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# EARLY PLEISTOCENE POLLEN-BEARING SEDIMENTS AT SZAFLARY, WEST CARPATHIANS, POLAND

## Wczesnoplejstoceńskie osady z florą pyłkową w Szaflarach, Karpaty Zachodnie, Polska

ABSTRACT

Geological and palynological investigations of a Pleistocene succession at Szaflary, West Carpathians (Poland) were carried out. The succession begins with thin regolith (0·1—3 m) filling karst holes in the Jurassic limestone substratum. Higher up occur: reworked regolith (0·05—0·5 m) and lower gravel (up to 1·4 m), banded clay (0·3—1 m) and upper gravel (1—8 m), the latter representing fluvioglacial cover correlated with the Mindel Glaciation. The banded clay palynologically investigated at two sites (Szaflary I: 25 samples, and Szaflary II: 10 samples) represents lacustrine deposit formed during a warm climatic phase prior to the Mindel Glaciation. On comparison with palynological profiles of the Miocene, Pliocene and Early Pleistocene deposits in southern Poland, Slovakia and Transcarpathian Ukraine, the age of the banded clay was estabilished as Early Pleistocene: Tegelen s.l. or another, younger, warm (interglacial) phase preceding the Mindel Glaciation.

CONTENTS

# I. GEOLOGICAL PART

(by K. Birkenmajer)

## INTRODUCTION

The Szaflary quarry near Nowy Targ, West Carpathians (Poland) is a well-known site (Text-figs. 1, 2) of Pleistocene deposits discovered by Małkowski (1924, 1928) and regarded by him as a moraine laid down by an ancient glacier of the Tatra Mountains. This view was also shared by Romer (1929) but opposed by Halicki (1930) who considered the deposit to be fluvioglacial gravel correlated with the oldest, maximum glaciation of the Tatra Mountains (Cracovien = Mindel). Halicki's view was accepted by Klimaszewski (1948, 1951, 1961a, b) and Birkenmajer (1958, 1968).

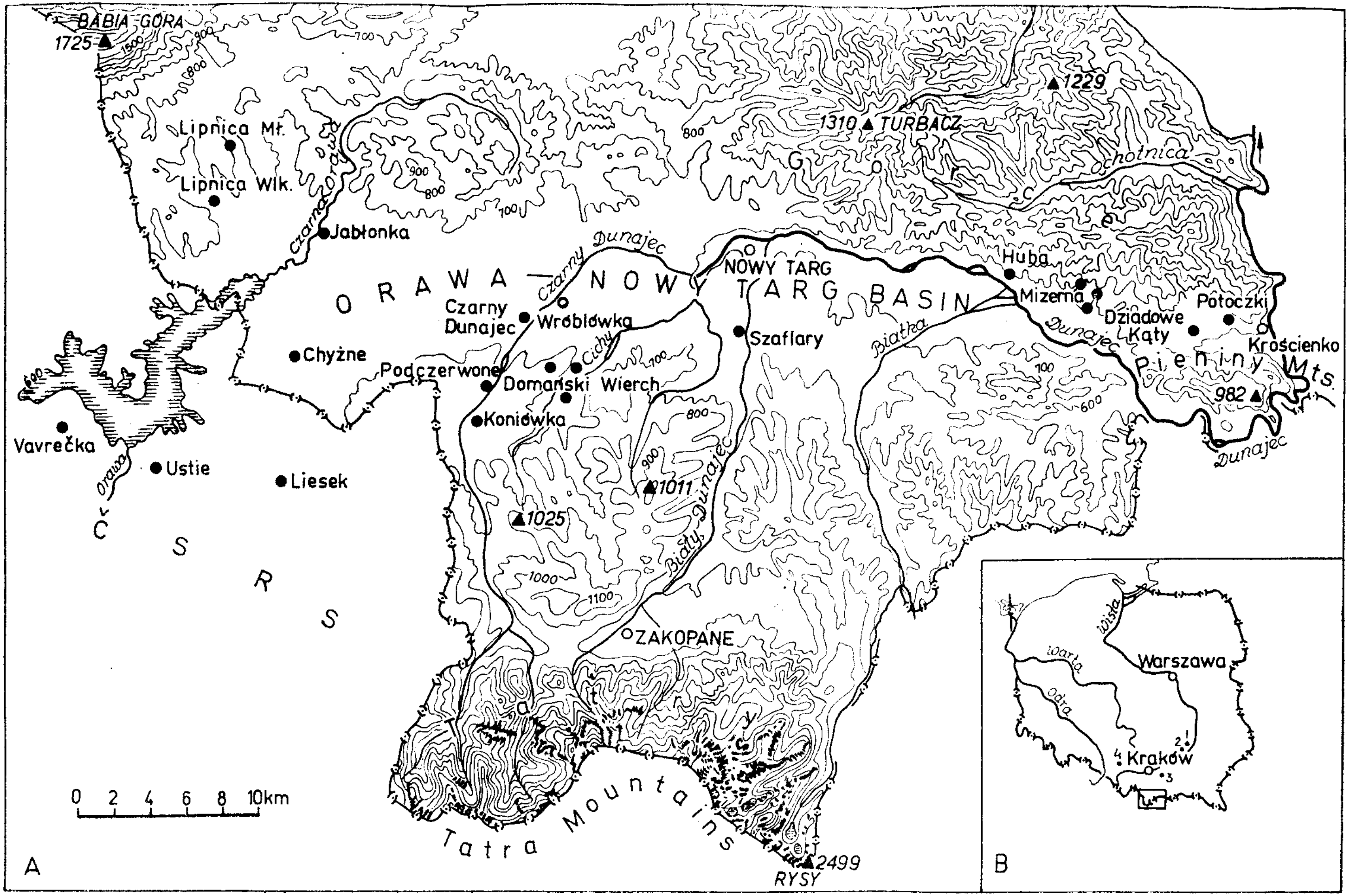
Between 1950 and 1959 the Szaflary quarry was enlarged and in 1959 the present author found under the Mindel fluvioglacial cover varve-like banded clays (profiles III and IV — see below). Much better exposures of similar banded clay underlain by another (lower) gravel were found by the author in 1968 (Birkenmajer 1968) in the south-western part of the quarry (profiles I, IA, II and IIA — see below) — Text-figs. 3—7.

Samples for palaeobotanical investigations were taken the same year from banded clays by the present authors in the company of doc. dr M. Łańcucka-Środoniowa, dr J. Oszast and prof. dr A. Środoń. The results of geological and palynological investigations of the whole Pleistocene profile at Szaflary are presented in this paper.

## SUCCESSION OF STRATA

### 1. Substratum

The substratum of the Pleistocene cover is formed by the Jurassic and Cretaceous rocks of the Czorsztyn Succession, mainly by the white crinoid limestone (Bajocian), partly also by sedimentary breccias and limestone




Text-fig. 1. Key maps to show the location of the Szaflary site in the Polish Carpathians (*A*) and in Poland (*B*). Main Neogene and Pleistocene sites marked by full circles. 1 — Piaseczno, 2 — Świniary, 3 — Kłaj (Gdów Bay), 4 — Gliwice Stare

Ryc. 1. Położenie stanowiska Szaflary w mapie polskich Karpat (*A*) i Polski (*B*). Główne stanowiska neogenu i plejstocenu zaznaczono na mapie pełnymi kółkami. 1 — Piaseczno, 2 — Świniary, 3 — Kłaj (Zatoka Gdowska), 4 — Gliwice Stare couqinas (Tithonian) — Text-fig. 4. Upper Cretaceous (Cenomanian to Senonian) marls belonging to the Czorsztyn Succession are present under the Pleistocene cover in the eastern part of the quarry (Birkenmajer 1952, Figs. 2, 5; 1958, Figs. 38—42; 1963a, Pl. VI, Figs. 1, 2).

The surface of the substratum is very uneven, weathered, often covered with limonite and manganese-oxide glaze with manganese-oxide veins and dendrites penetrating down the limestone along cracks. The relief of the substratum shows features of surficial karst weathering (lapiez) in the form of usually narrow ridges and much wider depressions (Małkowski 1924, 1928; Wójcik 1960; Birkenmajer 1968). The depressions are 2—8 m deep and 10—60 m wide, smaller pockets 0·5—2 m wide and down to 8 m deep may occur between sharp limestone ridges (Text-figs. 4—7). Fragments of a cave directly connected with the lapiez have been found by Małkowski (*op. cit.*) and Wójcik (*op. cit.*).

## 2. Regolith

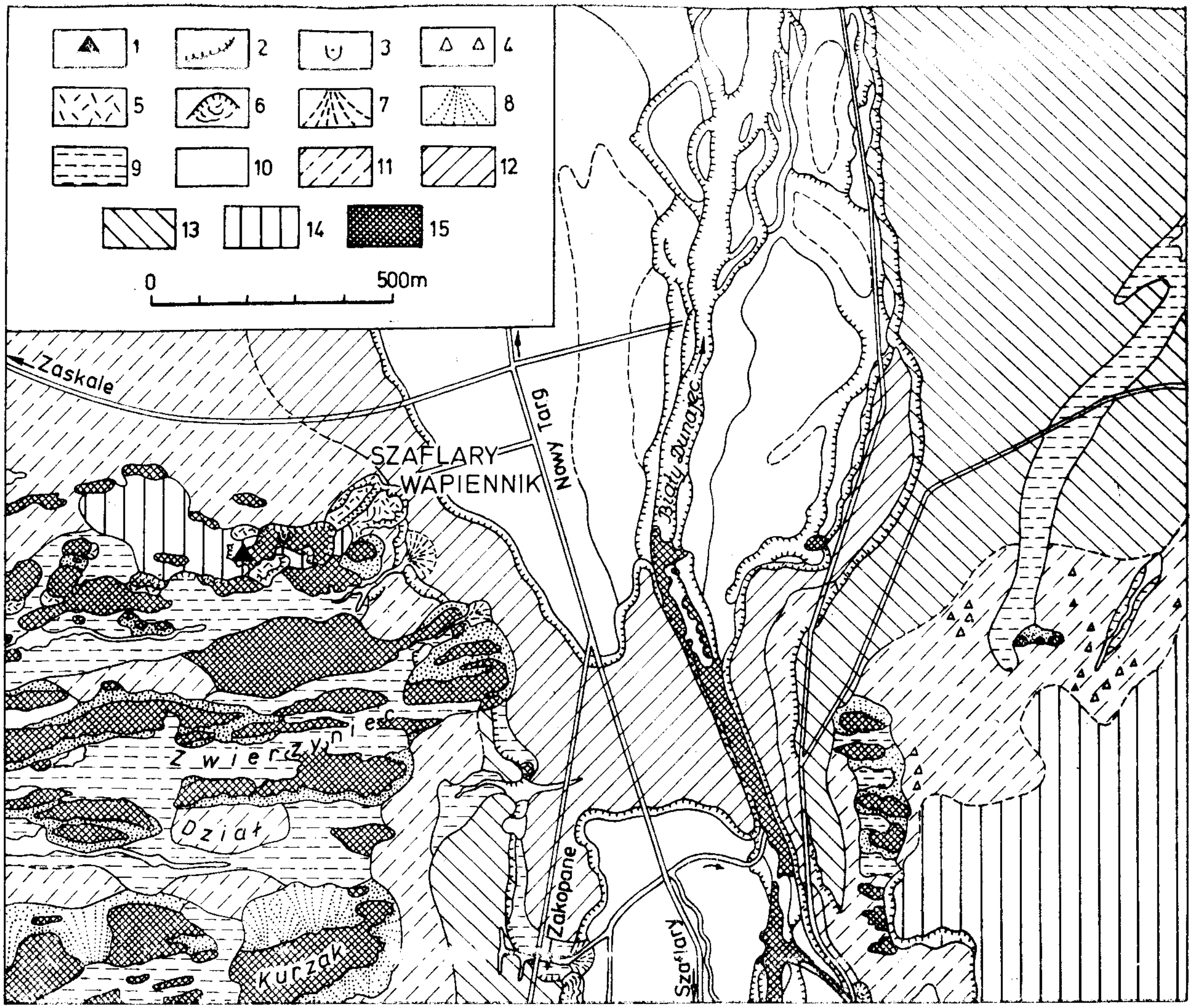
Immediately upon Jurassic rocks in the south-western part of the quarry rests a discontinuous layer described here as the regolith (Text-figs. 4—7), and by Wójcik (1960) as residual clay. It fills pockets and depressions in the limestone substratum, but disappears over its ridges. The thickness of the regolith attains up to 2—3 m, but usually it is barely 0·1—0·3 m.

