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Late Quaternary evolution of the Czyżynka river valley, Walbrzych Upland, Middle Sudetes Mts, southwestern Poland

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Abstract The lower part of the Czyzynka river valley (Wałbrzych Upland, Sudetes) was formed entirely after the early Saalian (Odranian) stage. The subsequent, 60–80 m deep, valley was incised into the mountain plateau. The valley is generally narrow with an alternating wide and narrow segments, and characterized by steep slopes, including common subvertical rock walls. Three terraces, formed most probably during the Wartanian/Eemian, Middle Weichselian and Late Weichselian represent the main stages of fluvial activity. Fluvial sequences show that sinuous to meandering rivers were active throughout the late Quaternary. Two phases of loess deposition are inferred (Wartanian and Middle Weichselian), as the deposits of the older terraces contain large admixtures of loess-like deposits. Moreover, two phases of large angular debris production and formation of extensive slope covers and fans have been recognized. The older occurred during the Upper Pleniglacial of the Weichselian stage. A continuum of slope colluvium was formed at that time, from fine-grained sheet wash deposits (including redeposited loess) to coarse grained deposits formed by cohesive debris flows, noncohesive debris flows and grain flows, and open-work loose material formed by debris avalanches. Frost activity and permanently moist conditions have been reported for that time, most probably with permafrost. Also, all these slope deposits contain an admixture of loess, suggesting loess deposition that time, too. The second phase of coarse debris production occurred, most probably, during the the Younger Dryas forming less extensive slope covers.

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INTRODUCTION

The Czyżynka river valley is a deeply incised (60–80 m) and narrow (50–600 m) valley in the central part of the Walbrzych Upland in Middle Sudetes (Fig. 1). The Czyżynka river is the largest tributary of the Strzegomka river in the mountainous region.The paper describes the lowermost part of the valley, 7 km long, between the Cisy Castle and the Strzegomka river valley (Fig. 2). Observations have been collected also in the adjacent part of the Strzegomka valley and small tributary valleys of the Czyżynka. Field data were collected during seasons 1984, 1988–1992 and 1994. The general evolution of the landscape and formation of the late Quaternary valleys of the Walbrzych Upland have been described by Krzyszkowski & Stachura (1998a, b). This paper describes in detail late Pleistocene slope deposits, together with their morphological context, and discusses their possible origins. Also, the stratigraphic superposition of the alluvial terraces and slope covers is discussed and this serves a basis to present an evolutionary history of the valley.

GEOLOGICAL AND GEOMORPHOLOGICAL BACKGROUND

BEDROCK GEOLOGY

A major part of the valley investigated is located within the Świebodzice Synclinorium, with Lower Carboniferous polimictic conglomerates as the main bedrock (culm from Chwaliszów) (Teisseyre, 1956, 1968, 1969; Teisseyre & Gawroński, 1965) (Fig. 3). The lowermost valley fragment is located in the boundary zone between the Świebodzice Synclinorium and the Kaczawskie Góry Zone. This boundary is manifested as a distinct fault zone

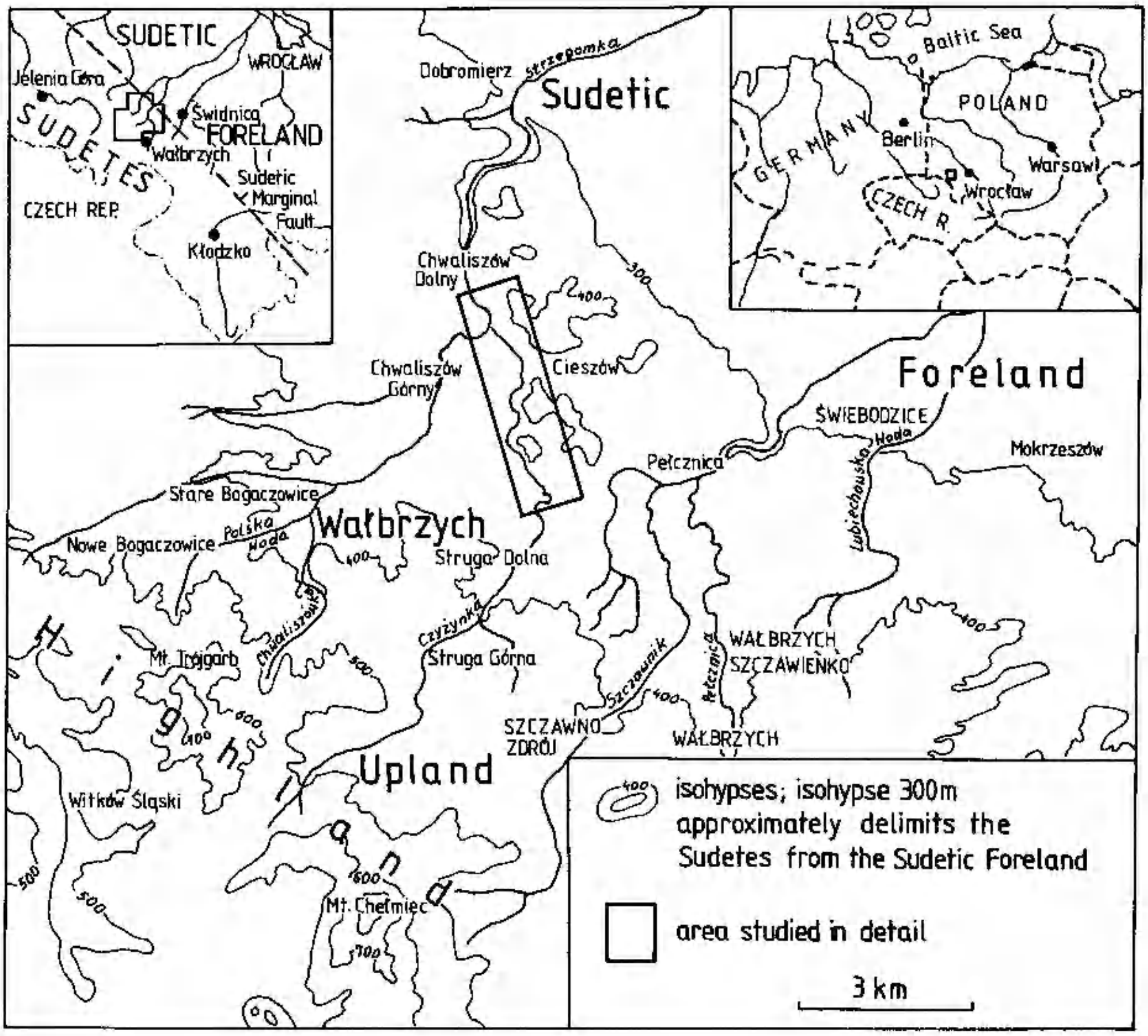

Fig. 1. Area of investigation (lower part of the Czyżyka river valley) within local topography of the Wałbrzych Upland, Sudetes Mts.

and by strong folding of the bedrock series. The Czyżynka river cross the fault zone but its right-side tributary valleys are consequent, and at least one, the Cieszówka river valley, is located along the fault zone (Fig. 2, 3). The main rocks exposed in the lower part of the Czyżynka river valley are Cambrian spilites and Devonian mudstones, sandstones and conglomerates. Along the fault, there are thick bodies of cataclasites and mylonites as well as chlorite and sericite schists and small bodies of limestones (Teisseyre, 1969; Teisseyre & Gawroński, 1965) (Fig. 3). The plateau adjacent to the Czyżynka river valley is covered in places by glacial deposits; till and glaciofluvial sands and gravels. Glacial cover is thin, reaching up to 10 m (Dathe, 1892; Szczepankiewicz, 1954; Krzyszkowski & Stachura, 1998b) (Fig. 3).

GEOMORPHOLOGY

The Czyżynka river valley is cut into the mountain plateau which lies at about 380–420 m a.s.l., and has been named the Cieszów horizon (Szczepankiewicz, 1954; Krzyszkowski & Stachura, 1998a, b). The plateau is a flat to slightly undulating surface with several, isolated monadnocks up to 450 m a.s.l. (Fig. 4). It represents, at least in part, a late Tertiary/early Pleistocene surface, with traces of a former, early Tertiary landscape (Szczepankiewicz, 1954; Krzyszkowski & Stachura, 1998a, b).

The Cieszów horizon was extensively incised during the Middle and Late Pleistocene and at least twice was covered by the Scandinavian ice-sheet (Krzyszkowski & Stachura, 1998b). The last glaciation occurred during the Odranian (early Saalian) stage. The old fluvial landscape is poorly preserved, although it seems that the pre-Odranian (pre-Saalian) Czyżynka river was further east and that the recent tributary valleys may have trended westwards, directly to the Strzegomka river valley forming the consequent fluvial pattern (Krzyszkowski & Stachura, 1998a, b)(Fig. 3). The upper parts of small, tributary valleys (*e.g.* Cieszówka and Cisówka river valleys) as well as some slope flattenings lying at 350–370 m a.s.l. may together represent former, pre-Odranian river routes, although there are no data to confirm this hypothesis. Recently, these small valleys were infilled with post-glacial fluvial and slope deposits and the flattenings are covered by tills, glaciofluvial deposits and in places by thick slope covers (Fig. 4).

The lower part of the Czyżynka river valley was entirely incised after the Odranian (early Saalian) glaciation and forms a subsequent drainage pattern (Fig. 3). This new valley is 60–80 m deep, box-shaped, with, usually, steep slopes including rock walls, and a flat, alluvial bottom (Fig. 2, 5). Also, the upper edge of the valley gives way sharply to the Cieszów horizon (Fig. 4). The valley is formed of several segments with different width and slope cha-racteristics: narrow valley sections (gorges) are about 50 m wide, "normal" sections 150– 300 m and wide sections 400–600 m. The last occur only in connection with tributary valleys, the Cisówka and Cieszówka river valleys, and are named "depressions" (Fig. 4). The wide fragments of the valley are characterised by gentle slopes (up to 15–20°), which are covered by glacial deposits and loessic colluvium (Fig. 5). Valley depressions have well developed terrace system, with two (Ci-sów) or three terraces (Cieszów). The narrow valley segments are 100–250 m long and are characterized by steep slopes (Fig. 5), at least with one side of the valley forming a rock wall up to several metres high. The "normal" valley is characterised by steep slopes (20– 40°) with bare bedrock only in the upper parts and usually with a thick colluvium below (Fig. 4, 5). Both "normal" and narrow valley segments contain only the youngest, Lower Terrace, that forms an extensive, flat alluvial surface (Fig. 4). The present channel is incised 1–3 m into this surface and the channel is usually only about 5–10 m wide. The Middle and Upper Terraces are much narrower, usually 10–50 m wide (max.100 m near Cisy) and discontinuous benches on both sides of the valley (Fig. 4). The Middle Terrace is 5–6 m high above the channel, whereas the Upper Terrace is 7–8 m near Cieszów and 13–15 m near Cisy Castle. The Upper Terrace is a rock terrace; both the Middle and Lower Terraces are alluvial, cut and fill, forms.

The modern channel of the Czyzynka river is formed in alluvial deposits; bedrock is observed only on the valley sides. The channel gradient along the Czyżynka river is independent of valley shape. It is uniform at about 1–1.5%, except in the Cieszów depression, where the longitudinal profile shows a distinct break with the channel slope up to 2–2.5% (Fig. 5). This zone lies directly on the fault line dividing the Świebodzice Synclinorium and Kaczawskie Góry Zone (Fig. 3).

There are numerous dry valleys with dif-

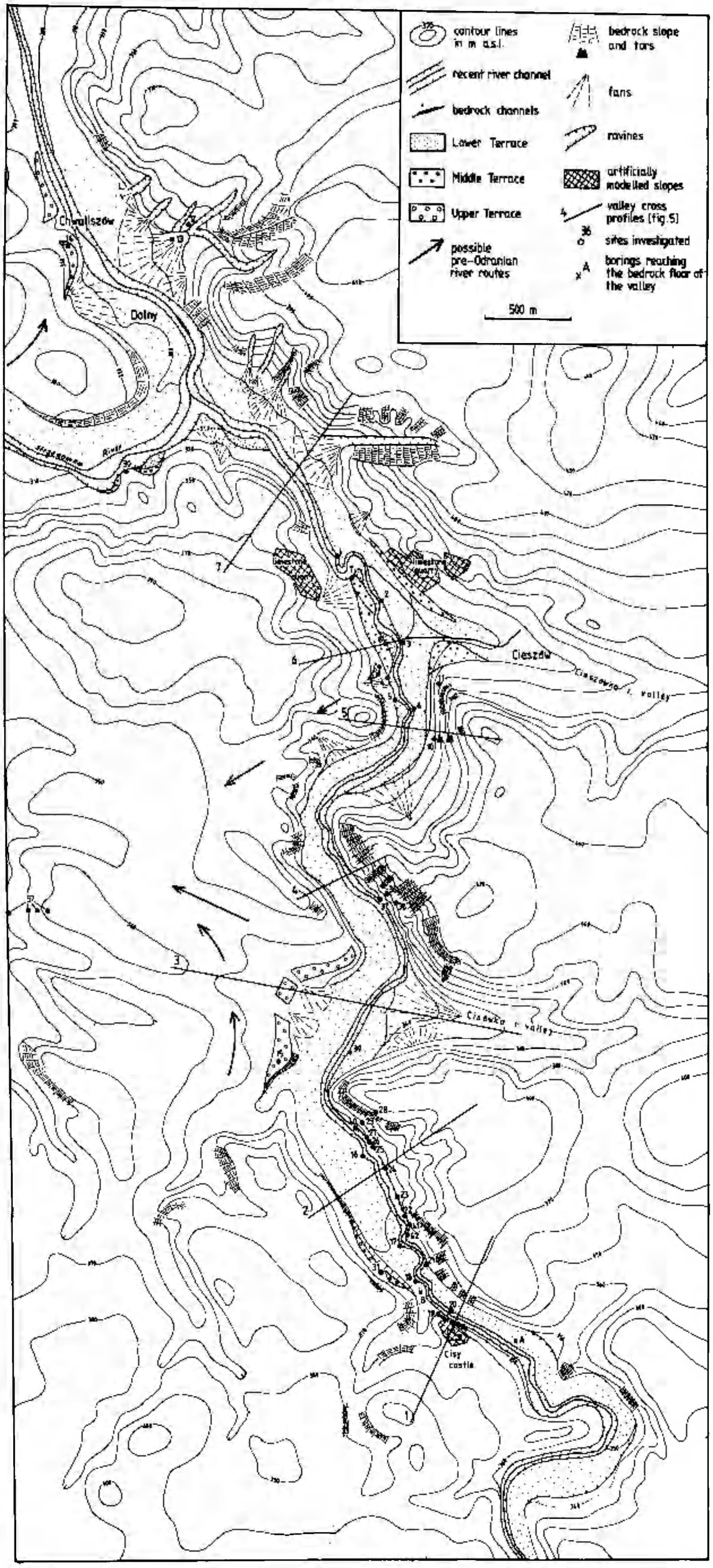

Fig. 2. General outline of the Czyżynka river valley with location of valley cross sections and sites investigated. Cross section are in Fig. 5.

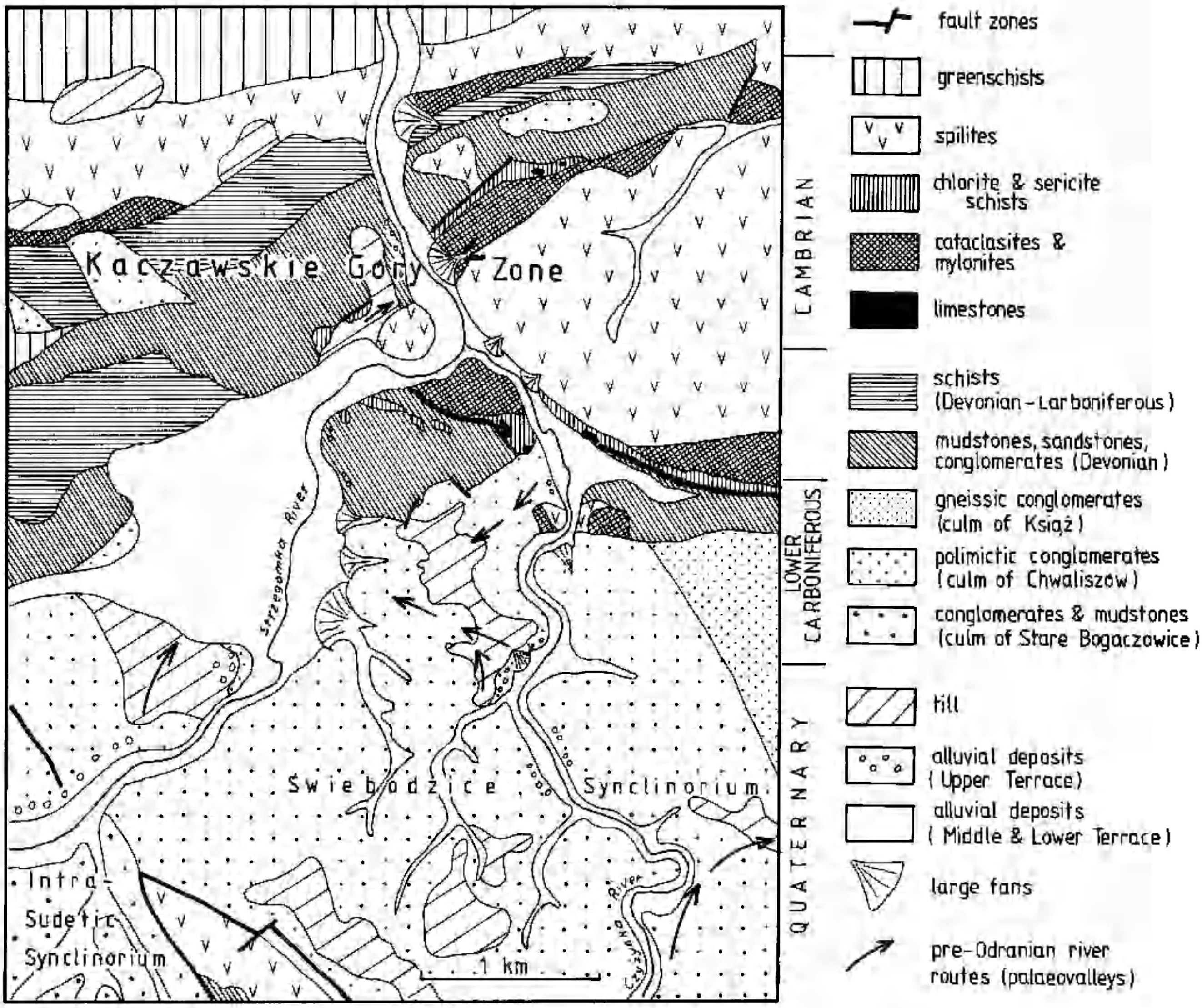

Fig. 3. Bedrock geology of the lower Czyżynka river valley and adjacent regions (based on Teisseyre, 1969 and Teisseyre & Gawroński, 1965; pre-Odranian fluvial pattern after Krzyszkowski & Stachura, 1998b).

ferent sizes and shapes on both slopes of the main valley. They may be grouped into three types: medium to large trough valleys, small trough valleys with bedrock slopes (bedrock ridges), and ravines with both bedrock walls and bottoms. The trough valleys are from few to several metres deep, usually 50–100 m wide and 100–700 m long. Their longitudinal profiles are 5–20° steep, often irregular (Fig. 6). The trough valleys are filled with thick colluvium, usually with different types of diamictons and/or redeposited loess. The largest are in part box-shaped and have fans in the downvalley position (Fig. 4, 6). The small trough valleys are located between bare bedrock (small ridges) and tors (Fig. 7). They are shallow, only several metres wide and up to 100 m long. Their longitudinal profiles are steep, reaching 15–25° and they are filled with thin colluvium, usually with loose blocks. Ravines occur only in the northern part of the valley with Cambrian bedrock (Fig. 4). These are deeply incised (up to 40–50 m), V-shaped, narrow valleys with steep rocky walls (Fig. 8, 9). The bottoms of the ravines are in part covered by loose blocks (in footslope positions) elsewhere there is bare bedrock. Longitudinal profiles are irregular. The ravines develop from large trough valleys, hence valleys are often trough-shaped in their upper part and become ravines downslope (Fig. 4).

