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PHYSIOGRAPHY OF BED-LOAD MEANDERING STREAMS: IMBRICATED GRAVELS IN FINE-GRAINED OVERBANK DEPOSITS

CONTENTS

Abstract

In the drainage basins of the meandering Central Sudetic rivers, the Holocene valley-floor deposits consist of three divisions: coarse gravel at the bottom (channel-lag deposits), fine gravel and coarse sand (point bar deposits) and silty clay to sandy clayey silt at the top (overbank deposits known also as so-called "alluvial loams"). As a rule, the latter contain imbricated pebbles that may be scattered throughout the "loam" or grouped into streaks. Field investigation shave demonstrated that the gravels are attributable to occasional overbank flows connected with heavy floods. C-fabric measurements of such gravels may serve as a directional, however, only in a statistic sense. The scatter in C-axis dip directions of the gravels is considerable but in general similar to that typical of channel-lag gravels of the same meandering stream. Fabric measurements in both overbank- and channel-lag gravels tend to indicate local downcurrent directions which almost always are deviated from a local downvalley direction. The deviations are clearly attributable to each channel sinuosity, bank effects and processes of lateral accretion. However, these highly variable downcurrent directions give low-concentration cumulative fabric diagrams of a well-defined monoclinic symmetry. It has been also found that the axis of symmetry of such diagrams may precisely indicate a mean downvalley direction provided that a sufficiently large number of fabric data is available.

INTRODUCTION

Recent mountain rivers of the Central Sudetes are almost everywhere meandering streams, especially within flat alluvial valleys. The Holocene deposits of the rivers can be frequently seen in natural cuttings located primarily along active meander cutbanks. Sometimes the cuttings are up to 4 or 5 metres high. These commonly exhibit typical fining, upwards sequences (cf. Allen 1965 1970). In general, the sequences start as cobble-pebble gravels which grade upwards into silty clays or clayey sandy silts known also as "alluvial loams" (pl. I; II, *1*). The fine-grained deposits range in thickness from several decimetres to 3 metres. They are thought to represent typical overbank deposits connected genetically with the mountain meandering streams. For the most part, they correspond to the youngest Holocene alluvia the origin of which may be simply related to the activity of man: deforestation of the mountains and intensive farming (Teisseyre 1977). In the drainage basins of the upper River Strzegomka and Bóbr, the modifications began as early as in the XIII-th and XIV-th century, respectively.

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A typical, complete fining-upwards sequence comprises three main lithologic divisions. In the ascending order, these include: (1) cobble-pebble gravels, (2) granule-pebble gravels and coarse sands, and (3) so-called "alluvial loams". The two coarse-grained divisions are extremely variable in both texture and structure (cf. Allen 1970). The cobble-pebble gravels reveal poorly developed subhorizontal stratification and may locally contain streaks of very coarse-grained to medium-grained sands (pl. I). Not uncommon in the sequences are large-scale erosional features and fossil channels (pl. II, *1*) involving both shallow symmetrical features and deeper asymmetrical ones. As a rule, the gravels are strongly imbricated (pl. II, *2*). However, pebble fabric changes commonly from one layer to another and typical herringbone patterns (Teisseyre 1975) are rather common structures. Stratification may even be so poorly developed that individual layers can be only hardly distinguished thanks to detailed observations of fabric and rock structure. Generally, the layers range in thickness from a dozen or so centimetres to several decimetres. It is evident from field investigations that the gravels accumulated mostly as channel-lag deposits. In particular, they include meander-pool gravels, crossover gravels and bar-platform gravels (for terminology of coarse-grained point bars see Bluck 1971). In the geologic record, however, the three main channel subenvironments of a meandering bed- load stream can be identified rather sporadically.

The fine gravels and coarse sands (division 2) occur in lens-shaped or wedge-shaped strata (pl. II, *1*). Crossbedding may be found in both sands and gravels. However, it is important to distinguish between bedform crossbedding and bar-form crossbedding (cf. Bluck 1971, 1974, 1976). The former resulting from a downcurrent migration of bedforms includes ripple crossbedding (or lamination) and dune crossbedding. In the deposits in question, ripple crossbedding is restricted to occasional thin strata of fine-to-medium grained sands. Also co-sets of trough-crossbedded sands (dune crossbedding) occur rather sporadically. Bar-form crossbedding, on the other hand, includes two distinct types: microdelta crossbedding (in both sands and fine sandy gravels) and chute-bar crossbedding (in gravels and sandy gravels). Sedimentation units revealing chute-bar crossbedding correspond to lobate gravelly accumulations up to 1.5 m high called by McGowen and Garner (1970) chute bars. Clayey silts occur occasionally in drapes up to several centimetres thick. The deposits in question are thought to be laid down on coarse-grained point bars or strictly speaking on bar heads and supra-platform bars according to the terminology suggested by Bluck (1971). In particular, they include deposits of such subenvironments as bar heads, supraplatform flats, chute bars and chute channels, microdeltas, partly cut-off channels, local depressions on the supra-platform bars and bar-tail flats.

Finally, the fine-grained deposits (division 3) correspond to so-called "alluvial loams" (pl. III, IV). Petrographically, these are all possible mixtures of silt, sand and clay. In some localities the deposits are almost homogeneous or only indistinctly bedded, while in others they reveal a well-developed horizontal or slightly inclined bedding. Individual strata range in thickness from several millimetres to several decimetres. Distinctly laminated silty clays occur occasionally, mostly as deposits of abandoned channels (pl. III, *2*). From place to place the "loam" in interbedded with well washed sands and framework gravels up to 20 cm thick (pl. IV, *2*). As a rule, the gravels are strongly imbricated. The deposits are believed to represent typical overbank alluvia. In particular, they include deposits of the following subenvironments: local flood basins, crevasse splays, temporal oxbow lakes and abandoned channels. Locally, they are accompanied by swamp deposits and deposits of alluvial fans fed by tributaries.