The regolith consists of residual clay derived from weathered Jurassic and Cretaceous rocks of the immediate substratum or of the nearest vicinity: red marl (Turonian — Senonian), red limestone (Tithonian), white crinoid limestone (Bajocian) and altered black or yellow shale (Bajocian). Limonite and manganese-oxide infiltrations are abundant.

Irregular stratifications in the regolith is generally conformable with

Text-fig. 2. Geological sketch-map of the vicinity of Szaflary. 1 — Szaflary site, 2 — erosional escarpments, 3 — cave, 4 — loose granite and quartzite boulders in solifluction clay, 5 — dump heaps, 6 — landslide, 7 — alluvial cone, 8 — talus, talus cone, 9 — weathering, partly solifluction clay (5—9 — Holocene), 10 — terrace gravel and alluvia (Holocene), 11 — deluvial and solifluction clay (late Würm), 12—14 — fluvioglacial terrace gravelly-clayey covers, 12 — Würm, 13 — Riss, 14 — Mindel, 15 — Jurassic and Cretaceous rocks of the Pieniny Klippen Belt

Ryc. 2. Szkic geologiczny otoczenia Szaflar. 1 — stanowisko Szaflary, 2 — skarpy erozyjne, 3 — jaskinia, 4 — luźne głazy granitowe i kwarcytowe w glinie soliflukcyjnej, 5 — hałdy, 6 — osuwisko, 7 — stożki napływowe, 8 — usypisko, stożek usypiskowy, 9 — gliny zwietrzelinowe, częściowo soliflukcyjne (5—9 holocen), 10 — żwiry tarasowe i aluwia (holocen), 11 — gliny deluwialne i soliflukcyjne (późny Würm), 12—14 — pokrywy żwirowo-gliniaste tarasów, 12 — Würm, 13 — Riss, 14 — Mindel, 15 — utwory jurajskie i kredowe pienińskiego pasa skałkowego


1
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500m
Zaskale
SZAFLARY
WAPIENNIK
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Zwierzyniec
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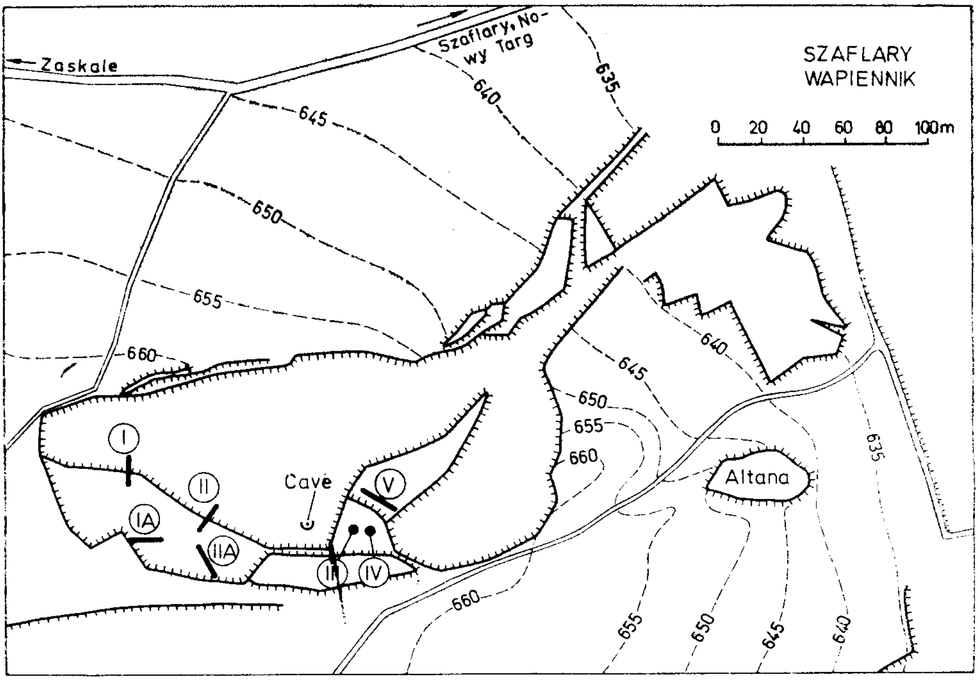


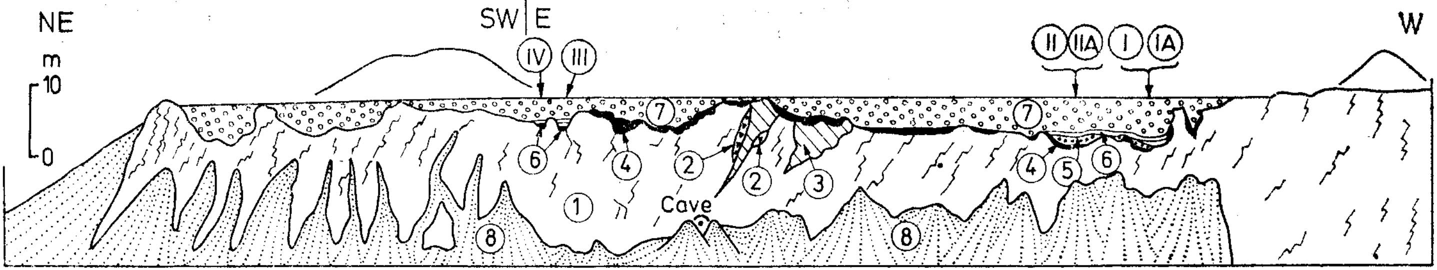

Text-fig. 3. Location of geological profiles (I—V) at Szaflary quarry
Ryc. 3. Sytuacja profilów geologicznych (I—V) w kamieniołomie szaflarskim

the relief of the substratum. This is expressed in the alternation of grey-green, yellow, brown and red clay and sandy clay bands, the colouration of the deposit being often directly related to the character of the substratum or depending on rock fragments contained in the clay.

## 3. Reworked regolith and lover gravel

Conformably upon the regolith rests another clayey band described here as the reworked regolith, which is 0·05—0·5 m thick. As a rule, it consists of the same material as in the underlying regolith, but is often mixed with fluvial material (Tatra granite and Podhale flysch sandstone pebbles), and laterally passes into the lower gravel (Text-figs. 5—7).

The lower gravel (Text-fig. 6A, B) was found only in the deepest depressions of the substratum in the south-western part of the quarry (Text-fig. 4), where it is up to 1·4 m thick. This is a river deposit of channel type consisting of granite (5—40 cm in diameter) and quartzite (5—50 cm in diameter) pebbles and cobbles, well rounded to subrounded, with some admixture (up to 25%) of flat sandstone pebbles, in greenish sandy-clayey matrix. Intercalations enriched in sandy clay may occur




Text-fig. 4. Southern face of the Szaflary quarry with position of profiles I—V. 1 — white crinoid limestone (Bajocian), 2 — limestone sedimentary breccias (Tithonian), 3 — red coquina limestone (Tithonian), 4 — regolith and reworked regolith, 5 — lower gravel, 6 — banded clay, 7 — upper gravel (Mindel), 8 — scree

Ryc. 4. Profil geologiczny południowej ściany kamieniołomu szaflarskiego z zaznaczoną pozycją profilów I—V. 1 — biały wapień krynoidowy (bajos), 2 — wapienne brekcje sedymentacyjne (tyton), 3 — czerwony muszlowiec (tyton), 4 — regolit i przerobiony regolit, 5 — dolne żwiry, 6 — ił wstęgowy, 7 — górne żwiry, 8 — usypisko within the gravel. The majority of pebbles and cobbles came from the Tatra Mts. (Carboniferous granite and Lower Triassic quartzite), the remaining ones (Eocene Podhale flysch sandstone) — from the area of the Podhale syncline (between the Pieniny Klippen Belt and the Tatra Mts.).

The lack of material from the Pieniny Klippen Belt is characteristic. Granite pebbles and cobbles are generally strongly weathered, soft, easily disintegrating into granitic sand. This is due to weathering *in situ*, post-dating the deposition of the gravel.

### 4. Banded clay

This is a very characteristic layer 0·3 to 1 m thick, resembling varved clay, consisting of alternating very thin laminae of clay or clayey silt. The colouration of the sediment varies between grey, bluish or green and brown and black, depending on the admixture of carbonaceous organogenic matter. The thickness of particular laminae is usually below 1 cm, the lighter ones usually being thicker than the darker ones. Still thinner microlaminae (0·1—1 mm) may be distinguished in both darker and lighter laminae.

The sediment is very fine, between silt and clay grade, admixture of fine sand or of small angular fragments of sandstone or limestone may sometimes be found.

No transition has been observed between the banded clay and the underlying regoliths (layers *2* and *3*) or the lower gravel (layer *3*). The banded clay often comes into direct contact with uneven substratum of crinoid limestone (Text-figs. 4—7).

### 5. Upper gravel

This is the highest Pleistocene layer studied in the exposures of the Szaflary quarry, unconformably covering all the previously described units. Its thickness varies due to the relief of the substratum from 1 to 8 m, the layer often disapears over the highest limestone ridges (Text-fig. 4).

The predominant element of the upper gravel are Lower Triassic quartzite and Carboniferous granite pebbles, cobbles and boulders (2—60 cm, sometimes up to 1 m in diameter), derived from the Tatra Mountains. Admixture of flat flysch sandstone pebbles (from the Podhale flysch: Eocene), 1—5 cm in diameter, usually does not exceed 1% but locally, especially in the lower part of the layer, may increase to 25% or more. The same can be said of radiolarite (Oxfordian) or marl (Upper Cretaceous) fragments derived from the klippes of the nearest vicinity, which may predominate in some exposures near the bottom of the gravel (Text-fig. 7A, B). The matrix of the gravel consists of yellow-rusty or brownish sandy clay.

Granite pebbles-boulders are usually strongly weathered, soft, easily disintegrating into granitic sand, radiolarite and marl fragments and sandstone pebbles are weathered to a less extent; only quartzite pebbles-boulders are fresh. The percentages of particular rock types of the gravel depend on the degree of weathering of granites which is strongest just below the soil layer. Thus, quartzites are most abundant at or near the

Table 1
Tabela 1

Mean petrographic composition of the upper gravel (volume percents)
Średni skład petrograficzny żwirów (w % objętościowych)

| Type of rock | Surface | Deeper part of the layer |
|---|---|---|
| Granite | 5 | 60 |
| Quartzite | 35 | 35 |
| Flysch sandstone, radiolarite, marl, limestone | 1 | 1 |
| Granitic sand and clay | 59 | 4 |
| | 100 | 100 |

Table 2
Tabela 2

Roundness of quartzite fragments, Pettijohn's (1949) scale. 100 fragments analysed, $a$ axis = 17—210 mm
Stopień obtoczenia fragmentów kwarcytów wg skali Pettijohna. Analizowano 100 fragmentów, oś $a$ = 17—210 mm

| | |
|---|---|
| Angular | — |
| Subangular | 24 |
| Subrounded | 52 |
| Rounded | 22 |
| Well rounded | 2 |
| | 100% |

surface, where granites have been completely transformed into sandy clay (Tab. 1).

The roundness of quartzite and granite fragments is usually high, between well rounded and subrounded, changing with the grade of the pebbles and with their petrographic character: granite pebbles-boulders are usually better rounded than quartzite ones. About 5% of quartzite pebbles were broken after rounding. Table 2 shows roundness of 100 quartzite fragments collected near the surface.