Two generations of small fans have been recognized in the Czyżynka river valley (0.5–1.5 ha). The older fans, usually connected with the main tributary valleys and large trough valleys, are truncated in their lower part and are older than the Lower Terrace. In turn, the younger fans, usually connected with ravines, are superimposed on the Lower Terrace (Fig. 4).

The slopes of the Czyżynka river valley have varying shapes, from concave in valleys, convex-concave or straight where they are not eroded, to convex slopes and subvertical rock walls (Fig. 6). Also, in many places slopes are step-like, with several rock cliffs. Tors and slumps although rare, are also present (Fig. 4, 7).

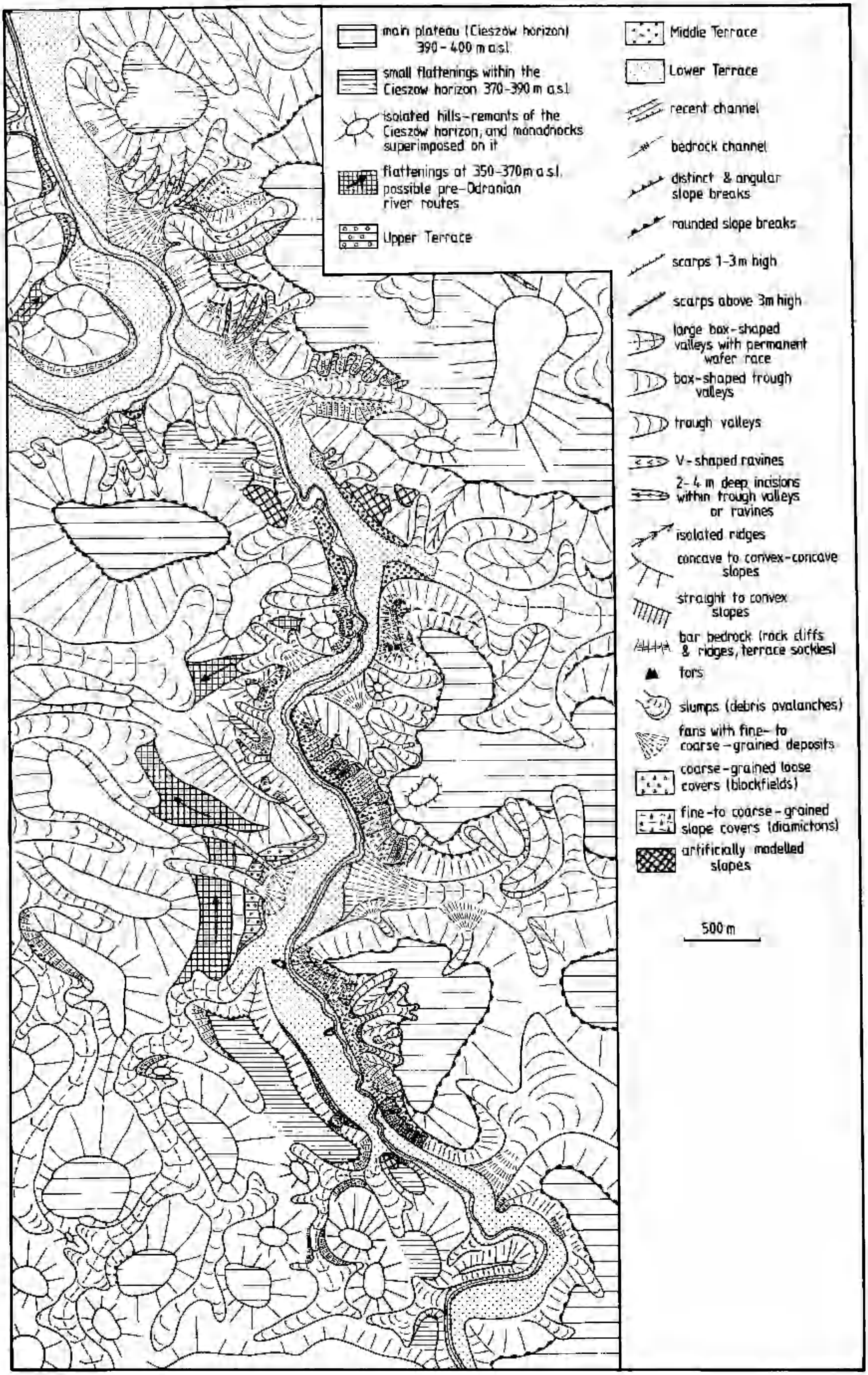

Fig. 4. Geomorphological map of the lower Czyżynka river valley of the Wałbrzych Upland, Middle Sudetes.

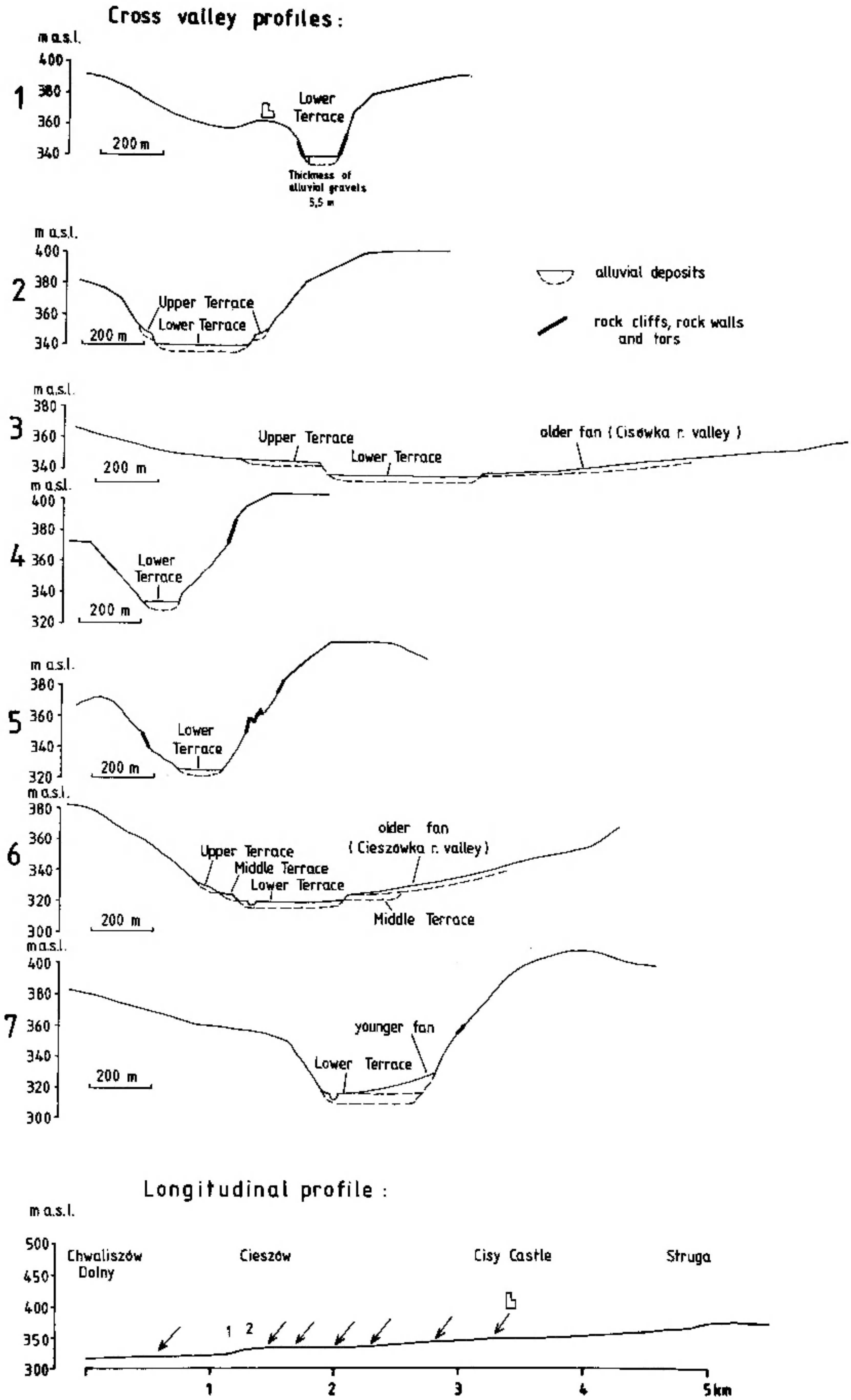

Fig. 5. Valley cross profiles (location in fig. 2) and longitudinal profile of the investigated part of the Czyżynka river valley. Arrows indicate location of cross profiles along the river; 1 – site Czyzynka 1, 2 – site Czyzynka 2, see discussion in the text.

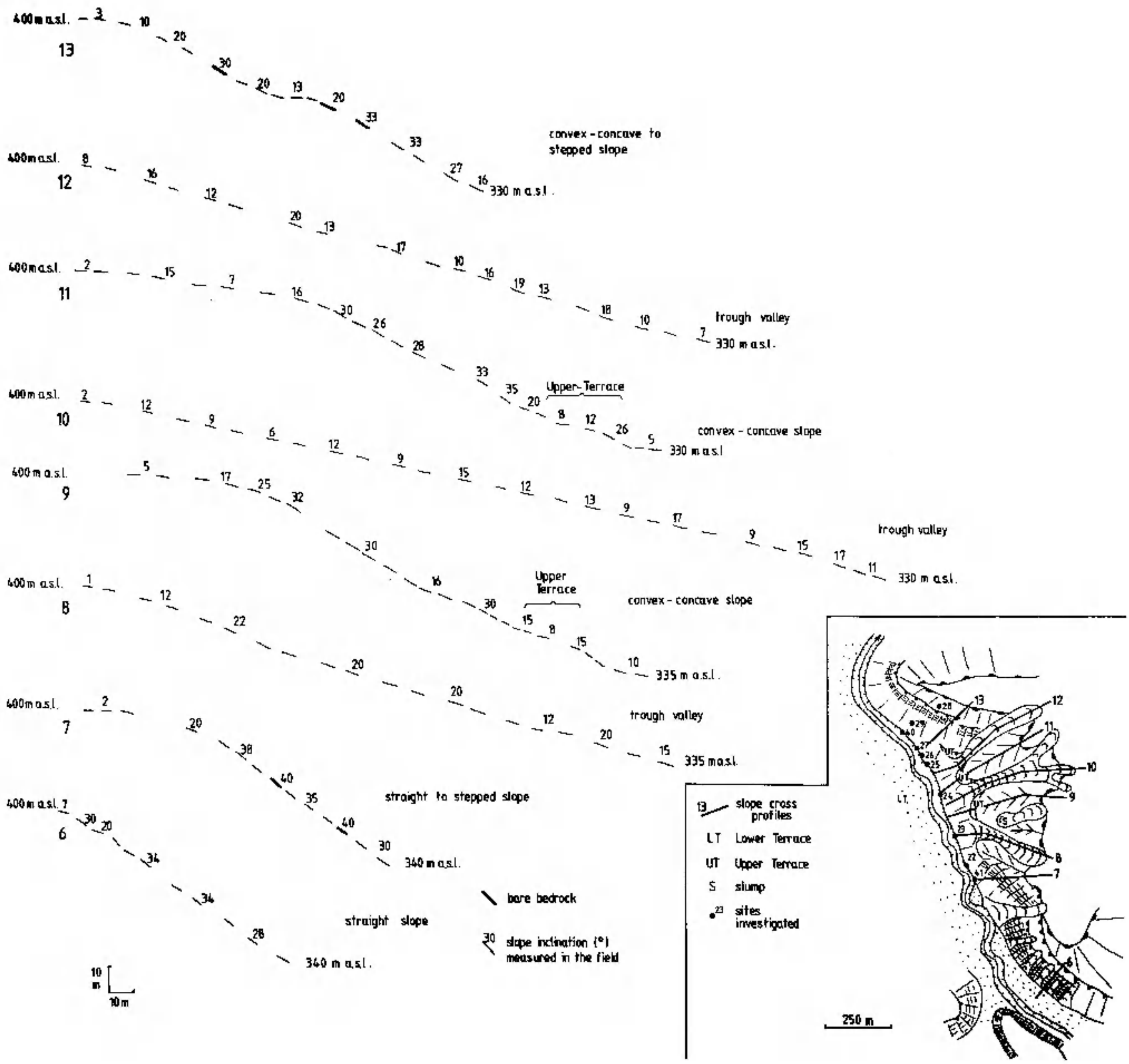

Fig. 6. Slope characteristics of the Czyżynka river valley near Cisy Castle: shallow trough valleys, convex-concave and straight slopes. The inset map shows the morphological context of the sites with slope colluvium.

FLUVIAL DEPOSITS

Fluvial deposits have been investigated in detail at thirteen sites; two in the Upper Terrace, three in the Middle Terrace and the others in the Lower Terrace (Fig. 2). Gravel studies of the fluvial deposits of the Czyżynka river valley (Krzyszkowski & Stachura, 1998b) indicated similar petrographic composition in all terraces and that local rocks prevail (conglomerates, quartz, quartzites, porphyry, gneiss and other local crystalline rocks, metamorphic shists, greenschists and spilites), although a small admixture of glacially-derived rocks is present (1–5%).

LOWER TERRACE

The fluvial sequences of the Lower Terrace are 1–3 m thick and commonly bipartite. Their lower parts comprise pebbles, pebble sands with single cobbles or coarse-grained sand and some layers of fine-grained deposits, whereas the upper parts of the fluvial sequences are formed of matrix-supported diamictons (Fig. 10, 11).

Coarse members of fluvial sequences, representing channel sedimentation, are massive or cross bedded. Massive pebble sands predominate, with well developed clast imbrication and maximum size of single cobbles up to 60

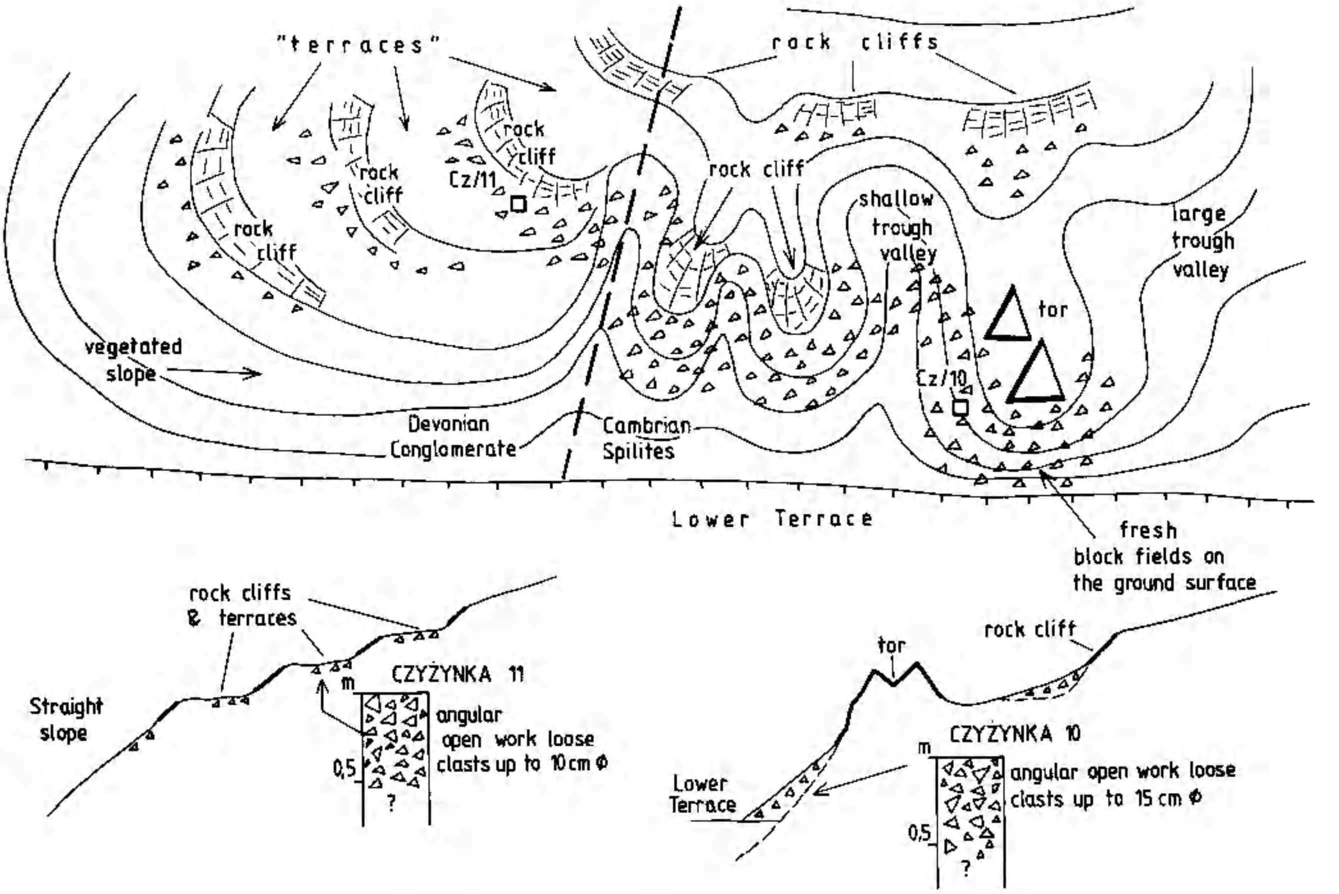

Fig. 7. Slope characteristics of the Czyzynka river valley near Cieszów and morphological context of the recently formed coarse-grained blockfields near Czyżynka 10 and 11.

