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SOIL SAND: ITS ORIGIN, TRANSPORTATION AND PART PLAYED IN THE CONSTRUCTION OF MUD-SUPPORTED FLOODPLAINS IN A HUMID, TEMPERATE CLIMATE

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Detrital, pelletal cohesive materials of sand size have long been known from aeolian environment, where they occur, among others, as so-called clay dunes (Price 1963; Bowler 1973; Butler 1974; Wasson 1983). Recently, pelletal sand-sized deposits composed of soil (clay) aggregates were described from fluvial environment by Nanson *et al.* (1986, 1988) and Rust and Nanson (1986, 1989). According to the authors cited, on the Cooper and Diamantina Rivers (Lake Eyre Basin, central Australia), the deposits originate owing to floodplain erosion of cohesive, clay-rich overbank deposits in a system of shallow, braided floodplain channels (mud braids) that are active only during flood. The origin of these cohesive granular deposits is attributed to pedogenic processes that transform the top layer of tough, clay-rich overbank deposits into more or less loose, deeply cracked soil composed of sand-sized mud aggregates. During flood, these mud aggregates are transported in the mud braids as bed-load and redeposited in the form of mud bars. Another example of clay pellets in fluvial Quaternary deposits was reported by Williams (1970). All these deposits are attributable to warm, arid or at least semi-arid climate.

However, similar deposits and analogous phenomena of floodplain erosion have been observed by the present author on some Silesian rivers of south-western Poland, in an area of wet temperate climate.Originally, pelletal soil deposits were found in the Błażkowa study reach of the upper River Bóbr (Central Sudetes, ca. 480 m a.s.l., mean annual precipitation ca. 700 mm) after the low March 1983 flood. Subsequently, similar deposits were observed during four floods in the Kazanów and Gębice study reaches of the upper River Oława (Sudetic Foreland, ca. 174 – 178 m a.s.l., mean annual precipitation 591 mm) during and after the May 1984, March 1986, June 1987, and June 1989 floods. Again, pelletal soil deposits were encountered in the Błażkowa study reach after the March 1985 flood. These data clearly indicate that the formation of pelletal cohesive deposits is neither an exceptional nor a local phenomenon.

The deposits, called by the author "soil sand" (Teisseyre, in press) are composed exclusively or almost exclusively of soil aggregates ranging in median diameter from coarse sand to granule gravel (+0.4 to −1.2 phi). These are characteristically the product of floodplain erosion of both vegetated and ploughed cohesive overbank deposits occasioned by extra-channel (flood) flows. Floodplain erosion is concentrated mostly on the top (crest) part of natural levees, in crevasses and crevasse channels where flood flows attain relatively large velocities (not uncommonly in the order of 1 to 2 m s^{-1} or more; Teisseyre 1985, 1988a,b). During flood, *soil sand is transported mostly as bed-load* and/or saltation load and redeposited in the form of sheets, sediment shadows, microdelta embankments or local sediment patches. The top surface of these depositional landforms is flat, smooth or rippled.

THE BŁAŻKOWA STUDY REACH

The Błażkowa study reach is situated in a small intramontane basin to the north of Lubawka (Teisseyre 1984, Fig. 1). The flat valley floor of the basin is underlain by a continuous horizon of Holocene overbank deposits, 0.5 to 3.5 m thick, which vary from tough clayey alluvial loam to silty sand. The mean water table lies 0.6 to 1.3 m below the floodplain surface. The upper part of the overbank deposits is normally dry being subjected to soil-forming processes accompanied by repeated wetting and drying as well as freezing and thawing. As a result, the top part of the soil is porous and granular in character revealing *crumb structure* near the floodplain surface, *blocky structure* in the middle of the drying layer and *prismatic structure* in its lower part (Fig. 1). Moreover, in many places the upper part of the overbank deposits displays *columnar jointing* that penetrates the soil from the surface and disappears gradually near the limit of capillary rise (Fig. 1; Teisseyre 1984, Fig. 13, 14, Pl. IX 1, 3, XI 1, 2, XII).