## DESCRIPTION OF PROFILES

### Profile I

(Text-fig. 5 B)

Succession and lithology

Thickness in metres

5. Upper gravel. Incomplete thickness . . . . . . . . . 0·3

Granite and quartzite pebbles 2—30 cm in diameter, well rounded to subrounded, in yellow-rusty sandy clay. Granite pebbles completely weathered, soft, easily disintegrating into granitic sand, quartzite pebbles fresh. Admixture (about 5 %) of flat sandstone pebbles, 1—5 cm in diameter, derived from the Podhale flysch (Eocene). *(Erosional break)*

4. Banded clay . . . . . . . . . . . . . . . . 1·0

i. Weathered, upper part of layer *4h*, consisting of alternating thin laminae of rusty-yellow clay (0·1—0·2 cm), black carbonaceous clay (0·1—0·2 cm) and yellowish or greenish clay (0·6—0·8 cm).

h. Alternating laminae of grey or bluish clay (0·6—0·8 cm) and dark-grey or greenish clay (0·2—0·3 mm). Limonitic infiltrations present.

g. Clay, greenish or greenish-grey, with faintly marked lamination every 0·5—1 cm.

f. Alternating laminae of black clay (1—0·5 mm) and chocolate-brown lustrous clay (0·8—1 cm). Fairly abundant quartz grains and calcite detritus (1—2 mm in diameter).

e. Alternating laminae of brownish-grey clay (4—5 mm) and dark-brown clay (0·5—0·2 mm).

d. Alternating laminae of dark-brown carbonaceous, lustrous clay (1—0·5 mm) and dark-grey, nearly black, more argillaceous clay (0·7—0·8 mm).

c. Clay, bluish, with brownish streaks, alternating every 1—2 cm with green clay (0·5—1 mm).

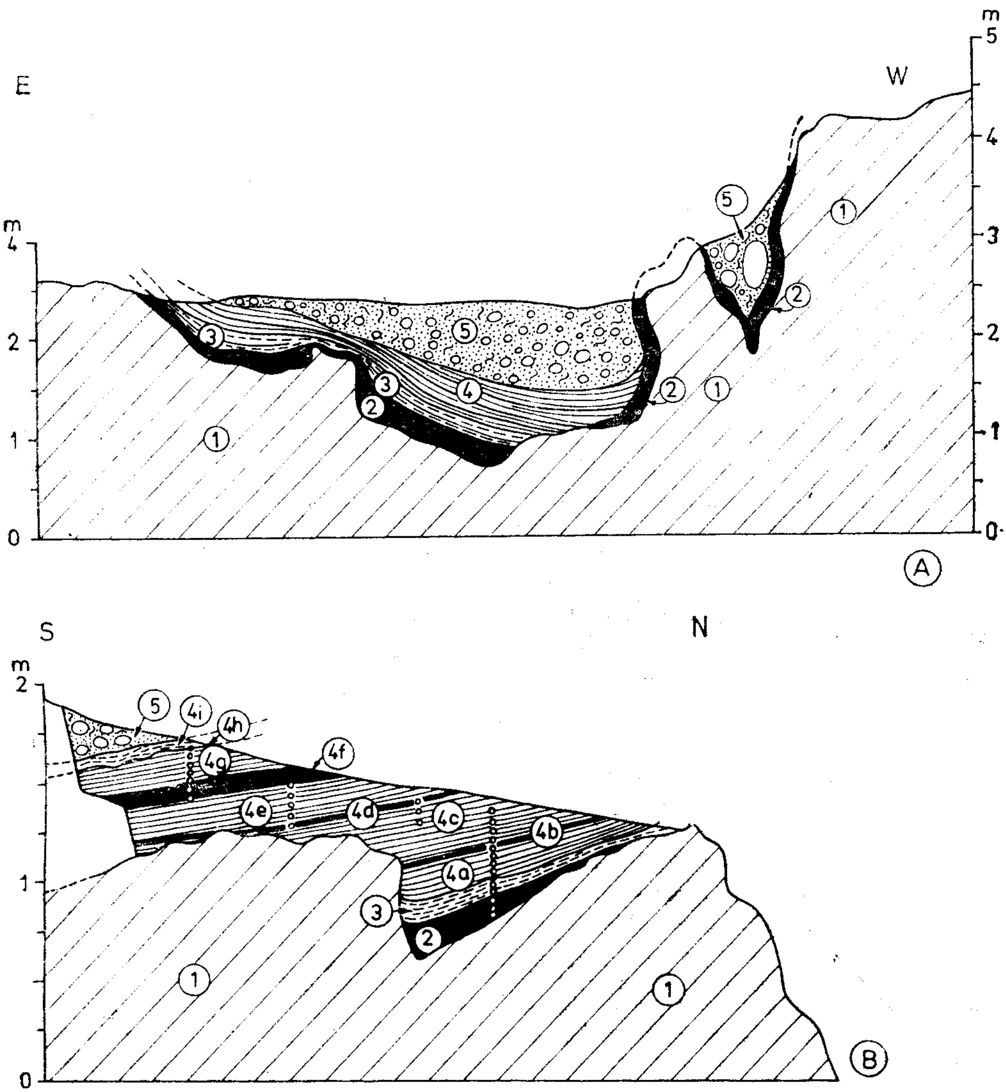
b. Alternating black or dark-brown, strongly carbonaceous clay (2 mm) and light-brown clay laminae (1—0·5 mm).

a. Alternating bluish-grey and brownish-grey plastic clay laminae, resting either upon the regoliths (layers *3* and *2*) or directly upon crinoid limestone substratum (layer *1*). Varve-type lamination visible best in the upper part of the layer: lighter laminae being thicker (0·5 cm), darker laminae being thinner (0·1—0·2 cm). A single fragment of crinoid limestone 10 cm in diameter has been found in the upper part of the layer.

(*Sedimentary hiatus*)

3. Reworked regolith . . . . . . . . . . . . . . . 0·05—0·12

Clay, slightly arenaceous, ocre-yellow, with streaks or lumps of red marl and shale (Turonian-Senonian), transisting toward the east into




Text-fig. 5. Szaflary quarry, profiles IA (*A*) and I (*B*), exposures in 1968. 1 — white crinoid limestone (Bajocian), 2 — regolith, 3 — reworked regolith, 4a-i — banded clay, 5 — upper gravel (Mindel). Small open circles denote palynological samples

Ryc. 5. Kamieniołom szaflarski, profile IA (*A*) i I (*B*), stan z 1968 r. 1 — biały wapień krynoidowy (bajos), 2 — regolit, 3 — przerobiony regolit, 4a-i — ił wstęgowy, 5 — górne żwiry (Mindel). Małe puste kółka oznaczają miejsca próbek palinologicznych green or greenish-brown clay with red streaks (reworked Upper Cretaceous marls). Fragments of weathered sandstone and granite present, the latter disintegrating to quartz-feldspar sand. Lack of transition to the overlying layer (4).

2. Regolith . . . . . . . . . . . . . . . . . . . . 0—0·15

Clay, arenaceous, rusty-brown, with limonite and manganese-oxide infiltrations, with fragments of weathered yellow shale (from the Bajocian shale) and red marl (Upper Cretaceous).

(*Sedimentary hiatus*)

1. Substratum

White crinoid limestone (Jurassic: Bajocian), weathered and limonitized at the upper surface, often disintegrating into crinoid-stem fragments.

## Profile II

(Text-fig. 6 B)

| Succession and lithology | Thickness in metres |
|---|---|
| 5. Upper gravel. Incomplete thickness . . . . . . . . . | 0·5 |

b. Granite and quartzite pebbles, well rounded to subrounded in rusty or rusty-brown sandy clay, derived from weathered granite pebbles. Granite pebbles weathered, soft, 2—20 cm in diameter, quartzite pebbles fresh, 5—20 cm in diameter.

a. Arenaceous clay, yellow, and argillaceous sand, fine- to medium-grained, yellow, rusty-yellow, with fragments of red marl (Upper Cretaceous) and small granite fragments.

(*Erosional break*)

4. Banded clay . . . . . . . . . . . . . . . . . 0·35

f. Clay, bluish-grey or brownish, better or worse laminated, weathered, with rusty and ocre-yellow limonite streaks.

e. Clay, dark-grey and black, with faint lamination.

d. Alternating laminae of black, carbonaceous, lustrous clay (1—4 mm) and dark-brownish clay (0·5—1 mm).

c. Clay, dark-grey or black, with faintly developed lamination.

b. As layer 4d.

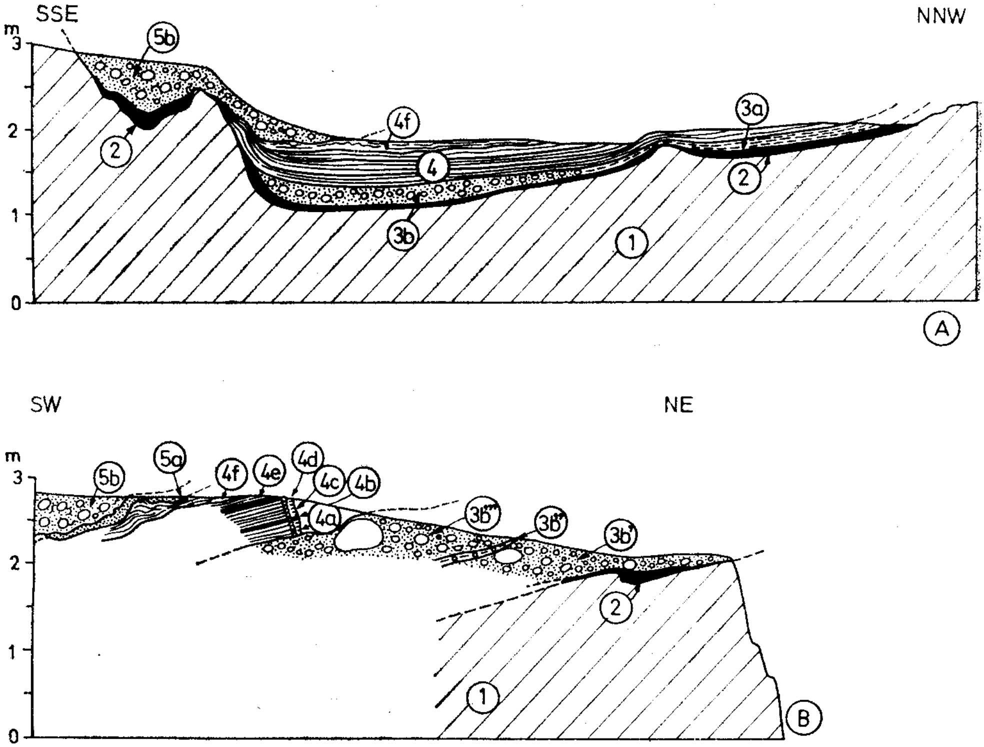
a. Alternating laminae of grey-brownish clay (1 mm) and light-brownish clay (2—3 mm). Still thinner lamination visible in both darker and lighter laminae.

(*Sedimentary hiatus*)

3. Lower gravel . . . . . . . . . . . . . . . . . 1·4

b‴. Granite-quartzite-sandstone mixed gravel in greenish sandy-clayey matrix. Pebbles of granite (5—30 cm in diameter) and quartzite (up to 50 cm in diameter) well rounded to subrounded. Granite pebbles weathered, quartzite pebbles fresh. Abundant, weathered, flat sandstone pebbles (from the Podhale flysch).

b″. Sandy clay, yellow-green, rusty or black (due to manganese-oxide




Text-fig. 6. Szaflary quarry, profiles IIA (*A*) and II (*B*), exposures in 1968. 1 — white crinoid limestone (Bajocian), 2 — regolith, 3a — reworked regolith, 3b′ — b‴ — lower gravel, 4 — banded clay, 5 — upper gravel (Mindel) with sandy clay at the bottom (5a). Small open circles denote palynological samples

Ryc. 6. Kamieniołom szaflarski, profile IIA (*A*) i II (*B*), stan z 1968 r. 1 — biały wapień krynoidowy (bajos), 2 — regolit, 3a — przerobiony regolit, 3b′ — b‴ — dolny żwir, 4 — ił wstęgowy, 5 — górne żwiry (Mindel) z warstwą piaszczystej gliny w spągu (5a). Małe puste kółka oznaczają miejsca próbek palinologicznych

infiltrations), with granite, quartzite and sandstone pebbles, 2—5 cm in diameter.

b′. Granite-quartzite-sandstone mixed gravel in rusty-yellow sandy clay, with black manganese-oxide streaks. Pebbles of granite (5—40 cm in diameter) and of quartzite (5—30 cm in diameter) well rounded to rounded. Granite pebbles weathered, quartzite pebbles fresh. Admixture (20—25%) of flat pebbles of green weathered sandstone (from the Podhale flysch).