Besides the interbeddings of framework gravels the "loams" commonly contain imbricated pebbles up to 60 mm across (pl. III, *3*; pl. IV). These may be scattered throughout the "loam" or clustered into streaks up to several tens of metres wide. Many streaks are only one or two pebble diameters in thickness. The number of streaks in the vertical seems to be a function of a distance from an active channel. In some profiles up to twenty streaks may be seen sandwiched between relatively thin strata of "loam". In such streaks, pebbles are as a rule strongly imbricated. Generally, individual streaks show preferred orientation of flat pebbles indicative of a unidirectional flow. In the vertical, however, the scatter in C-axis dip directions is as a rule considerable. Field investigations of Recent overbank floodings clearly indicate that the gravels are simply overbank deposits similar in character to crevasse splays and connected genetically with heavy floods. In the last 15-year period (1962—1977) such overbank floods appeared only three times: in 1965, 1971 and 1974. On valley flats, the gravels and coarse sands were laid down as a bed-load material. In active channels, however, the same materials were transported as a suspension load, which has been many times observed by the author during personal inspections to the field.

One of the main goals of this study has been to investigate pebble fabric of the overbank gravels and to examine them as environmental and directional indicators. What we measure in the field are usually local downcurrent directions, which as a rule are deviated from both channel- and downvalley trends. It has been among the chief purposes of the investigation how to convert the field measurements to more regional (paleo) current data. This study is part of a more comprehensive investigation into fluvial processes of mountain meandering streams carried out at the Institute of Geological Sciences of the Wrocław University. Field measurements and observations have been completed mostly in autumn '76.

FIELD PROCEDURES

The Holocene deposits of the modern Sudetic meandering rivers have been investigated in 89 randomly selected cutbanks on an area of some 400 square kilometres between Dobromierz, Marciszów, Lubawka and Wałbrzych (Central Sudetes). In the cuttings, a total of 1,809 C-fabric measurements of imbricated flat pebbles have been made in the "alluvial loams". Additionally, 1,312 C-fabric readings of imbricated flat pebbles and cobbles have been collected from the cobble-pebble gravels underlying the "loams". Finally, in order to compare the measurements with those from Recent gravels flooring meandering channels a total of 1,080 C-fabric measurements have been gathered from a natural meandering reach of the Lesk Creek in Czarny Bór (the Czarny Bór study reach). The accuracy of all the measurements was 5°. The measurements have been converted directly in the field to angular deviations from a local downvalley direction. Then all the three groups of readings have been plotted on collective fabric diagrams (fig. 1, 3, 4). In the figures, the arrows indicating the downvalley direction have no geographic sense, of course. Indeed, the main scope of the diagrams has been to analyse in some detail the overall character of pebble dip dispersion in relation to an abstract downvalley direction. The results thus obtained can be easily read from figures 1 to 4.

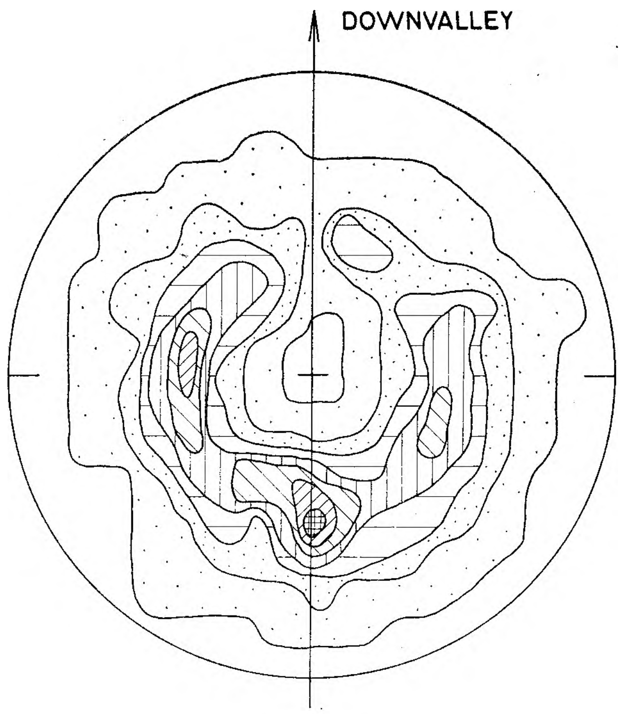

Fig. 1
Cumulative contour diagram of 1,809 C-fabric measurements of flat pebbles in fine-grained Holocene overbank deposits. Readings gathered in 89 randomly selected cut banks. Upper hemisphere. Downvalley direction has no geographic sense. Concentration lines: 0—1—2—3—(3.5)—4—(4.2) per cent. Dip mean = 37°, dip median = 37°, dip standard deviation = 12.8°

Kumulatywny diagram konturowy 1809 pomiarów osi C fragmentów i otoczaków płaskich w drobnoziarnistych holoceńskich osadach pozakorytowych. Pomiary zebrano w 89 przypadkowo wybranych naturalnych skarpach nadrzecznych. Górna półkula. Kierunek w dół doliny (strzałka) nie ma znaczenia geograficznego. Linie koncentracji: 0—1—2—3—(3,5)—4—(4,2)%. Mediana kąta zapadu = 37°, średni kąt zapadu = 37°, odchylenie standardowe = 12,8°

