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STRATIGRAPHY OF QUATERNARY DEPOSITS OF THE ROŻNÓW FOOTHILLS, POLISH WEST CARPATHIANS

INTRODUCTION

The paper deals with Quaternary deposits occuring in the Rożnów Foothills, situated to the north both of the Nowy Sącz Basin and the Beskid Wyspowy Mts. (cf. Fig. 1). The principal aim of our studies, besides description and a new cartographic presentation of these deposits, is to establish a relative chronology of fluvial and slope covers, by using morpho-, climato-, and lithostratigraphic criteria, aided sometimes by thermoluminescent datings. The latter were performed by J. Butrym at the TL Laboratory of the Institute of Earth Sciences, M. Curie-Skłodowska University, Lublin. The second author, in turn, is responsible for geological part of this paper.

STATE OF KNOWLEDGE

Quaternary deposits of the Dunajec valley and its tributaries within the confines of the Rożnów Foothills have been studied for over 100 years. Uhlig (1888) distinguished alluvia, "terrace diluvium", loesses and erratic boulders, while Szajnocha (1902) gave a first description of Pleistocene deposits in the lower reach of the Łososina river valley. Fluvial deposits, slope loams, and glacilimnic sands between Tropie and Kurów were mapped by Sokołowski (1932, 1935). The first detailed characteristics of Pleistocene fluvial covers, however, are presented in numerous papers by Klimaszewski (1937, 1948, 1961, 1967), who put forward an hypothesis of high aggradation within the Dunajec valley during the South-Polish (Cracovian) glaciation. At that time, a series of "mixed gravels", composed of both local and Scandinavian material, was to be deposited in front of a glacial lobe, protruding far into the Dunajec valley. River terraces occurring higher upslope

were, hence, parallelised with the Günz stage, whereas those situated beneath the "mixed gravel series" should have associated with the Middle-Polish and Baltic (North-Polish) glacial stages, as well as with Holocene times. In later papers, Klimaszewski (1961, 1967) revised his previous opinions on the high valley aggradation, by describing separate rock socles of consecutive Pleistocene terraces. Such a view has also been upheld by Starkel (1972, 1983, 1984).

Dudziak (1961) gave a detailed description of erratic boulders occurring in the vicinity of Czchów, Iwkowa, Piaski Drużków and Witowice. Kozikowski (1953), in turn, distinguished three Pleistocene and two Holocene Dunajec terraces within a structural water-gap between Marcinkowice and Dąbrowa. Petrographic studies of terrace gravel series at Witowice were performed by Kucharska-Słupikowa (1964).

In the last decade, detailed geomorphic and geological studies were carried out by Zuchiewicz (1983, 1984, 1985) who distinguished eight Pleistocene and three Holocene terrace steps, preserved on the Dunajec valley sides between Dąbrowa and Tabaszowa. Aeolian and washout deposits in southern part of the Rożnów Foothills were described by Butrym and Zuchiewicz (1985) while the results of malacological studies on loess-like deposits, occurring at Sienna and Roztoka, were presented by Alexandrowicz and Zuchiewicz (1988, in print).

Active landslides modelling the Dunajec valley-sides at Gródek were characterised by Bargielewicz (1958), whilst a more detailed characteristics of landslide-forming processes in the whole of the Rożnów Foothills was given by Ziętara (1974 a, b). Recent depositional processes on a delta plain, shed by the Dunajec river into the Rożnów Lake, were presented by Klimek (1979) and Klimek *et al.* (1986).

GEOMORPHIC SETTING

The area under study belongs to the Rożnów Foothills (Fig. 1), distinguished either as a subregion within the Ciężkowice Foothills, belonging to the Wieliczka Foothills (Klimaszewski, Starkel 1972; Gilewska 1986), or as a subregion within the Middle Beskidy Foothills (Kondracki 1988). As far as their geological structure is concerned, these foothills are developed on rocks belonging to the Silesian, Grybów (Dukla), and Magura thrust sheets (Książkiewicz 1977), composed of sandstone, sandstone-shaly and shaly flysch complexes of various age (Cretaceous — Oligocene). There also occur younger, Miocene deposits resting unconformably on eroded flysch members at Iwkowa, their age ranging from late Badenian to early Sarmatian (cf. Połtowicz, Waśniowska 1975; Cieszkowski *et al.* 1988).

The Rożnów Foothills region comprises a number of ridges, attaining 400—450 m a.s.l., dissected by river valleys that show dendritic, trellis or radial pattern, the drainage density being 2.5 km/km^2. The relief does not exceed 250 m. Some of the ridges display flat-topped crests arranged within three altitudinal levels that can be assigned to the intramontane (250 m of relative altitude), foothills (150—200 m), and riverside (100—150 m) planation surfaces (cf. S t a r k e l 1972, 1980).

The area in question is drained by the Dunajec river and its tributaries. Their valley-sides bear flights of rock-cut, erosion-accumulational and cut-and-fill terraces, formed during consecutive Quaternary stages. The convex-concave slopes are modelled by numerous landslides, landslumps and landslips, some of them showing traces of recent activity. Rocky landslides accompany slopes inclined at 30—60°, the other ones prefer smaller (15—40°) inclinations. The valley sides are also dissected by densely spaced small valleys, including gullies, dellen, tilke, and corrasion furrows.