(*Sedimentary hiatus*)

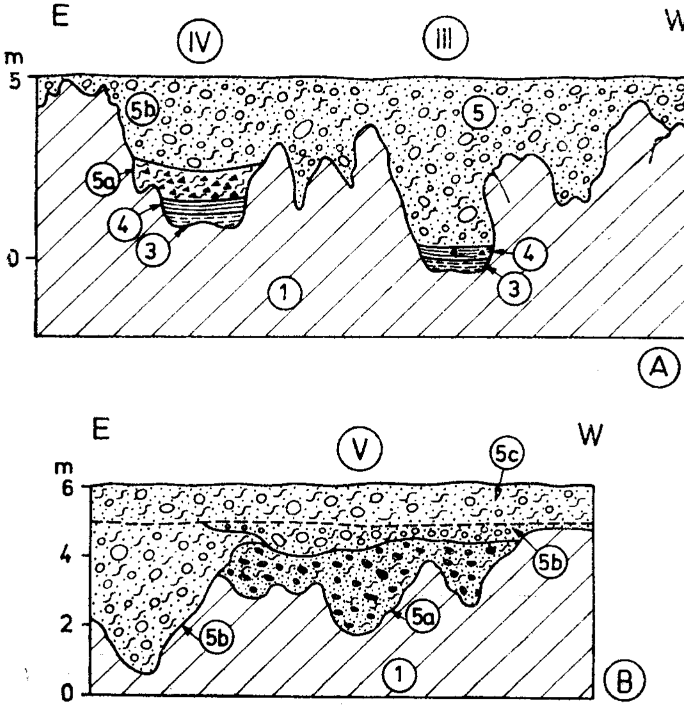
2. Regolith . . . . . . . . . . . . . . . . . . 0—0·2

Sandy clay, yellow or rusty-black (from limonite and manganese-oxide infiltrations), irregularly stratified.

(*Sedimentary hiatus*)

1. Substratum

White crinoid limestone (Jurassic: Bajocian), weathered and limonitized at the surface, often with black manganese-oxide veins and dendrites.




Text-fig. 7. Szaflary quarry, profilles III, IV (*A*), exposures in 1959, profile V (*B*), exposure in 1958. 1 — white crinoid limestone (Bajocian), 3 — reworked regolith, 4 — banderd clay, 5a-c — upper gravel (a — with flysch sandstone or rodiolarite fragments predominating, b — with quartzite and weathered granite fragments predominating, c — with quartzite and completely decomposed granite fragments
Ryc. 7. Kamieniołom szaflarski, profile III, IV (*A*), odsłonięcia z 1959 r. i profil V (*B*), odsłonięcie z 1958 r. 1 — biały wapień krynoidowy (bajos), 3 — przerobiony regolit, 4 — ił wstęgowy, 5a-c — górne żwiry (Mindel); a — z materiałem piaskowców fliszowych i radiolarytów, b — z materiałem granitowo-kwarcytowym, c — z materiałem kwarcytowym i kompletnie zwietrzałymi granitami

## Profile III

(Text-fig. 7 A)

| Succession and lithology | Thickness in metres |
|---|---|
| 5. Upper gravel . . . . . . . . . . . . . . . | 1·5—4·8 |

Granite and quartzite pebbles to boulders, well rounded to rounded, 2—50 cm in diameter, in yellow-rusty sandy clay. Granite pebbles

completely weathered, soft in the upper part of the layer, less weathered in the lower part of the layer.
Quartzite pebbles fresh.
(*Erosional break*)

4. Banded clay . . . . . . . . . . . . . . . . 0·5
b. Alternating laminae ("varves") of grey clayey silt (0·5—1 cm) and carbonaceous clayey silt (0·1—0·2 cm), with streaks of quartz sand 0·1—0·5 cm thick.
a. Alternating laminae ("varves") of grey and bluish clayey silt (0·1—0·3 cm), with some admixture of angular fragments of grey sandstone (0·5—1 cm in diameter) derived from the Podhale flysch.
(*Sedimentary hiatus*)

3. Reworked regolith . . . . . . . . . . . . . . 0·4
b. Clay, yellowish-rusty, with black manganese-oxide infiltrations
a. Alternating pink, brown and rusty clay and fine-grained quartz-sand laminae. Weathered red marl fragments (Upper Cretaceous).
(*Sedimentary hiatus*)

1. Substratum
White crinoid limestone (Jurassic: Bajocian), weathered and limonite-coated at the surface.

## Profile IV

(Text-fig. 7 A)

Succession and lithology — Thickness in metres

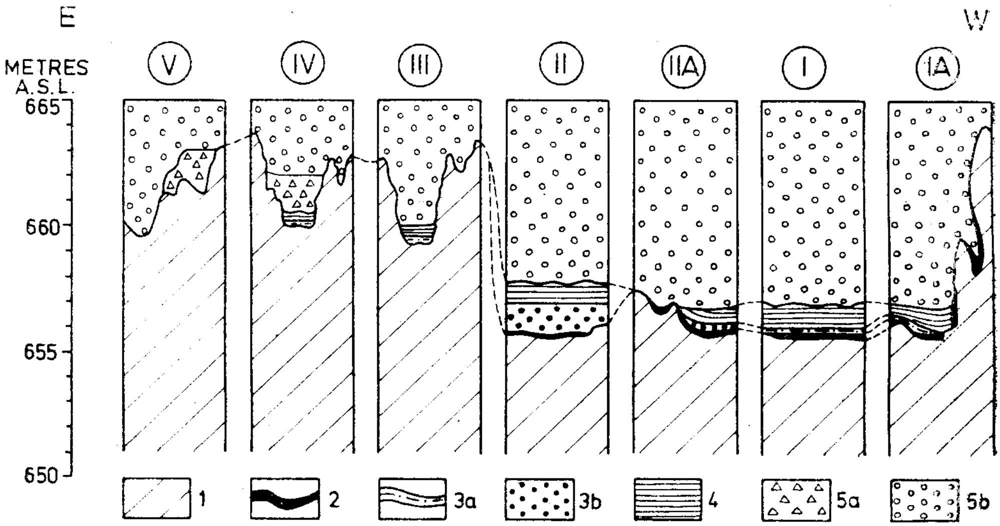
5. Upper gravel . . . . . . . . . . . . . . . . 1·5—4
b. As in profile III.
a. Clay, brownish, with angular fragments of weathered radiolarite (Jurassic: Oxfordian), 1—5 cm in diameter.
(*Sedimentary hiatus*)

4. Banded clay . . . . . . . . . . . . . . . . 0·3
Alternating laminae ("varves") of black carbonaceous silt or clay (0·5—1 cm) and grey silt or clay (1—3 cm).
(*Sedimentary hiatus*)

3. Reworked regolith . . . . . . . . . . . . . . 0·5
Sandy clay, grey-green and yellow.
(*Sedimentary hiatus*)

1. Substratum
As in profile III.

The stratigraphical correlation of profiles I—IV is shown in Text-fig. 8.




Text-fig. 8. Correlation of Pleistocene profiles at Szaflary. 1 — substratum (Jurassic limestones), 2 — regolith, 3a — reworked regolith, 3b — lower gravel, 4 — banded clay, 5a — upper gravel, short transport material (radiolarite, flysch sandstone etc.), 5b — upper gravel, long transport material (granite, quartzite)

Ryc. 8. Korelacja stratygraficzna profilów plejstoceńskich w Szaflarach. 1 — podłoże (wapienie jurajskie), 2 — regolit, 3a — przerobiony regolit, 3b — dolne żwiry, 4 — ił wstęgowy, 5a — górne żwiry, materiał krótkiego transportu (radiolaryty, piaskowce fliszowe itp.), 5b — górne żwiry, materiał dalekiego transportu (granity, kwarcyty)

## ORIGIN OF DEPOSITS

Highly diversified relief of the crinoid limestone klippe, the result of surficial karstic processes (Małkowski 1924, 1928; Wójcik 1960), was formed prior to the deposition of the lower gravel and its equivalents (reworked regolith). The depressions and pockets resulting from dissolution of the limestone were filled with residual clays (regolith — layer 2). The red colouration of the regolith is mostly due to the presence of red Upper Cretaceous and Tithonian marl and limestone fragments, however, lateritic weathering simultaneous with the formation of residual clays cannot be excluded. Rich limonite and black manganese-oxide infiltrations and veins, penetrating from the regolith along cracks in the limestone substratum, suggest weathering under moderate climate, though possibly warmer than at present.

Appearance of river channels in which lower gravel (layer 3) was deposited, marked an important change in the drainage pattern of the area. The Jurassic klippe at Szaflary, so far isolated and elevated as a monadnock, was partly buried under an alluvial fan deposited by a river which flowed directly from the Tatra Mountains (granite and quartzite pebbles) across the Podhale syncline (flysch sandstone pebbles). This would imply a rapid increase of gravel supply from the Tatra Mountains source area, correlated with a rapid increase of accumulation rate in river fans in the morphologic depression around Nowy Targ. Tectonic and climatic factors may be considered the causes. The tectonic factor would involve an uplift in the Tatra Mountains and/or relative subsidence of the Orawa — Nowy Targ basin. Climatic factor would involve an increase of precipitation in the whole area on a regional or global scale.

It is difficult to solve the problem whether tectonic or climatic factors were the sole causes, or whether both had a share in the change of environmental conditions. Climatic factor alone could explain the change of environment from relatively warm and dry, favouring development of karst phenomena and terra rossa-type regolith, to moderate or cool, characterized by rapid increase in precipitation. If so, this climatic change could be correlated with one of the Early Pleistocene glaciations as known from the Alps. This would agree with the appearance of the subsequent varve-like banded clay sediments (layer 4).

The lithologic character of the banded clay indicates sedimentation in a very quiet lacustrine basin, possibly an isolated lake at the margin of alluvial fan, dammed from the river by a point bar, being reached by melt-waters only during floods. Seasonal changes in sediment supply in suspension may explain banding of the sediment, the darker laminae and bands enriched in carbonaceous matter corresponding to seasons of relative decrease of sediment supply (winter), the lighter ones, poorer in carbonaceous matter — to periods of floods (summer).

Palynological investigations by L. Stuchlik (see part II of this paper) indicate that at the beginning of lacustrine cycle, conifers predominated over angiosperms in the vicinity of Szaflary. Higher up in the succession, coniferous forests gave way to forests of wet habitats, being replaced at the end of lacustrine cycle again by coniferous forests. This succession of flora indicates cooling of the climate at the end of lacustrine cycle.

The highest Pleistocene deposit of the discussed section at Szaflary is represented by the upper gravel (layer 5) deposited unconformably upon the banded clay or directly upon its substratum. Its Mindel age seems well established on correlation with tills of this age present at the foot of the Tatra Mountains, though the opinions as to the origin of the deposit varied between glacial till (Małkowski 1924, 1928; Romer 1929) and fluvioglacial gravel (Halicki 1930; Klimaszewski 1948, 1951, 1961a, b; Birkenmajer 1958, 1968). The character of the deposit and its relation to the substratum, discussed in detail in the preceding chapter, excludes the possibility of a glacial till. The following features decidedly support its fluvioglacial origin (Birkenmajer 1968): (1) high degree of roundness of long-transport gravel (granite and quartzite); (2) comparatively high degree of roundness of short-transport gravel (flysch sandstone); (3) lack of glacial striae on even the most resistant gravel (quartzite and granite); (4) lack of glacial striae on the limestone substratum; (5) lack of roches mountonnées on the highly sculptured (karstic) limestone surface; (6) lack of glacitectonic phenomena in the whole Pleistocene profile.

A peculiar feature of the deposit is the lack of prefered orientation and imbrication of pebbles, which are obvious features in the younger Pleistocene and Holocene gravel covers in the Podhale area. This, however, could be explained by strong weathering of the upper gravel and reorientation of pebbles due to cryoturbation during later glacial stages of the Pleistocene history of the area.