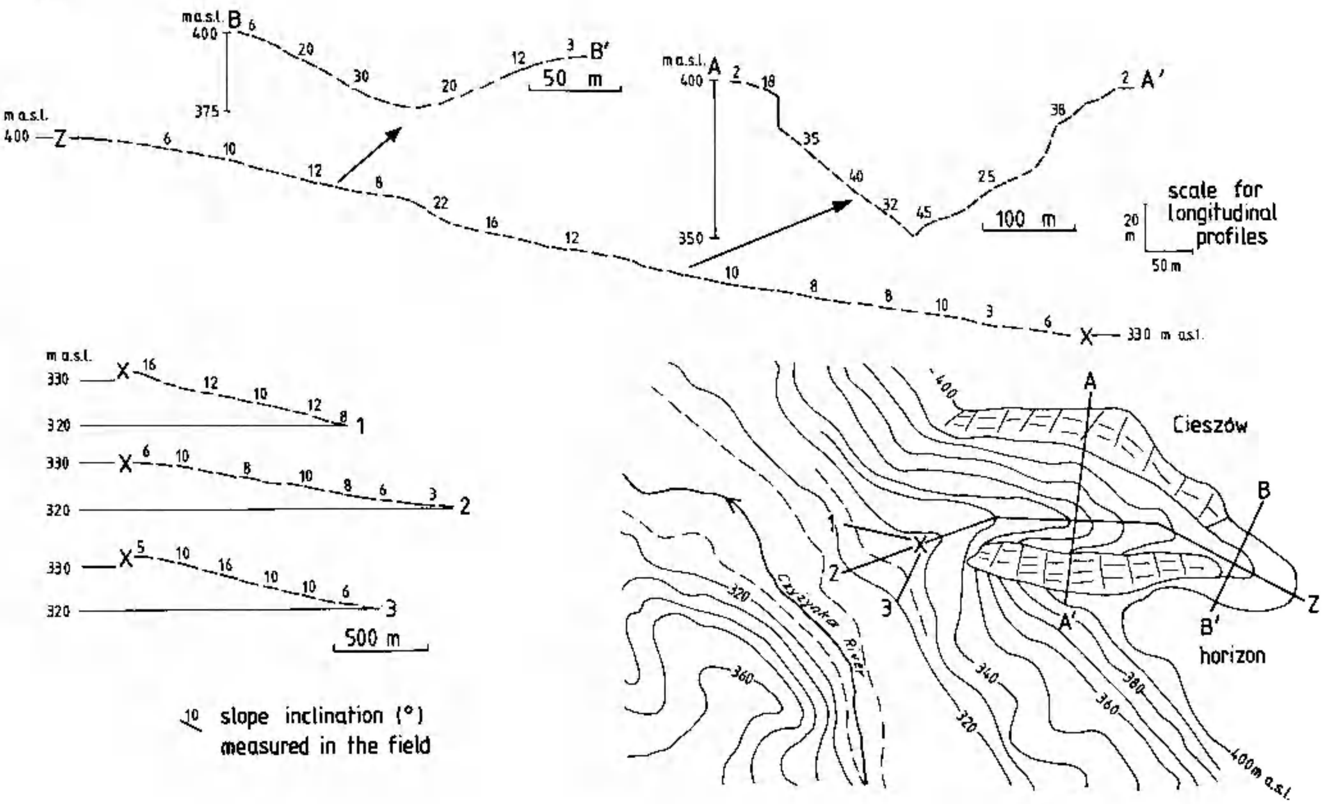

Fig. 8. Morphometrical characteristics of the ravines and younger fans of the Czyżynka river valley near Cieszów.

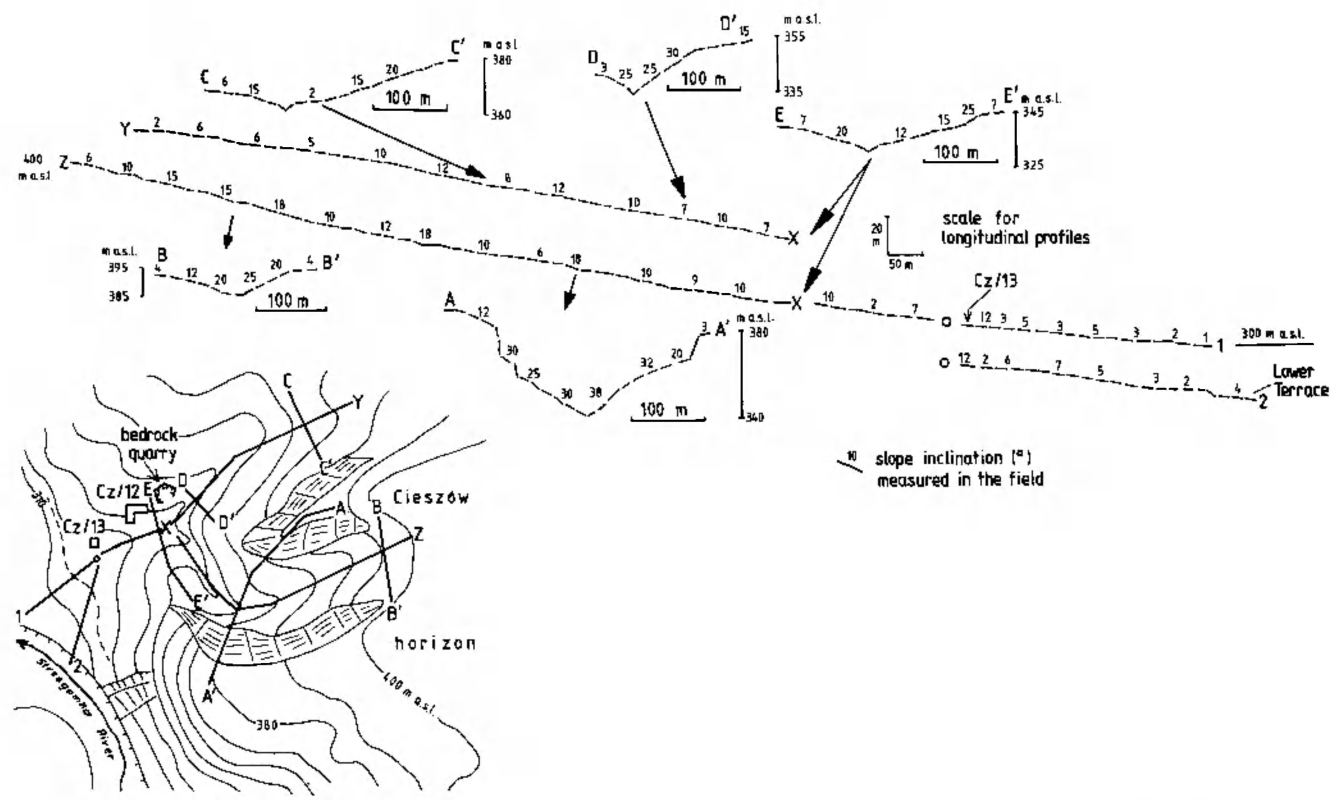

Fig. 9. Morphometrical characteristics of the ravines and younger fans of the Strzegomka river valley near Chwaliszów Górny (sites 12 and 13).

cm. Medium-scale trough and planar cross-bedding were observed only in a few sites (*e.g.* Czyżynka 1 and 3; Fig. 10). Also, low angle bedding, that may represent a lateral accretion (point bar) sequences, was observed (*e.g.* Czyżynka 2 and 6A; Fig. 10, 11). Massive and cross bedded deposits usually alternate with each other, suggesting pulsatory water discharge, with floods (massive, coarser deposits) followed by normal channel activity with sedimentation on point bars and formation of two- and three-dimensional structures in central channel. The fine-grained beds are composed of sandy silts, silts and clays. The thick clay layers may contain sandy laminae and single pebbles. These beds are from a few centimetres to 1 m thick. Their lateral extents are variable; many sites do not contain fine-grained beds, at others comprises only small lenses (*e.g.* Czyżynka 3 and 6B; Fig. 10, 11) whereas several sites have clay beds that are continuous along 5–15 m long sections (*e.g.* Czyżynka 16; Fig. 11). Moreover, these sites have a complexes of several silt/clay beds alternating with massive pebble sands.

The uppermost diamicton is massive to crudely bedded, matrix-supported and characterized by very poor sorting. The matrix is mainly sandy, with up to 20% of silt and clay is almost absent. The diamicton comprises granules and pebbles and some cobbles with diameters up to 25 cm. An alluvial and overbank origin of the diamicton layers is assumed both from their stratigraphic position as and the occurrence of numerous sub-rounded clasts and gravel lenses.

MIDDLE TERRACE

The Middle Terrace sequences are 3–5 m thick and comprise three layers (Fig. 12). The lower fluvial bed is formed of massive, strongly imbricated pebbles to cobbles and pebble sands. The maximum size of the cobbles is up to 30 cm. In one site, Czyżynka 4 (Fig. 12), a low angle lamination has been observed in the pebble sands, and this may represent a lateral accretion deposit. The middle fluvial bed is composed of alternating, 10–50 cm thick, layers of massive pebble sands and fine-grained deposits (silt, clay). The upper bed of the Middle Terrace sequence is formed of either alluvial, matrix supported diamicton with numerous sub-rounded clasts (Czyżynka 8) or mixed, alluvial and slope diamicton (Czyżynka 7), or slope deposits of the mouth of the trough valley (older fan) and/or loess (Czyżynka 4)(Fig. 12). In contrast to the alluvial diamicton of the Lower Terrace, this of the Middle Terrace comprises 10–20% of clay and almost 40% of coarse silt (loess).

UPPER TERRACE

Deposits of the Upper Terrace have been exposed only in one site (Fig. 13). The sequence is 2–3 m thick and comprise 1–2 m of fluvial deposits covered by 1 m of thick loess-like sediment. The latter, although closely resembling loess, comprises many granules and some pebbles, that suggest at least in part re-working on slopes or in the

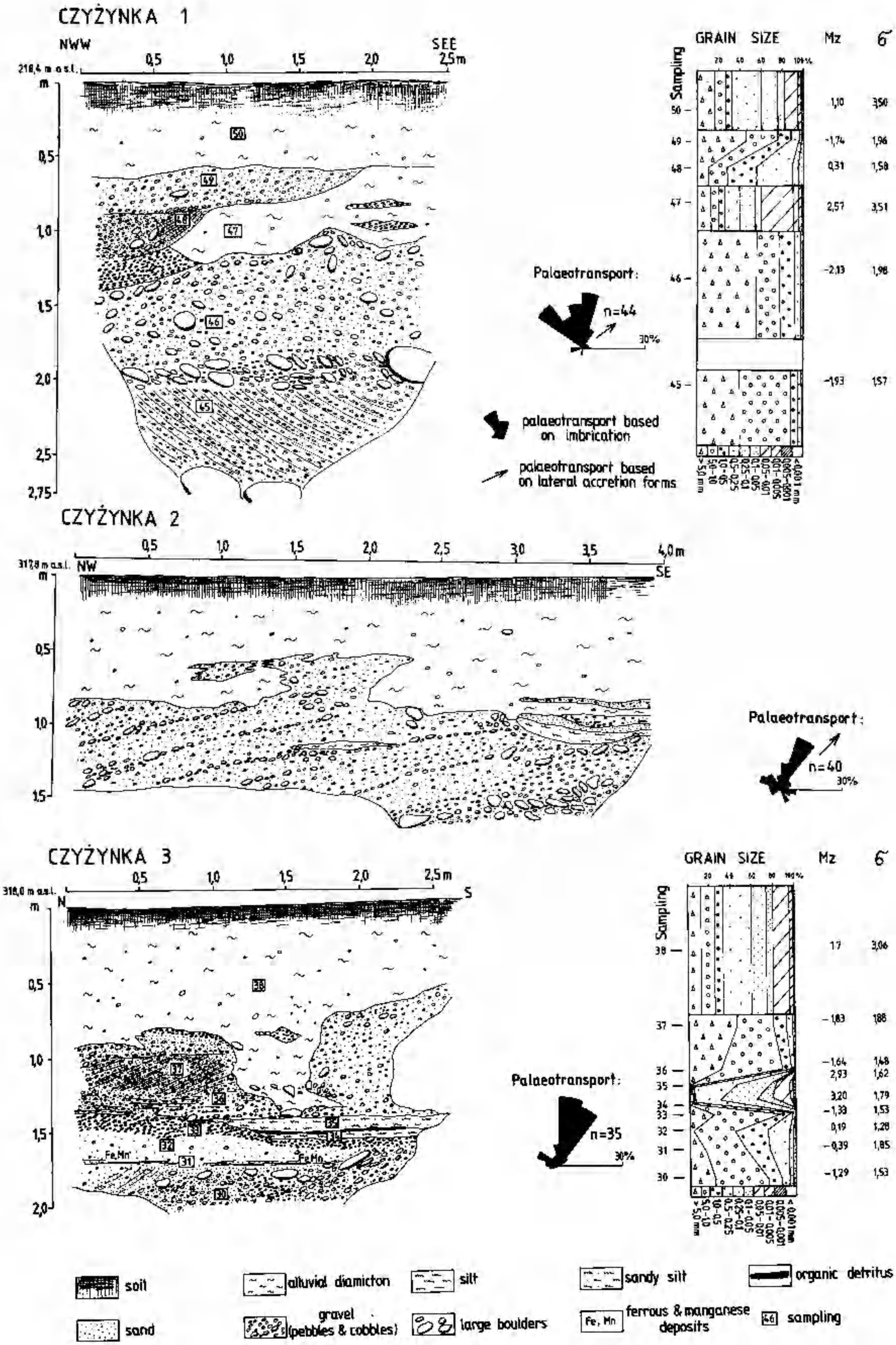

Fig. 10. Sedimentary structures, palaeotransport and grain size characteristics of the alluvial deposits of the Lower Terrace at sites 1, 2 and 3 of the Czyżynka river valley.

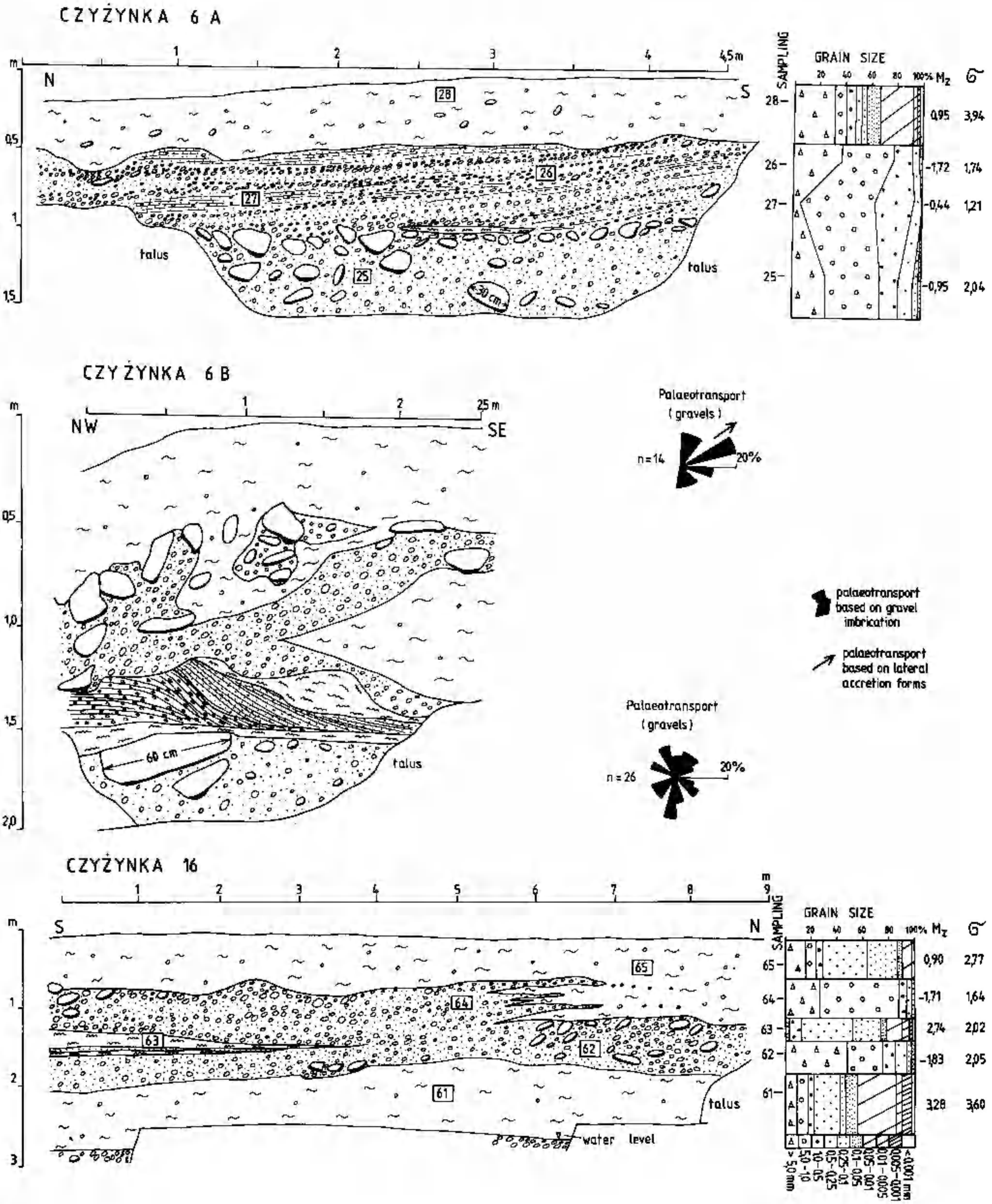

Fig. 11. Sedimentary structures, palaeotransport and grain size characteristics of the alluvial deposits of the Lower Terrace at sites 6 and 16 of the Czyżynka river valley.

fluvial environment. In places the loess-like and fluvial deposits interdigitate. Fluvial deposits comprise alternating beds of pebbble sands and fine-grained deposits. Pebble sands are 20–50 cm thick and are mainly massive and imbricated, although occasionally trough cross bedding has been observed. The maximum size of the gravels is up to 20 cm. Fine-grained beds are from a few centimetres to 50 cm thick, have limited lateral occurrence, and are found in two facies. The first is a massive to slightly laminated coarse silt, similar to the upper loess-like deposit, and the

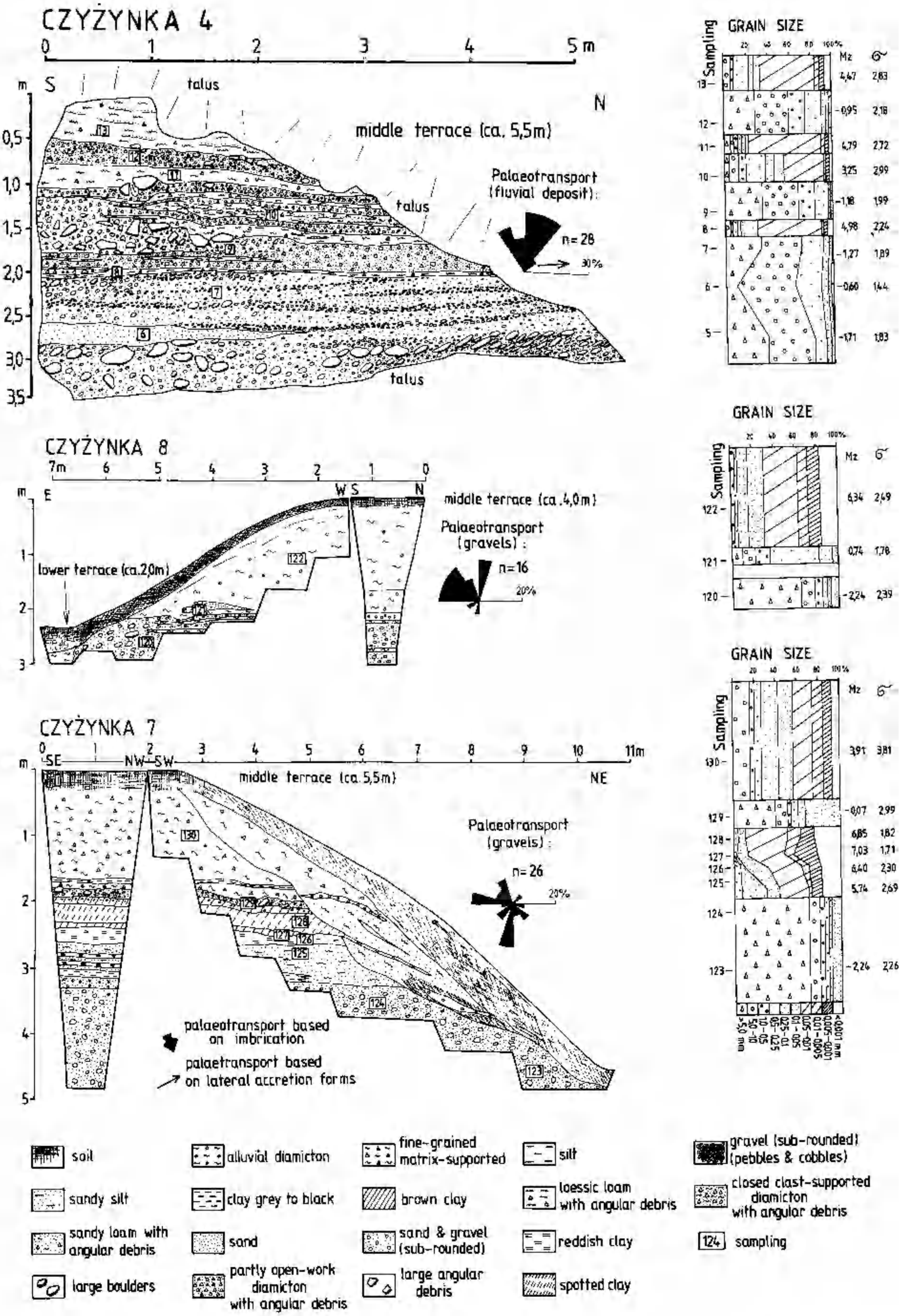

Fig. 12. Sedimentary structures, palaeotransport and grain size characteristics of the alluvial deposits of the Middle Terrace of the Czyżynka river valley.