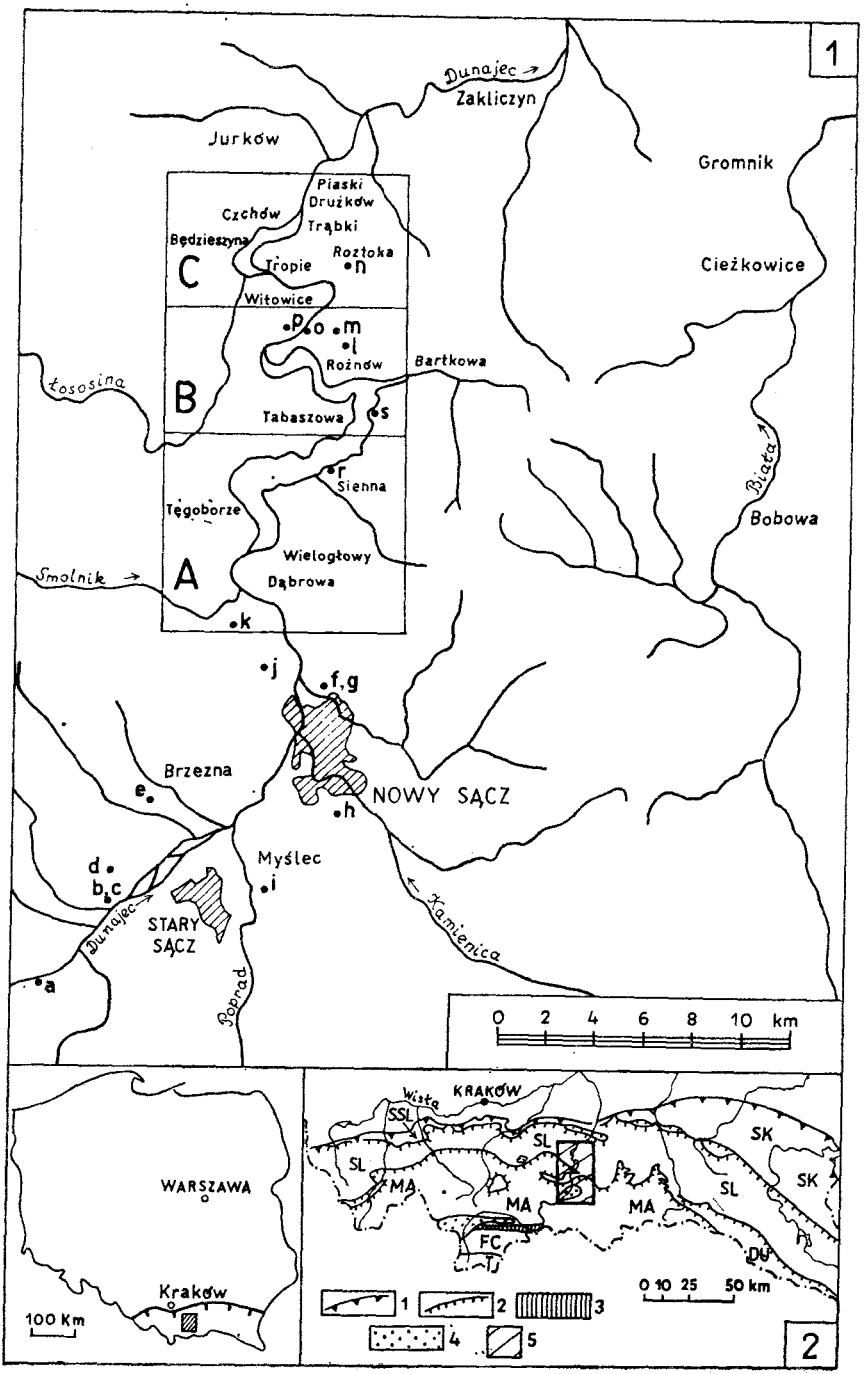
QUATERNARY DEPOSITS

Quaternary deposits of the Rożnów Foothills show diversified thickness and are confined to valley bottoms and talus feet. These are fluvial, glacifluvial, solifluction, washout, landslide colluvia, aeolian, organogenic (peat), calcareous tufas, and waste cover deposits. Some of them have been dated by the thermoluminescence method (cf. Fig. 2). In the following part of our paper we shall deal chiefly with fluvial and slope deposits which enable us to establish a relative chronology among Quaternary depositional and erosional events in that part of the West Carpathians.

FLUVIAL DEPOSITS

Fluvial deposits of the Rożnów Foothills include alluvia of terraces of the Dunajec river and its tributaries, as well as those of alluvial fans. The valley sides of main rivers (Dunajec, Łososina) bear traces of several erosion-accumulational and cut-and-fill terraces, formed during Pleistocene and Holocene times. As far as smaller valleys are concerned, there preserved only Holocene and last glacial fluvial covers, the older episodes of fluvial activity being marked by erosional breaks of slope and/or rock benches.

The age of fluvial deposits has tentatively been estimated on the basis of their relations to slope (mainly solifluction) covers, as well as by


1
Dunajec
Zakliczyn
Jurków
Gromnik
Ciężkowice
Piaski
Drużków
Czchów
Trąbki
Będzieszyna
Roztoka
Tropie
Witowice
C
B
A
Łososina
Bartkowa
Tabaszowa
Biała
Bobowa
Sienna
Tęgoborze
Wielogłowy
Dąbrowa
Smolnik
Brzezna
NOWY SĄCZ
Myślec
STARY SĄCZ
Dunajec
Kamienica
Poprad
0 2 4 6 8 10 km
WARSZAWA
Kraków
100 Km
Wisła
KRAKÓW
SSL
SL
MA
FC
SK
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0 10 25 50 km
1
2
3
4
5
2

analysing typical sequences of terrace flights at different sections across consecutive valley reaches (Figs. 2, 3, 4). Of special importance is also the position of investigated terrace covers in respect to glacifluvial sands and pebbles, forming intercalations within gravel series (Fig. 4), associated with the maximum extent of the Scandinavian ice-sheet (Sanian, Sanian-2, Wilga). A relative morphostratigraphic chronology of the oldest terraces has been established by considering their position versus Early Quaternary riverside planation levels and the above mentioned series bearing glacifluvial material (Fig. 5).

OTWOCK STAGE

The Early Quaternary phases of increased fluvial activity led to the formation of rock-cut and erosion-accumulational terrace steps, 85 to 110 m high. These benches have preserved exclusively on the left-hand Dunajec valley side at Rąbkowa and Będzieszyna (Figs. 1, 5). In the other valley segments, there occur rock-cut benches or flattenings devoid of alluvial covers, exposed at 110—120 m in the Rożnów Plateau, 100 m in the Łososina river valley, and 85—120 m in the vicinity of Czchów. The fluvial deposits at Będzieszyna rest on a 85 m high rock socle, and attain 4—5 m in thickness. These are strongly weathered and devoid of poorly resistant components fluvial pebbles, 2—5 cm in diameter, intermixed with fine gravel, ϕ 0.5—1 cm, and fine-grained, loamy and rusty sands. There prevail pebbles composed of flysch-derived sandstones (2—5 cm ϕ), less frequent are Werfenian quartzites (ϕ 3—5 cm), and egzotic granitoids (ϕ 3 cm). Granites of the Tatra provenance have been completely weathered and removed.

Fig. 1. Sketch showing distribution of TL-dated Quaternary deposits. 1 — Topography, a—s: TL-dated sections presented in Fig. 3; A, B, C — areas for which stratigraphic schemes shown in Fig. 5 have been constructed. 2 — Localization of the area studied in the tectonic sketch of the Polish Carpathians: 1 — Carpathian frontal thrust, 2 — subordinate thrusts, 3 — Pieniny Klippen Belt, 4 — intramontane troughs, 5 — area studied in detail. Tectonic units. Inner Carpathians: T — Tatra units, FC — Central Carpathian Flysch. Outer Carpathians: MA — Magura nappe, DU — Dukla nappe, SL — Silesian nappe, SSL — sub-Silesian nappe, SK — Skole nappe