This granular, porous, discontinuous structure of the upper part of soil determines its behaviour when subjected to flowing water of appropriate competence. In river cutbanks, it is columnar jointing which plays an important part in the process of bank erosion and determines to a large extent the rate and mode of bank failure during and after floods and freshets, particularly in the warm months of the year (Teisseyre 1984). Floodplain erosion, on the other hand, is attributable mostly to crumb structure of soil underlying pastures and meadows or occurring on local arable lands.

In the Błażkowa study reach, the generation, transportation and redeposition of soil sand was observed for the first time after the low March 1983 flood (Teisseyre, in press). Intense floodplain erosion occurred here on a small cornfield situated on a natural levee, close to the Bóbr channel. Flood flow, concentrated in a local crevasse, ran downslope along the cornfield cutting a new crevasse channel, which after the next flood in March 1985 was up to 50 m long, 8 to 12 m wide, and ca. 0.5 to 0.6 m deep. Soil eroded from

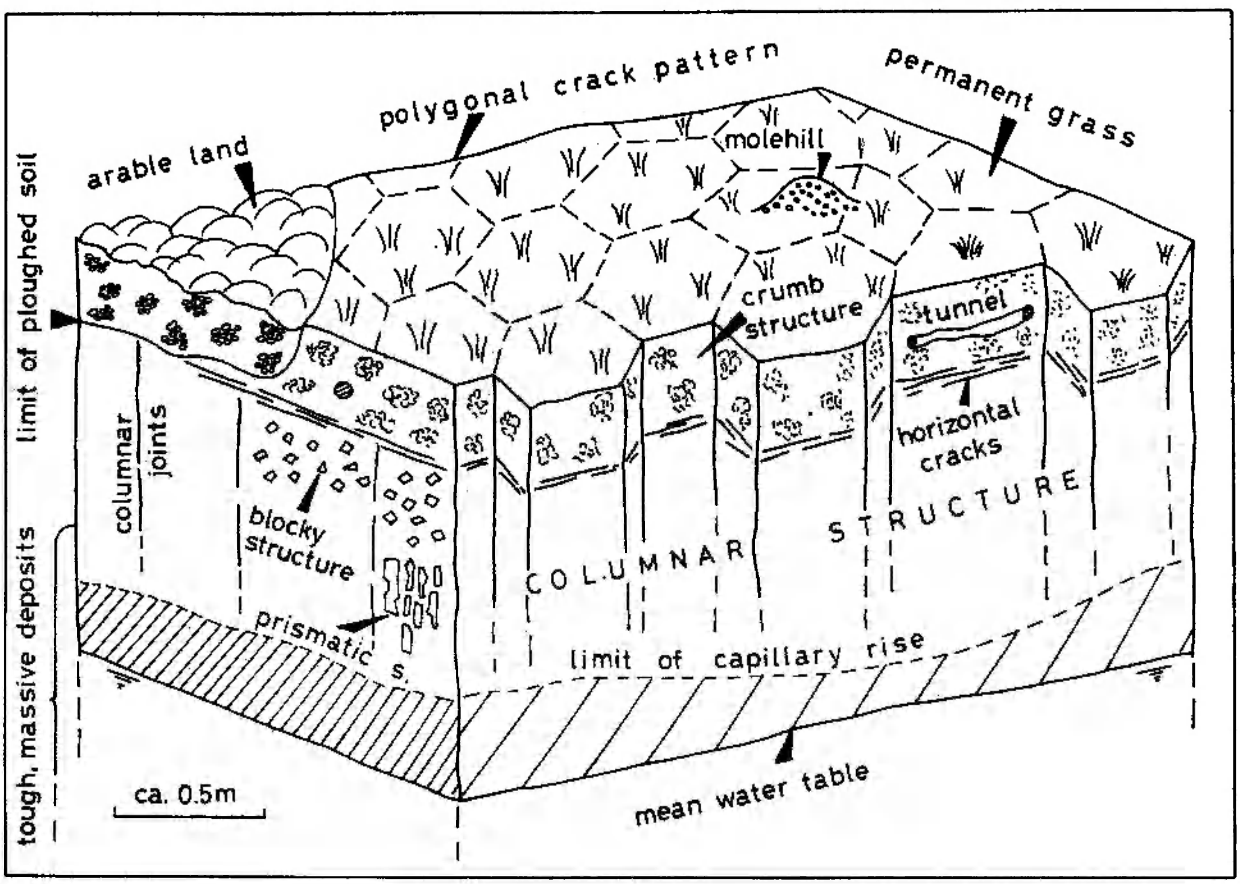


Fig. 1. Structure of top part of soil developed from cohesive overbank deposits typical of flat-floored, mud-supported floodplains of south-western Poland

