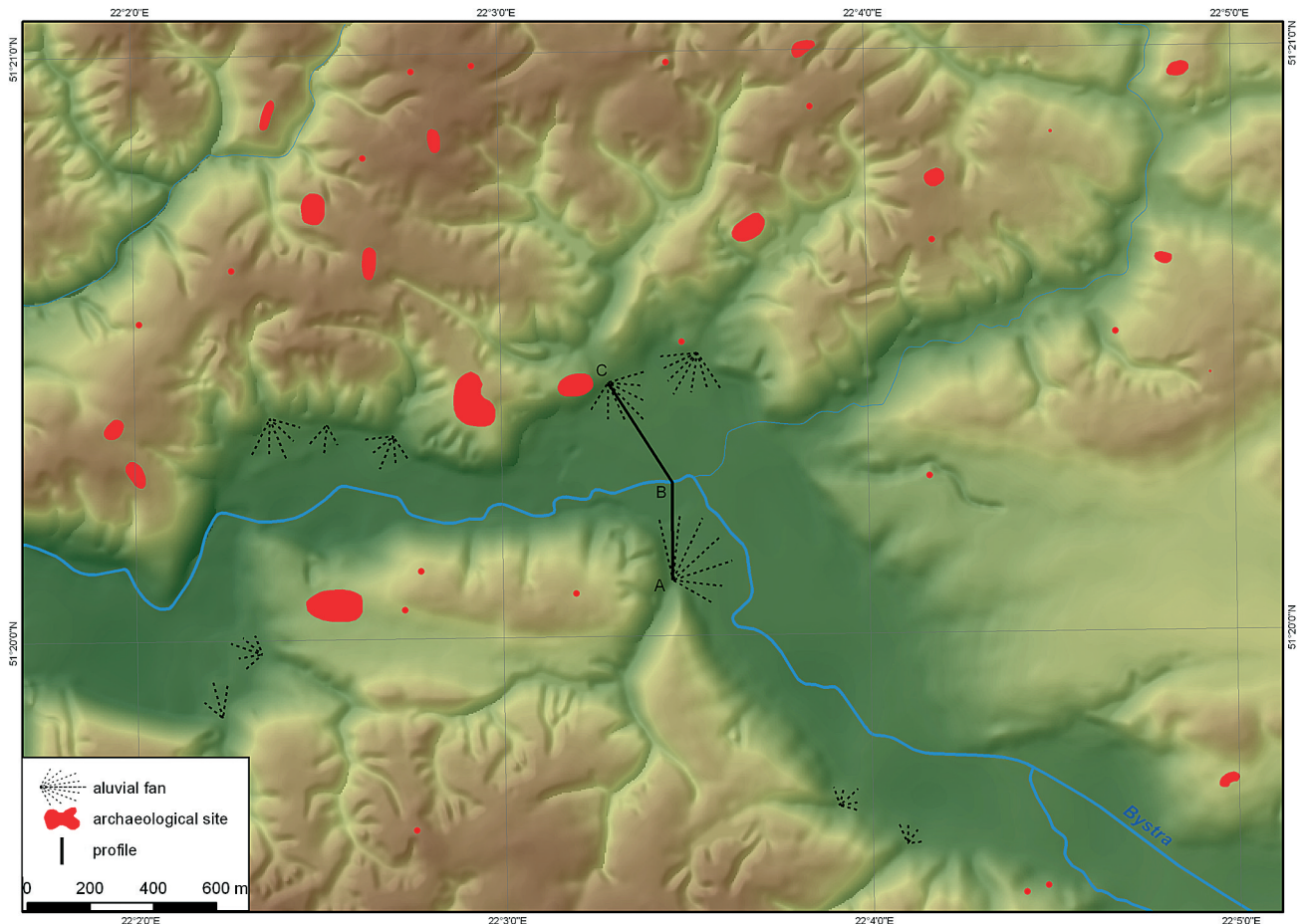


Fig. 1. Relief and archaeological sites of studied area

the 3rd millennium BC (Kadrow & Zakościelna 2000, Nogaj-Chachaj 1991). People of the Neolithic and Bronze Age cultures that followed probably settled in the same locations and inherited deforested areas from their predecessors. The fan and flood sediments point to the fact that only the loess was eroded, and eroded material was deposited in water-logged valley bottom as it is evidenced by the gleying of sediments. Fossil soils are absent in fans, which may indicate sedimentation in the flooded area. However, no data are available concerning the duration of the first phase of sedimentation at the mouths of gullies. Sedimentation probably continued until the Bronze Age.

Archaeological materials indicate a distinctly lower number of settlement structures and limited human activity in this area for approx. 1.5 thousand

years. The next stage of settlement occurred in the early Middle Ages (from 6th century AD). This phase was not very intensive and limited only to the southern part of catchment area. In that period, however, there were considerably fewer settlements than in the Neolithic.

The subsequent, sand-gravel series probably formed as a result of a single, very dynamic sedimentation episode. It could have been triggered by catastrophic rainfall events that washed out fluvio-glacial deposits to the forefield of the gullies. The radiocarbon date of twig remains lying at the top of the sand-gravel series may indicate that the catastrophic rainfall events occurred in the 10th c.