Ryc. 1. Szkic rozmieszczenia stanowisk datowanych termoluminescencyjnie. 1 — Szkic topograficzny, a—s: lokalizacja profili przedstawionych na Ryc. 3; A, B, C — obszary, dla których skonstruowano schematy stratygraficzne przedstawione na Ryc. 5. 2 — Położenie obszaru badań na tle głównych jednostek tektonicznych Karpat polskich: 1 — główne nasunięcie karpackie, 2 — nasunięcia podrzędne, 3 — pieniński pas skałkowy, 4 — zapadliska śródgórskie, 5 — położenie obszaru badań. Jednostki tektoniczne. Karpaty Wewnętrzne: T — jednostki tatrzańskie, FC — flisz podhalański. Karpaty Zewnętrzne — płaszczowiny: MA — magurska, DU — dukielska, SL — śląska, SSL — podśląska, SK — skolska

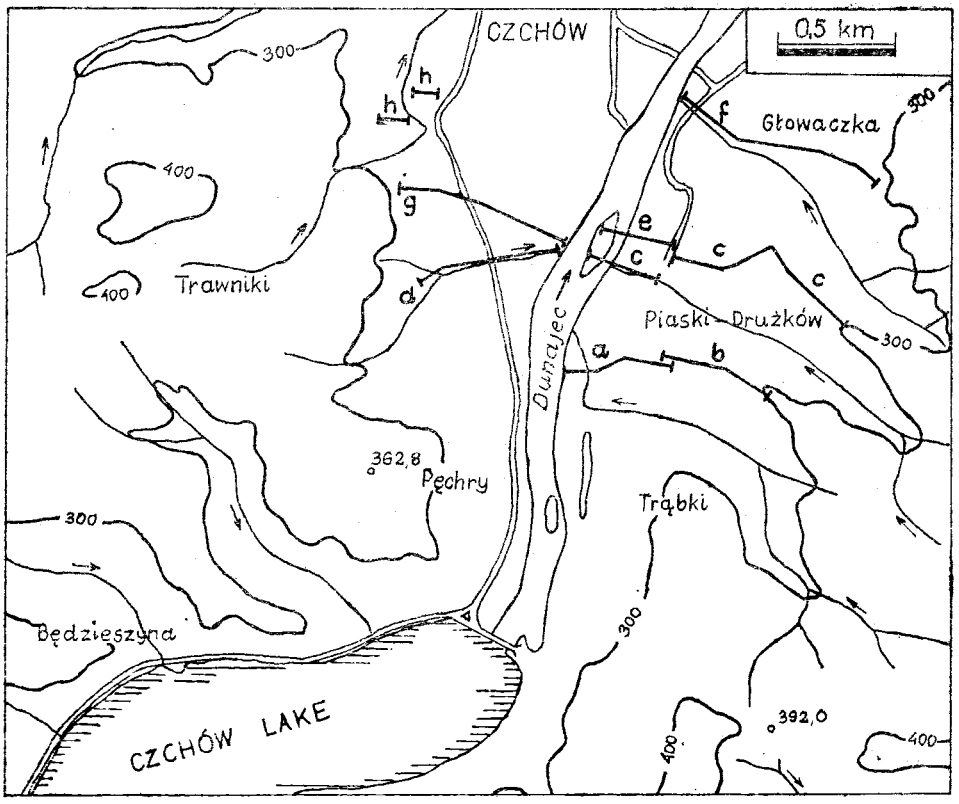

Fig. 2. Topographic sketch of northern part of the Rożnów Foothills showing localization of cross-sections presented in Fig. 4

Ryc. 2. Szkic topograficzny północnej części Pogórza Rożnowskiego obrazujący rozmieszczenie przekrojów przedstawionych na Ryc. 4

NAREWIAN STAGE

Fluvial deposits laid down during the Narewian cooling can be found at altitudes of 65—80 m above river beds. They are preserved on the Dunajec valley sides at Wielogłowy, Znamirowice, Trąbki and Piaski Drużków (cf. Figs. 1, 4). In southern part of the area in question, they represent poorly developed gravel series, 1—5 m thick. These series are composed of flysch-derived sandstones and Werfenian, Tatra-derived quartzites, showing poor to moderate rounding and poor sorting, ranging from 2—5 to 10—15 cm in diameter. The pebbles rest within medium-grained sands, being mixed with angular sandstone debris. Further to the north, one can observe a gradual decrease in rock socle altitudes. Both slopes and interfluves of ridges, separating right-hand tributaries to the Dunajec river at Piaski Drużków (Figs. 1, 4), bear isolated patches