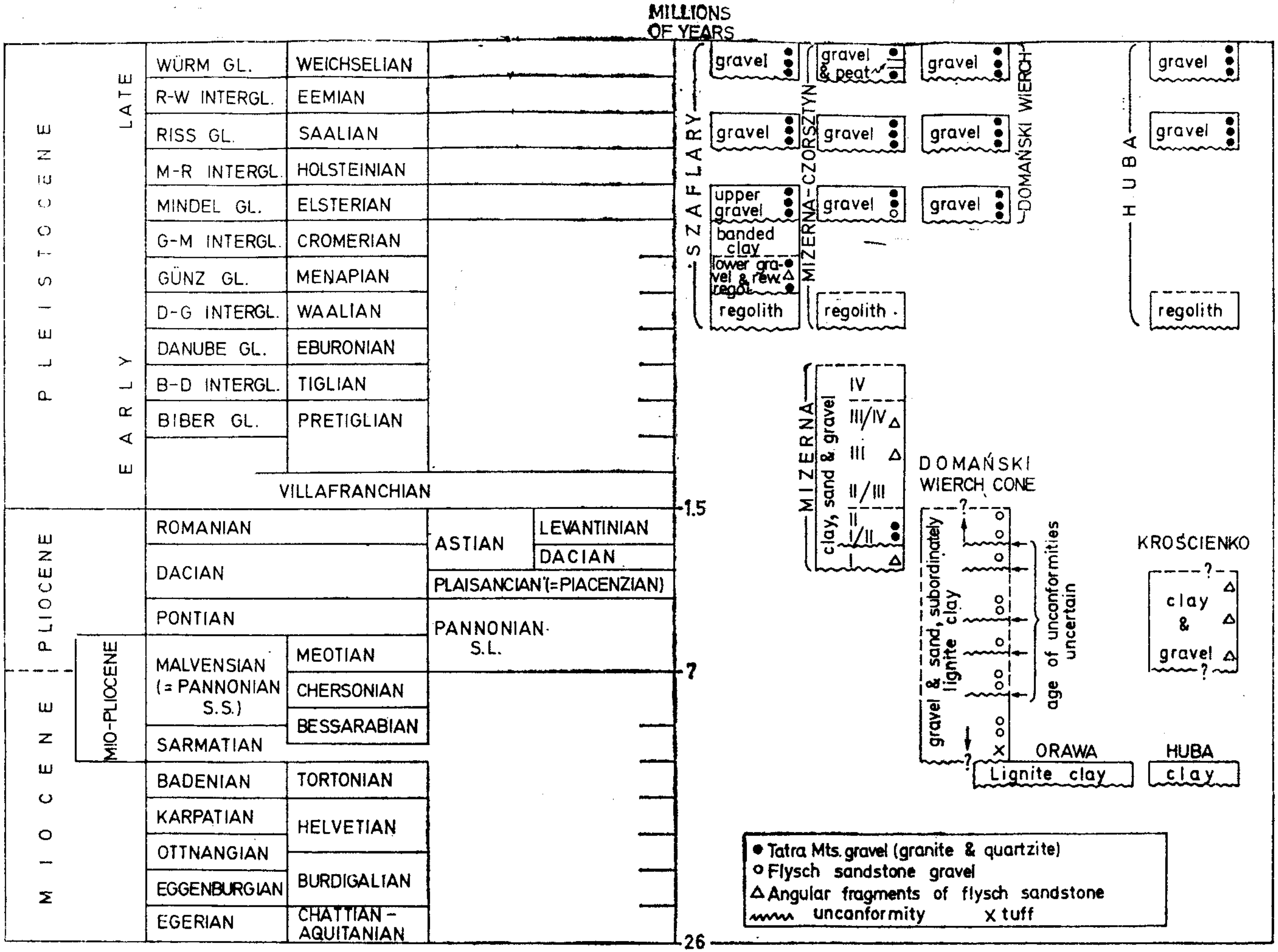
Some limestone pockets filled with upper gravel resemble potholes. This refers first of all to those pockets in which the gravel rests directly upon the limestone, suggesting that older Pleistocene sediments have been washed out by turbulent river waters during the Mindel Glaciation.

The distribution of the Mindel fluvioglacial gravel covers in the vicinity of Szaflary indicates a direct connection of the upper gravel with the Biały Dunajec River pattern (Text-fig. 2).

## AGE OF SEDIMENTS

The Mindel age of fluvioglacial gravel cover (upper gravel — layer *5*) at Szaflary clearly indicates a pre-Mindel age of the underlying banded clay (layer *4*), the lower gravel, the reworked regolith (layer *3*) and the regolith (layer *2*). It should be noted that "Preglacial" (Pliocene-Early Pleistocene) age of residual clays at Szaflary (= regolith — layer *2* in the present paper) was postulated already by Wójcik (1960). Birkenmajer (1968) suggested preliminarily that the layers *5*—*3* could correspond to the Mindel Glaciation, thus the banded clay would correspond to an interstadial. However, palynological spectrum of the banded clay elaborated by Stuchlik (see part II of this paper) shows interglacial and not interstadial characteristics.

The Early Pleistocene age of the banded clay is based on its palynological spectrum and on comparisons with other palaeobotanically dated sites in the Orawa—Nowy Targ basin. This is especially evident from




Stratigraphic correlation of selected Neogene and Pleistocene sites in the Orawa— Nowy Targ basin and the Pieniny Mountains
Korelacja stratygraficzna wybranych stanowisk neogenu i plejstocenu w Kotlinie Orawsko—Nowotarskiej i Pieninach

comparison with the Early Pleistocene (Tiglian) part of the Mizerna profile (Szafer 1954; Szafer, Oszast 1964). Geological evidence discussed in the preceding chapters suggests that the banded clay (layer 4) could be correlated with the Günz-Mindel Interglacial, and the underlying gravel lower and reworked regolith (layer 3) — with the Günz Glaciation. Finally, the regolith (layer 2) and the related karst weathering of the Jurassic-Cretaceous klippes at Szaflary, would correspond to a still older climatic phase, e.g. the Danube-Günz Interglacial. If this were true, the karst weathering and formation of regolith would be subsequent to fluvial-solifluction phase evidenced by the Tiglian deposits at Mizerna.

A similar Early Pleistocene age could be suggested for red weathering-clays developed on Palaeogene flysch rocks prior to the Mindel gravel cover at Mizerna (Birkenmajer 1963b) and at Huba (Birkenmajer 1963c), where they are covered by the Riss fluvioglacial gravel. Their Pliocene age tentatively suggested by Birkenmajer (1963b, c) and Gerlach (1967) finds no confirmation, as neither the Pliocene-Early Pleistocene deposits at Mizerna, nor the Miocene-Pliocene deposits at Domański Wierch show red colouration of the sediments.

Table 3 shows possible stratigraphical position of selected Miocene, Pliocene and Early Pleistocene sites in the intramontane Orawa-Nowy Targ basin and its vicinity, based mainly on the latest palaeobotanical investigations (Oszast 1970, 1973; Zastawniak 1972; Tran Dinh Nghia 1974) and on geological evidence discussed in the present paper.

## POST-MINDEL EVENTS

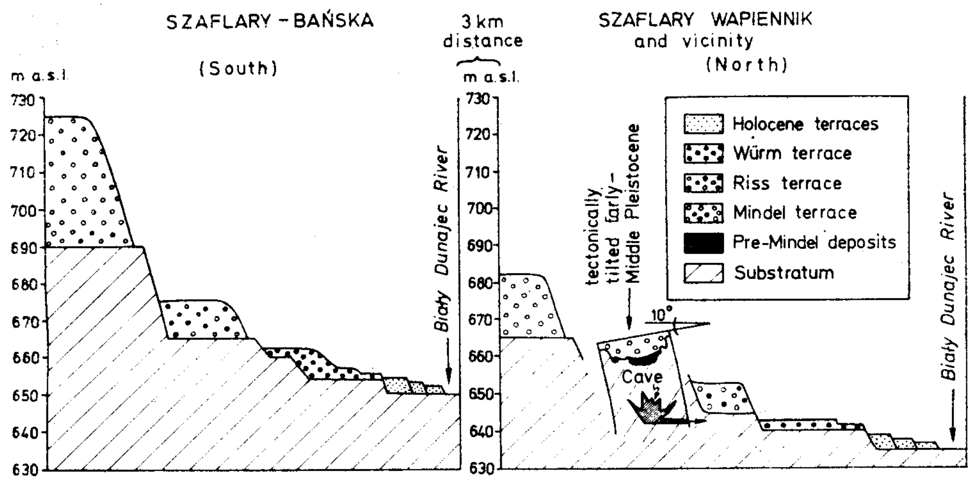
The profile of Pleistocene deposits at Szaflary shows tectonic tilt of the layers *3*—5 toward the south of the order of 10 degrees (Text-figs. 5, 6). This tilt and the related plastic deformations of soft sediments are the result of differential vertical movements of the Jurassic-Cretaceous klippe, stronger on the north. The tilting was younger than the Mindel Glaciation but possibly older than the Riss Glaciation, as is shown by distribution of undisturbed fluvioglacial covers in the nearest vicinity (Text-fig. 9). The causes and effects of this tilting will be discussed in a separate paper.

A cave has been found at Szaflary (Birkenmajer 1968) in the Jurassic limestone below the investigated Pleistocene section, with an outflow of water at 642 m above sea level (Text-figs. 4, 9) corresponding to the upper level of the Würm terrace of the nearest vicinity. A late Pleistocene age is thus suggested as the time of formation of the cave.