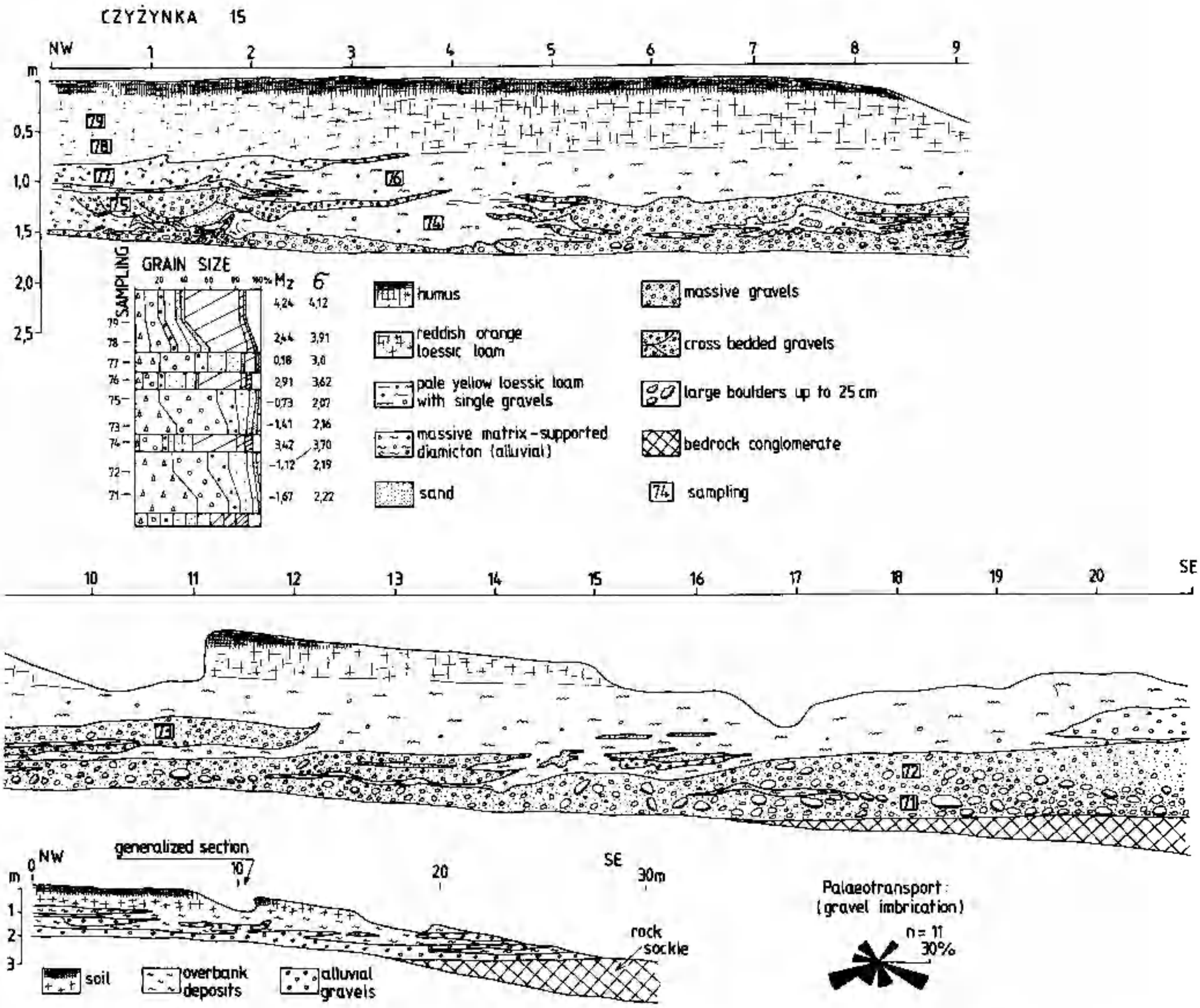

Fig. 13. Sedimentary structures, palaeotransport and grain size characteristics of the alluvial deposits of the Upper Terrace of the Czyzynka river valley.

other is a sandy diamicton with poor sorting and numerous subrounded granules. It seems, that both loess-like silty beds and diamictons represent an overbank accumulation and pebble sands were deposited in river channel.

FANS AND THEIR DEPOSITS

YOUNGER FANS

The best developed younger fans are located in the lowermost part of the Czyżynka river valley and in the adjacent part of the Strzegomka river valley (Fig. 4). They are formed always at the base of the valley slope and at the mouths of the deeply incised bedrock ravines (Fig. 4, 8, 9). These younger fans have semi-conical morphology, with a plano-convex cross profile. Longitudinal profiles are straight to concave, with mean inclination between 4° and 12°, with the largest inclination near apices about 12–16°. The younger fan sediments have been investigated in a 2 m deep trench (Czyżynka 13; Fig. 14), in the apex zone of the fan in the Strzegomka river valley.

The sequence investigated was only 2.25 m thick, whereas the total thickness of the sequence is assumed to about 8–10 m. It seems, however, that the fan sediments are uniform and the uppermost deposits characterize the entire fan sequence. The fan sequence contains three types of deposit. These are matrix-poor clast-supported, massive to crudely laminated diamictons, fine grained matrix-supported diamictons (sandy loam) and loessic loam (Fig. 14). In both types of diamictons clasts are only angular. The loessic loam occurs as silt balls or thin and discontinuous

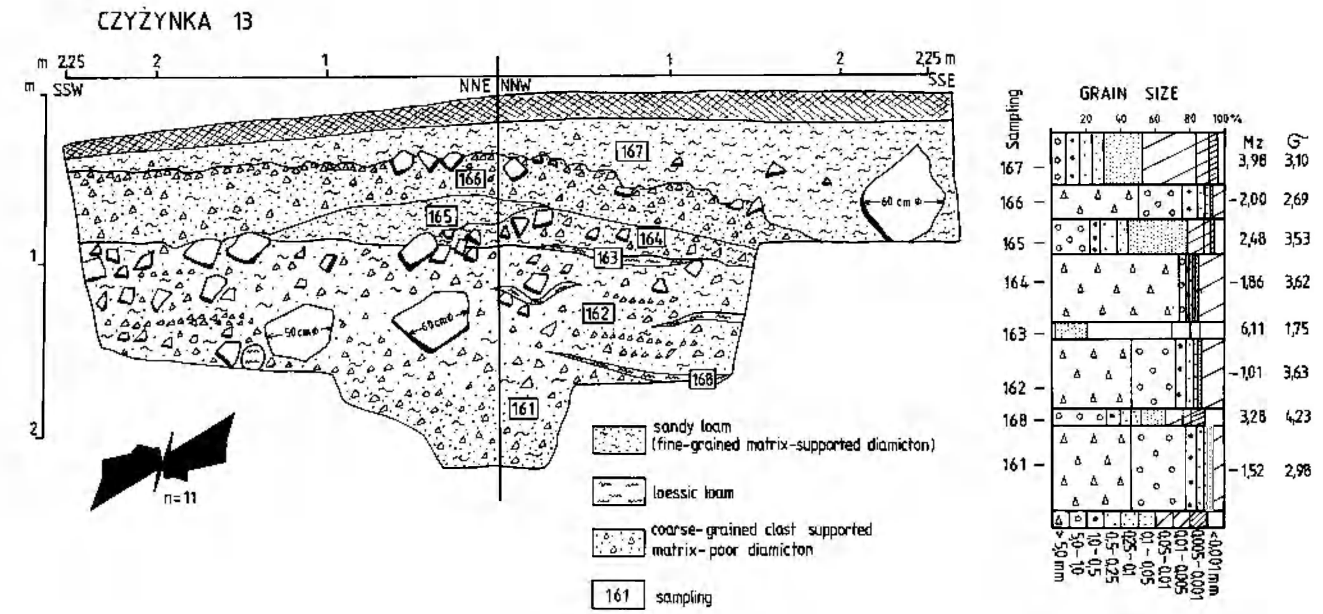

Fig. 14. Sediment sequence of the younger fan at Czyzynka 13, with palaeotransport and grain size characteristics (location of site in Fig. 2 and 9).

lenses (*e.g.* sample 163 in Fig. 14) and was redeposited from the older fans preserved in the upslope position (Fig. 15).

Petrographic composition of the clasts at site Czyżynka 13 shows distinct bipartite division of the profile. The lowermost layer (sample 161; Fig. 14) is composed only of cataclasite, whereas all deposits above contain 47–66% of cataclasites, 22–45% of spilites and 8–10% of other rocks. The last are represented by quartzite, metamorphic schist, crystalline rocks and conglomerates; all absent in the adjacent valley slope, although common in fluvial deposits of the region. Both cataclasite and spilite occur in the upslope position adjacent to the fan, although spilite occurs only in the upper part of the "southern" ravine and the cataclasite in both feeder ravines (Fig. 15A). Thus, it is clear that the younger fan was supplied by deposits of different ravines, at first only from the "northern" one, and later from both the "northern" and "southern" ravines. At this stage, older fluvial deposits must have been incorporated into the slope coluvium too, most probably due to destruction of older terraces.

OLDER FANS

Deposits of the older fans are found at Czyżynka 12 (Fig. 16) and Czyżynka 4 (Fig. 12). The section at Czyżynka 12 comprises distinctly separate and alternating beds of reddish, coarse grained (angular) colluvium and loessic loam. The coarse-grained colluvium is represented by three facies: matrix-negligible, clast-supported polimictic gravels; matrix-poor clast-supported diamicton, and coarse grained (red), matrix-rich clast supported diamictons. The matrix of the last is composed of redeposited loess, thus it seems that the colluvium was partly an open-work deposit, which was mixed with loess in the downslope position. The coarse grained beds are inclined 10–15° to the west. Petrographic composition of clasts is uniform throughout the section, with only cataclasite. This suggests deposition from the "northern" ravine, which is generally consistent with E-W slope transport (Fig. 15A). The loessic loam beds (fine-grained matrix-supported diamictons) of the upper part of the sequence contain either a large admixture of angular clasts which "float" in the loess matrix (samples 83 and 84) or only few clasts and a higher clay content (sample 86) (Fig. 16). These sediments are crudely laminated. In turn, the lowermost part of the sequence is occupied by a massive deposit, which is very similar to loess (loessic loam), although also with some coarse grains (samples 81, 81A) (Fig. 16). The lowermost part of the loessic loam contained molluscs. Sample 81 contained about 300 shells of *Succinea oblonga elongata* Sandberger, and sample 81A about 52 shells of *Succinea oblonga elongata* Sandberger and several fragments of *Arianta arbustorum* (Linnaeus) (S. W. Alexandrowicz, *pers. inf.*). This site was described before by Dathe & Zimmermann (1912) who found, in loessic material, shells of *Succinea oblonga* (common) and *Pupa muscorum* (rare).

The uppermost part of the sequence of the site Czyżynka 4 (Fig. 12) is formed of an alternating loessic loam and coarse grained (angular) colluvium, similarly to site 12, although here loess layers are thin. The coarse-grained deposits are represented by matrix-poor clast-supported diamictons. Petrographic composition of clasts indicate 94–96% of Carbonifeous conglomerates, which also represent the local bedrock. Small ammounts of quartz, lydite, quartzite, and red (Scandinavian) crystalline rocks indicate, however, redeposition of older fluvial sequences (Fig. 15B).

A model of fan deposition is presented in Fig. 15. The first stage of deposition was connected with the formation of the shallow trough valleys. Repeated downslope transport of loessic loam and coarse grained colluvium formed

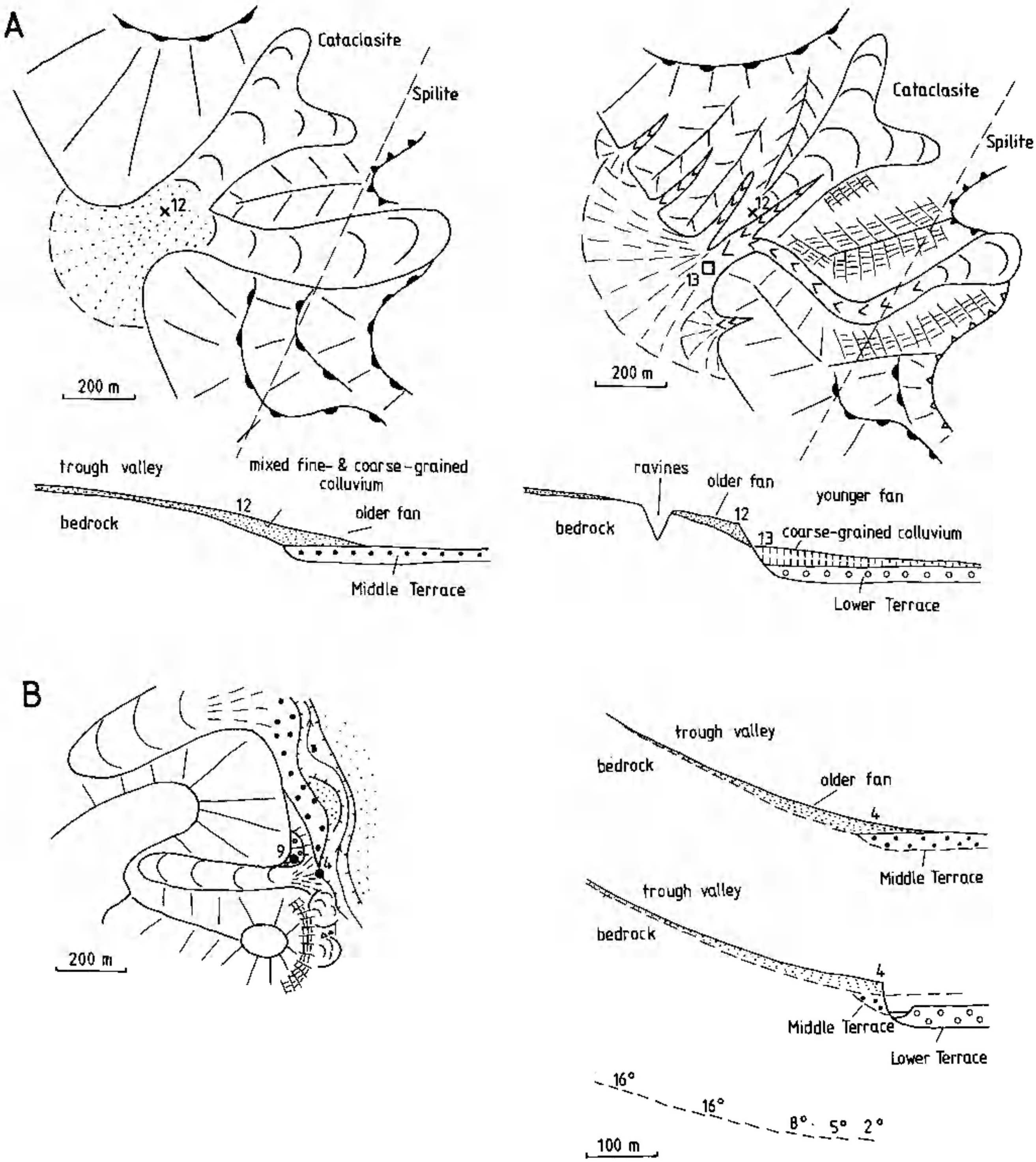

Fig. 15. **A** – Evolution of the trough valleys and their remodelling into ravines and formation of older and younger fan sequences near Czyżynka 12 and 13 (left – situation from Middle and Upper Weichselian Pleniglacial; right – situation from Younger Dryas to present-day); **B** – Geomorphological context and evolution of the shallow trough valley near Czyzynka 4 (right down – slope inclination along this trough valley).

the fan, most probably, superposed partly on the alluvial sequence of the Middle Terrace. During the next stage, the older fans were partly eroded and finally, when ravines were incised in some former trough valleys, the younger (coarse grained) fans were deposited (Fig. 15).