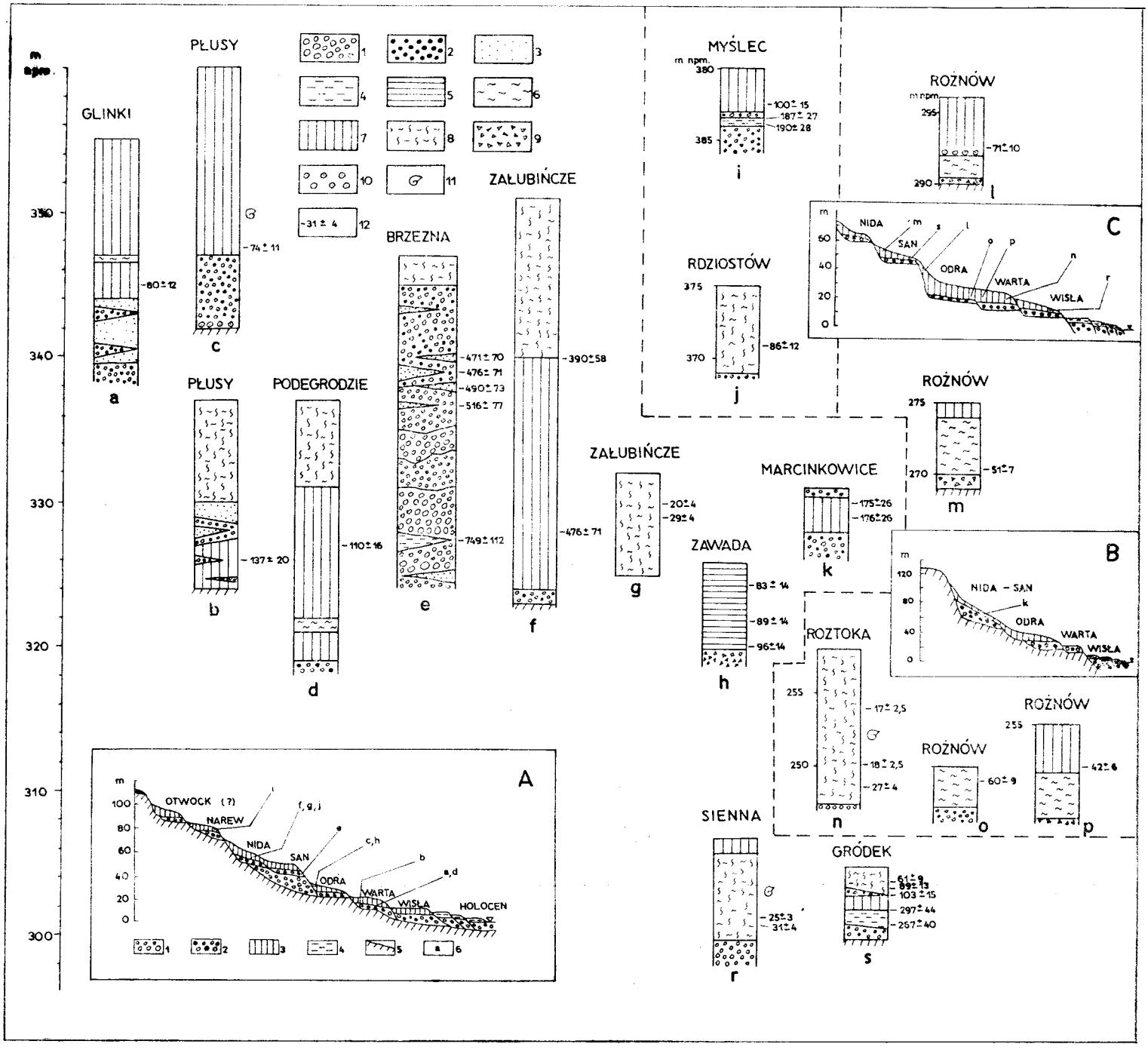

Fig. 3. TL-dated sections of Quaternary deposits of the Nowy Sącz Basin, Beskid Wyspowy Mts. and Rożnów Foothills (for localization — see Fig. 1). 1 — fluvial gravels composed of flysch--derived material, 2 — fluvial gravels composed of Tatra-derived material, 3 — sands, 4 — muds of overbank facies, 5 — sandy clays, 6 — solifluction loams, 7 — washout deposits, 8 — loess--like deposits, 9 — angular debris, 10 — carbonate concretions, 11 — sites bearing malacofauna, 12 — TL dates given in ka BP. Stratigraphic schemes of Quaternary fluvial deposits: A — Nowy Sącz Basin, B — SE part of the Beskid Wyspowy Mts., C — middle part of the Rożnów Foothills

Ryc. 3. Zestawienie profili utworów czwartorzędowych datowanych termoluminescencyjnie z obszaru Kotliny Sądeckiej, Beskidu Wyspowego oraz Pogórza Rożnowskiego (lokalizacja profili a—s: por. Ryc. 1). 1 — żwiry rzeczne złożone z materiału fliszowego, 2 — żwiry rzeczne złożone z materiału tatrzańskiego, 3 — piaski, 4 — mułki facji pozakorytowej, 5 — iły piaszczyste (deluwialne?), 6 — gliny soliflukcyjne, 7 — gliny i pyły deluwialne, 8 — utwory lessopodobne, 9 — rumosz ostrokrawędzisty zwietrzelinowy, 10 — konkrecje węglanowe, 11 — malakofauna, 12 — daty TL w tys. lat BP. Schemat stratygrafii utworów rzecznych: A — obrzeżenia Kotliny Sądeckiej, B — SE części Beskidu Wyspowego, C — środkowej części Pogórza Rożnowskiego

of 6—7 m thick pebble series, exposed at an altitude of 60—70 m. These deposits are overlain by solifluction-washout loams and sands, attaining 2—6 m in thickness.

SOUTH-POLISH (NIDANIAN, SANIAN) STAGES

Fluvial deposits assigned to this time-span build gravel series of erosion-accumulational terrace steps, exposed at altitudes of 35—60 m above the Dunajec, Łososina, and Smolnik river beds. As far as smaller valleys are concerned, there preserved only rock benches or breaks of slope. The South-Polish terraces comprise two steps, showing separate rock socles. The higher step (Nidanian?) changes its altitude in the Dunajec valley from 60—70 m (rock socle 50—55 m) between Wielopole and the mouth of the Smolnik river, through 58—62 m (rock socle 58 m) at Gródek and Rożnów, to 55—60 m (rock socle 45—53 m) between Tropie and Czchów (cf. Figs. 1, 4). The lower one (Sanian?), in turn, attains 30—40 m (rock socle 27—30 m) in the southern valley reach, as well as 40—50 m (38—40 m) and 37—40 m (28 m) in the vicinity of Piaski Drużków and Czchów. Fluvial series are 4—5 to 10—15 m thick. In the Łososina river valley, the two steps of South-Polish terraces are mainly confined to the right-hand valley side, being exposed at altitudes changing downstream, from 50 m (rock socle 42—45 m) to 40—45 m (30 m) and 30—35 m (22—27 m). Channel facies deposits are composed of poorly to moderately rounded and poorly sorted pebbles, the diameters of which change from 2—4 to 8—10 cm in northern part of the Rożnów Foothills, to 6—10 and 25—30 cm in its southern part. These pebbles are mixed with fine gravels, ⌀ 0.5—3 cm, and bear intercalations of fine to medium-grained sands, 2—4 to 70 cm thick. The pebble size diminishes towards the top of fluvial series. At some places, a distinct imbrication can also be seen.

At Piaski Drużków (Figs. 2, 4), there occur 1—1.5 m thick pebble complexes, forming poorly lithified, carbonate-cemented conglomerates. Their petrographic composition includes flysch-derived sandstones, alongside with the Tatra-derived granites and quartzites, bearing an admixture of egzotic material. Granite pebbles are usually strongly weathered and disintegrated. The degree of weathering of the local material depends largely on water-saturation of fluvial series.

The overbank facies deposits comprise limonitised, fine to very fine-grained sands, together with muds and sandy loams, attaining 2—5 m in thickness.

Fluvial series associated with the lower terrace step (Sanian) intertongue with glacifluvial sands and pebbles, deposited during the regressional phase of the maximum Scandinavian glaciation (cf. Klimaszewski 1948, 1961, 1967; Starkel 1972, 1984, 1988).

At Piaski Drużków (Fig. 4), glacifluvial deposits are exposed at an altitude of 47—49 m above the Dunajec river bed, and form a depositional cover of the erosion-accumulational terrace (rock socle at 47 m), being overlain by solifluction loams. Glacifluvial material does also occur within a gravel series, resting on 39—40 m high rock socle, and attaining an altitude of 55 m. These are poorly and moderately rounded and poorly sorted pebbles, 3—6 to 8—10 cm in diameter, closely packed within fine to medium-grained sands, and composed of the flysch, Tatra (Werfenian quartzites being predominant), and Scandinavian material, the latter containing red and pink granitoids. Some of erratics attain 30 cm in diameter.

On the right-hand side of the Łososina river valley at Witowice (Fig. 1), these "mixed gravels" crop out at relative altitudes of 43—44 m and 22—26 m. They compose poorly preserved gravel series, comprising poorly rounded pebbles of the flysch-derived sandstones, alongside with Scandinavian granites, granitogneisses, gneisses and porphyries. Pebble size ranges from 1—5 to 10—16 cm. Fluvial gravels bearing admixtures of Scandinavian erratics do also occur at Czchów, being exposed at 68—70 m above the Dunajec river bed.