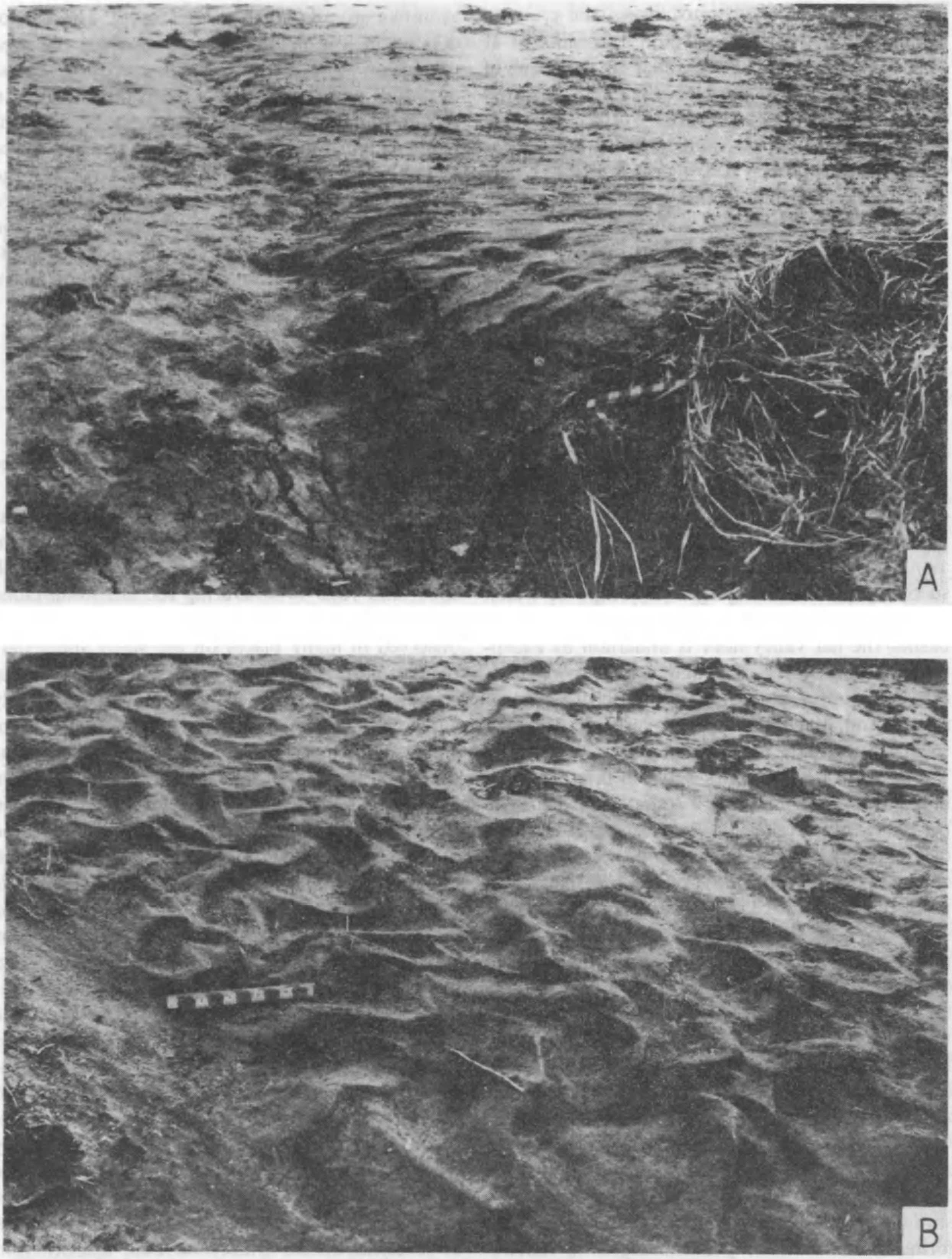


Fig. 2. Soil sand in the crevasse channel, Błażkowa study reach, the upper River Bóbr north of Lubawka (Central Sudetes). In photo A flow was generally from left to right, but in part also towards the observer (bottom). Note flat bed with minute sediment shadows and current lineation (top and centre), and current ripples and desiccation cracks (bottom). In photo B flow was from upper left to lower right. Note three-dimensional ripples of various kinds. 2-cm scale on the ruler. March 31, 1985. Photos by the author