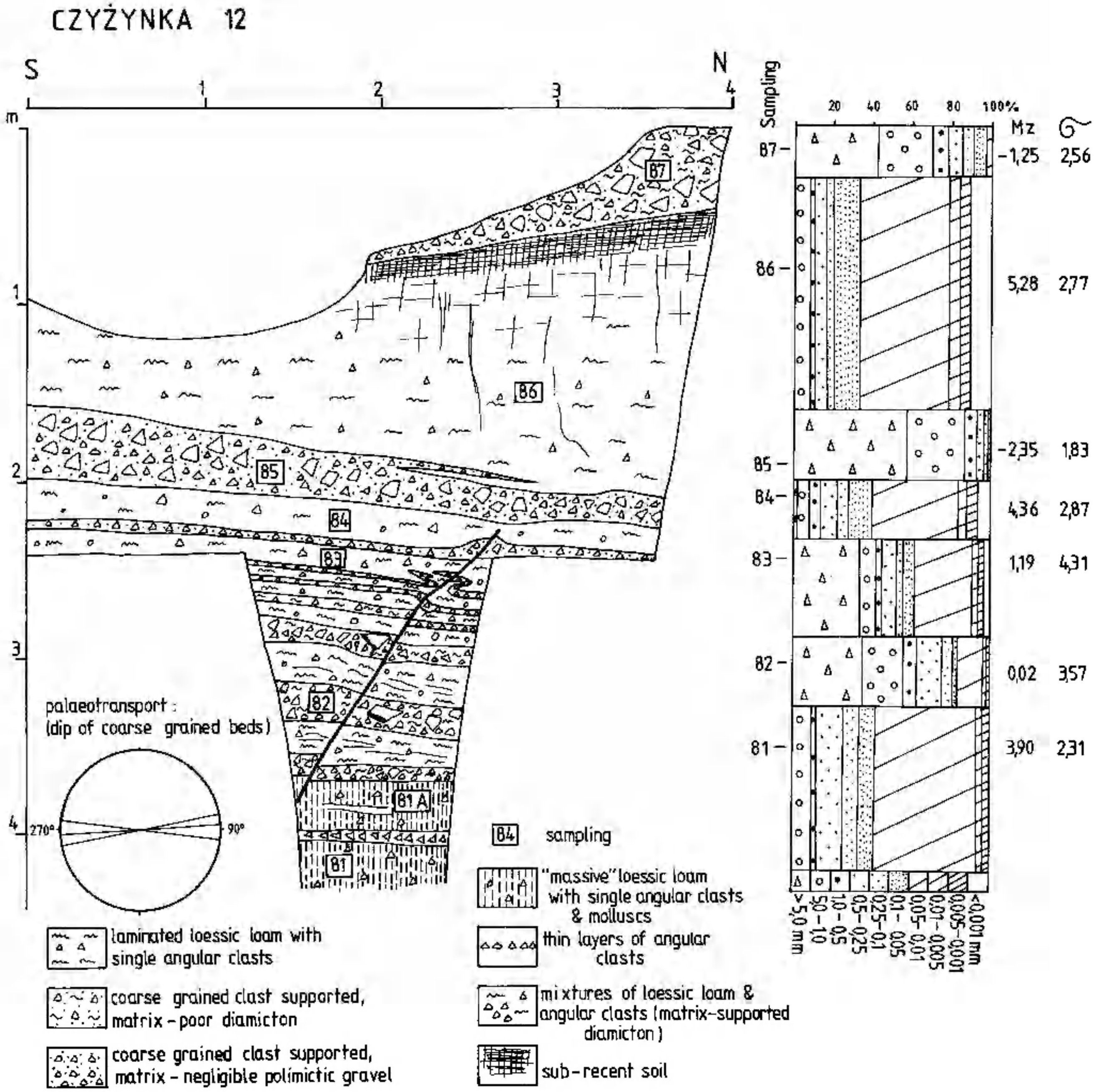

Fig. 16. Sediment sequence of the older fan at Czyżynka 12, with palaeotransport and grain size characteristics; molluscs were found in the lowermost beds (samples 81 and 81A).

SLOPE DEPOSITS

Twenty sites with slope deposits have been examined. The recently formed (fresh) slope covers have been found in six sites and others contained only buried colluvium, completely or partly covered by forest or grassland (Fig. 2).

BURIED SLOPE COVERS

Czyżynka 57

Site 57 is typical of its region, grass-covered, convex-concave slope. Sediments were exposed in a 1–2 m deep and 800–900 m long trench (Fig. 17). Slope inclination, measured along the trench, is 20–25° in the upper, straight to convex part of the slope, and 10–15° in the lowermost, concave part. Three types of slope deposits have been recognized which are superposed on each other (Fig. 17). The upper, convex slope contains the open-work loose angular debris with blocks up to 50 cm (usually 10–20 cm), underlain by bedrock. Downslope (straight to convex slope), matrix-negligible clast-supported polimictic gravels with clasts up to 30 cm occur. The footslope (concave slope) is

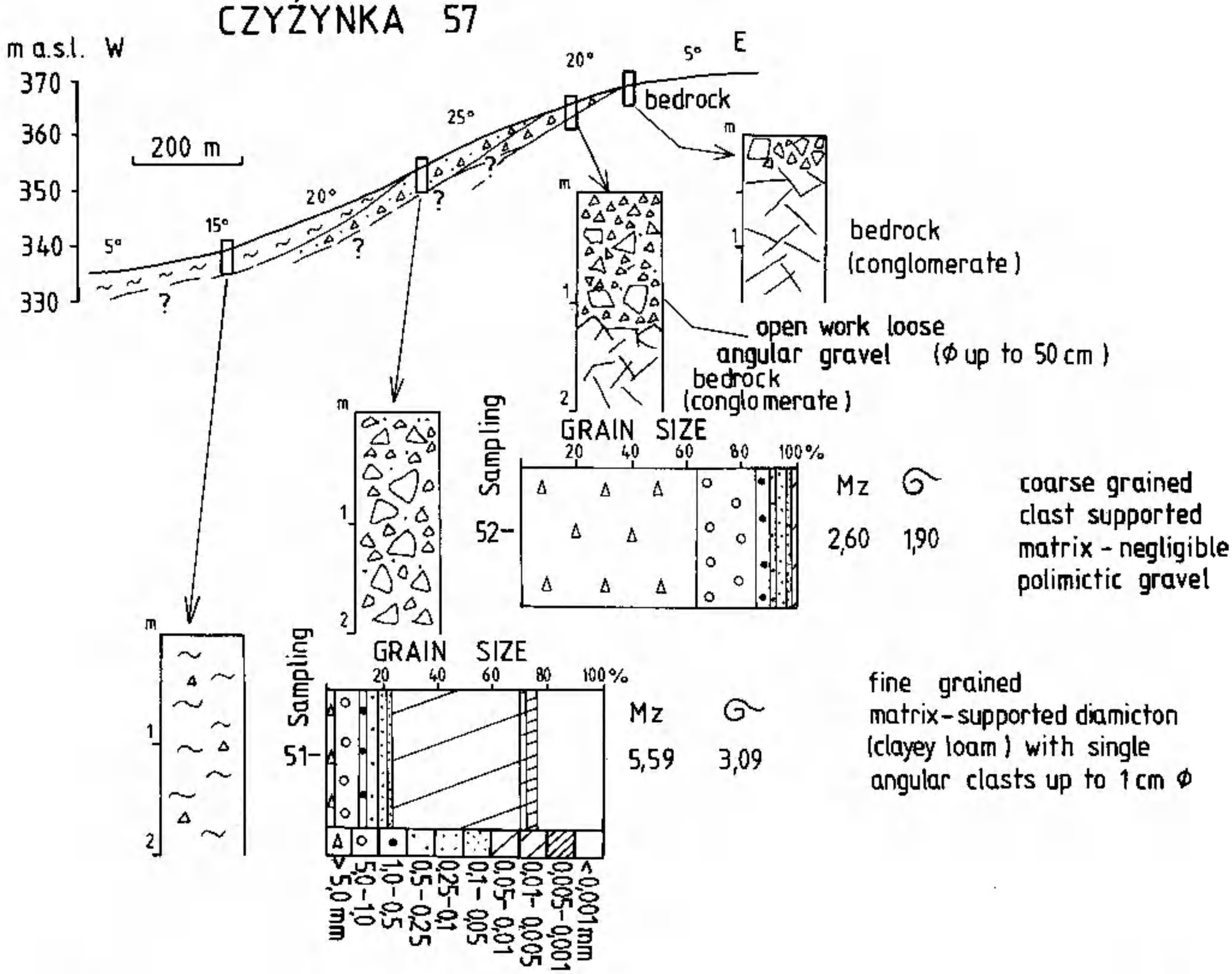

Fig. 17. Sequence of slope colluvium and its grain size characteristics at Czyzynka 57. Morphological context can be seen in Fig. 2 and 4.

characterised by an occurrence of fine grained matrix-supported diamicton (clayey loam), which contains only occasional angular clasts up to 1 cm in diameter. Transitions between the deposits described are gradual. All the clasts are angular and are formed of Carboniferous conglomerates, with no erratics.

Czyżynka 30

This site is located within the lower part of a trough valley at the base of a 20° inclined convex-concave slope (Fig. 2, 18). Fragments of the Middle Terrace (6–7 m high) have been observed at the valley piedmonts, on both sides of the slope cover under discussion. Hence, it is possible that the slope deposits are superposed on this terrace.

Three types of slope colluvium have been observed. These are fine-grained matrix-supported diamictons (clayey loam) (samples 106, 104); matrix-poor clast-supported diamictons which occur in two sub-types, coarse- (samples 101, 102, 103, 105) and fine-grained (samples 108, 109); and an open-work loose angular debris (sample 107) (Fig. 18). The last occur only as thin, festoon-like layers (15–50 cm) within the matrix-poor clast-supported diamictons. Clasts are angular, with maximum size 20 cm in open-work layers and 35 cm in coarse-grained diamictons.

The lower part of the profile (6–7 m thick) is composed of alternating beds of clayey loam and coarse grained matrix-poor clast-supported diamictons. Boundaries between these two facies are usually gradual; the sediments are often deformed. The clayey loam beds have varying thickness and are wedge-shaped, with thickness increasing downslope. Both the clast orientation and dip of beds show transport from SE to NW, which indicate an "eastern" trough valley as the source area of colluvium (Fig. 18). Petrographic composition of clasts shows more complex history. The lowermost bed (sample 101) contains 61% chlorite schists, 37% of cataclasites, 1% quartz and 1% red granitoid, most probably of Scandinavian origin (glacially-derived). Cataclasites form the nearest bedrock, and schists occur only in the uppermost part of the trough valleys (Fig. 18). Quartz and red granitoid may come from redeposition of the fluvial sequence of the Upper or Middle Terraces. Other diamicton layers contain only chlorite schist (+ single quartz grains). This means, that the colluvium was transported from upslope position, and with no

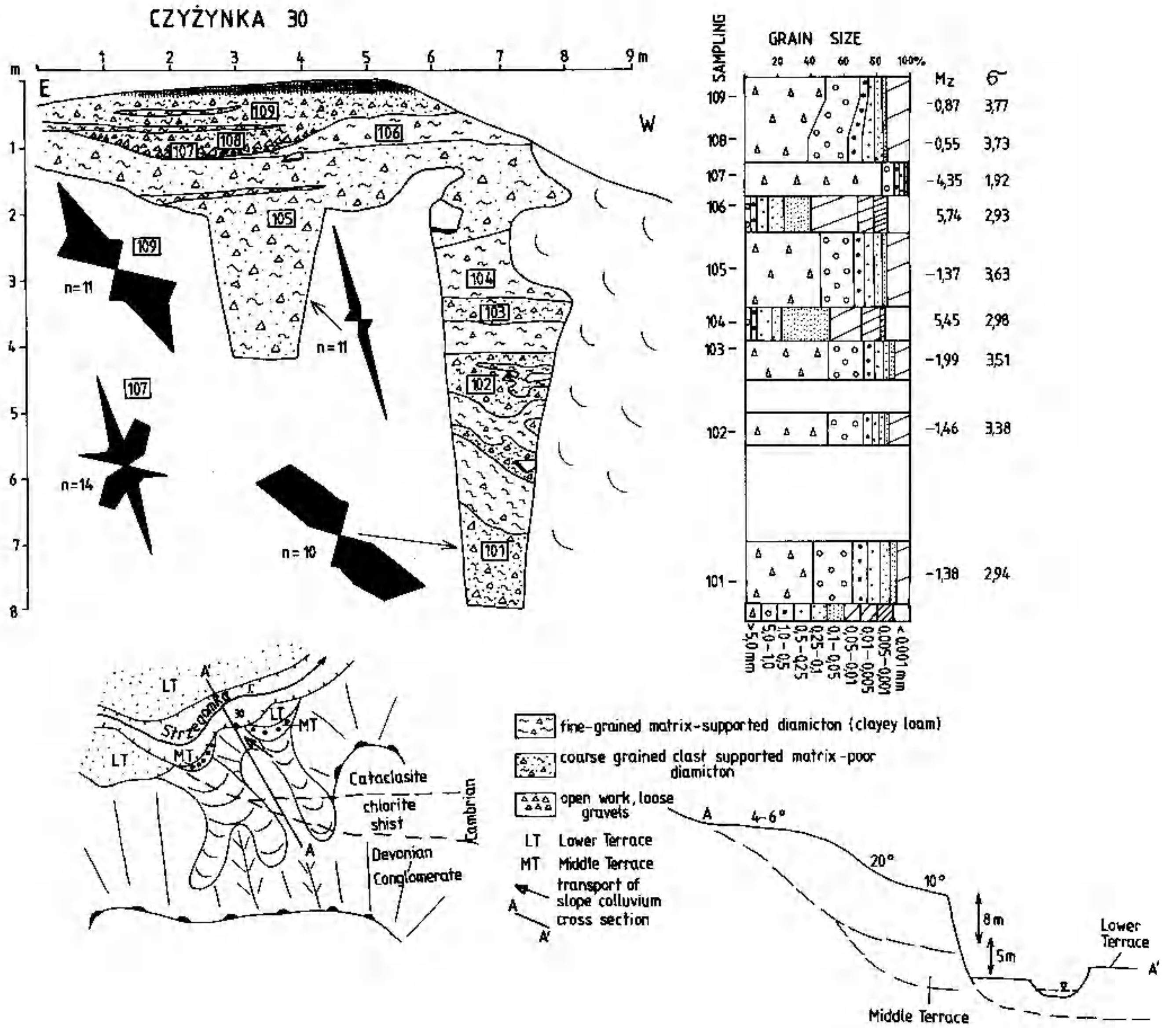

Fig. 18. Sequence of slope colluvium, morphological context, palaeotransport and grain size characteristics at Czyżynka 30.

contact with bedrock (cataclasite), most probably due to a former thick cover of colluvium.

The upper part of the profile is 1–2 m thick and is formed of fine-grained matrix-poor clast-supported diamicton with two 5–10 cm thick lenses of clayey loam and two 15–50 cm thick festoon-like beds of open-work clasts. The entire sequence fills a distinct erosional form cut in the older colluvium (Fig. 18). Palaeotransport was from the same direction as in the lower sequence (chlorite schists are up to 99%).

Czyżynka 5

This site is located within a debris tongue with distinct avalanche morphology. The avalanche slope consists of a spilite bedrock wall in the head position and a convex (in cross section) and irregular (in longitudinal section) tongue downslope. The avalanche area is small (ca 100 m^2); total thickness of deposits is up to 6–8 m. The lower part of the avalanche tongue is truncated by fluvial erosion (Fig. 19).

The sediment sequence is uniform and comprises only massive, coarse-grained, matrix-rich clast supported, distinctly bimodal diamicton (Fig.19). The matrix is silty (25–35% coarse silt = loess fraction), with an abundant clay admixture (5–8%). Large clasts float in the matrix and all are angular and formed of spilite. Maximum size of clasts is up to 1.3 m, with the average between 15 to 50 cm. Clast orientation shows paleotransport from SW to NE, which is generally consistent with the W–E orientation of an avalanche tongue. However, an additional clast orientation, transverse to the main one, is also documented (Fig. 19).

Czyżynka 23, 24, 22 and 41

Sites 22 and 24 are located in the base of convex-concave 20–30° inclined slopes and site 41 at the footslope of a 40° inclined straight slope (Fig. 6). Site 23 is located at the mouth of a trough valley, within the flat area, inclined

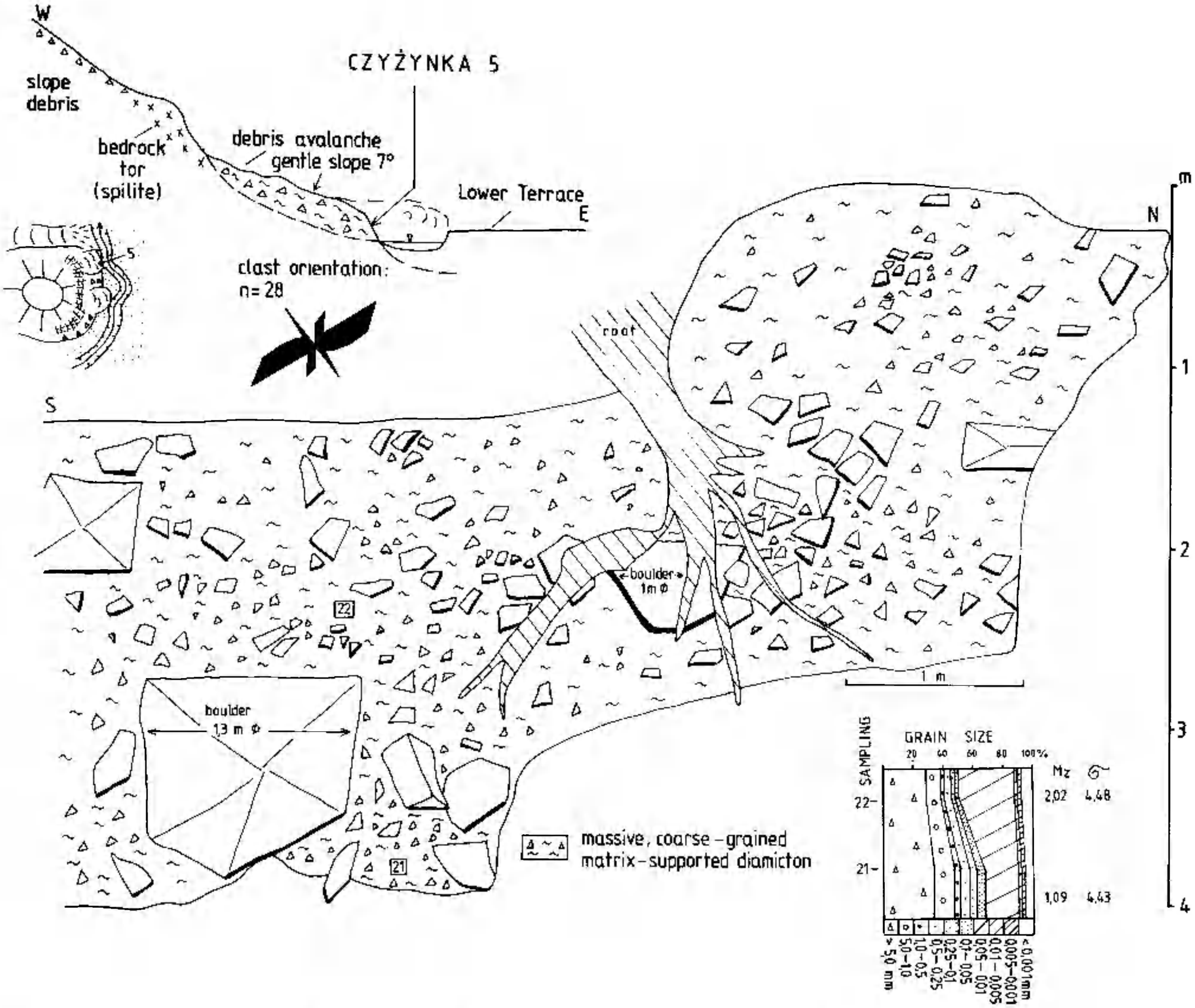

Fig. 19. Sequence of slope colluvium, morphological context, palaeotransport and grain size characteristics at Czyzynka 5.

only at about 9° (Fig. 6). In spite of different positions, these sites comprise similar and very homogeneous slope deposits. This is a massive, coarse grained, matrix-rich clast supported, distinctly bimodal diamicton, like in Czyżynka 5. The diamicton bed is up to 5 m thick. Clast fabrics show generally palaeotransport from NE or ENE, and besides the main direction, there are also distinct transverse orientations. Dips of clasts indicate both downslope and upslope directions. Petrographic composition shows only angular Carboniferous conglomerates or clast-components of these conglomerates (*e.g.* gneiss, quartz), except site 23 with 5-8% of well rounded, quartz (3-7%), lydite (0.5-1%), Sudetic porphyry (0.5-1.5%), quartzite (0.5-1%) and one Mesozoic flint (0.5%). Well rounded clasts, including the glacially-derived flint, must have been redeposited from fluvial deposits. The Upper Terrace surface is the best candidate as a source area, as its remnants have been found between trough valleys supposed to be main source areas of the slope coluvium (Fig. 4, 6).