The stage in question (Sanian, Sanian-2, Wilga) was also a time when a large amount of erratic boulders was laid down. These boulders and cobbles can presently be found at Czchów, Piaski Drużków, Trąbki, Iwkowa and Witowice, their diameters ranging from 3—6 to 30—65 cm.

MIDDLE-POLISH (ODRANIAN, WARTANIAN) STAGES

Fluvial deposits of this age build gravel series of the so-called "middle" terraces, occurring in the Dunajec, Łososina, Smolnik and Biała Iwkowska valleys (Fig. 1), being exposed at altitudes of 15 to 30 m. The sides of larger valleys bear traces of two different terrace steps, showing separate rock socles. In the Dunajec valley, the higher step (Odranian?) attains an altitude of 25—30 m, the height of rock socle diminishing northwards, from 19—20 m to 16—19 m. The lower terrace step (Wartanian?) changes its height from 20 m at Rożnów to 15 m at Roztoka, the rock socles being exposed at 12 m. The fluvial series are overlain by 5—6 to 10—11 m thick sands and sand-silty washout loams (Marcinkowice), loess-like deposits (Roztoka), or solifluction covers (Rożnów). In the Łososina river valley, the terraces in question do not exceed 15—20 m (rock socles 5—7 m) of relative altitudes.

Gravel series are usually 5 to 8 m thick, the overbank facies deposits not exceeding 2—4 m. As far as the Dunajec river valley is concerned, densely packed pebbles of the flysch and Tatra-derived rocks, reveal poor sorting, moderate to good rounding, and change in size from 2—4 to 5—7 cm (10—16 cm). These pebbles rest within fine-grained,

partly limonitised sands. Terrace alluvia intertongue in the near-slope parts of terrace covers with solifluction loams and are, in turn, overlain by yellow sandy loams and fine to very fine-grained washout sands. Within smaller valleys, these terraces attain a dozen or so metres of relative altitude, their sedimentary cover being composed of poorly rounded, 2—8 cm in diameter, strongly loamy pebbles, frequently intermixed with angular debris.

VISTULIAN STAGE

Terraces formed during the last cold stage occupy vast surfaces in the valley bottoms of the Dunajec river and its tributaries. The main, Pleniglacial terrace step rises, in the Dunajec and Łososina valleys, 8—13 m above river beds. Within smaller valleys it does not exceed 6—7 m. Altitudes of rock socles vary to a great extent: rising from 2—3 m beneath the present river bed at Wielogłowy, to 4.5 m at Bartkowa and 8 m at Rożnów (cf. Fig. 1). Terrace plains are frequently being overlain, up to 14—15 m of relative altitude, by alluvial fans shed by main tributaries.

During Late Glacial times, a lower step was eroded within the Pleniglacial cover. The height of this step is 5—7 m in the Dunajec and 5 m in the Łososina and Biała Iwkowska valleys.

Channel facies deposits range from 5 to 10 m in thickness, the muds and sands of the overbank facies being 1—3 to 5 m thick. Alluvial series are composed of pebbles, 2—10 to 20—30 cm in diameter, averaging at 4—5 to 6—8 cm, that show poor sorting and moderate and poor rounding. These pebbles rest within fine gravels, ϕ 0.5—3 cm, and fine to very fine-grained sands. In the Dunajec terrace covers the local, flysch-derived material, is accompanied by relatively fresh Tatra-derived granites and quartzites. The overbank facies deposits are represented by horizontally, rarely cross-laminated, fine to fery fine-grained sands, bearing intercalations of gravels, ϕ 1—5 cm, as well as those of light-grey silty sands, muds, and sandy loams. These deposits interfinger with solifluction loams and are sometimes overlain by sandy deluvia or loesses (Sienna).

HOLOCENE STAGE

The Holocene alluvia build two steps of higher terraces (4—5 m, 3—3.5 m) and two steps of flood-plains (1—1.5 m, 2—2.5 m), occurring commonly within valleys of the Rożnów Foothills.

The higher terrace steps represent accumulational, cut-and-fill landforms, showing rock socles situated 0.5 to 3 m beneath the present river beds. Fluvial covers are composed of pebbles, ranging from 2—5 to

5—7 cm in diameter, as well as of cobbles, attaining 10—12 to 45—50 cm, being moderately and poorly rounded, poorly sorted, packed within fine to medium-grained sands and bearing a small admixture of fine gravel, ϕ 0.5—3 cm. The overbank deposits contain, in turn, fine to very fine-grained sands and muds, alongside with sandy loams and silty sands.

The two lower floodplains are also cut-and-fill landforms, the sedimentary covers of which are built of poorly to moderately rounded and poorly sorted pebbles, 2—5 to 8—20 cm in diameter, loosely packed within medium and fine-grained sands, as well as sandy loams. Channel deposits are overlain by muds, sandy muds, silty and very fine-grained sands, showing parallel, rarely cross lamination. Organogenic deposits can also be found at some places. The width of terrace plains becomes considerably reduced within structural water-gaps.

SLOPE DEPOSITS

Slope deposits are represented by solifluction-deluvial loams, sands and silts, sand-silty loess-like deposits, as well as landslide colluvia.

SOLIFLUCTION COVERS

Solifluction covers, 2 to 6 m thick, overlie and/or intertongue with alluvia of terrace covers formed during glacial stages. These are sandy, sand-clayey, and sand-silty loams, clays and sandy silts, containing fragments of disintegrated shales and/or flat, angular sandstone scraps, 2—5 to 8—15 (20—30) cm in diameter, aligned parallel to the slope surface.

The oldest TL-dated solifluction covers comprise sand-silty deposits occurring on top of gravel series of the South-Polish terrace at Gródek (Fig. 3). These deposits date back to the Odra glacial stage. Solifluction-deluvial deposits can also be found within slope covers of the Wartanian age, encroaching upon older terrace alluvia. TL ages of solifluction loams at Rożnów (Fig. 3) point to the older pleniglacial of the last cold stage (Lub-816: 51 ± 7 ka BP, Lub-818: 60 ± 9 ka BP, cf. Fig. 3). These deposits occur, most frequently, on slopes built up from poorly resistant shale and shale-sandstone flysch complexes and, in the Iwkowa region, rest on clay-sandy Miocene deposits.