this channel was transported down the crevasse channel, mostly as bed-load , on a distance of at least 40 to 50 m, and deposited in the form of sheets (up to 0.2 m thick) or sediment shadows (up to 0.3 m thick). The top surface of these despositional landforms were smooth (under conditions of flat moving bed) or rippled (lower part of lower flow regime conditions; Fig. 2). Internal structure of the deposits varied from parallel, subhorizontal lamination (smooth sheets) to sets or co-sets of ripple cross-lamination (rippled sheets). In sediment shadows, a characteristic shevron-like cross-lamination was found. The area of deposition was many times larger than the area of erosion. The prosesses of soil erosion, transportation and deposition of soil sand resulted in the development of a new crevasse (and floodplain) channel running across the natural levee and in vertical accretion on a local part of the adjacent floodplain. The formation of such a channel increasse the risk of avulsion and/or the development of a new anabranch. Also, deposition of soil sand on the floodplain tends to mask the pre-existing floodplain relief.

KAZANÓW AND GĘBICE STUDY REACHES

The two study reaches on the upper Oława are located in local basins situated to the south of Strzelin. Prior to river regulation, the Oława was an anastomosing/meandering river flowing along a somewhat irregular valley composed of successive basins and gorges the origin of which is very likely to be tectonic in character. In basins, the flat valley floor is underlain by exceptionally thick layer of tough clays (up to 5 m thick) the upper part of which is rich in organic matter and black (Holocene overbank deposits; their bottom part may be dated at 6,000 y BP). The mean water table lies between 0.7 to 1.15 m below the surface, although some floodbasins are permanently waterlogged. Anastomosing channels of the Oława were flanked by natural levees characterized by steep transverse slope (mean slope of the Oława is ca. $S \approx 0.002$, while transverse slope of the natural levees is up to $S \approx 0.08$ or more). The channels were stable or almost static (mean per cent of clay in banks, $B > 90\%$, Md_ϕ for bank materials = 6 to 9 phi) and their banks were densely vegetated, mostly by willows (type IV channel according to Thorne *et al.*, 1988). In a quassi-natural wild reach of the Oława near Kazanów, flood flows tended to crevasse the river banks; several new crevasses were observed by the author during a 6-year period (1984 – 1989, prior to river regulation). In part, bank crevassing was stimulated by massive plant jams that commonly formed within the irregular, overgrown, narrow and deep channel (channel width was only 4 to 8 m, $F = w/d_{max} = 1.5$ to 3). With the exception of narrow strips of willows or osier beds lining the channel banks, the natural levees were grassy, but in places local cornfields encroached upon them sometimes being separated from the channel only by a narrow belt of a densely vegetated levee crest.

In the Kazanów study reach, soil sand was formed both on grassy and ploughed natural levees during three floods: in May 1984, March 1986, and June 1987. During the last flood (June 28 – 30, 1987), critical or supercritical flow was observed in many places on the steep upper part of the natural levees. Under such conditions, crumb-structured soil was easily eroded, mostly along a system of relatively narrow (< 1 m) crevasse channels some of which were as wide as deep. Soil sand so formed was transported over a distance up to 200 to 300 m and deposited on the floodplain or within local floodbasins (some of them were ponded for several weeks after each flood). In the Kazanów study reach, soil sands were slightly coarser than on the upper Bóbr (Fig. 3) and contained numerous mud balls or soil blocks up to 64 – 128 mm in diameter (Fig. 4). Fragments of soil larger-than-sand were evidently rounded owing to water transport in the form of bedload. The differences in texture of soil sand may be explained by the fact that in Kazanów floodplain erosion cut deeply into the soil profile sometimes reaching even the zone of prismatic structure (Fig. 1). In the Gębice study reach, soil sand was eroded mostly from the upper part of natural levees, transported down the levees and deposited at the levee/floodplain or levee/floodbasin transition. Flat, smooth thin sheets of soil sand were the most abundant depositional landforms. In cross-section, they reveal delicate parallel lamination, which for the most cases was subhorizontal, or graded bedding of pensymmetrical type (the coarsest material within the deposit) or of reversed type.