Czyżynka 25

This site is located at the footslope of a 25-30° inclined slope but it comprises different slope deposits from those described above. Three types of colluvium are present: fine-grained matrix-poor clast-supported diamicton and coarse-grained matrix-poor clast-supported diamict, both with a very small admixture of sandy-silty or silty matrix; and the open-work gravel layers.

The sediment sequence consists of two distinct layers (Fig. 20). The lower bed is represented by fine-grained matrix-poor clast-supported diamicton with a sandy-silty matrix admixture of 15%. The silt fraction of the matrix is characteristic of loess (coarse silt). Clasts sizes are usually between 1-5 cm, although single clasts may reach up to 30 cm in diameter. The sediment is massive or interbedded with several 10-20 cm thick festoon-like beds of open-work gravels, with the mean diameter of the clasts 5-15 cm (Fig. 20). The upper bed is composed also of matrix-poor clast-supported diamicton, though the matrix reaches up

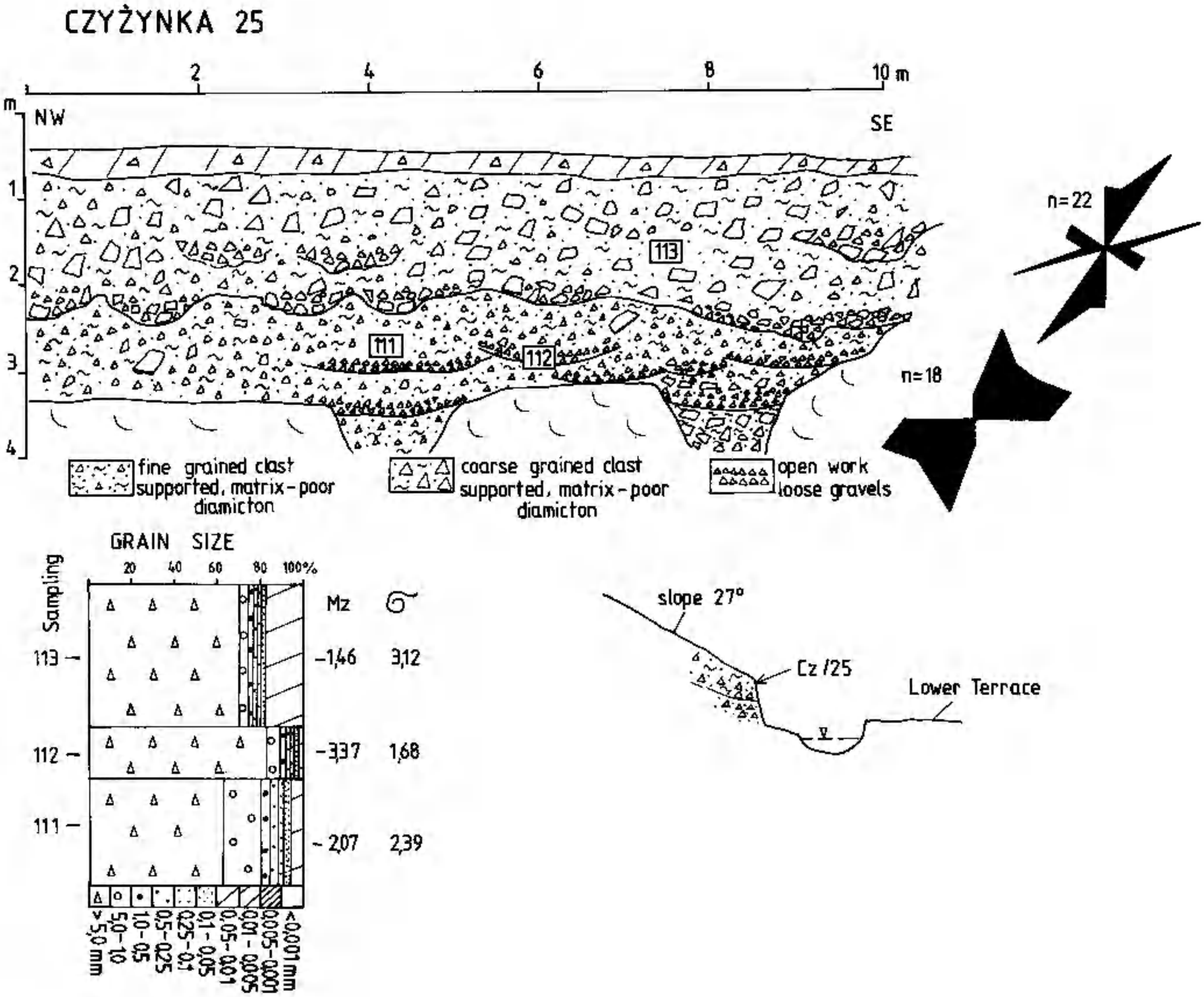

Fig. 20. Sequence of stratified slope colluvium, palaeotransport and grain size characteristics at Czyżynka 25. Morphological context can be seen in Fig. 4 and 6.

to 25% with mainly coarse silt (= loess) (18–20%). Clasts are distinctly larger than in the lower bed and are usually 10–30 cm. The sediment is usually massive, although some 10–20 cm thick festoons of the open-work clasts with mean diameters of 10–15 cm are also observed, especially at the lower boundary of the bed.

Palaeotransport in both diamicton layers is similar, from NE to SW. The upper bed indicates some transverse orientations of clasts and both down and upslope dips. The lower bed and festoons of open-work material indicate only downslope (and parallel to the slope) dips of clasts. Both types of diamictons comprise 98–99% of conglomerates and their clast-components. Additionally, well rounded quartz is found (1–2%) and local quartzite (grey) and Scandinavian red quartzite.

Czyżynka 27 and 26

These sites are located at the base of steeply inclined (35°), straight slope (Fig. 6, 21). The section comprises, besides the bedrock, four distinct beds, from bottom (Fig. 21): 1. a massive, coarse-grained matrix-poor clast-supported diamicton, with clast diameter up to 70 cm. This bed is ca 1.5 thick; 2. a stratified deposit with alternating beds of fine-grained matrix-poor clast-supported diamicton and open-work gravel (samples 114 and 115). The diamicton layers are usually thicker, reaching 15–30 cm. The average clast size is 1–5 cm, with single clasts up to 20 cm. The matrix is sandy-silty and reaches up to 20%. The open-work gravel beds are 5–10 cm thick and contain clasts with an average size of 1–3 cm. They are festoon-like or form straight and parallel layers. This bed is up to 2.5–3.5 m thick. Lower boundary of this bed is erosional; 3. a massive, matrix-negligible clast-supported polimictic gravels (sample 116), with average clast sizes 1–5 cm, and some larger clasts up to 30 cm. The matrix is sandy-silty and only up to 10–15%. This bed is 0.5–1 m thick. The lower boundary, though distinct, is probably gradual; 4. a coarse-grained matrix-poor clast-supported diamicton (sample 117), with clasts up to 30 cm and silty matrix. The matrix contains almost only coarse silt (=loess, 18%) with a small

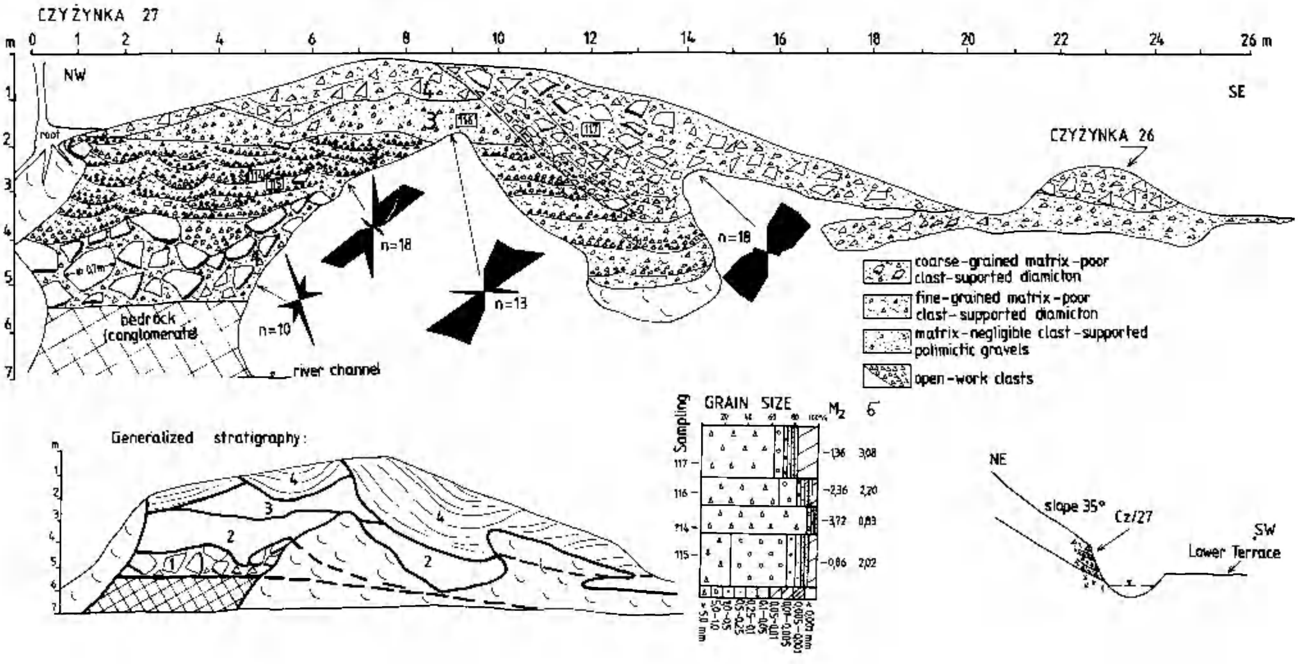

Fig. 21. Sequence of complex slope colluvium, palaeotransport and grain size characteristics at Czyzynka 26 and 27. Note festoon-like occurrence of open-work beds within the matrix-poor diamicton (bed 2), tabular occurrence of matrix-negligible coarse-grained polimictic gravels (bed 3), and a lobate structure of the uppermost, matrix-poor clast-supported diamictons (bed 4). Morphological context can be seen in Fig. 4 and 6.

(5–7%) admixture of sand. The sediment is massive and forms distinct lobate structures, suggesting strongly erosional lower boundary. Maximum thickness of this bed is up to 4 m (Fig. 21).

The palaeotransport directions are generally in accord with a possible source of the material in the straight slope above the site (Fig. 21). Beds 2 and 3 are characterized by dips parallel to the slope (downslope orientation) whereas the diamictons of beds 1 and 4 have both down- and upslope oriented dips of clasts. The petrographic composition is uniform, with 97–100% angular conglomerates and their clast-components. There is, however, 1–2% of well rounded quartz in almost all beds and 1% of Sudetic porphyry (one clast) and local quartzite (one clast) in beds 2 and 4.

Czyżynka 40

Site 40 is located at the footslope of a steeply inclined (36°), straight slope. The section is composed of stratified deposits which contains alternating beds of matrix-poor clast-supported diamicton and open-work gravel beds, which are similar to deposits of the bed 2 at Czyżynka 27 (Fig. 22). The diamictons may be fine-grained (lower part) or coarse grained (upper part), with average clast sizes about 2–5 cm, and maximum sizes up to 30 cm. The open-work beds contain clasts up to 20 cm, though on average 2–5 cm. These beds are 10–30 cm thick, and are mostly festoon-like (Fig. 22). Sometimes, matrix-negligible clast-supported polimictic gravels are present in festoons, instead of pure open-work gravels.

Palaeotransport is uniform throughout the bed, generally from NE to SW, with both down- and upslope dip orientations. This direction well corresponds with a possible source area of colluvium in upslope position as the petrographic composition of clasts indicate only Carboniferous conglomerates.

RECENTLY FORMED (FRESH) SLOPE COVERS

Shallow trenches have been dug in the fresh debris cover lying on the convex and straight slope formed of Carboniferous conglomerates (Fig. 22). They contained only the open-work clasts, with average clast sizes 5–10 cm (site 28) and alternating beds of the open-work clasts and matrix-poor clast-supported diamictons (site 29). It seems, that the sequence is typical sequence of a debris talus formed below exposed bare bedrock or tors (Fig. 22).

Trenches at sites 36 and 38 have also been dug in the 40° inclined, straight slope, covered by fresh open-work blockfields (Fig. 4, 23). The clasts have varying sizes and are angular. All of them are formed of Carboniferous conglomerate, that is also exposed in tors. Downslope, at site 37 (Fig. 23), this blockfield is exposed in 4.5 m high section. It contains alternating matrix-poor clast-supported diamictons and open-work gravels, similar to the sequence of site 40.

Another two trenches in fresh, angular open-work debris covers have been located within the Cambrian spilites (site 10) and within the Devonian sandstones and conglomerates (site 11) (Fig. 7). The slope debris occurs in different morphological positions. The spilite zone is characterized by an occurrence of tors separated by shallow trough valleys. The Devonian zone (Fig. 7) is characterized

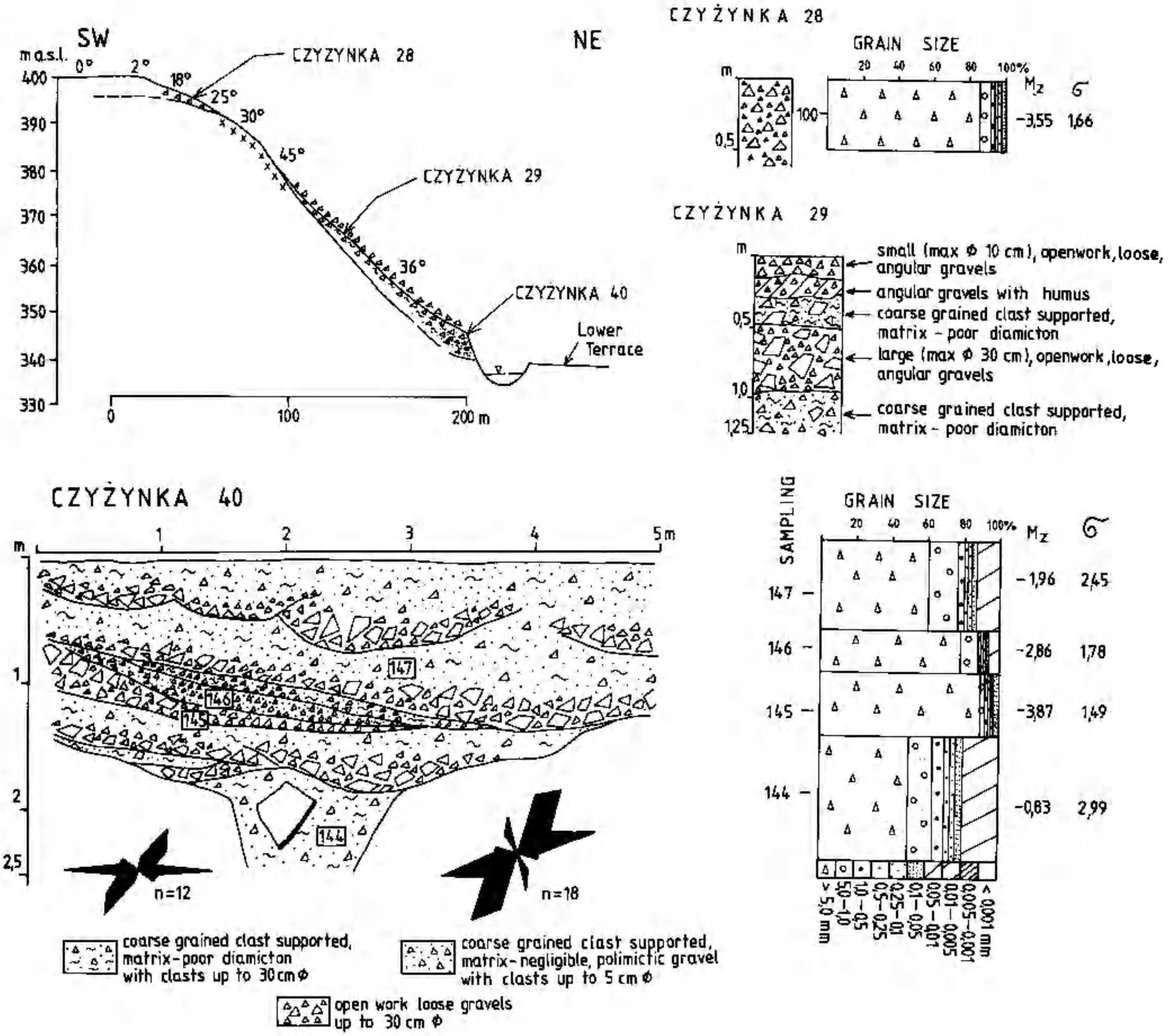

Fig. 22. Sequence of stratified slope colluvium, palaeotransport and grain size characteristics at Czyżynka 40, 28 and 29. Morphological context can be seen also in Fig. 4 and 6.

by an occurrence of stepped slope morphology with at least two or three, 2–3 m high rock cliffs separated by gentle inclined surfaces. The cliffs and flat surfaces together may be interpreted as cryoplanation terraces, that were formed during periglacial conditions, although surficial clasts are very fresh and they, most probably, were formed due to recent winter frost activity.

INTERPRETATION

FLUVIAL DEPOSITS

The Lower Terrace deposits were formed in a sinuous to meandering river, as indicated by an occurrence of alternating coarse- and fine-grained deposits, fining upward sequences as well as lateral accretion bedding. Also, palaeoflow measurments show variable orientations of palaeochannels, diagonal or even perpendicular to the orientation of valley. The river channels were, however, gravel-bearing and suggesting a mountain river, very similar to the present one. The uppermost (alluvial) diamicton layer of the Lower Terrace may in part represent a recent flood deposit (Teisseyre, 1977, 1979). At least the upper parts of the Middle and Upper Terrace sequences have been deposited in sinuous to meandering rivers, as they exhibit similar deposits and sedimentary structures to the Lower Terrace (Table 1). An additional characteristic, not present in the Lower Terrace, is a possible aeolian (loess) supply.