WASHOUT (DELUVIAL) DEPOSITS

Washout (deluvial) deposits mantle talus feet and encroach upon river terraces, their thickness ranging from 5 to 8 m. These are represented by vari-grained sands, silty sands, sandy and sand-silty loams,

as well as sandy silts, showing parallel, cross and lenticular lamination. These deposits are usually poorly sorted and contain a relatively small amount of silt (12—16%). Washout covers mantle fluvial deposits dated to the Sanian (Gródek), Odranian (Rożnów), Wartanian (Roztoka), and Vistulian (Sienna) stages. Deluvia occurring on top of older gravel series are usually Early Vistulian in age (Gródek) and may be correlated with the lowest and lower younger loess horizons (*sensu* Maruszczak 1980, 1985). Washout deposits of the Rożnów area (Fig. 2) are, in turn, older Vistulian Pleniglacial in age and may refer to the lower younger loess. Interpleniglacial age, however, is characteristic for deluvial covers that overlie solifluction series at Rożnów-Roztoka (Fig. 3), whereas sandy loams occurring immediately above the Sanian gravels at Marcinkowice (cf. Figs. 1, 3), seem to represent the Wartanian.

The described washout deposits occur either on top of solifluction loams or overlie fluvial series. At some places, they also over- and underlie loess-like sediments.

LOESS-LIKE DEPOSITS

The patches of loess-like silts and sandy silts are preserved on the right-hand Dunajec valley side at Wielogłowy, Dąbrowa, Sienna, Rożnów, and Roztoka, as well as on the left valley side at Rdziostów (Figs. 1, 3). Their thickness changes from 2—3 m to 10—11 m. These deposits overlie either alluvial series of terraces and alluvial fans, deposited during the penultimate and last glacial stages, or rest on washout deposits (Sienna). These sediments are composed of sands (2—7%), coarse (8—27%), medium (41—60%), and fine (7—10%) silts, as well as clays (12—27%). The above figures fall into grain-size ranges typical of the Vistulian loesses in Poland (cf. Maruszczak 1985).

The loess-like deposits exposed at Sienna and Roztoka contain abundant, although irregularly spaced malacofauna, determined by Prof. Dr. S. W. Alexandrowicz (cf. Alexandrowicz and Zuchiewicz 1988, in print). Malacofaunistic assemblages include species typical of loess communities, indicating that deposition of silt-sandy deposits in the Rożnów Foothills could have taken place at the turn of the last interpleniglacial and pleniglacial times. Such a conclusion is also partly supported by the results of TL datings of the Sienna (31—25 ka BP) and Roztoka (27—17 ka BP) sections (cf. Fig. 3). Hence, most of the investigated loess patches on either side of the Dunajec river valley can be assigned to the upper younger loess horizon (*sensu* Maruszczak 1980, 1985).

DISCUSSION

The above description of fluvial and slope deposits enables us to distinguish several episodes of increased fluvial activity which made their appearance in the development of the Rożnów Foothills in Quaternary times.

The oldest preglacial episodes of fluvial deposition can be assigned to the Otwock and Narewian stages (cf. Różycki 1978, 1980; Lindner 1980), during which 85—110 m and 65—80 m high erosion-accumulational terraces were formed. These can also be correlated with the oldest Quaternary terrace covers mapped by Zuchiewicz (1983, 1984) in the Beskid Sądecki, Łącko-Podegrodzie Foothills and Nowy Sącz Basin and named, according to an allostratigraphic division (Zuchiewicz 1988), the Maszkowice and Obidza alloformations, respectively. Using a revised West European stratigraphic scheme, one can assign these covers to the Eburonian and Menapian (Donau) stages (cf. Brunnacker *et al.* 1982; Šibrava 1986).

The two lower, South-Polish (cf. Klimaszewski 1948, 1967) terrace steps (35—60 m), bearing alluvia intermixed with erratic material, testify to fluvial deposition in a close proximity to the Scandinavian ice-sheet, which protruded far into the Dunajec valley at the time of formation of the lower terrace step. The latter, therefore, can be associated with the Sanian (Günz, Elster - 2, Sanian - 2) stage. The higher step, in turn, should be correlated with a cooling stage preceding the maximum advance of the Scandinavian ice-sheet onto the Carpathian Foothills. The stage in question has been called Nidanian, Elster - 1 or Sanian - 1 (cf. Brunnacker *et al.* 1982; Šibrava 1986; Lindner 1988; Starkel 1988). These two South-Polish stages (Klimaszewski 1967; Starkel 1988) refer to the Wietrznica alloformation and the Myślec allomember, distinguished by Zuchiewicz (1988) in upper reaches of the Dunajec valley.

Following a prolonged period of climatic amelioration and associated erosion during the Masovian (Holsteinian, Great Interglacial) stage, another two-fold glacial cooling took place, being called in the extra-Carpathian area the Middle-Polish glaciations. That was a time of formation of two lower terrace steps, 25—30 and 20 m high, which may be assigned to the Odranian and Wartanian stages (Saale, Mindel and Warthe, Riss, cf. Brunnacker *et al.* 1982; Šibrava 1986), basing on mutual relationships between fluvial and solifluction-deluvial covers and the presence of two separate rock socles. These terraces refer to the Podegrodzie alloformation and the Nowy Sącz allomember, distinguished in other sectors of the Dunajec valley (Zuchiewicz 1988). The oldest TL-dated solifluction and washout deposits, found at Gródek and Marcinkowice, also belong to these stages.

The lowest Pleistocene fluvial cover refers to the youngest Vistulian stage, during which two terrace steps, Pleniglacial and Late Glacial ones, were formed. These alluvial covers correlate with the Łącko alloformation of Zuchiewicz (1988). The last cooling stage was also a time of washout (Early Vistulian, Older Pleniglacial, Interpleniglacial), solifluction (Older Pleniglacial), and loess (Younger Pleniglacial) deposition.

CONCLUSIONS

The only link between extra-Carpathian and Carpathian Quaternary stratigraphic schemes is provided by those fluvial deposits which intertongue with glacifluvial material, deposited during the maximum advance of the Scandinavian ice-sheet (Figs. 4, 5). Following this way of thinking, we can make an attempt at correlating the lower South-Polish terrace, preserved on the Dunajec valley-sides, with the Sanian (Różycki 1978, 1980; Lindner 1980), Sanian-2 (Lindner 1988), Mogielanka (Lindner 1984), or Wilga (Mojski 1985) glacial stage. The remaining river terraces can tentatively be assigned to various glacial stages solely on the basis of their relation to solifluction and washout covers, and in respect to those terraces which contain glacifluvial material.

The hypsometric and stratigraphic position of the so-called „mixed gravels", composed of both local and Scandinavian material, enables one to revise some of previous opinions (cf. Klimaszewski 1937, 1948) on high valley aggradation during the South-Polish Glaciations. The majority of glacifluvial gravels intermixed with fluvial ones occurs within an interval of 40—55 m of relative altitude, i.e., following that of the South-Polish terraces. The presence of scanty Scandinavian pebbles on fluvial series deposited during the older, Narewian stage, may point to a damming up of the Dunajec valley by the South-Polish (Sanian, Sanian-2, Wilga?) glacial tongue by 15—20 m, at its greatest.

Thermoluminescent datings are still of a limited number and dubious meaning. Moreover, they are confined nearly exclusively to slope deposits. Any future stratigraphic investigations should look forward to using a set of various methods, palaeobotanical and magnetostratigraphic determinations being of special importance.