**Szaflary I profile. Absolute numbers of sporomorphs**

**Profil Szaflary I. Bezwzględne liczby sporomorf**

| Numbers of samples<br>Numery prób | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alnus | 25 | 16 | 61 | 62 | 69 | 80 | 167 | 106 | 13 | 56 | – | 49 | 38 | 31 | 43 | 31 | 111 | 125 |
| Araliaceae | – | – | 1 | 3 | 3 | 1 | – | – | – | – | – | – | – | – | – | – | – | – |
| Betula | 9 | 12 | 23 | 22 | 36 | 18 | 44 | 17 | 2 | 17 | – | 36 | 17 | 15 | 44 | 20 | 42 | 23 |
| Carpinus | 1 | – | 7 | 6 | 3 | – | 2 | 2 | – | 1 | – | 2 | 3 | – | 1 | 1 | 2 | 2 |
| Carya | 1 | – | – | 2 | 2 | 3 | 2 | 3 | – | – | – | – | – | – | 3 | – | – | – |
| Castanopsis | – | – | – | – | 1 | 4 | – | – | 1 | – | – | 3 | 1 | – | 1 | 3 | 1 | – |
| Celtis | – | – | – | 1 | 1 | 2 | – | – | – | – | – | 1 | 1 | 1 | – | – | – | – |
| Corylus | 2 | 1 | – | – | 3 | 5 | 1 | 2 | 1 | – | – | 5 | 9 | 2 | 2 | 5 | 3 | 6 |
| Cryptomeria | – | – | – | 2 | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Cyrillaceae | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Elaeagnus | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Engelhardtia | – | – | – | – | – | – | 4 | 2 | – | 3 | – | 2 | – | – | – | 2 | – | 2 |
| Eucommia | – | – | – | 1 | – | – | – | – | – | – | – | – | 1 | – | – | – | – | 1 |
| Fagus | – | – | 3 | 25 | 9 | 2 | – | – | – | – | – | 1 | – | – | – | 1 | – | 1 |
| Glyptostrobus | – | – | – | 1 | 2 | 2 | 4 | – | – | – | – | – | – | – | 1 | – | – | – |
| Hedera | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Ilex | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| Keteleeria | 1 | – | 2 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Ligustrum | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| Liquidambar | – | – | – | 1 | – | – | – | – | – | – | – | – | – | 2 | – | – | – | – |
| Myrica | – | – | 1 | 1 | 1 | – | 1 | 1 | – | 1 | – | – | – | – | – | – | – | – |
| Myrtus | 1 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Nyssa | – | – | – | 4 | 2 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Oleaceae | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – |
| Ostrya | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – |
| Pasania | – | – | – | 8 | 18 | 8 | – | – | – | – | – | – | – | – | – | – | – | – |
| Picea | 49 | 19 | 51 | 11 | 6 | 2 | 1 | – | – | – | – | – | 2 | 2 | 16 | 14 | 30 | 5 |
| Pinus t. haploxylon | 5 | 4 | 4 | 2 | 1 | 4 | – | – | – | – | – | – | 7 | 1 | 9 | 10 | – | 1 |
| Pinus t. silvestris | 190 | 205 | 210 | 125 | 45 | 54 | 190 | 54 | 4 | 14 | – | 124 | 82 | 62 | 260 | 180 | 198 | 117 |
| Platycarya | – | – | – | – | – | 1 | 2 | – | – | – | – | – | – | – | 2 | – | 4 | – |
| Pterocarya | 6 | 6 | 3 | 11 | 4 | 2 | 5 | 5 | – | 4 | – | – | – | 1 | 18 | 11 | 5 | 14 |
| Quercus | 1 | – | 4 | 10 | 5 | – | 3 | – | – | 5 | – | 4 | 1 | 2 | 7 | 9 | 6 | 6 |
| Rhus | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Salix | – | – | 7 | – | – | – | – | – | – | – | – | – | – | – | 2 | – | – | 2 |
| Sapotaceae | – | – | – | – | 1 | 1 | – | – | – | – | – | – | – | – | 1 | 1 | – | – |
| Sciadopitys | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Symplocos | – | – | – | – | – | – | – | 1 | – | 1 | – | – | – | – | – | – | – | – |
| Taxodiaceae-Cupresseceae | – | 1 | – | 17 | 16 | 7 | 8 | 12 | 1 | 3 | – | – | – | – | – | 1 | – | – |
| Tilia | – | – | – | – | – | 1 | – | – | – | 1 | – | – | 1 | – | 1 | 1 | 3 | – |
| Tsuga | 5 | 7 | 6 | – | – | 1 | 1 | 1 | – | – | – | – | – | 1 | – | – | – | – |
| Ulmus | 4 | 11 | 15 | 15 | 10 | 12 | 13 | 12 | 3 | 5 | – | 12 | 23 | 7 | 27 | 15 | 30 | 12 |
| Vitis | – | – | – | 1 | 2 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Alsophila | – | – | – | – | 1 | 1 | 1 | – | – | – | – | – | – | – | – | – | – | – |
| Anthoceros | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – |
| Artemisia | – | – | 1 | – | – | 1 | 1 | – | – | – | – | 5 | – | 1 | – | 1 | – | – |
| Botrychium | – | 1 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Campanulaceae | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 2 | – | – | 2 |
| Chenopodiaceae | – | – | – | 2 | – | – | 1 | – | – | – | – | 1 | – | – | – | – | – | – |
| Compositae | 1 | – | 2 | 2 | 4 | 3 | 5 | 2 | – | 2 | – | 2 | 2 | 1 | 2 | 2 | – | – |
| Cyatheaceae | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – |
| Cyperaceae | 3 | 1 | 29 | 31 | 14 | 15 | 39 | 43 | 8 | 3 | – | 1 | – | 6 | 6 | 2 | 20 | 5 |
| Ericaceae | – | – | – | – | 3 | – | 1 | – | – | – | – | 16 | 5 | 3 | 3 | 1 | 3 | 4 |
| Filipendula | – | – | 1 | 2 | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – |
| Gramineae | 15 | 4 | 31 | 53 | 47 | 80 | 94 | 80 | 11 | 46 | – | 38 | 33 | 35 | 91 | 69 | 44 | 75 |
| Labiatae | – | – | – | – | – | 1 | – | – | – | 1 | – | – | – | – | 1 | 1 | 1 | – |
| Leguminosae | – | – | – | – | 1 | 5 | 1 | 2 | – | – | – | – | – | – | – | 1 | – | – |
| Liliaceae | – | – | – | 1 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Lycopodium | 3 | 5 | – | 2 | – | – | 10 | 1 | – | 7 | – | 1 | 1 | 1 | 2 | – | 1 | 1 |
| Lythraceae | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Myriophyllum | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – |
| Osmundaceae | – | – | – | – | – | 1 | – | – | – | – | – | 1 | – | 1 | 4 | 5 | 3 | – |
| Plantago | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Polygonum t. aviculare | – | – | – | – | – | – | – | – | – | – | – | 1 | – | – | 1 | – | – | – |
| Polygonum t. persicaria | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – |
| Polypodiadeae | 490 | 252 | 640 | 278 | 146 | 40 | 79 | 46 | 16 | 21 | – | 46 | 92 | 108 | 236 | 260 | 519 | 330 |
| Potamogeton | 1 | – | 4 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Pteridium | – | – | – | – | – | – | – | 10 | 1 | 9 | – | 5 | – | 6 | – | 1 | 3 | 2 |
| Ranunculaceae | – | – | 4 | 1 | 3 | – | 1 | – | – | 2 | – | – | – | – | – | – | 3 | – |
| Rubiaceae | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Sphagnum | – | – | 1 | 4 | 2 | 38 | 124 | 159 | 30 | 88 | – | 147 | 70 | 54 | 30 | 12 | 49 | 14 |
| Thalictrum | – | – | 8 | 5 | 9 | 18 | 1 | 1 | – | 2 | – | – | – | – | – | – | – | – |
| Umbelliferae | – | – | – | 1 | – | 3 | – | 2 | 3 | – | – | 2 | – | – | 2 | 2 | 2 | – |
| Valeriana | – | – | – | 1 | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – |
| Viscum | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Total sum of sporomorphs<br>Suma totalna sporomorf | 813 | 547 | 1123 | 719 | 472 | 419 | 809 | 566 | 94 | 293 | – | 505 | 588 | 344 | 818 | 662 | 1083 | 751 |
| Sum of Quaternary trees and shrubs<br>Suma czwartorzędowych drzew i krzewów | 286 | 268 | 385 | 279 | 190 | 179 | 421 | 193 | 23 | 99 | – | 233 | 183 | 122 | 412 | 287 | 425 | 300 |
| Sum of Tertiary elements<br>Suma elementu trzeciorzędowego | 14 | 15 | 15 | 55 | 52 | 34 | 28 | 25 | 2 | 13 | – | 6 | 2 | 5 | 26 | 18 | 10 | 18 |
| Sum of herbaceous plants<br>Suma roślin zielnych | 23 | 12 | 82 | 103 | 82 | 128 | 157 | 131 | 22 | 63 | – | 68 | 41 | 49 | 114 | 84 | 77 | 85 |




Text-fig. 9. Correlation of Quaternary gravel covers in the vicinity of Szaflary, and the position of tilted Pleistocene cover at Szaflary quarry

Ryc. 9. Korelacja żwirowych pokryw czwartorzędowych w okolicy Szaflar i pozycja tektonicznie nachylonych osadów plejstoceńskich w kamieniołomie szaflarskim

## II. PALAEOBOTANICAL PART

(by L. Stuchlik)

### INTRODUCTION

Palynological investigations of the Pleistocene profile at Szaflary were carried out on 25 samples from profile I (Text-fig. 5A) and on 10 samples from profile II (Text-fig. 6A). After mechanical pre-treatment of the samples, the material was treated in hydrofluoric acid and by Erdtman's acetolysis (Erdtman 1943, 1960) in succession. After maceration, 5 microscopic preparations were made from each sample with the use of AK 2000 silicone oil, covered by coverglasses 20 × 20 mm. All pollen grains and spores were counted in two preparations per horizon, within the effective area of 8 square cm.

Pollen spectra obtained allowed to preparation of tables of absolute number of sporomorphs (Tabs. 4, 5) which were then used for construction of the pollen diagram for the Szaflary I profile (Text-fig. 10). In the Szaflary II profile only some of samples contained sporomorphs, therefore no pollen diagram was prepared. Percentages for the diagram were calculated with respect to the sum of sporomorphs, spores of *Polypodiaceae* and *Sphagnum* exclusively. Values below 1% are marked with +.

## CHARACTERISTICS OF PLANT REMAINS

From the banded clay at Szaflary (layer *4* — see part I of this paper) 74 sporomorphs were determined to the family and genus levels in profiles I and II (Tabs. 4, 5). Only the pollen grains of *Pinus* type *silvestris* and

Table 5
Tabela 5

Szaflary II profile. Absolute numbers of sporomorphs
Profil Szaflary II. Bezwzględne liczby sporomorf

| Numbers of samples<br>Numery prób | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Alnus | – | 8 | – | – | – | 29 | – | 20 | – | 26 |
| Betula | – | 4 | – | – | – | 9 | – | 4 | – | 10 |
| Carpinus | – | – | – | – | – | 2 | – | – | – | – |
| Castanopsis | – | – | – | – | – | – | – | – | – | 1 |
| Celtis | – | – | – | – | – | – | – | – | – | 1 |
| Picea | – | – | – | – | – | – | – | – | – | 1 |
| Pinus t. silvestris | – | 8 | – | – | – | 26 | – | 2 | – | 41 |
| Pterocarya | – | – | – | – | – | – | – | – | – | 1 |
| Quercus | – | – | – | – | – | 3 | – | – | – | 1 |
| Taxodiaceae-Cupressaceae | – | – | – | – | – | – | – | 1 | – | – |
| Tilia | – | – | – | – | – | – | – | – | – | 1 |
| Ulmus | – | 11 | – | – | – | 4 | – | 2 | – | 3 |
| Compositae | – | – | – | – | – | – | – | – | – | 4 |
| Cyperaceae | – | – | – | – | – | – | – | – | – | 11 |
| Ericaceae | – | – | – | – | – | – | – | – | – | 1 |
| Gramineae | – | 8 | – | – | – | 25 | – | 7 | – | 17 |
| Osmundaceae | – | – | – | – | – | – | – | – | – | 2 |
| Polypodiaceae | – | 48 | – | – | – | 30 | – | 3 | – | 60 |
| Pteridium | – | – | – | – | – | 7 | – | – | – | 1 |
| Sphagnum | – | 2 | – | – | – | 35 | – | 9 | – | 37 |
| Total sum of sporomorphs<br>Suma totalna sporomorf | – | 89 | – | – | – | 172 | – | 47 | – | 221 |

type *haploxylon*, *Picea*, *Alnus*, *Betula*, *Corylus*, *Pterocarya*, *Quercus* and *Ulmus*, and of herbaceous plants — *Cyperaceae*, *Graminae* and spores of *Polypodiaceae* and *Sphagnum* were more abundant and present in nearly all samples of the Szaflary I profile. The remaining sporomorphs were encountered only sporadically and in small amounts, though some of them, on some sections of the diagram, form continuous curves.

Only 4 samples from the Szaflary II profile showed frequency of pollen high enough to allow calculations of pollen spectra. Their composition was much poorer than that in profile I. Only 21 forms were determined, of which only *Pinus*, *Betula* and spores of *Polypodiaceae* were more numerous (Tab. 5). Profiles I and II did not differ significantly in their floristic character and may be regarded as representing the same sedimentary cycle.

A sample of banded clay from profile III (Text-fig. 7A) taken by Birkenmajer in 1959 was devoid of sporomorphs, but yielded leaves and stems of mosses, determined by the late prof. Bronisław Szafran as: *Aulacomium palustre* Schwägr. var. *imbricatum* (montane element occurring in wet habitats — peats, *Bryum alpinum* Huds. (montane element occurring on wet rocks), *Dicranum* sp. (probably *neglectum* Jacq. — montane element occurring on slopes), *Drepanocladus* sp., *Paludella squarrosa* Brig. (subarctic element occurring on peat-bogs), *Polytrichum juniperinum* Willd. (pancontinental element, known from Europe, Asia, Africa, North and South America, Australia, New Zealand and Tasmania), *Tayloria froelichiana* Lindl. *vel. T. lingulata* Lindl. (arctic-alpine element, occurring on wet humus on rocks; in the Tatra Mts. — above timber line) and *Tortula ruralis* Ehrh. (pancontinental element, occurring on rocks).

## DESCRIPTION OF POLLEN DIAGRAM AND CHARACTERISTICS OF VEGETATION

Three group of sporomorphs were distinguished in the diagram (Text-fig. 10). The first group comprises tree and shrub genera known to-day from Middle Europe: *Coniferae* saccatae, and deciduous plants — *Alnus, Betula, Carpinus, Corylus, Fagus, Quercus, Tilia* and *Ulmus.*

The second group comprises trees known from the Tertiary and Early Pleistocene deposits: *Carya, Castaneaoideae, Platycarya, Pterocarya, Taxodiaceae-Cupressaceae, Tsuga,* as well as *Araliaceae, Celtis* and *Myrica* found only as traces. Some of these plants, e.g. *Pterocarya* (according to Zagwijn 1960) and *Engelhardtia* (according to Walter, Straka 1971) pass up to the Middle Pleistocene.

The third group comprises all herbaceous plants exclusive of *Polypodiaceae* and *Sphagnum* which were shown separately in the diagram.