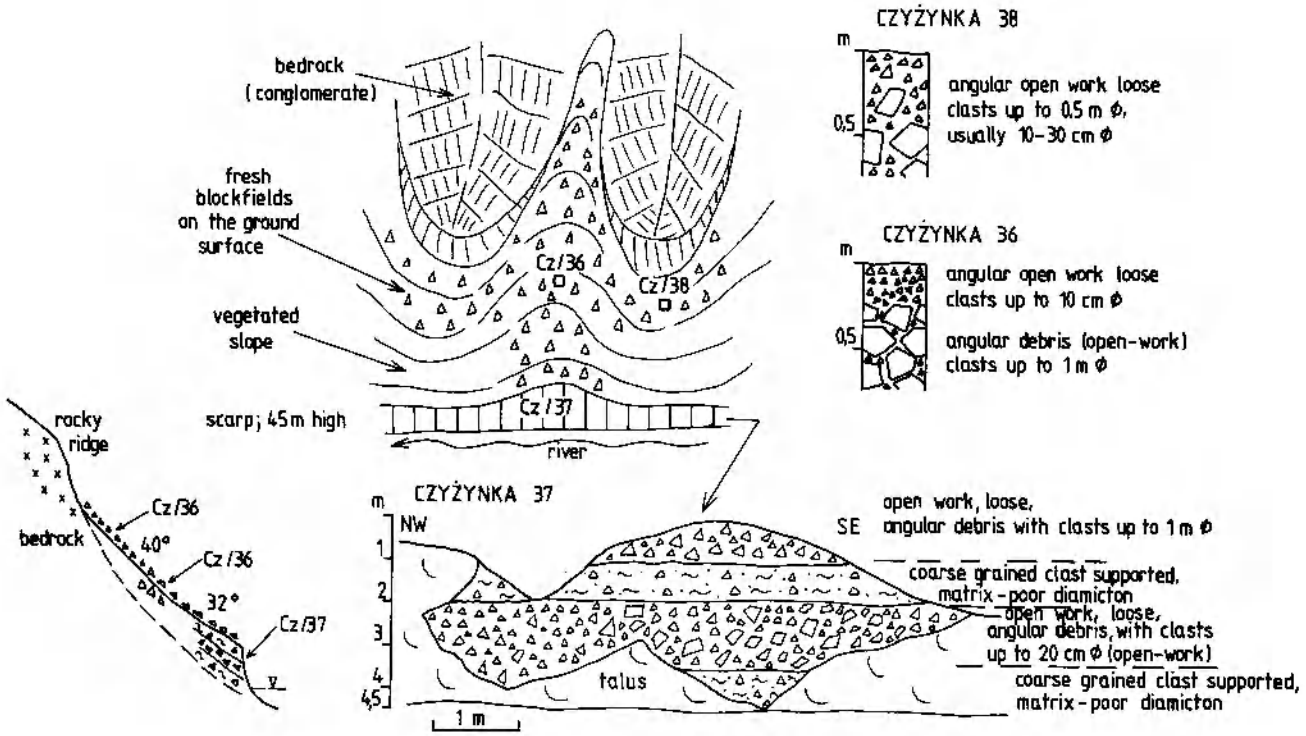

Fig. 23. Morphological context of the surficial, recently formed coarse-grained blockfields near Czyżynka 36, 37 and 38 and a sequence of slope deposits at Czyzynka 37.

However, the lower parts of the older terraces, and especially the Middle Terrace, may have been formed in braided rivers. Thus, all terrace systems in the Czyżynka river valley were formed at least partly in sinuous to meandering rivers (Table 1), which is rather unexpected, as usually the Upper and Middle Terraces sequences in the Sudetes were interpreted as forming only in braided rivers (Szczepankiewicz, 1953, 1954; Walczak, 1954; Jahn & Szczepankiewicz, 1967; Teisseyre, 1969, 1973).

Krzyszkowski & Stachura (1998a, b) have described a strong neotectonic influence on fluvial deposition and valley morphology in the Wałbrzych Upland. Among others, this influence led to the formation of quite new, postglacial valleys cut into the bedrock. Hence, the lower part of the Czyżynka river valley is entirely of neotectonic origin. The most intensive neotectonic features have been found in the Upper and Middle Terraces, such as tilting of alluvial surfaces, their convergence and divergence, as well as formation of fault scarps. The Czyżynka river valley has poorly developed systems of these two older terraces, although the height difference of the Upper Terrace near Cisy Castle (13–15 m) and near Cieszów (7–8 m) may reflect a downstream convergence, which is common in other valleys of the region (Krzyszkowski & Stachura, 1998a, b).

Additional features, which may suggest neotectonic movements are varying gradients of the river longitudinal profiles and thicknesses of the youngest alluvial deposits (Krzyszkowski, 1990; Krzyszkowski & Stachura, 1993, 1998a, 1998b; Stachura, 1993). These features have also been observed in the Czyżynka river valley. The absolute height of the Lower Terrace near Cieszów is usually uniform and gentle dipping downstream (average terrace gradient is 0.5–1.0%). However, within one short valley fragment, the channel gradient is steeper (2.0–2.5%) and the channel is distincly more incised into the Lower Terrace (Fig. 5). Also, the terrace height here almost doubles, from 1.5–2.0 m to 3.0–3.5 m within a 100 m between Czyżynka 2 and 1. Moreover, the channel pattern changes in this zone, with the formation of high amplitude meander (Fig. 2). All these features suggest increased erosional power in a very short distance and this is undoubtedly connected with the fault line between the Świebodzice Synclinorium and the Kaczawskie Góry Zone (Fig. 3). Changes in planform characteristics of the river as well as changes in sediment thickness and relative terrace height are simple responses to neotectonic movements along this fault.

SLOPE DEPOSITS

A continuum of slope deposits is present in the Czyżynka river valley, from very fine grained (M_z 5.74ϕ) to coarse grained (M_z −4.35ϕ). Nevertheless, five general groups of slope deposits can be interpreted (Table 2), which reflect specific slope processes, which will be discussed below.

Fine grained matrix-supported diamictons (1)

These are matrix-dominated deposits with scattered large clasts. The matrix is massive or locally shows crude-lamination (with sands to granules). The matrix may be

Table 1
Main features of the fluvial deposits of the Czyżynka river valley

Sediment features	Lower Terrace	Middle Terrace	Upper Terrace
lateral accretion bedding	+	+?	–
fining upward sequences	+	+?	+
alternating fine- and coarse-grained beds	+	+	+
palaeotransport perpendicular or diagonal in relation to recent valley	+	+	–
slope colluvium on the terrace surface	+ (younger fans)	+ (older fans)	–?
loess admixture	–	+	+

+ common occurence; +? possible occurence; - absence; -? absence not sure

clayey, silty to sandy, and accordingly the sediments have been named: clayey loam (type 1A), loessic loam (type 1B) and sandy loam (type 1C) respectively (Table 2). Similar slope deposits have been described in the Carpathian valleys by Krysowska-Iwaszkiewicz & Zuchiewicz (1992).

The clayey loam is usually found in the footslope (sites 57 and 30), where it usually forms laterally continuous, although wedge-shaped, covers with increasing thickness downslope. It seems that this deposit was formed due to sheetwash activity on slopes and/or in trough valleys. Fine material was selectively washed down from upslope, whereas coarser material was generally too heavy for such transport and its admixture in footslope deposits is small.

The sandy loam is usually found in fans (sites 4, 13). This, together with coarser lithology suggest more vigorous transport, most probably connected with sheet floods on the fans. Melt- or rainwater was concentrated in trough valleys and/or ravines (rill wash, gullying), reaching rather high energy conditions, enabling transport of coarse material, including large clasts. Sheet flood conditions occurred when water was dispersed on the fan surface. This short-distance transport (up to 700 m) made effective sorting of material impossible, hence the final depositional product is a diamicton.

The loessic loam is a special case. Its matrix contains practically only coarse silt (=loess), which also macroscopically looks like a typical loess. Mollusc fauna at site 12 suggests a loess origin for this deposit, too. It seems that the loessic loam is a redeposited loess. The subaerial (aeolian) loess was deposited in upslope positions, most probably in permanently moist trough valleys. This loess was later washed down and mixed with other colluvium, forming finally diamicton beds in downslope/fan positions.

Coarse grained matrix-rich clast supported diamictons (2)

These are diamictons containing numerous large clasts floating in silty-clayey matrix (Table 2). This deposit has been found at or below straight slopes (sites 5, 22, 24, 41) or at the mouths of trough valleys (site 23). At least in one site (5), this deposit is clearly connected with slump morphology (rock cliff with a distinct debris tongue below).

The coarse grained matrix-rich clast supported diamicton was, most probably, formed by cohesive debris flows (Lowe, 1979; Lewis *et al.*, 1980; Nemec & Steel, 1984). These flows could have originated from rock avalanches under moist conditions on steep slopes (sites 5, 22, 24, 41)

Table 2
Main features of the colluvium found on slopes and fans of the Czyżynka river valley

Type of sediment	Matrix total (%)	Coarse silt (%)	Clay (%)	Sediment structures	Mean size (ϕ)	Sorting (ϕ)	Large clast size (cm)	Sediment origin
1A. Fine grained matrix-supported diamicton (clayey loam)	80–90	20–40	10–25	massive or locally laminated	5.45–5.74	2.93–3.09	3–5	sheet wash (sieve deposit) formed at slope foot
1B. Fine grained matrix-supported diamicton (loessic loam)	80–90	50–60	5–10	massive or locally laminated	4.36–5.28	2.24–2.87	3–5	sheet wash (loess redeposition at slope and fans)
1C. Fine grained matrix-supported diamicton (sandy loam)	80–90	10–35	2–10	laminated (locally massive)	2.28–3.98	2.99–4.23	10–15 max. 60	sheet flood deposit formed on fans
2. coarse-grained, matrix-supported diamicton (matrix-rich, strongly bimodal)	30–50	25–40	5–10	massive	0–2.02	4.29–4.59	30–60 max. 130	cohesive debris flow
3. coarse grained clast-supported diamicton (matrix poor)	10–20	10–20	–	massive (interbedded with facies 4)	- 0.55– -2.07	2.02–3.77	15–30 max. 70	noncohesive debris flow
4. coarse grained clast-supported polimictic gravel (matrix-negligible)	5–10	0–6	–	massive	-2.35– -2.86	1.78–2.20	10–30	grain flow deposit
5. open work loose gravels	–	–	–	massive (festoon-like beds)	-3.37– -4.35	0.83–1.92	5–15 max. 30	falling and sliding of loose material (avalanche deposit)

or due to full saturation of slope debris and lowering of the basal shear stress in the less steep trough valleys (site 23). The latter type of debris flow developed from sliding movements (Innes, 1983) and correspond with valley-confined flows (Brunsden, 1979). A rapid (turbulent), viscous flow may have formed dispersed clast orientations, especially transverse orientations and up-slope dips of clasts, though this could reflect only short transport distance (Enos, 1977). Formation of cohesive debris flows is usually connected with the occurrence of fine deposits within coarse debris, preferable with a small admixture of clay (Lowe, 1979, 1982; Innes, 1983; Nemec & Steel, 1984). The clay content present, 5–10%, is quite enough to initiate viscous flow. However, in the case of these sites, clay cannot come from the substratum, which is coarse-grained (conglomerate, spilite). The coarse silt fraction may be a result of aeolian supply and deposition of loess. The finer fractions must have been formed due to weathering of exposed slopes before the formation of debris flows. Frost weathering during a very cold climatic conditions is assumed to be a main factor (Washburn, 1979).

Coarse grained matrix-poor clast supported diamictons (3)

This deposit is predominated by poorly sorted clasts with very few fines (Table 2). Matrix is represented practically only by coarse silt (loess) which ranges between 10–20%. Two sub-types can be recognized taking into account the clast sizes: fine grained diamictons with average clast sizes 1–10 cm (M_z –0.55 to –0.95ϕ) and coarse grained diamictons with average clast sizes about 10–30 cm (M_z –1.18 to –2.07ϕ). In both of them, silt (loess) content is the same (Table 2). This deposit is the most common among the slope covers investigated. It occurs at or below steep slopes, both straight and convex-concave one (25°) (sites 25, 26, 27, 30, 40) or within the fan sequences (sites 12, 13). Sometimes (*e.g.* site 27), it forms distinct lobate structures, though most often it occurs as tabular beds.

It seems, that the matrix-poor clast-supported diamicton was formed by cohesionless debris flows (Lowe, 1979; Rodine & Johnson, 1980; Lewis *at el.*, 1980; Nemec & Steel, 1984). These flows were formed from thick, oversaturated debris covers, that caused high-density mixtures. Laminar flow is expected and it forms highly preferred orientation of clasts. The common occurrence of this type of colluvium within the fan sequences suggests that high-density mixtures could have originated in the feeder valleys (or ravines) and then transported downvalley over 400–700 m long distances. During this transport, the debris/water mixture probably developed a large erosional power, enabling the formation of deeply incised ravines. When formed on steep slopes, the initial conditions of the formation of coarse-grained matrix-poor clast supported diamictons were probably the same as for cohesive flows. However, variations in the matrix content, with only a small admixture of loess and no clay, caused different flow mechanisms. It is suggested that both, cohesive and noncohesive flows represent a continuum of processes and formed a sequence of deposits grading into one another, as the clay/silt contents are variable.

Coarse grained matrix-negligible clast supported polimictic gravels (4)

This deposit is predominated by poorly sorted clasts with virtually no fines (Table 2). These deposits form only thin beds within the more complex colluvial sequences. In two cases (sites 57 and 12, samples 52, 85) this deposit is connected with middle part of slope, in two other (sites 27 and 40, samples 116, 146) it has been found in lower slope sequences. In both cases, slope inclination was above 25°.

The coarse grained matrix-negligible clast-supported polimictic gravels may have been initiated by grain flows that occurred on steep slopes. The main flow mechnism was probably density-modified grain flow (Middleton & Hampton, 1973; Hampton, 1975; Lowe, 1976, 1982; Lewis *at al.*, 1980). In comparison to cohesionless flows, dispersive grain pressure has played a more significant role during flow. It seems, the partly open-work diamicton and the coarse-grained matrix-supported diamicton form the end members of a continuum of debris flow deposits. Their initiation and the formation of different diamictons depend simply on the availability of fines. The matrix-negligible clast supported gravels were formed in zones with small production or redeposition of fines. Their rather limited occurrence, always as a part of thicker sequences with other types of colluvium, suggests that climatic (too little frost weathering) or local (too much redeposition of loess) conditions were not favorable for this kind of slope movements.

Open-work loose gravels (5)

This deposit occurs in thin, festoon-like beds that occur in sequences, usually alternating with matrix-poor clast-supported diamictons. Clasts have preferred orientations and are parallel to the slope.

The open-work gravel beds are most probably a result of falling or sliding of clasts derived from rock cliffs and tors. The formation of loose and angular rock fragments is usually connected with gelifraction (Washburn, 1979) and the formation of blockfields, with transport of loose blocks on snow patches or frozen ground surface (Cailleux, 1963; Washburn, 1979; Steijn *et al.*, 1984). The occurrence of clasts in festoons suggest sliding *en mass* of a large portion of loose slope cover. However, an occurrence recently formed covers of the loose blocks (sites 28, 29, 36, 38, 10 and 11) may suggest that periglacial conditions are not necessary to create open-work beds, although in a cold climate it must have been much more effective than present-day processes in the temperate zone.

Summary

Some slope deposits occur in sequences, which suggests the occurrence of two or three slope processes at the same time and alternating deposition of different types of slope colluvium. The older fans are characterized by an alternating occurrence of sheet wash deposits (loessic loam and sandy loam) and cohesionless debris flow deposits (matrix-poor clast-supported diamictons), sometimes supplied by avalanche grain flows (matrix-negligible clast-supported polimictic gravels). The younger fans are dominated by cohesionless debris flows deposits from sheet flood (sandy loam). The younger fans are much coarser-grained than the older fans; loessic loam occurs in them only as balls or very thin lenses.

Straight to concave slopes with no rock cliffs are characterized by the occurrence of repeated cohesionless debris flows (matrix-poor clast-supported diamictons) and sheet wash processes (clayey loam) in downslope positions, though debris avalanche deposits and sliding of loose material may have dominated in the upslope positions. Straight to convex-concave slopes and stepped slopes with rock cliffs and tors are dominated by cohesionless debris flows (matrix-poor clast-supported diamictons) which occurred alternatively with clast sliding or falling that produced festoons of open-work gravels. These two processes were, in several sites, supplied by grain flow deposition (matrix-negligible clast-supported polimictic gravels). Stratified slope covers which contain alternating coarse, open-work gravels and finer matrix- to clast-supported diamictons have been described extensively, with the most common name as *grezes-litees* (Caileux 1963; Guillien 1964; Wasson 1979; Washburn 1979, Steijn *et al.*, 1984). Sequences described in this paper correspond well with grezes-lites formation, although usually beds with differing lithologies are described as parallel to each other. Here, festoon-like coarse-grained lobes occur, which probably reflects more intensive and *en mass* slope movement of debris.

Only one deposit type occurs always separately. This is a coarse grained matrix-rich clast supported diamicton formed by cohesive debris flows. It seems, that this type of sedimentation was connected with large debris' flows/slumps which were formed on steep slopes or in trough valleys and exhibited distinct (lobate) and localised morphology. This sedimentation was accidental, and special conditions, such as increased clay content, must have occurred to initiate the process. Other, cohesionless debris flows were common and most probably formed sheet-like, very extensive slope covers with weakly developed morphology.

STRATIGRAPHY AND A MODEL OF VALLEY DEVELOPMENT

As the lowermost part of the valley of the Czyzynka river was formed entirely after the last glaciation of the region, *i.e.* after the Odranian (early Saalian) stage (Krzyszkowski & Stachura, 1998a, b), all terraces filling the valley must be younger. Their detailed ages have not been established, because the fluvial deposit do not contain any organic material suitable for palynology or radiocarbon dating. Correlation with other Sudetic fluvial sequences also is not possible, as these have no good dating; only the youngest terraces have some radiocarbon dates (Dumanowski *et al.*, 1962; Wroński, 1974). However, a conventional terrace stratigraphy has been introduced, and according to it, the terrace ages are as follows: the Upper Terrace formed during the Wartanian (late Saalian) stage, the Middle Terrace the Weichselian and the Lower Terrace the Holocene (Szczepankiewicz, 1953, 1954; Walczak, 1954; Jahn & Szczepankiewicz, 1967; Wroński, 1974; Teisseyre, 1973). Both the Upper and Middle Terraces are usually interpreted as formed by braided rivers during glaciations (pleniglacials of the Wartanian and Weichselian stages), and the Lower Terrace as formed by meandering rivers during postglacial times (Fig. 24). This interpretation was in part supplied by depositional models from lowland areas (Zeuner & Schultz, 1931; Bartkowski, 1957; Szczepankiewicz, 1959; Kozarski, 1965; Falkowski, 1975; Kozarski & Rotnicki, 1977; Starkel, 1968, 1977), where the "Wartanian" and "Weichselian" terraces contain braided river sequences and formation of meandering rivers starts almost during the Lateglacial. However, it seems that the terraces described in the Czyżynka river valley may not be simple equivalents of the lowland terraces and/or that quite different palaeohydrological conditions dominated in the mountainous region. Probably, sinuous to meandering rivers were active throughout the late Quaternary in the Wałbrzych Upland despite climatic changes, both during cold and warm stages as well as during erosion and accumulation phases.

The conventional ages of terraces may be discussed in relation to deposition of loess and slope covers (Fig. 24). The Upper Terrace sequences contain loessic loam in overbank beds. This may suggest loess deposition before or synchronous with accumulation of the fluvial deposits. The Middle Terrace sequences also contain admixtures of loessic loam in overbank deposits, and additionally this terrace level is covered by slope sequences of the older fans (redeposited loess and debris flow deposits) and by slope covers formed on steep slopes (debris flow deposits, grezes litees). Both the Middle Terrace and slope covers are truncated and do not continue on the younger alluvial surfaces. The Lower Terrace is covered in places only by younger fans.