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STRESZCZENIE

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Stratygrafia utworów czwartorzędowych Pogórza Rożnowskiego, polskie Karpaty Zachodnie

Osady rzeczne i przykrywające je utwory stokowe Pogórza Rożnowskiego (Ryc. 1) umożliwiają ustalenie morfo-, a w przypadku utworów młodszych także chronostratygraficznego podziału czwartorzędu tej części Karpat. Autorzy paralelizują kolejne stopnie terasowe, których aluwia zazębiają się i/lub są nadbudowane przez pokrywy soliflukcyjne z piętrami chłodnymi, wydzielanymi na Niżu Polskim, oraz z jednostkami allostratygraficznymi wprowadzonymi dla górnych odcinków doliny Dunajca. W przypadku utworów stokowych wykorzystano wyniki datowań termoluminescencyjnych (Ryc. 3) oraz oznaczeń malakologicznych. Czwartorzędowe osady fluwialne były akumulowane w trakcie pięter (Ryc. 2,4-5): otwockiego, Narwi, Nidy, Sanu, Odry, Warty i Wisły oraz w holocenie. Pokrywa osadowa terasy wiązanej z piętrem Sanu, zawierająca w swoim składzie materiał glacifluwialny, umożliwia przeprowadzenie korelacji teras doliny Dunajca z piętrami chłodnymi, wydzielanymi na północ od Karpat, jak również pozwala na ustalenie względnej chronologii wyższych i niższych stopni terasowych w obszarze pogórskim.

РЕЗЮМЕ

В. Зухевич, Е. Бутрым

СТРАТИГРАФИЯ ЧЕТВЕРТИЧНЫХ ОБРАЗОВАНИЙ РОЖНОВСКОГО ПРЕДГОРЬЯ (ПОЛЬСКИЕ ЗАПАДНЫЕ КАРПАТЫ)

Благодаря речным отложениям и прикрывающим их склоновым образованиям Рожновского предгорья (Рис. 1) можно определить морфо-, а в случае же младших образований, и хроностратиграфическое деление четвертичного периода в этой части Карпат. Авторы параллелизируют очередные террасообраз-

ные ступени, аллювии которых соприкасаются друг с другом и/или надстраиваются солифлюкционными покровами с холодными ярусами, выделяющимися на Польской низменности, а также с аллостратиграфическими единицами, вошедшими в верхние участки долины р. Дунаец. В случае склоновых образований использовались результаты термолюминесцентных датирований (Рис. 2) и малакологических обозначений. Четвертичные флювиальные отложения аккумулировались в ходе ярусов (Рис. 2,4-5): отвоцкого, Нарви, Ниды, Сана, Одры, Варты и Вислы, а также в голоцене. Возникший в результате отложения наносов покров террасы, связанной с ярусом Сана, содержащий в своем составе гляцифлювиальный материал, позволяет провести корреляцию террас долин р. Дунаец с холодными ярусами, расположенными к северу от Карпат, а равно и определить относительную хронологию высших и низших террасообразных ступеней на территории предгорья.

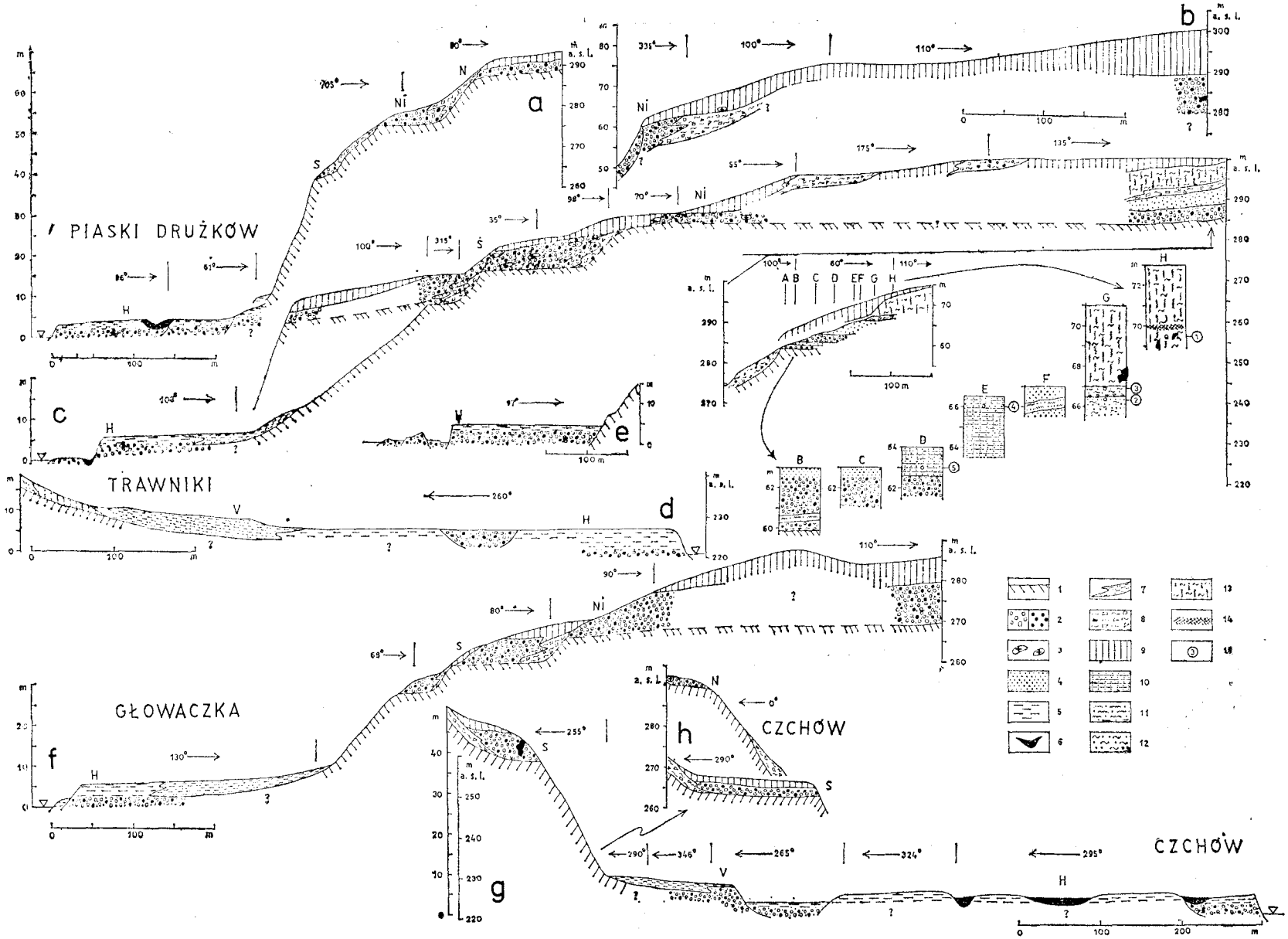

Fig. 4. Selected cross-sections through the Dunajec valley sides in the northern part of the Rożnów Foothills (for localization — see Fig. 3). 1 — rock socle, 2 — fluvial gravels: a — composed of flysch-derived material, b — composed of Tatra-derived material, 3 — erratics, 4 — sands, 5 — muds of overbank facies, 6 — infillings of abandoned channels, 7 — alluvial fans, 8 — solifluction loams, 9 — washout deposits. Additional explanations to sections A—H: 10 — parallel laminated sands, 11 — sandy silts, 12 — sandy loams, 13 — loess-like deposits, 14 — fossil soils, 15 — samples. Stratigraphic letter symbols: N — Narewian, Ni — Nidanian, S — Sanian, V — Vistulian, H — Holocene