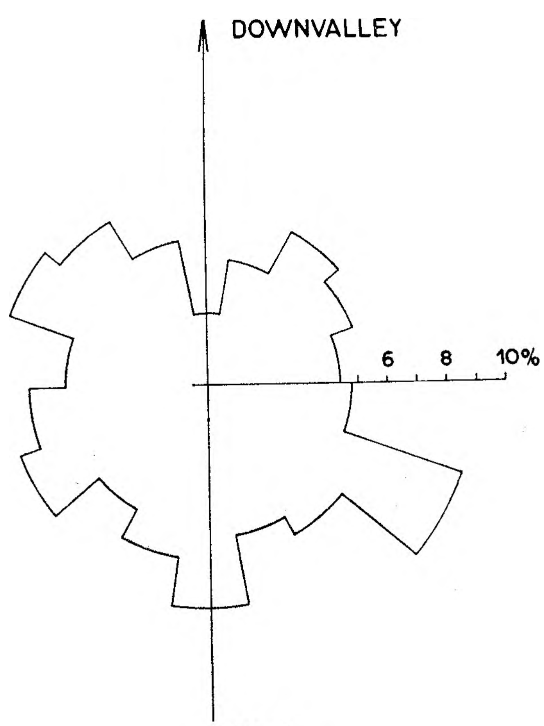

Fig. 2
Pie diagram illustrating dispersion in dip directions of the A-B planes of flat pebbles same as in figure 1

Diagram sektorowy ilustrujący rozrzut kierunków zapadu powierzchni A-B otoczaków płaskich (fig. 1)

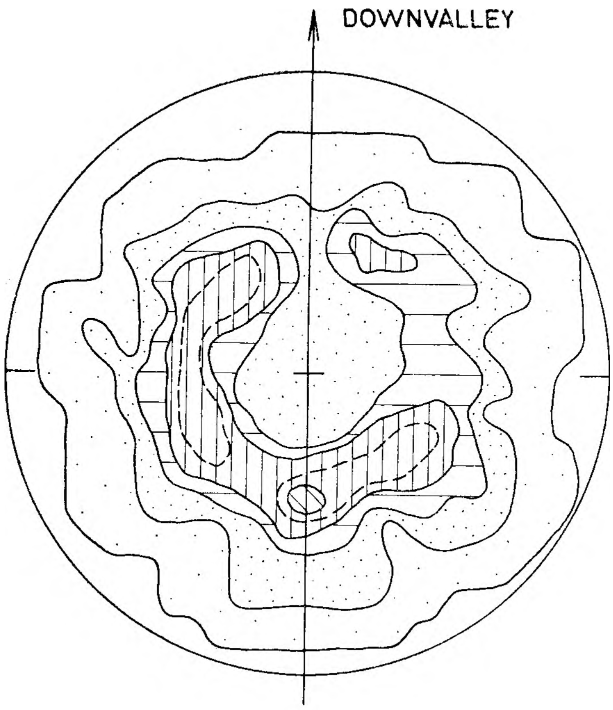

Fig. 3
Cumulative contour diagram of 1,312 C-fabric measurements of flat pebbles in cobble-pebble gravels (channel-lag, meander-pool and crossover deposits). Readings made in the same 89 cut banks. Upper hemisphere. Concentration lines: 0—1—2—3—4—5—6—(6.4) per cent. Median dip = 38°, mean dip = 38°, dip standard deviation = 9.5°

Kumulatywny diagram konturowy 1312 pomiarów osi C otoczaków płaskich w żwirach korytowych (32—256 mm). Pomiary pochodzą z tych samych 89 podcięć brzegowych. Górna półkula. Linie koncentracji: 0—1—2—3—4—5—6—(6,4)%. Mediana kąta zapadu = 38°, średni kąt zapadu = 38°, odchylenie standardowe = 9,5°

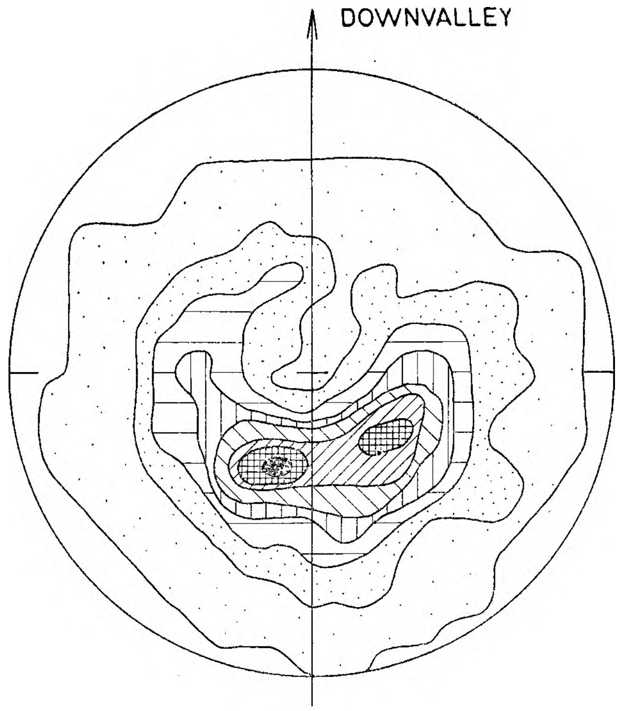

Fig. 4
Cumulative contour diagram of 1,080 C-fabric measurements of flat pebbles and cobbles in 42 randomly selected stations along meandering channel of the Lesk Creek (Czarny Bór study reach). Included were channel lag gravels, pool gravels, crossover gravels and bar platform gravels below the mean water level. Downvalley is oriented to the north. Upper hemisphere. Concentration lines: 0—1—2—3—4—5—6—7—(7.1) per cent. Median dip = 34°, mean dip = 34°, dip standard deviation = 12°