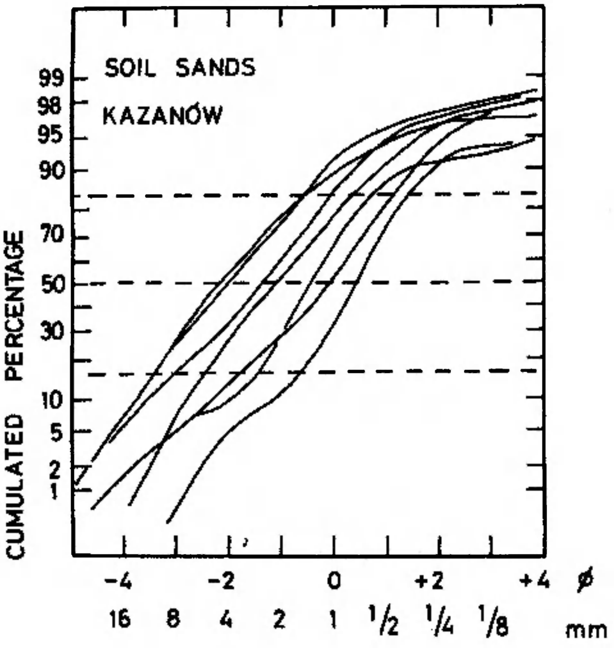


Fig. 3. Grain-size distributions of soil sands from the Kazanów study reach, the upper River Oława south of Strzelin (Sudetic Foreland). Range of statistical parameters: $Md_\phi = -1.15$ to $+0.55$ phi, $M_z = -1.05$ to $+0.58$ phi, $\sigma_I = 1.41$ to 1.72, $Sk_I = -0.13$ to $+0.23$, $K_G = 0.99$ to 2.0. Soil sands were sifted very delicately by hand using sieves graded at 1.0 phi scale.

In the Kazanów study reach, a spectacular assemblage of lobate microdelta-embankments was found after the May 1984 flood (Figs. 4, 5). These depositional landforms were composed exclusively of cohesive soil sand. They were characterized by flat, almost horizontal top surface, a well-developed lobate microdelta front with slip faces of angular type (Fig. 5), and an internal cross-laminated structure typical of microdelta embankments (Jopling 1963a,b, 1964). In places, individual lobes were in part re-moulded owing to falling-stage flows that carried only diluted suspended load. It is important to stress that these lobate microdelta embankments accumulated at least several hundred cubic metres of soil sand that filled in part a local floodbasin. A lobe, deposited on meadow, was systematically investigated during a year after the flood in order to establish the preservation potential of its internal structure. It was found that the structure was almost completly destroyed within several weeks after deposition, mainly as a consequence of the activity of plant roots and earth-worms (*Lumbricus*). In May 1985, the deposit revealed a typical crumb structure and its alluvial origin was completly obliterated.

CONCLUSIONS

he preliminary investigations on soil sand may be summarized as follows (a detailed study is in preparation):

1° Soil sand or detrital, cohesive pelletal material composed of soil aggregates may originate under conditions of wet temperate climate on mud-supported, vegetated or ploughed floodplains such as those described from south-western Poland. With the exception of permanently waterlogged areas, such floodplains are underlain by more or less thick layer of soil with a well--developed crumb structure at the top passing downwards, through blocky and prismatic structure, to tough clay or mud. The latter occurs below the limit of capillary rise. This vertical succession of soil structures seems to be independent of land use. Such a soil is susceptible to floodplain erosion with grain-by-grain type of entrainment, very similar to that typical of non--cohesive detrital alluvia. Floodplain erosion is particularly effective on upper parts of natural levees oving to both the effect of choking of the flow and the effect of large transverse slope.