Ryc. 4. Wybrane przekroje przez zbocza doliny Dunajca w północnej części Pogórza Rożnowskiego (lokalizacja — por. Ryc. 3). 1 — cokół skalny, 2 — żwiry rzeczne: a — złożone z materiału fliszowego, b — złożone z materiału tatrzańskiego, 3 — materiał eratyczny, 4 — piaski, 5 — mułki facji pozakorytowej, 6 — wypełnienia starorzeczy, 7 — stożki napływowe, 8 — gliny soliflukcyjne, 9 — utwory deluwialne. Dodatkowe objaśnienia do profili A—H: 10 — poziomo laminowane piaski, 11 — pyły piaszczyste, 12 — gliny piaszczyste, 13 — utwory lessopodobne, 14 — gleby kopalne, 15 — numery prób. Oznaczenia literowe pięter czwartorzędowych: N — Narew, Ni — Nida, S — San, V — Wisła, H — holocen

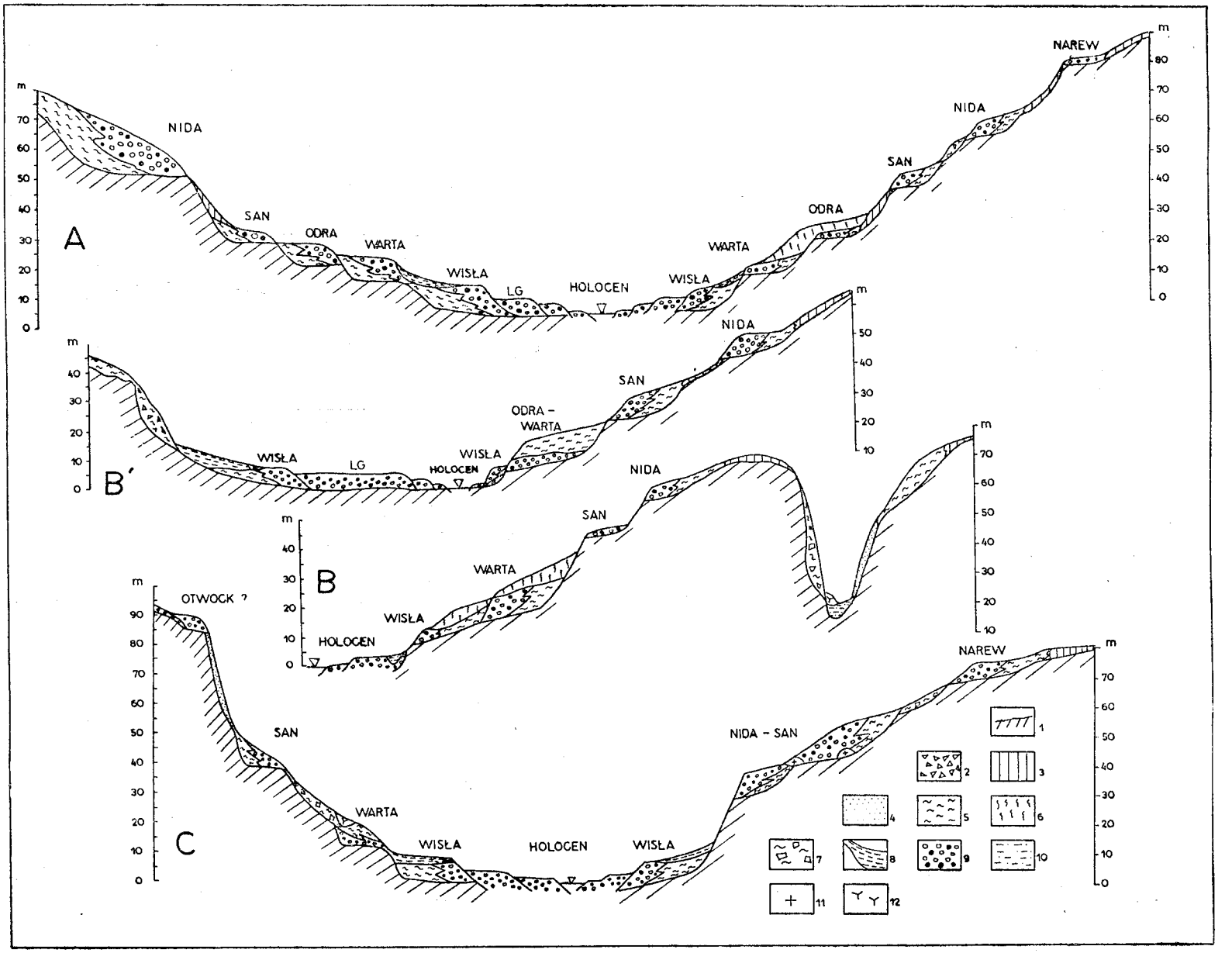

Fig. 5. Stratigraphic schemes of Quaternary deposits of the Rożnów Foothills constructed for areas shown in Fig. 1: A — southern part, B — middle part (B′ — scheme for the Łososina valley), C — northern part. 1 — rock base, 2 — angular weathering debris, 3 — washout loams and silts, 4 — washout sands, 5 — solifluction loams, 6 — loess-like deposits, 7 — landslide colluvia, 8 — alluvial fans, 9 — fluvial deposits, 10 — muds infilling small valley bottoms, 11 — erratic boulders, 12 — calcareous tufas

Ryc. 5. Schemat stratygrafii utworów czwartorzędowych Pogórza Rożnowskiego (por. Ryc. 1): A — części południowej, B — części środkowej (B′ — schemat dla doliny Łososiny), C — części północnej. 1 — cokół skalny, 2 — rumosz ostrokrawędzisty zwietrzelinowy, 3 — gliny i pyły deluwialne, 4 — piaski deluwialne, 5 — gliny soliflukcyjne, 6 — utwory lessopodobne, 7 — koluwia osuwiskowe, 8 — stożki napływowe, 9 — utwory rzeczne, 10 — mułki wypełniające dna małych dolin, 11 — eratyki, 12 — martwice wapienne