Kumulatywny diagram konturowy 1080 pomiarów osi C otoczaków płaskich (32—256 mm). Pomiary wykonano w 42 przypadkowo wybranych punktach wzdłuż meandrującego koryta Lesku (odcinek badawczy w Czarnym Borze). Żwiry reprezentowały następujące podśrodowiska: bruki korytowe, żwiry głębi meandrowych, żwiry bystrzyków międzymeandrowych oraz żwiry podwodnych części platform łach meandrowych. Kierunek w dół doliny (strzałka) jest zorientowany ku północy. Górna półkula. Linie koncentracji: 0—1—2—3—4—5—6—7—(7,1)%. Mediana kąta zapadu = 34°, średni kąt zapadu = 34°, odchylenie standardowe = 12°

FIELD RESULTS

It is apparent from both the field evidence and a review of the literature that the streaks of imbricated pebbles embedded in "alluvial loams" are products of heavy floods spreading from active channels onto valley flats (cf. Jahns 1947; Wolman and Eiler 1958; Hack and Goodlett 1960; Stewart and LaMarche 1967; Malde 1968; Scott and Gravlee 1968; Malde 1968; Baker 1973; Costa 1974; Ritter 1975). Such floods may result in more or less widespread flashy flows that in fact are analogous to ordinary crevasse splays known better from more distal meandering rivers. Observations of Recent overbank floodings made by the present author on the Central Sudetic rivers have demonstrated that imbricated pebbles may be laid down directly on pressed grass and that a grassy substratum has only a slight effect on the position of pebbles resting on it. After deposition, however, some pebbles may be reoriented and the orientation of still others may be modified even after burial, i.e., owing to root- and animal activity. In sections studied in detail, the degree of such reorientations was rather small or unperceptible.

It seems to be clear from the field investigations that fabric measurements of imbricated flat pebbles set in "alluvial loams" may serve as a directional only in a statistic sense. In general, the measurements have revealed a considerable dispersion in C-axis dip directions. The dispersion appears to be a characteristic property of coarse-grained alluvial deposits and is simply attributable to fluvial processes themselves including channel sinuosity and channel migration, bank effects, processes of lateral accretion and flow separation (Buck 1971, 1974, 1976; Collinson 1971; Johansson 1965, 1976; Klimek 1972; Teisseyre 1975). Consequently, the number of measurements necessary to get real (paleo) current directions is rather large and even tens of readings may fail to give a true downvalley direction. In practice, it is convenient to plot the field data on cumulative diagrams. However, great care should be exercised in applying the method to fossil deposits (we ought to be sure that a mean downvalley direction did not change substantially over the area of our investigations). If it is really the case, such measurements produce characteristically low-concentration diagrams of a well-defined monoclinic symmetry (fig. 1). These reveal well-developed gaps in the downvalley direction and a week maximum pointing upvalley (provided that the upper hemisphere projection is used). Thus it may be concluded that the axis of symmetry of such diagrams may indicate precisely a mean downvalley direction. Furthermore, similar diagrams seem to be characteristic of both fossil- and Recent channel-phase gravels of pebbly meandering streams (fig. 3, 4). The results appear to indicate that the dispersion in C-axis dips may be statistically to a large degree independent on a subenvironmental differentiation of valley floors themselves. Or, in other words, it may be unrelated to the apparent lithological differentiation of fining upwards sequences (cf. Allen 1970).

Finally, it may be concluded that the so-called "alluvial loams" of the Central Sudetic valley flats are in fact mostly fluvial in origin. They are thought to represent typical overbank deposits of the Sudetic bed-load meandering rivers. Aeolian processes might have also contributed to the formation of the deposits but in the valleys studied their role seems to be rather unimportant. At valley margins, the deposits may be accompanied by both colluvial deposits and slope washes. It should be stressed, however, that pebbly "alluvial loams" differ substantially from mudflow deposits with which they were sometimes erroneously identified. It also seems that fabric analysis may serve as an important tool in recognizing between the two types of deposits (cf. Johansson 1965, 1976).

CONCLUSIONS

"Alluvial loams" flooring many mountain valleys in the Central Sudetes are in fact ordinary overbank deposits. They are indicative of a meandering character of the mountain Sudetic rivers, at least from the beginning of the historical period. Almost everywhere the deposits contain imbricated pebbles, both isolated and clustered into streaks. The gravels are thought to represent local overbank deposits similar in character to crevasse splays and connected genetically with heavy floods. It has been found that C-fabric measurements of imbricated flat pebbles set in the "loams" may be utilized as a directional, however, only in a statistic sense. The dispersion in C-axis dip directions is considerable and, consequently, a large number of readings is needed. In contrast, the distribution of dip angles is perfectly normal with mean angles of dip ranging from 34° to 38°. Field investigations have also demonstrated that C-fabric measurements of flat pebbles of each channel- and overbank gravels produce similar cumulative diagrams. It seems, therefore, that at least in a statistic sense the dispersion in C-axis dip directions is to a large degree independent on a subenvironmental differentiation of the mountain valley floors themselves.