From the above it may be assumed that the Upper Terrace may have been deposited either in a cold climate with loess deposition or during the warm conditions with loess redeposition. The formation of sinuous rivers, though typical in vegetated regions inferring warm/temperate conditions, is also possible in cold climates when water supply is sufficient to create permanent flow and stable palaeohydrological conditions. Thus the Upper Terrace could have formed in either the Wartanian or the Eemian stages.

The Middle Terrace must have been deposited before the formation of the continuous slope cover. The Lower and Middle Pleniglacials of the Weichselian stage are probably the most likely periods, the more so as loess sedimentation could have occurred that time too. Moist conditions, that enabled permanent flow in rivers that time may be inferred also from the palaeoecological data: molluscs from site 12 (loessic loam) represent wet habitats. The thick slope covers, representing sedimentation on steep slopes and in trough valleys, were formed during a periglacial climate, most probably during the most severe

CHRONOSTRATIGRAPHY	EVENT STRATIGRAPHY		LITHOSTRATIGRAPHY
	Valley	Slope	
HOLOCENE	flood activity and deposition of the uppermost diamicton layer on the Lower Terrace	formation of fresh, loose block fields	recent floodplain deposit & slope covers
	ca 2-5 incision and formation of recent channel		
WEICHSELIAN – LATE: Younger Dryas	deposition of younger fans and redeposition of older suites	frost weathering, formation of coarse debris, ravine erosion	Younger fans
Allerød, Older Dryas, Bølling	deposition of the main suite of the Lower Terrace by sinuous river		Lower Terrace
Oldest Dryas, Epe	ca 5-10 m incision and formation of the Middle Terrace		
MIDDLE: UPPER PLENIGLACIAL	frost weathering, formation on tors, rock cliffs, etc., and an extensive slope covers (fine grained-sheet & rill wash; coarse grained-debris flows & avalanches) and their redeposition into the valley (older fans); loess deposition		Older fans * @ & slope covers
MIDDLE PLENIGLACIAL	deposition of the Middle Terrace suite by sinuous river; loess deposition	frost weathering and formation of debris covers; loess deposition in wet habitats	Middle Terrace *
LOWER PLENIGLACIAL	ca 10-15 m incision and formation of the Upper Terrace		
EARLY: Oderade, Brørup			
EEMIAN	deposition of the Upper Terrace suite by sinuous river; possible loess deposition		Upper Terrace *
SAALIAN: WARTANIAN (Late Saalian)		possible loess deposition	
Pilica Interstadial	60 - 80 m incision	formation of patches of glacial deposits in watershed positions	
ODRANIAN (Early Saalian)	Deposition of till & glaciofluvial deposits by the Scandinavian ice-sheet		Till Glaciofluvial deposits

* loess admixture , @ mollusc fauna,

Fig. 24. Stratigraphy of sediments and the possible age of forms of the Czyżynka river valley.

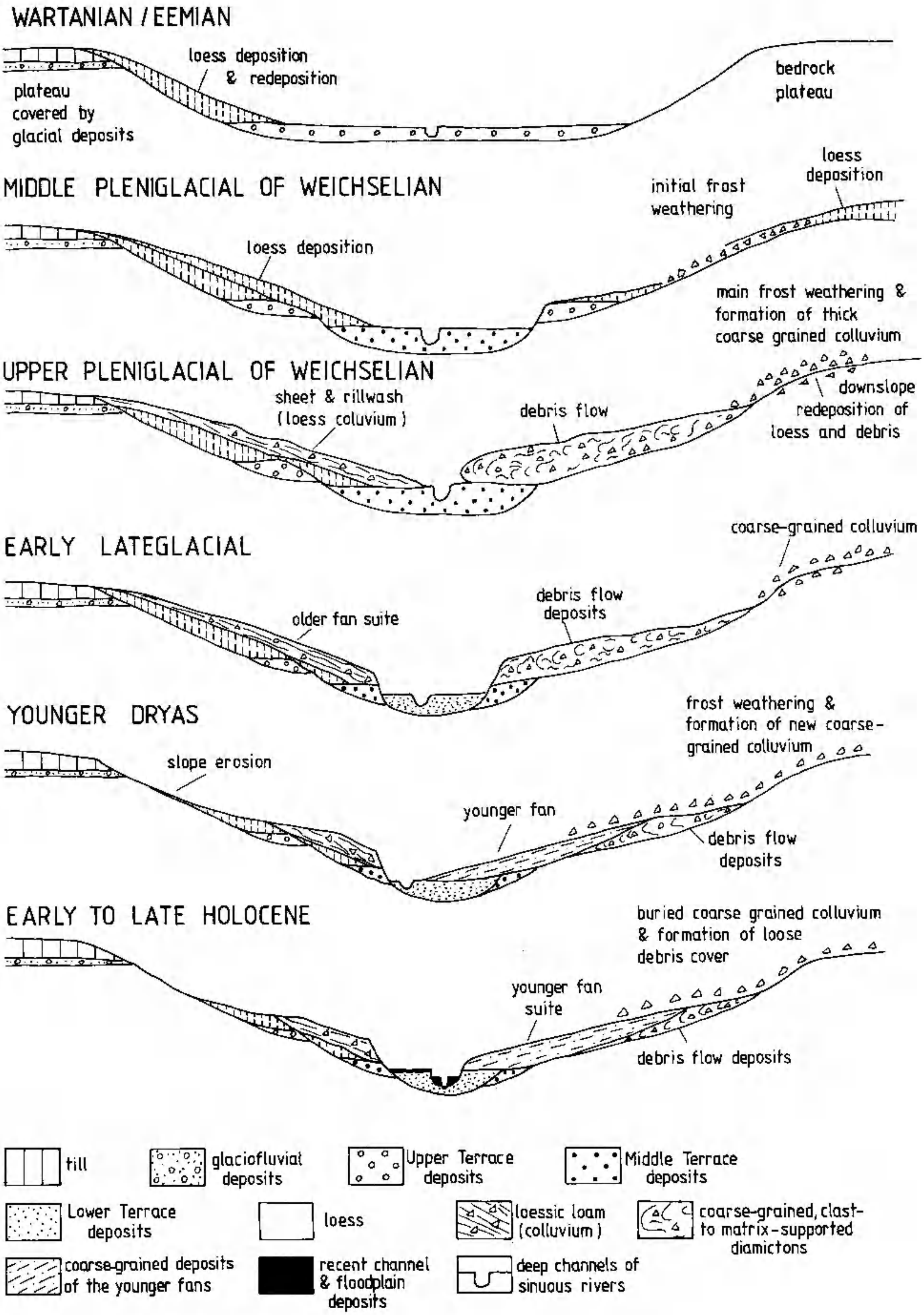

Fig. 25. Stages of the post-glacial (post-Odranian) Czyżynka river valley development.

Upper Pleniglacial of the Weichselian. This is inferred from the large production of angular blocks and permanently moist and unstable slope conditions, which must have been associated with permafrost and strong frost weathering. Also, an admixture of coarse silt within debris may suggest synchronous loess deposition.

The Lower Terrace was initiated during the Weichselian Lateglacial, as it infills the incisions within the Upper Pleniglacial slope covers. On the other hand, this terrace is covered by the coarse-grained sequences of the younger fans.The coarse grained fans must have occurred during cold conditions and at least with sparse vegetation cover, which enabled large-scale production of angular clasts. The Younger Dryas cold chronozone is probably the best candidate and the formation of younger fans and deep ravines are considered to have formed during this period. If so, the accumulation of Lower Terrace deposits occurred during the early part of the Weichselian Lateglacial, and its further incision and formation of sub-recent channels must have occurred during the Holocene. However, Teisseyre (1977, 1979) has suggested that the alluvial diamicton, which forms an extensive top cover on the Lower Terrace, formed later, in historical times, due to flood activity. Thus, the Lower Terrace formed continuously from Lateglacial to present-day, though in two distinct phases (Fig. 24).

In conclusion, a brief history of the Czyzynka river valley may be presented (Fig. 25). Ten stages of the valley development have been recognized:

1. Post-glacial (post-Odranian) deep incision and formation of narrow valley. Incision down to the level of the Upper Terrace rock base (in total 60–70 m). Glacial covers left on the uplands, watersheds and in pre-glacial (pre-Odranian) valleys.
2. Formation of the alluvial sequences of the Upper Terrace by a sinuous to meandering river. Loess deposition and redeposition on slopes. Possible age: Wartanian and/or Eemian stages.
3. Incision and formation of the Upper Terraces. Possible age: Early Weichselian to Lower Pleniglacial of the Middle Weichselian.
4. Formation of the alluvial sequences of the Middle Terrace firstly by braided, then by a sinuous river. Loess deposition on slopes and/or alluvial plains. Possible age: Lower to Middle Pleniglacial of the Weichselian stage.
5. Formation of continuous slope covers on steep slopes and in shallow trough valleys (including the formation of older fans). Partial redeposition of older fluvial sequences. Loess deposition in upslope positions and its incorporation into colluvium. Possible age: Upper Pleniglacial of the Weichselian stage.
6. Incision of both Middle Terrace and slope covers. Possible age: early Weichselian Lateglacial (Epe-Bölling chronozones?).
7. Formation of the main alluvial sequence of the Lower Terrace by a sinuous to meandering river. Possible age: early Weichselian Lateglacial (Bölling-Allerod chronozones?).
8. Deposition of younger fans and formation of deep ravines. Partial redeposition of older fluvial deposits and loess. Possible age: Younger Dryas chronozone.
9. Incision of deposits of the Lower Terrace and younger fans; formation of the modern channel and alluvial diamictons at the top of Lower Terrace. Possible age: Early to Late Holocene.
10. Modern valley: flood activity with continued overbank flood deposition on the Lower Terrace and within the channel zone. Formation of loose blocks on steep slopes below rock cliffs. Possible age: historical times to present-day.

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REFERENCES

BARTKOWSKI, T., 1957. Rozwój polodowcowej sieci hydrograficznej w Wielkopolsce środkowej. *Zeszyty Naukowe Uniwersytetu A. Mickiewicza, Geografia*, 1: 3–79 {in Polish only}.

BRUNSDEN, D., 1979. Mass movements. In: Embleton, C. & Thornes, J. (Eds.), *Process in Geomorphology*, 130–186, E. Arnold, London

CAILLEUX, A., 1963. Processus supranivaux et grezes litées. *Biuletyn Peryglacjalny*, 12: p.144.

DATHE, E., 1892. Geologische Beschreibung der Umgebung von Salzbrunn. *Abhandlungen der Königlisch Preussischen Geologischen Landesanstalt, Neue Folge*, 13: 1–157.

DATHE, E. & ZIMMERMANN, E., 1912: Erläuterungen zur Geologischen Karte von Preussen und benachbarten Bundestaaten, blatt Frieburg. *Königlische Preussische Geologische Landesanstalt*, Berlin, 136 pp.

DUMANOWSKI, B., JAHN, A. & SZCZEPANKIEWICZ, S., 1962. The Holocene of Lower Silesia in the light of results of the first radiocarbon dating. *Bulletin of the Polish Academy of Science, Earth Sciences*, 10: 47–52.

ENOS, P., 1977. Flow regimes in debris flows. *Sedimentology*, 24: 133–142.

FALKOWSKI, E., 1975. Variability of channel processes of lowland rivers in Poland and changes of the valley floors during the Holocene. *Biuletyn Geologiczny*, Uniwerstet Warszaw-

ski, 19: 45–78.
GUILLIEN, Y., 1964. Les grezes litees comme depods cyclothemiques. *Zeitschrift für Geomorphologie, Supplement-Band*, 5: 53–59.
HAMPTON, M. A., 1975. Competence of fine-grained debris flows. *Journal of Sedimentary Petrology*, 45: 834–844.
INNES, J. L., 1983. Debris flows. *Progress in Physical Geography*, 7: 469–501.
JAHN, A. & SZCZEPANKIEWICZ, S., 1967. Osady i formy czwartorzędowe Sudetów i ich przedpola. In: Galon, R. & Dylik, J. (Eds.), *Czwartorzed Polski*, 397–430, PWN, Warszawa.
KOZARSKI, S., 1965. Zagadnienie drogi odplywu wód pradolinnych z zachodniej części pradoliny Noteci-Warty. *Poznańskie Towarzystwo Przyjaciol Nauk, Prace Komisji Geograficzno-Geologicznej*, 5: 3–97 {in Polish only}.
KOZARSKI, S. & ROTNICKI, K., 1977. Valley floors and changes of river channel patterns in the North Polish Plain during the Late-Wtrm and Holocene. *Quaestiones Geographicae*, 4: 51–93.
KRYSOWSKA-IWASZKIEWICZ, M. & ZUCHIEWICZ, W., 1992. Slope-wash deposits of the Zakliczyn Depression, West Carpathians: sedimentological and mineralogical aspects. *Studia Geomorphologica Carpatho-Balcanica*, 25/26: 55–88.
KRZYSZKOWSKI, D., 1990. Late Pleistocene faulting in the Czyzynka river valley, Sudeten, Southwestern Poland. *Bulletin of the INQUA Neotectonics Commission*, 13: 27–28.
KRZYSZKOWSKI, D. & STACHURA, R., 1993. The thickness of alluvial deposits as an indicator of neotectonic faulting: example from River Strzegomka Valley, Sudeten, Southwestern Poland. *Bulletin of the INQUA Neotectonics Commission*, 16: 26–28.
KRZYSZKOWSKI, D. & STACHURA, R., 1998a. Neotectonically controlled fluvial features, Walbrzych Upland, Midlle Sudeten Mts, southwestern Poland. *Geomorphology*, 22: 73–91.
KRZYSZKOWSKI, D. & STACHURA, R., 1998b. Late Quaternary Valley Formation and Neotectonic Evolution of the Walbrzych Upland, Middle Sudeten Mts., Southwestern Poland. *Annales Societatis Geologorum Poloniae*, 68: 23–60.
LEWIS, D. W., LAIRD, M. G. & POWELL, R. D., 1980. Debris flow deposits of Early Miocene age, Deadman Sream, Marlborough, New Zealand. *Sedimentary Geology*, 27: 83–118.
LOWE, D. R., 1976. Grain flow and grain flow deposits. *Journal of Sedimentary Petrolology*, 46: 188–199.
LOWE, D. R., 1979. Sediment gravity flows: their classification and some problems of application to natural flows and deposits. In: Doyle, L.J. & Pilkey, O.H. (Eds.), *Geology of Continental slopes, Soc. Econ. Paleont. Min,, Special Publication*, 27: 75–82.
LOWE, D. R., 1982. Sediment gravity flows: II. Depositional models with special reference to the deposits of high-density turbidity currents. *Journal of Sedimentary Petrolology*, 52: 279–297.
MIDDLETON, G. V. & HAMPTON, M. A., 1973. Sediment Gravity Flows: mechanics of flow and deposition. In: Middleton, G.V. and Bouma, A.H. (Eds.), *Turbidites and Deep-Water Sedimentation, Soc. Econ. Paleont. Min., Pacific section, Short Course*, 1–38.
NEMEC, W. & STEEL, R. J., 1984. Alluvial and coastal conglomerates: their significant features and some comments on gravelly mass-flow deposits. In: Koster, E.H. and Steel, R.J. (Eds.), *Sedimentology of Gravels and Conglomerates, Canadian Society of Petroleum Geologists, Memoir*, 10: 1–31.
RODINE, J. D. & JOHNSON, A. M., 1976. The ability of debris, heavily freighted with coarse clastic materials, to flow on gentle slopes. *Sedimentology*, 23: 213–234.
STACHURA, R., 1993. Geomorphology and alluvial stratigraphy of the Pełcznica River Valley near the Sudetic Marginal Faults, Middle Sudeten, SW Poland. *Bulletin of the INQUA Neotectonics Commission*, 16: 32–34.
STARKEL, L., 1968. Przebieg erozji i akumulacji rzecznej w holocenie. *Folia Quaternaria*, 29: 109–117 {in Polish only}.
STARKEL, L., 1977. Last Glacial and Holocene fluvial chronology in the Carpathian valleys. *Studia Geomorphologica Carpatho-Balcanica*, 11: 33–51.
STEIJN, VAN H., BREDERODE, VAN L. E. & GOEDHEER, G. J., 1984. Stratified slope deposits of the Grezelitees type in the Ardeche region in the south France. *Geografiska Annaler*, 66A: 295–305.
SZCZEPANKIEWICZ S., 1953, Rozwoj doliny górnego Bobru u krawędzi lądolodu w Sudetach. *Czasopismo Geograficzne*, 22/23, 122–137 {in Polish only}.
SZCZEPANKIEWICZ, S., 1954. Morfologia Sudetów Wałbrzyskich. *Prace Wrocławskiego Towarzystwa Naukowego, seria B*, 65: 5–152 {in Polish only}.
SZCZEPANKIEWICZ, S., 1959. Dolina Odry między Wrocławiem i Brzegiem Dolnym. *Czasopismo Geograficzne*, 30: 263–286 {in Polish only}.
TEISSEYRE, A.K., 1977. Współczesne procesy rzeczne w dorzeczu górnego Bobru i Strzegomki [Recent fluvial processes in drainage basins of the upper Bóbr and Strzegomka rivers in the Central Sudetes]. *Geologia Sudetica*, 12 (2): 93–112.
TEISSEYRE, A.K., 1979. Przebieg zjawisk fluwialnych w zimie na przykladzie małych rzek sudeckich [Fluvial processes in winter, with examples from small Sudetic rivers]. *Geologia Sudetica*, 14 (1):125–157.
TEISSEYRE, H., 1956. Depresja Świebodzic jako jednostka geologiczne [The Świebodzice Depression as the geological unit]. *Biuletyn Instytutu Geologicznego*, 106: 5–35.
TEISSEYRE, H., 1968. Stratigraphy and Tectonics of the Świebodzice Depression. *Biuletyn Instytutu Geologicznego*, 222: 77–106.
TEISSYEYRE, H., 1969. Szczegółowa Mapa Geologiczna Sudetów 1:25,000, arkusz Stare Bogaczowice. *Instytut Geologiczny*, Warszawa.
TEISSEYRE, H., 1973. Objaśnienia do szczegółowej mapy geologicznej Sudetów , arkusz Stare Bogaczowice. *Wydawnictwa Geologiczne*, Warszawa, 64pp.
TEISSEYRE, H. & GAWROŃSKI, O., 1965. Szczegółowa Mapa Geologiczna Sudetów 1:25,000, arkusz Świebodzice. *Instytut Geologiczny*, Warszawa.
WALCZAK, W., 1954. Pradolina Nysy i plejstoceńskie zmiany hydrograficzne na przedpolu Sudetów wschodnich. *Instytut Geografii i Przestrzennego Zagospodarowania Kraju, Prace Geograficzne*, 2: 7–51 {in Polish only}.
WASHBURN, A. L., 1979. *Geocryology. A survey of periglacial processes and environments*, 406 pp, E. Arnold, London.
WASSON, R. J., 1979. Stratified debris slope deposits in the Hindu Kush, Pakistan. *Zeitschrift für Geomorpologie, N.F.*, 23: 301–320.
WROŃSKI J., 1974. Wiek bezwzględny aluwiów niektórych rzek Dolnego Śląska. *Przegląd Geologiczny*, 12: 602–606 {in Polish only}.
ZEUNER, F. & SCHULTZ, G., 1931. Die Entwicklung des Entwasserungssystems des Landrückens zwischen Warthe und Oder seit der letzten Eiszeit. *Neues Jahrbuch für Mineralogie, Geologie und Paläontologie*, 65B: 197–287.