2° It was found that soil sand may be transported as *bed-load* over a distance up to several hundred metres being neither completly abraded nor slaken. On deposition, soil sand may form various depositional landforms including sheets (smooth or ripples), microdelta embankments, sediment shadows and isolated patches of sediment. Soil sand is mostly deposited on the levee/floodplain transitions or within local floodbasins. The deposition may be controlled by vegetation, particularly grass, or by backwater effects occasioned by ponding of the floodbasins. In general, deposition of soil sand leads to infilling of local depressions and makes the extra-channel (floodplain) relief more smooth and even.

3° Floodplain erosion of cohesive overbank deposits gives way to the devlopment of crevasse channels (cut into natural levees) and floodplain channels. These erosional landforms may be thought to be early phases of channel avulsion and/or river anabranching and, in so being, they favour channel anastomosis (Teisseyre, in press). Irrespective of the possibly low preservation potential of both individual landforms and their internal structures, it is suggested that the process

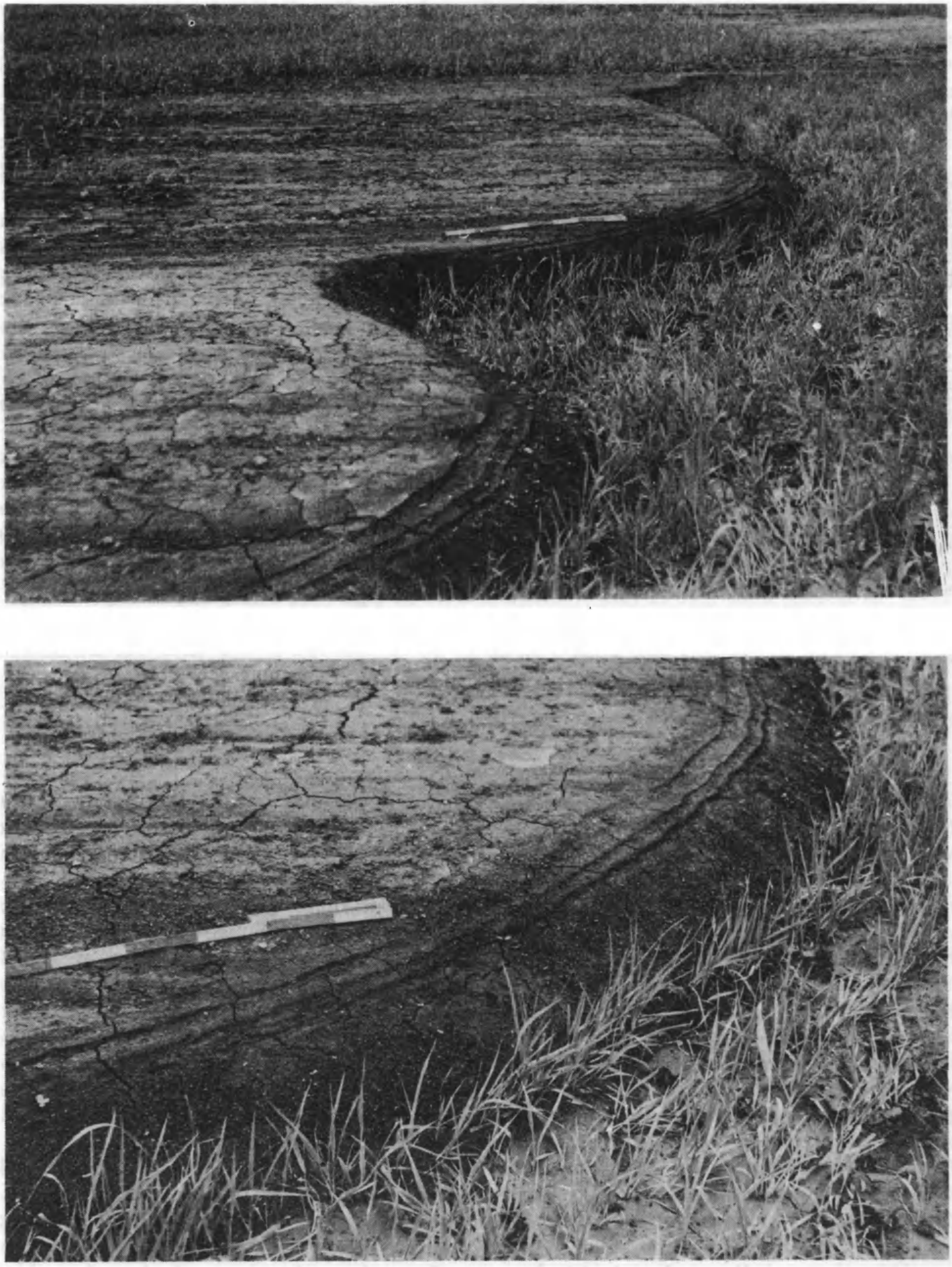
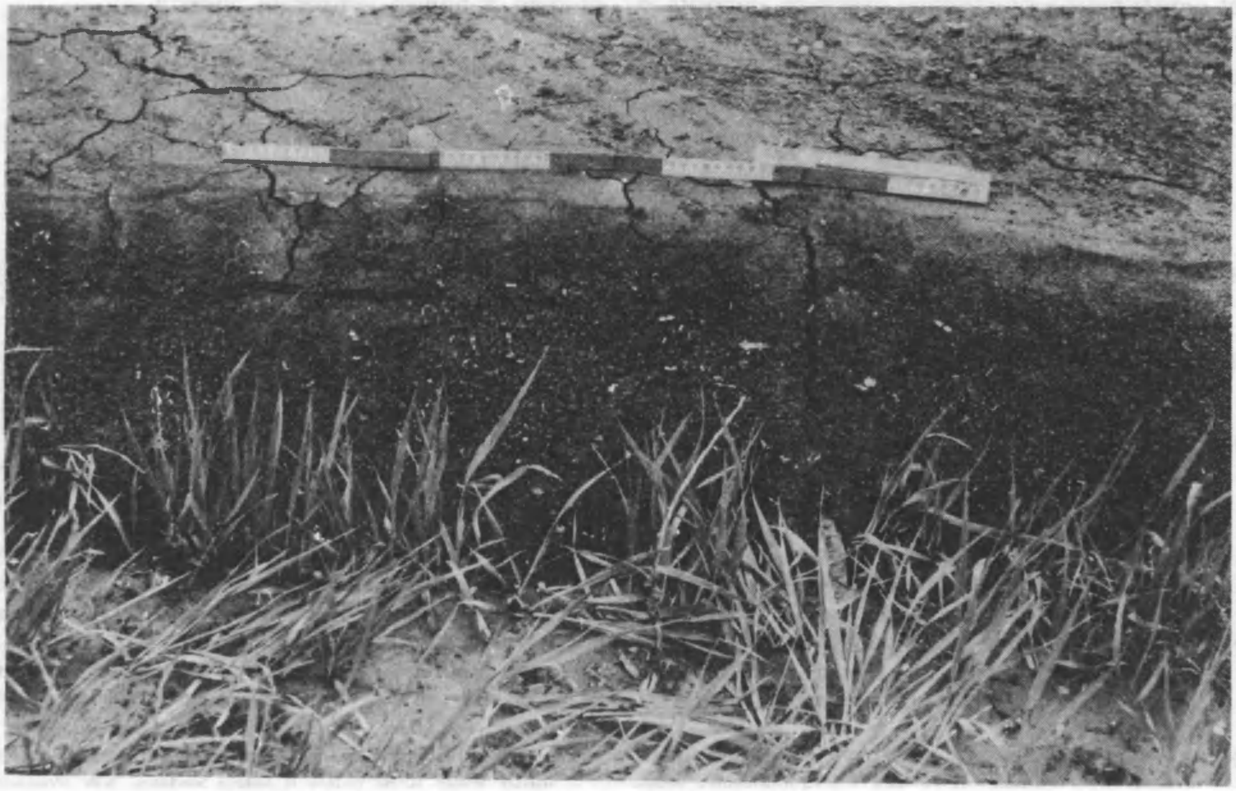