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FIZJOGRAFIA ŻWIRONOŚNYCH RZEK MEANDRUJĄCYCH: ZIMBRYKOWANE ŻWIRY W DROBNOZIARNISTYCH OSADACH POZAKORYTOWYCH

Streszczenie

Holoceńskie osady rzeczne w dorzeczach górnego Bobru i Strzegomki (Sudety Środkowe) składają się z trzech członów: grubych żwirów u dołu (osady bruków korytowych), drobnoziarnistych żwirów i gruboziarnistych piasków w środku (osady łach meandrowych) oraz tak zwanych glin aluwialnych w stropie (osady pozakorytowe). Osady te reprezentują typowe sekwencje o ziarnie malejącym ku górze (ang. fining upwards sequences). Gliny aluwialne z reguły zawierają zimbrykowane żwiry lub pojedyncze otoczaki do 60 mm średnicy. Otoczaki te mogą być luźno rozrzucone w glinach lub skupione w smugach, których grubość wynosi nierzadko jedną lub dwie średnice budujących je otoczaków, a zasięg poziomy dochodzi do kilkudziesięciu metrów. Autor przeprowadził pomiary orientacji zimbrykowanych otoczaków płaskich w 89 przypadkowo wybranych naturalnych podcięciach rzecznych odsłaniających osady holocenu. Dla porównania zmierzono też ułożenie otoczaków płaskich w gruboziarnistych żwirach podścielających gliny oraz wykonano podobne pomiary na współczesnych żwirach meandrującego koryta Lesku (dopływ Bobru) w Czarnym Borze. Azymuty zapadu osi C otoczaków płaskich były od razu w terenie przeliczane na kątowe odchylenia od lokalnego kierunku w dół doliny (ang. downvalley direction). Wyniki pomiarów przedstawione na diagramach zbiorczych ilustrują figury 1—4. Na pierwszych trzech figurach pomiary odzwierciedlają dyspersję azymutów zapadu osi C otoczaków płaskich względem abstrakcyjnego kierunku w dół doliny (strzałki na figurach nie mają znaczenia geograficznego). Wszystkie diagramy wykazują dużą dyspersję azymutów zapadu osi C otoczaków płaskich i wszystkie reprezentują ten sam typ diagramu o niskiej koncentracji i wyraźnie zaznaczonej jednoskośnej symetrii. Przy zastosowaniu projekcji górnej półkuli na diagramach tych widoczne jest pole niskiej koncentracji wyznaczające kierunek w dół doliny, a w przypadku osadów holoceńskich także słabe maksimum wyznaczające kierunek w górę doliny (ang. upvalley direction). Z powyższego wynika, że pomiary imbrykacji otoczaków płaskich w osadach pozakorytowych i osadach bruków korytowych żwironośnych rzek meandrujących mogą mieć znaczenie kierunkowe jedynie w sensie statystycznym. Ustalenie ogólnego kierunku transportu materiału na podstawie takich otoczaków wymaga dużej ilości pomiarów.

Występowanie smug zimbrykowanych otoczaków w glinach aluwialnych związane jest genetycznie z przypadkowymi przepływami pozakorytowymi w czasie wyjątkowo silnych powodzi. Przepływy te pozostawiają na równinach zalewowych lokalne, cienkie akumulacje silnie zimbrykowanych żwirów leżących wprost na sprasowanym trawiastym podłożu. Postdepozycyjna reorientacja części takich otoczaków na ogół nie zaciera utworzonych w ten sposób struktur dachówkowych, które mają duże szanse przetrwania w stanie kopalnym. W obszarze równin zalewowych omawiane żwiry stanowią typowy osad obciążenia dennego, deponowany przez lokalne przepływy pozakorytowe. Jednakże w strefie aktywnego koryta ten sam materiał wraz z piaskiem stanowi obciążenie zawiesinowe, co autor naocznie wielokrotnie stwierdził.

Wyniki powyższych badań potwierdzają wcześniej wysuniętą hipotezę o meandrującym charakterze omawianych tu rzek, co najmniej od początku okresu historycznego (Teisseyre, 1977). Wskazują one też na rzeczne pochodzenie żwironośnych glin aluwialnych, przynajmniej na obszarze dorzeczy górnego Bobru i Strzegomki. Interpretacja genezy żwironośnych glin wymaga zawsze dużej ostrożności, jak o tym świadczą dane zebrane z literatury.

Zdarzało się, że typowe aluwialne gliny żwironośne były opisywane jako osady koluwialne, osady potoków błotnych, a nawet utwory eoliczne (sic!). Wydaje się, że dokładna analiza ułożenia otoczaków zawartych w takich glinach może w dużym stopniu ułatwić prawidłową ocenę ich pochodzenia.

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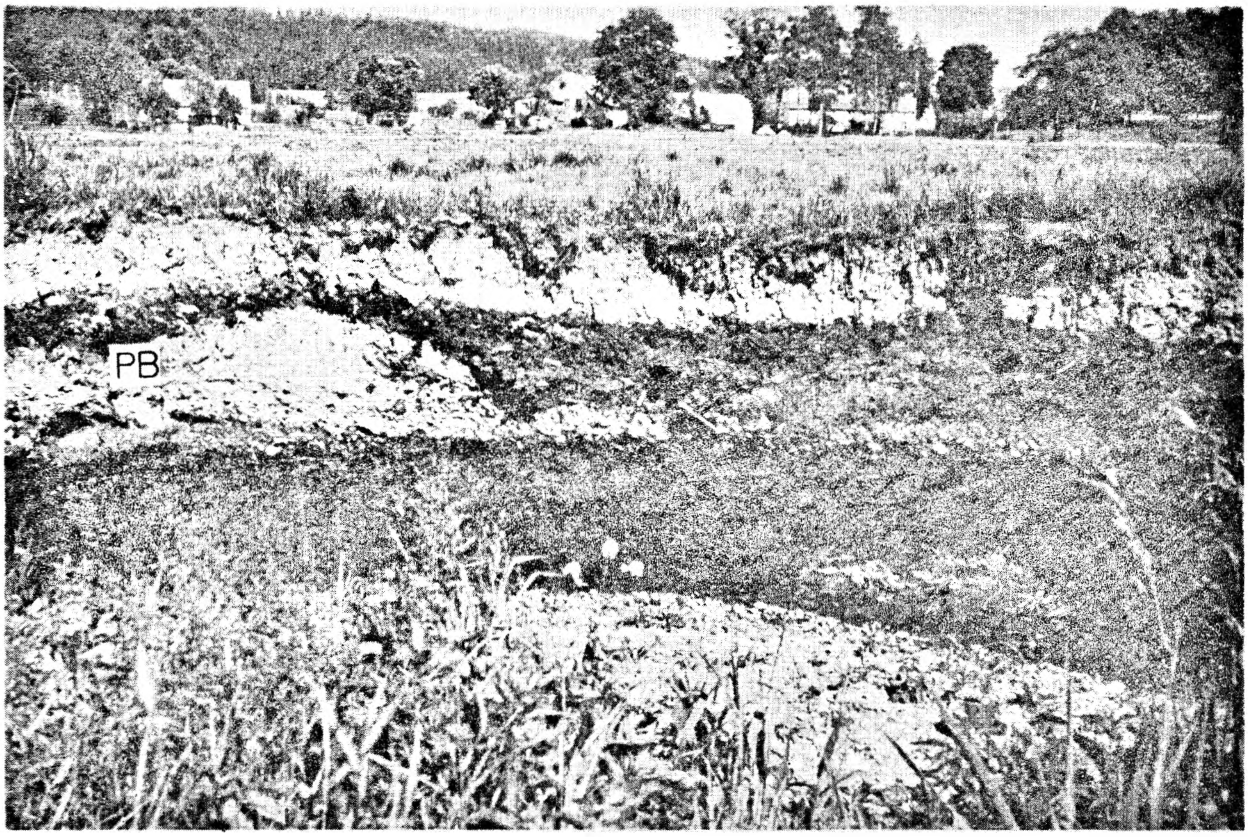
PLATE I