The subsequent phases of intensive gully erosion are documented by two series of fan sediments: sand-silt and silt. The lower series were deposited as

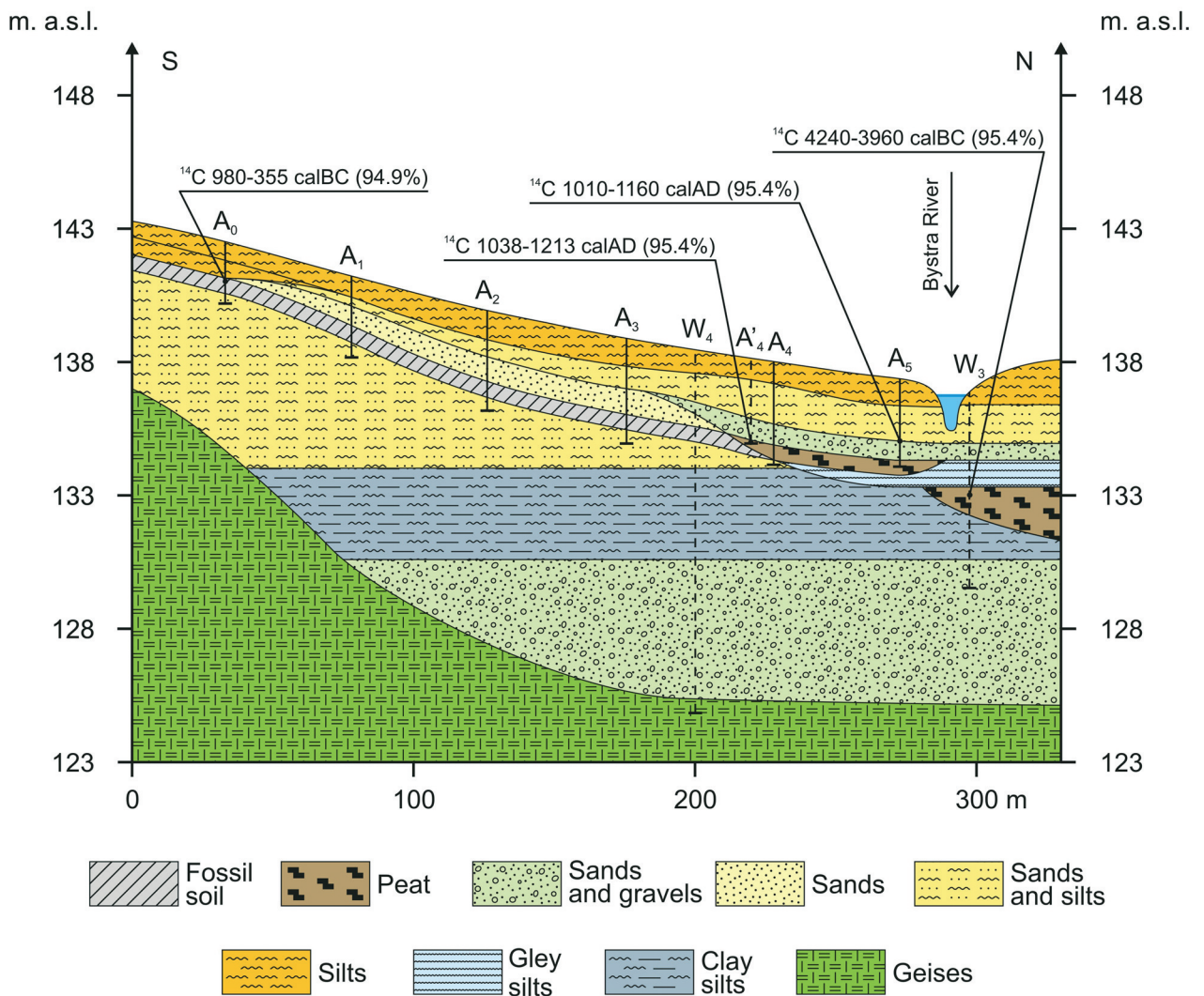


Fig. 2. Cross-section of the sediments in the Bystra river valley (location of the profile – Fig. 1)

a result of dynamically varied sheet floods, probably under changing climate conditions. The lithological variability of these series may also be linked to the fact that loess and sand sediments were exposed at different time. The top series are connected with low-energy flows on the fans. Above the main Holocene forest soil, two poorly developed soils occur, which indicates two phases of the reduction or even cessation of erosion processes as well as three phases of intensive erosion in the lower parts of gullies. At current stage of research, no data are available to enable the dating of these processes. Historical research indicates a dynamic development of settlements in the central part of the Bystra catchment in the Middle Ages (Rozwałka 1999) and in the period of the modern development of manorial economy. In modern times, soil has been forming on the surface of the fans, which indicates the absence of intensive transportation of sediments to the surface of the fans under study. The bulk of the eroded material has remained in the gullies.

Conclusions

1. Based on the analysis of colluvial, fan and flood sediments in the Bystra valley, it can be surmised that gullies in the Celejów area began to form in the Neolithic and were developing until the Bronze Age as a result of man's agricultural activity.
2. The subsequent phase in the development of gullies was linked to the catastrophic rainfall events that probably occurred in the 10th century.
3. Gully systems were developing very intensively in the Middle Ages as a result of manorial farming

and extensive deforestation of the catchment. The deposition of sediments in the forefield of the gullies occurred in several phases.

4. The development of contemporary soil on surface of fans indicates that sediments have been retained inside the extensive gully systems.

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