Fig. 4. Lobate microdelta embankments composed of soil sand in a floodbasin of the Kazanów study reach after the May 1984 flood. Flow was from left to right. Note flat, almost horizontal microdelta top with current lineation, desiccation cracks and small mud balls. Water level marks are seen in the upper part of the slip face. Note also "prodelta" clays deposited in the front of the microdelta lobes, between grass blades. 10-cm scale on the ruler. May 21, 1984



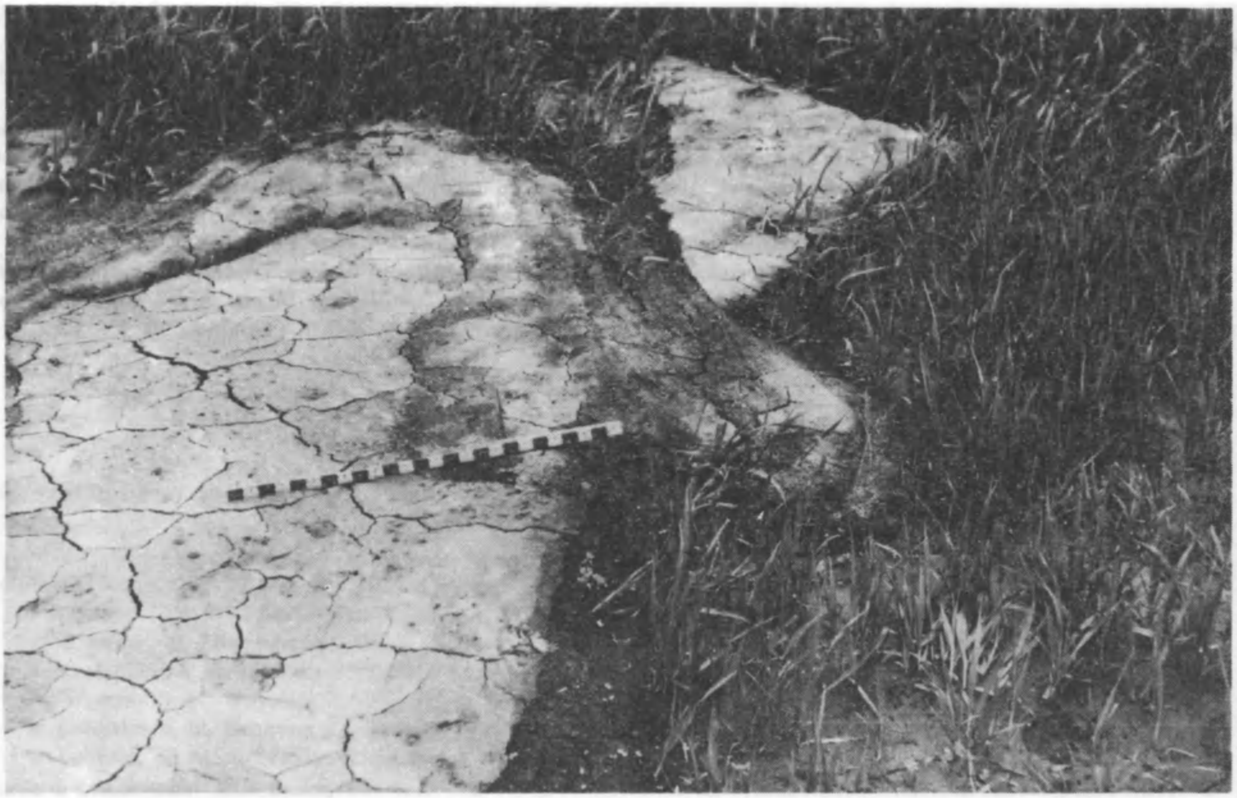


Fig. 5. Details showing the character of the slip face (top) and some secondary features of the lobate microdelta embankments (bottom) including desiccation cracks on a mud-veneered top surface and minor secondary forms originated owing to falling--stage modifications. 10-cm scale (top) and 2-cm scale (bottom) on the ruler. Photos by the author

of redistribution of cohesive overbank deposits in the form of *soil sand* is an important and still underestimated mode of floodplain construction, effective under different climatic conditions including a humid temperate climate.

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