PLANSZA I

1. Holocene deposits as seen in cut bank of the meandering Lesk Creek, Czarny Bór study reach. From bottom to top: channel-lag gravel, fine gravel and sand (point-bar deposits, PB), peat (black) and overbank "alluvial loam". Modern point-bar deposits in the foreground. The cutting is 1.8 m high
Osady holocenu odsłonięte w podcięciu meandrowym Lesku, odcinek badawczy w Czarnym Borze. Od dołu do góry: żwiry korytowe, drobnoziarniste żwiry i piaski łachy meandrowej (PB), torf (czarny), gliny aluwialne jako osad pozakorytowy. Na pierwszym planie współczesne osady łachy meandrowej. Skarpa ma 1,8 m wysokości

2. Holocene deposits, location as above. C — channel-lag gravels, PB — point-bar gravels and sands, O — overbank "loam". The cutting is 1.1 m high
Holoceńskie osady Lesku, lokalizacja jak wyżej. C — żwiry bruków korytowych, PB — żwiry i piaski łachy meandrowej, O — gliny aluwialne równi zalewowej. Wysokość skarpy około 1,1 m



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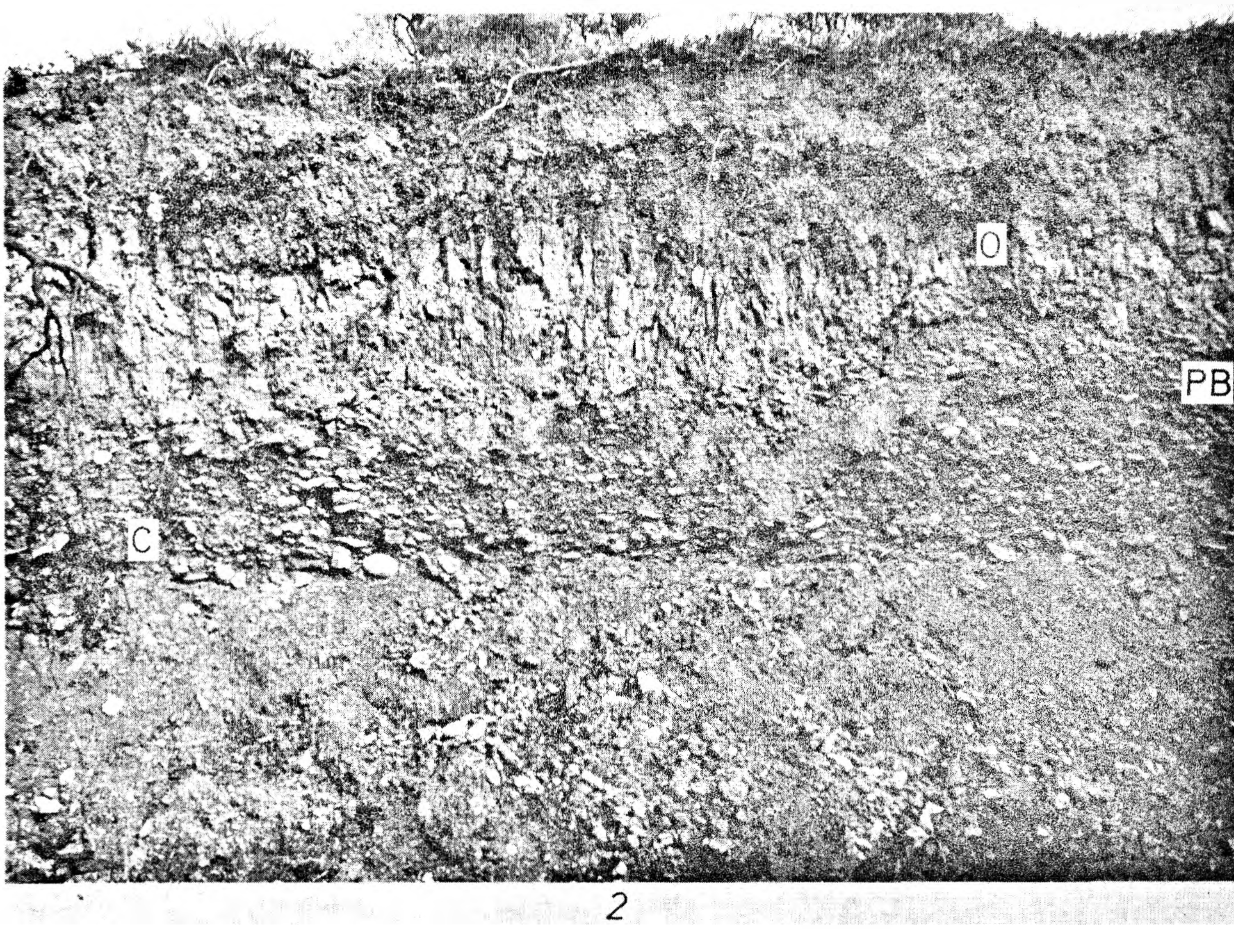