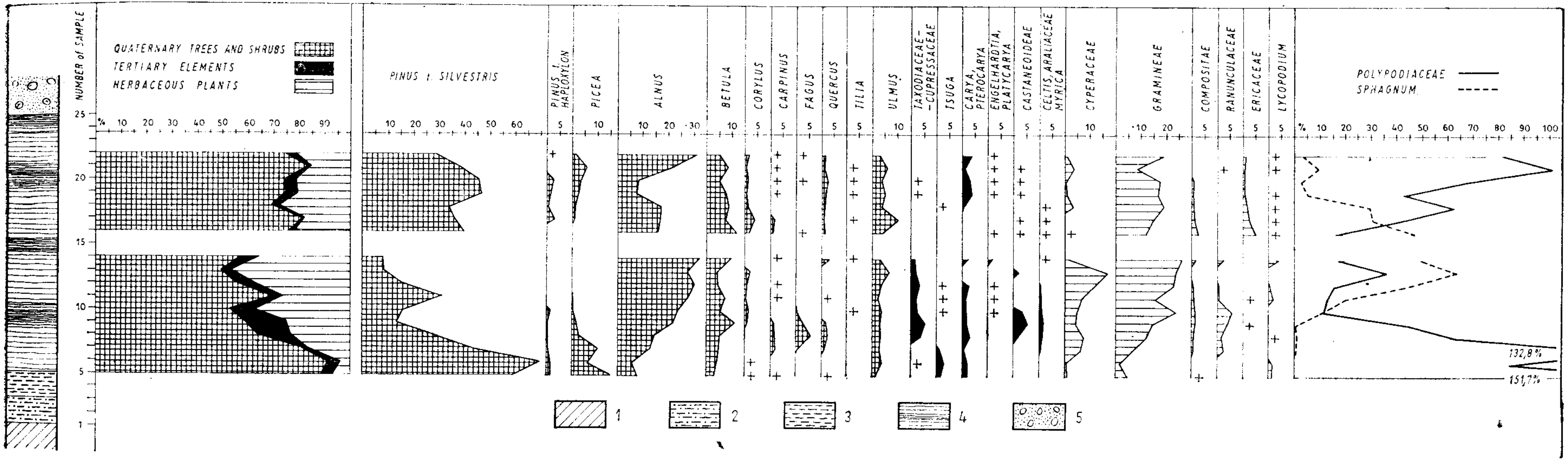
In the lower part of the Szaflary I profile, *Coniferae* decidedly predominate over angiosperms. Curves for the genera *Pinus* and *Picea* here reach their maxima, as is also the case with the genus *Tsuga.* Tree genera — *Alnus, Betula, Corylus, Pterocarya* and *Ulmus,* are represented by a small number of sporomorphs, and herbaceous plants are dominated by *Polypodiaceae* whose curve here reaches its culmination. *Cyperaceae* and *Gramineae* are rather frequent, while *Compositae* and *Lycopodium* are sporadic.

The pollen diagram (Text-fig. 10) clearly indicates that at the beginning of the sedimentary cycle of banded clay, coniferous forests consisting mainly of *Pinus, Picea* and *Tsuga* predominated. Ferns were a characteristic element of the undergrowth. Small *Alnus* groves with some admixture of *Ulmus* and *Pterocarya* may have occupied more wet habitats.

The middle section of the diagram shows decrease of pollen grains of the genera *Pinus* and *Picea* and an increase of *Alnus* and *Gramineae*. *Taxodiaceae* and *Fagus* show their culminations, as do the whole group of the Tertiary element. A marked increase of *Sphagnum* versus a marked decrease of *Polypodiaceae* spores is characteristic of the herbaceous plant group. The forests in the vicinity of the Szaflary reservoir changed significantly in character. Open pine and pine-spruce forests gave way to forests of wet habitats. *Alnus* groves dominated in the areas close to the banded clay reservoir, while wet low areas in river valleys were probably occupied by *Taxodiaceae-Cupressaceae* swamp forests. The presence of peat-bogs in the surroundings of the Szaflary reservoir is indicated by high percentages of *Sphagnum* spores and *Cyperaceae* pollen grains in the diagram. Open peat-bog communities with a high proportion of *Sphagnum, Cyperaceae, Gramineae* and *Ranunculaceae* may have developed besides taxodiaceous forests on marshy habitats.

Comparatively high percentages in pollen spectra of the trees *Betula, Corylus, Fagus, Tilia, Ulmus,* and of some Early Pleistocene elements, and *Pterocarya* in particular, indicate the presence of these trees *in situ*. They may have formed small mixed woods on more dry habitats which were characterized by the relatively importance of *Pterocarya* and other Tertiary genera. This group reaches its culmination in the middle section of the pollen diagram. The Tertiary sporomorphs totally disappear in the top part of the profile, *Pterocarya* excluded, whose curve shows a slight tendency to increase. In this part of the diagram, other foliaceous trees such as *Carpinus, Corylus, Fagus* and *Tilia* decrease in frequency. There is a decrease of *Sphagnum* spore frequency versus simultaneous increase of *Polypodiaceae* and of trees *Pinus, Picea* and *Alnus.*

At the close of the sedimentary cycle of banded clay at Szaflary, coniferous forests reappeared but were devoid of *Tsuga,* while being rich in ferns in the undergrowth. Wet habitats were occupied by *Alnus* groves with *Picea* and *Ulmus,* with the undergrowth rich in grasses. Communities rich in grasses developed possibly also on forest-free areas in the nearest vicinity of the banded clay reservoir. The character of open grassy vegetation clearly indicates a deterioration of the climate towards cool or even subarctic. The same conclusion may be deduced from the character of mosses (profile III), with alpine and subarctic elements predominating.




Text-fig. 10. Pollen diagram of the Szaflary I profile. 1 — Jurassic substratum (limestone), 2 — regolith, 3 — reworked regolith, 4 — banded clay, 5 — upper gravel with clayey matrix

Ryc. 10. Diagram pyłkowy profilu Szaflary I. 1 — podłoże jurajskie (wapień), 2 — regolit, 3 — przerobiony regolit, 4 — ił wstęgowy, 5 — górne żwiry w spoiwie gliniastym

AGE OF BANDED CLAY

The pollen diagram itself does not permit determination of the age of the banded clay with much precision. Geological data and comparison with other pollen diagrams are thus of great help. The banded clay at Szaflary underlies the Mindel fluvioglacial cover, thus being older than this Glaciation, and overlies another gravel (lower gravel) or reworked regolith, and regolithic clays resting upon the Jurassic klippe (see part I of this paper).

The pollen diagram has a distinctly Pleistocene character, and is characterized by predominance of Quaternary over Tertiary elements, the latter not exceeding 10% despite the presence of *Pterocarya* which is known to play an important role not only in the Tertiary but also in the Early Pleistocene deposits.

Contrary to the Tertiary element, herbaceous plants play an important role in the pollen spectrum of the Szaflary profile. They account for about 40%, exclusive of *Polypodiaceae* and *Sphagnum* which were not taken into account in frequency calculations.

By comparison of these two group of elements with the profiles described from southern Poland, we may exclude both Miocene and Pliocene as possible ages of the Szaflary banded clay. In the Miocene profiles at Huba (Oszast 1973), Nowy Sącz (Oszczypko, Stuchlik, 1972), Piaseczno (Oszast 1967) and Stare Gliwice (Oszast 1960), the proportion of the Tertiary element exceeds 50%, and in some of the profiles, e.g. Czarny Dunajec (Oszast 1973), reaches 90%. The proportion of herbaceous plants in these profiles is insignificant never exceeding 10% of the total sum of sporomorphs, in which it differs distinctly from the Szaflary profile. This comparison allows the exclusion the Miocene as the possible age of banded clay at Szaflary.

The Szaflary sediment also appears younger in comparison with the "Lower" Pliocene profile at Krościenko (Oszast 1973). At Krościenko, a total of 37 Tertiary plant taxa have been distinguished, versus 20 at Szaflary. Of these only *Carya, Pterocarya, Taxodiaceae-Cupressaceae* and *Tsuga* were represented in relatively higher numbers at Szaflary, the remaining 16 taxa only existing as traces. The total proportion of this group at Krościenko amounts to 50%, with herbaceous plant forming 15—25%, while at Szaflary the values of Tertiary elements are 10% and 40% respectively.

The Pliocene pollen diagram from Domański Wierch, which is younger than Krościenko (Oszast 1973), has more in common with the Szaflary profile. For both profiles the proportion of herbaceous plants is similar (40%), as is also the variation of Tertiary genera (about 20 taxa), however, their percentages are high (about 35%) at Domański Wierch. Despite some similarities, it seemes that the banded clay profile at Szaflary is stratigraphically younger than both the Kroscienko and Domański Wierch profiles. Our profile shows far more similarity to the Early Pleistocene part of the Mizerna profile, and especially to its upper section determined as "Tegelen" (S z a f e r 1954; S z a f e r, O s z a s t, 1964). In this part of the Mizerna profile, *Pinus* t. *silvestris* and *Picea* played the most important role, while *Abies* was second in importance. At Szaflary *Pinus* also dominates and the role of *Picea* is similar to that at Mizerna; the lack of *Abies* may have been the result of environmental conditions. At Mizerna, on flysch rocks, *Abies* formed an admixture in spruce forests, while at Szaflary, on limestone klippes, *Abies* was absent. *Alnus* played an important role at Szaflary, but a negligible role at Mizerna where it could have occurred only along river beds. Other thermophilous foliaceous plants are represented in similar amounts in both profiles, only the oak played a more important role at Mizerna than at Szaflary. The Tertiary plants *Pterocarya, Taxodiaceae-Cupressaceae* and *Tsuga,* played similar roles in both Mizerna and Szaflary profiles discussed, other genera were decidedly subordinate.

*Nyssa* played some role in the lower part of the "Tegelen" section at Mizerna (Mizerna III) but was either lacking or present only as traces at Szaflary. *Nyssa* could have occurred in a swampy valley of the Dunajec River near Mizerna, some 500 m south of the "Tegelen" sites, while in the banded clay reservoir at Szaflary, situated farther from the main stream of the Biały Dunajec River, conditions for growth were not favourable. *Ostrya, Rhus* and *Sciadopitys* which occur as traces in the Mizerna profile, are totally lacking at Szaflary. Little is known of the time unit between the Upper Pliocene and the Cracovian (Mindel) Glaciation from the palaeobotanical view point, hence it is difficult to give more detailed characteristics. Similary, it is difficult to correlate the banded clay flora from Szaflary with the time-units whose palaeobotanically characteristics were distinguished by S z a f e r (S z a f e r 1954; S z a f e r, O s z a s t 1964) at Mizerna. It seems, however, that the banded clay cycle at Szaflary preceding the Mindel Glaciation, corresponds to a moderate-warm or moderate climatic phase.

The Szaflary profile cannot directly be compared with the "Preglacial" of Ochota (S t a c h u r s k a 1961) which, based on an as yet unpublished pollen diagram, was correlated by R ó ż y c k i (1972) with the Middle Pliocene. The Ochota profile contains over 50% of Tertiary element and only a negligible amount of herbaceous plants, thus resembling rather some Miocene pollen diagrams (Ś r o d o ń 1962). It seems that the pollen analysis was made at Ochota from a Miocene floe glacitectonically intruded between "Preglacial" clays and sands. However, there are some similarities between pollen diagram of the profile Szaflary I and some diagrams of the Early Pleistocene profiles of the Otwock region, south-east of Warsaw (S t u c h l i k 1975).

From the Carpathians of Slovakia P l a n d e r o v á (1971) presented some palynologically elaborated profiles dating from the Middle Pliocene to the Cracovian (Mindel) Glaciation. Unfortunately, she did not publish full pollen diagrams what makes the comparison of her results with the pollen diagram from Szaflary difficult. On the basis of general similarities between P l a n d e r o v á' s profiles and ours, the Szaflary banded clay flora may be compared with the "Tegelen" s.l. of Slovakia. However, in P l a n d e r o v á' s profiles, contrary to those at Szaflary, the Tertiary element represented by *Pterocarya* and *Taxodiaceae-Cupressaceae* is absent, at Szaflary *Pherocarya* plays an important role and *Taxodiaceae-Cupressaceae* are sporadic. The profiles from Slovakia, contain, however, some Tertiary elements such as *Rhus* and *Sciadopitys*, which are absent in the Szaflary profile.

Numerous Pliocene pollen diagrams from the Transcarpathian Ukraine and South-west Ukraine (S y a b r y a i 1967, 1970; R y b a k o v a 1971; S h c h e k i n a 1971 a, b) differ rather markedly from our pollen diagram in their floristic composition. These profiles are richer in Tertiary element, steppe element including (S h c h e k i n a 1971 b), the latter being absent at Szaflary. It is therefore, difficult to present a closer correlation between such distant profiles, the Ukrainian ones being situated south of the Carpathian arc.