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PLATE II

PLANSZA II

1. Fossil channel (above black line) cut in overbank "alluvial loam" (light) underlain by point-bar and channel-lag gravels. Note crossbedded point-bar deposits in the channel. Czarny Bór study reach. The cutting is about 2.2 m high
Kopalne koryto (powyżej czarnej linii) wcięte w glinach aluwialnych (jasne) podścielonych żwirami łachy meandrowej i brukiem korytowym. W korycie widoczne skośnie warstwowane osady łachy meandrowej. Odcinek badawczy w Czarnym Borze. Podcięcie ma około 2,2 m wysokości

2. Channel-lag gravel (possibly crossover gravel?) overlain by pebbly "alluvial loam". Location as above. 10-cm scale on the hammer
Żwir bruku korytowego (być może osad bystrzyka?) przykryty gliną aluwialną ze żwirem. Lokalizacja jak wyżej. Na młotku skala co 10 cm

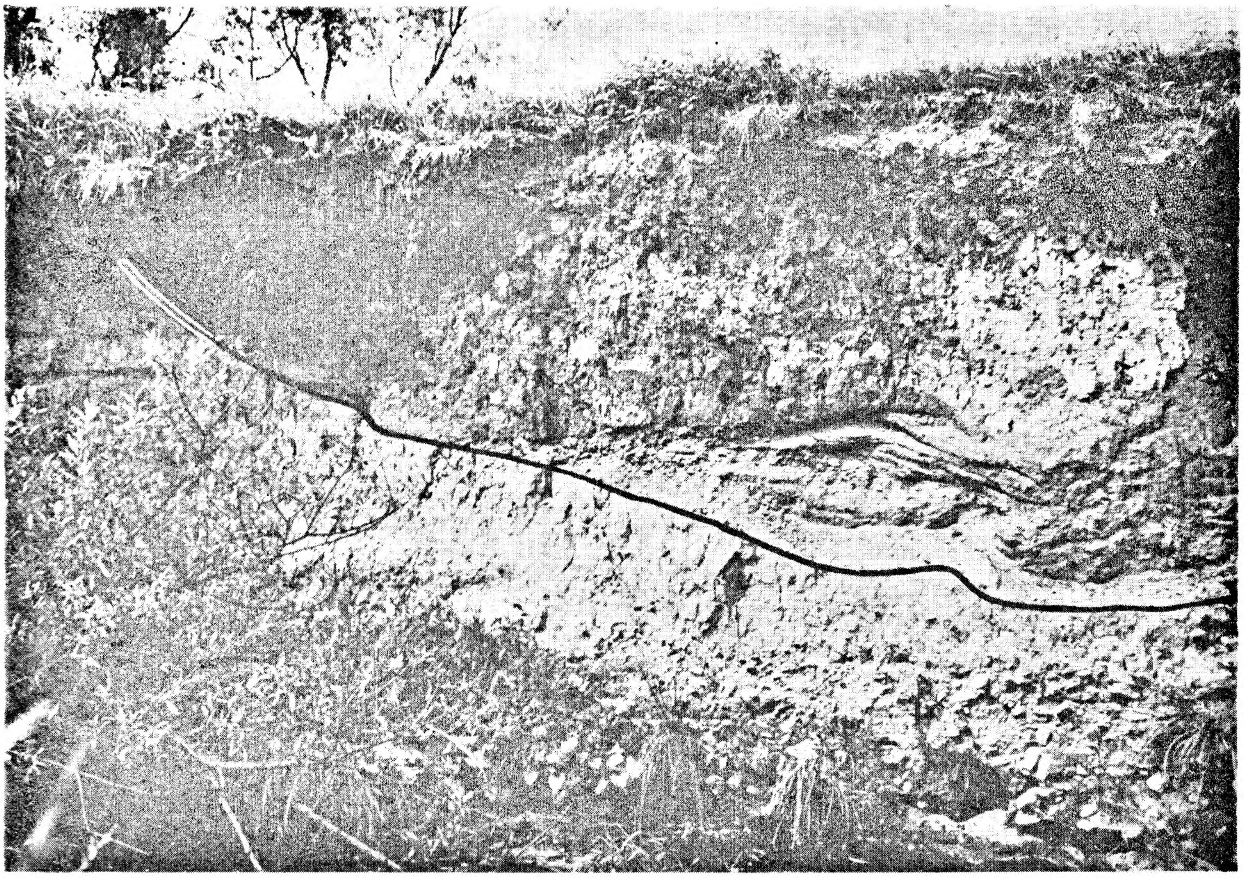

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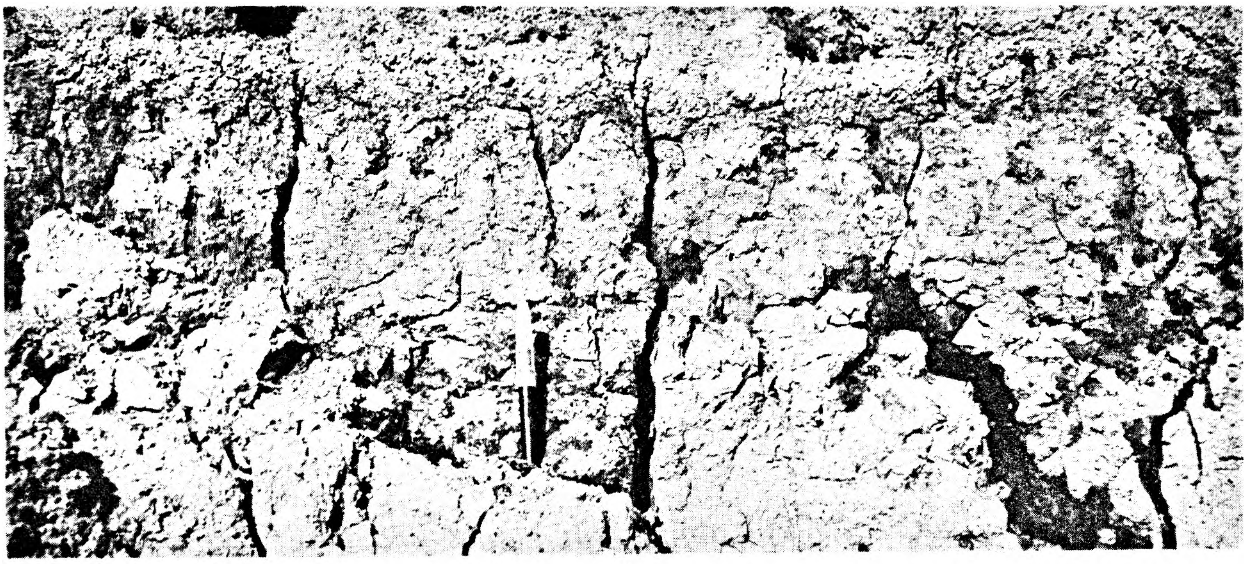
PLATE III

PLANSZA III

1. Showing typical "alluvial loam". Note indistinct bedding. Lesk Creek, Jaczków study reach. The ball-pointer is 11 cm long