There seem to be some similarities between our pollen diagram and some other Early Pleistocene profiles of West Europe, especially from the Netherlands and the German Democratic Republic. The Rippersroda profile from Thuringia, palaeobotanically investigated by M a i and M a j e w s k i (M a i et al. 1963), represents the youngest part of the Pliocene section and the beginning of the Pleistocene. In the bottom part of this profile, corresponding to Reuverian, the proportion of exotic genera is higher than at Szaflary, and the floristic spectrum more diversified. The top part of the Rippersroda profile, corresponding to the "Tegelen" Interglacial is more similar to the pollen diagram from Szaflary. In this part of the profile, the proportion of the Tertiary element decreases with a simultaneous increase in the proportion of herbaceous plants.

The Upper Pliocene and lowest Pleistocene sediments have been best elaborated floristically in the Netherlands, and Z a g w i j n (1960, 1963) was able to demonstrate the presence of several stratigraphic horizons. However, the Szaflary profile cannot be very closely correlated with any of Z a g w i j n's profiles. Our profile shows most features in common with Z a g w i j n' s profiles of the "Tegelen" Interglacial *sensu lato*, however, in his diagrams, *Ericaceae* and *Pterocarya* play a more important role than at Szaflary, and this is obviously correlated with the more Atlantic-

-type climate of the Netherlands. The Szaflary profile also shows some similarities to pollen diagrams from another warm stage (interglacial) of West Europe preceding the Günz Glaciation, known as the Waalian. However, this stage has not so far been palynologically characterized in Middle and East Europe.

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## STRESZCZENIE

## WCZESNOPLEJSTOCEŃSKIE OSADY Z FLORĄ PYŁKOWĄ W SZAFLARACH, KARPATY ZACHODNIE, POLSKA

### I. CZĘŚĆ GEOLOGICZNA

(K. Birkenmajer)

W obrębie pokrywy plejstoceńskiej, odsłoniętej na skałce jurajsko-kredowej w Szaflarach na Podhalu, wyróżniono cztery poziomy stratygraficzne. Bezpośrednio na skałce wapiennej występuje regolit (0·1—3 m), wypełniający kieszenie i zagłębienia krasowe w skałce. Wyżej pojawia się przerobiony regolit (0·05—0·5 m) i żwiry dolne (do 1·4 m), następnie ił wstęgowy (0·3—1 m) i żwiry górne (1—8 m).

Przedstawiono dowody na fluwioglacjalne pochodzenie pokrywy żwirów górnych, przez niektórych autorów uważanej za morenę najstarszego (maksymalnego) zlodowacenia tatrzańskiego. Z uwagi na to, że wiek tej pokrywy odpowiada zlodowaceniu krakowskiemu (Mindel), niżej leżące osady uznano za staroplejstoceńskie.

Ił wstęgowy reprezentuje osad spokojnego zbiornika wodnego, a jego profil palinologiczny wskazuje na fazę klimatyczną ciepłą, typu interglacjalnego. W interpretacji geologicznej profilu osad ten można uznać za odpowiadający interglacjałowi Günz-Mindel.

Żwiry dolne, składające się z materiału pochodzącego z Tatr i fliszu podhalańskiego, przechodzące obocznie w przerobiony regolit, reprezentują osad pochodzenia fluwialnego lub fluwioglacjalnego, odpowiadający prawdopodobnie chłodniejszej, bogatszej w opady fazie klimatycznej, którą można korelować ze zlodowaceniem Günz.

Regolit i współczesne mu zjawiska krasowe odpowiadają wcześniejszej fazie klimatu ciepłego, którą można korelować z interglacjałem Dunaj-Günz.

Cały profil plejstoceński z Szaflar uznany został za młodszy od plioceńsko-staroplejstoceńskiego profilu Mizernej koło Czorsztyna. Osady staroplejstoceńskie w Szaflarach zostały zaburzone ruchami tektonicznymi przed utworzeniem się pokrywy fluwioglacjalnej zlodowacenia środkowopolskiego (Riss), najprawdopodobniej w czasie interglacjału wielkiego (Mindel-Riss).

## II. CZĘŚĆ PALEOBOTANICZNA

(L. Stuchlik)

Zbadano palinologicznie 25 prób osadu iłu wstęgowego z profilu Szaflary I i 10 prób z profilu Szaflary II. Na podstawie diagramu pyłkowego scharakteryzowana została roślinność w okresie tworzenia się tego iłu. Na miejscach suchszych rozwijały się borealne lasy sosnowo-świerkowe z dużym udziałem drzew liściastych, a siedliska wilgotniejsze zajmowały małe laski olchowe z niewielką domieszką elementów cypryśnikowych lasów bagiennych. W środkowej części profilu wzrósł znacznie udział drzew liściastych, a także *Taxodiaceae* kosztem sosny i świerka. Nastąpiło znaczne zabagnienie najbliższej okolicy zbiornika sedymentacyjnego, na co wskazuje również znaczny wzrost udziału zarodników *Sphagnum* w spektrach pyłkowych. Na wyżej położonych suchych zboczach rozwijały się mieszane lasy liściaste ze stosunkowo dużym udziałem *Pterocarya*. W stropowym odcinku profilu ponownie nastąpiła ekspansja borealnych lasów sosnowo-świerkowych.

Określenie wieku iłu wstęgowego jest możliwe jedynie na podstawie przesłanek geologicznych i przez porównanie z innymi florami pyłkowymi. Badane osady zalegają w zagłębieniach jurajskich skał wapiennych i przykryte są materiałem fluwioglacjalnym zlodowacenia krakowskiego. Niewielki udział w spektrach pyłkowych elementów trzeciorzędowych (do 10%), a stosunkowo wysoki udział roślin zielnych (do 40%) pozwala na wykluczenie wieku mioceńskiego i plioceńskiego tych osadów. Diagram pyłkowy z Szaflar ma charakter plejstoceński i porównać go można w przybliżeniu do stropowej części profilu z Mizernej, określonej przez Szafera i Oszast (1964) jako Tegelen *s.l.* W podobnych ilościach występuje w Mizernej i Szaflarach sosna i świerk, a brakuje jodły w Szaflarach, gdzie w większych ilościach niż w Mizernej występowała olcha. Udział roślin trzeciorzędowych jest w obu profilach podobny, jedynie *Nyssa,* której w Szaflarach brak, odgrywała w Mizernej większą rolę.

# PLATES

# TABLICE

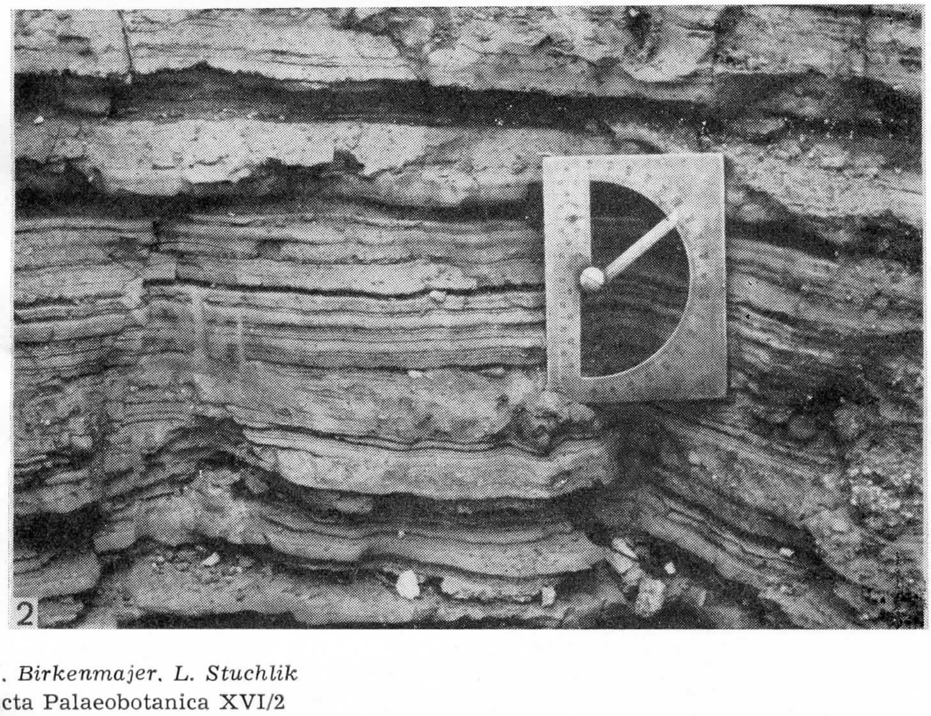
Plate I

1. Banded clay, Szaflary I profile (phot. L. Stuchlik, 1968)
2. Banded clay, Szaflary III profile. Scale = 10 cm (phot. K. Birkenmajer, 1959)

Tablica I

1. Ił wstęgowy, profil Szaflary I (fot. L. Stuchlik, 1968)
2. Ił wstęgowy, profil Szaflary III. Skala = 10 cm (fot. K. Birkenmajer, 1959)

1



2

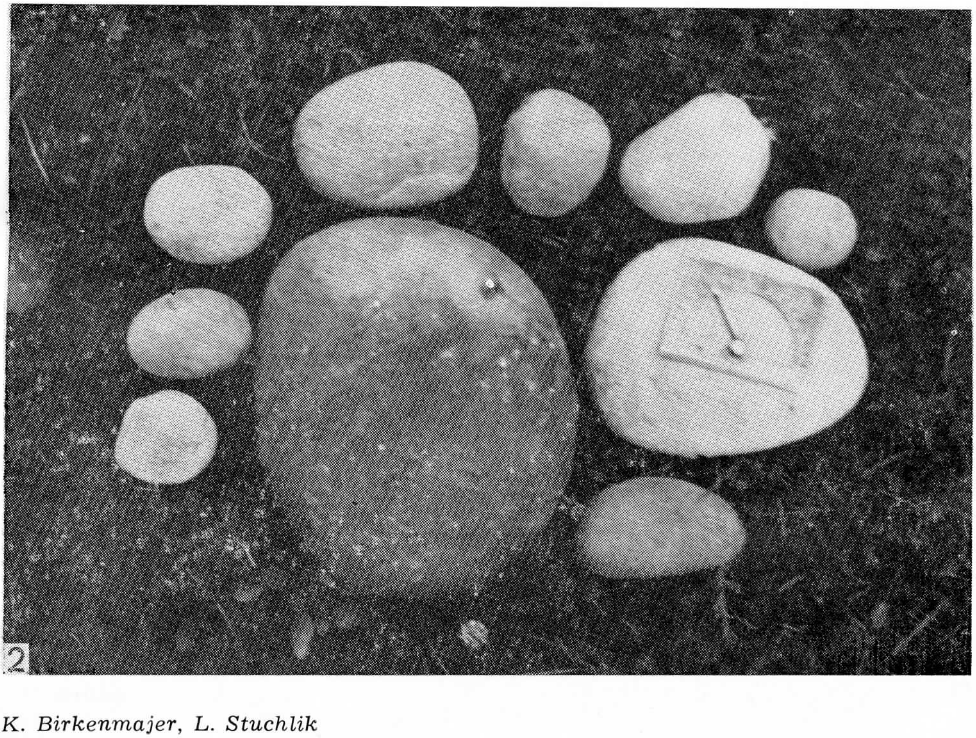
Plate II

1. Szaflary quarry, broken rounded quarzite boulders from the upper gravel, Mindel fluvioglacial cover (phot. K. Birkenmajer, 1961)
2. Szaflary quarry, rounded quartzite pebbles from the upper gravel, Mindel fluvioglacial cover. Scale = 10 cm (phot. K. Birkenmajer, 1959)

Tablica II

1. Kamieniołom w Szaflarach, popękane i obtoczone głazy kwarcytowe z górnych żwirów. Pokrywa fluwioglacjalna zlodowacenia krakowskiego (fot. K. Birkenmajer, 1961)
2. Kamieniołom w Szaflarach, obtoczone fragmenty kwarcytowe z górnych żwirów. Pokrywa fluwioglacjalna zlodowacenia krakowskiego. Skala = 10 cm (fot. K. Birkenmajer, 1959)

1



2