Typowy wygląd gliny aluwialnej. Słabo widoczne warstwowanie. Lesk, odcinek badawczy w Jaczkowie. Długopis ma 11 cm długości

2. Laminated sandy clayey silts and silty clays rich in plant matter as a deposit of abandoned channel. Location as above
Laminowane gliny aluwialne jako osady porzuconego koryta. Lokalizacja jak wyżej

3. Imbricated granules and pebbles in "alluvial loam", location as above
Zimbrykowany drobny żwir w glinie aluwialnej. Lokalizacja jak wyżej



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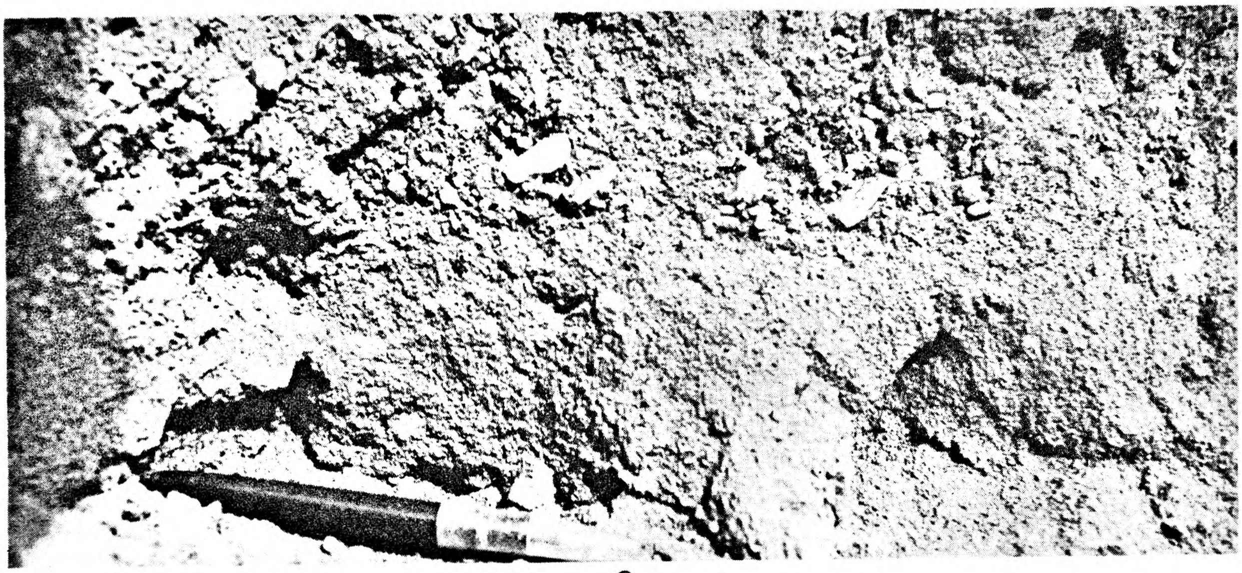

3

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PLATE IV

PLANSZA IV

1. Imbricated pebbles in pebbly "alluvial loam", Lesk Creek, Jaczków study reach
Zimbrykowane otoczaki w glinie aluwialnej. Lesk, odcinek badawczy w Jaczkowie

2. Wedge-shaped layer of imbricated pebbles in overbank "alluvial loam". Lesk Creek, Czarny Bór study reach. One fifth natural size
Klinowata warstwa zimbrykowanych otoczaków w glinach aluwialnych (osady pozakorytowe). Lesk, odcinek badawczy w Czarnym Borze. 1/5 wielkości naturalnej

All photos taken by the author

Wszystkie zdjęcia autora

1

2

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