ROCZNIK POLSKIEGO TOWARZYSTWA GEOLOGICZNEGO
ANNALES DE LA SOCIÉTÉ GÉOLOGIQUE DE POLOGNE
Tom (Volume) XXXI — 1961 Zeszyt (Fascicule) 2—4 Kraków 1961

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MATERIAŁY DO ZNAJOMOŚCI LESSÓW

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(Tabl. XVIII — XX i 3 fig.)

Remarks on the loess

in collaboration with W. Parachoniak, W. Kowalski, A. Manecki and B. Oszacka

(Pl. XVIII — XX and 3 fig.)

STRESZCZENIE

Treść. Autor podjął szeroko zakrojone studia metodyczne nad lessem. W pierwszej fazie badań wyzyskano zjawisko opadu pyłu w 1928 r., pędzonego wschodnimi wiatrami ze stepów azowskich na obszar Podola. Ustalono wtedy zarówno rodzaj materii opadowej, jako też i jej granulometryczne zróżnicowanie, zależnie od odległości od miejsca wywiewu. Na odpowiedniej mapie wykreślono charakterystyczne izarytmy wielkości ziarn pyłu, zwane „izogranami".

Autor stwierdził na obszarze Podola występowanie 3 lessów. Pomiary ich uziarnienia umożliwiły wykreślenie na mapie izogran stwiedzających zmniejszanie się średniego ziarna w spągowej części odkrywek w kierunku od N-W do S-E. Izograny wyższego poziomu lessowego stwierdziły takie samo zmniejszenie się od W do E. Takie zróżnicowanie izogranów mogło być wywołane jedynie zmianą kierunków wiatru. Liczne precyzyjne analizy chemiczne, mikroskopowe oraz ciężkich minerałów ustaliły ściśle jakość materiału lessowego.

W ten sposób zanalizowano też lessy okolicy Krakowa. Ten materiał okazał się identyczny z lessem podolskim. Ze wszystkich badań wynikł ten główny wniosek, że less pierwotny odznacza się niezmiernie charakterystycznym uziarnieniem, dającym się ustalić w pomiarach mikroskopowych. Ilościową ilustracją tego uziarnienia stała się krzywa „sumacyjna", której charakter ujęto matematycznie w odpowiednie równania. Lessy wtórne okazują pod tym względem odmienne stosunki.

W pracy niniejszej przedstawiono całokształt dotychczasowych wyników badań podejmowanych przez prof. J. Tokarskiego i jego współpracowników na temat zagadnienia lessu. Punktem wyjścia do tych prac była przyjęta zasada, że każdy „okruch skalny" jest przede wszystkim dokumentem historycznym, który w swoim składzie mineralnym i strukturze ma „zapisaną" historię swojej genezy i zmian ewolucyjnych. Odcyfrowanie tej historii jest zatem tylko kwestią użycia odpowiedniej metody w badaniach litologicznych.

Less jako element anemoklastyczny z tytułu swojej genezy i natury musi być uznany za walny dokument historii plejstocenu. Stąd wnikliwe rozpoznanie jego składu mineralnego, chemicznego i mechanicznego przy zastosowaniu badań regionalnych mogło przyczynić się do wyjaśnienia wielu zagadek wymienionego okresu geologicznego.

Odnośne prace autora zostały wykonane w dwóch okresach. W pierwszym poddano szczegółowemu studium lessy podolskie i karpackie w granicach dawnej Rzeczypospolitej. Był to zatem okres prac lwowskich. Drugi, późniejszy, objął badaniami lessy okręgu krakowskiego i dlatego nazywamy go okresem krakowskim. Wyniki tych prac wykonanych w obydwu okresach są następujące:

1. Impulsem do podjęcia badań lessowych na szerszą skalę był opad pyłu atmosferycznego w 1928 r., który pędzony wschodnimi wiatrami pokrył obszar Podola względnie dużą warstwą brunatnej gleby przyniesionej ze stepów azowskich. Szczegółowe badanie tego pyłu, dla którego zostało ustalone regionalnie miejsce wywiewu oraz miejsce opadu, przy znajomości kierunków ówczesnych wiatrów doprowadziły do ustalenia ścisłych metod rozpoznawczych w zastosowaniu do sedymentu anemoklastycznego. Najważniejszą zdobyczą metodyczną był wówczas fakt, że mikroskopowe pomiary ziarn pyłu oraz zdolność adsorpcji błękitu metylenowego przez składniki ilaste badanego materiału pozwoliły związać funkcyjnie materiał opadowy z odległością od centrum wywiewu. Stwierdzono przede wszystkim, że średnica ziarna pyłu zmniejszała się w kierunku od E-W (średnio o 1 mikr./50 km), a ilość ilastej substancji adsorbująca określone ilości wymienionego barwnika rosła w tym samym kierunku. Na odpowiednim rysunku (fig. 2) ustalono ten fakt izarytmicznie, za pomocą linii zwanych i z o g r a n a m i i i z o a d s o r b e n t a m i.

2. We wstępnej fazie badań podolskiego lessu poddano szczegółowemu opracowaniu 10-metrowy profil lessowy w okolicach Grzybowic pod Lwowem. Mikroskopowe pomiary średnicy kwarcu lessowego, dokonane na próbkach zbieranych tutaj w pionie profilu w odstępach co 1 m., wykazały znamienną cechę sedymentu. Oto w kierunku od spągu ku stropowi ziarno nie było równe, lecz okazywało wahania uwidoczniające się w stopniowym wzroście jego przeciętnych średnic aż do osiągnięcia w pewnym miejscu kulminacji, by po jej przejściu spadać do pewnej granicy. Od granicy tej zjawisko powtórzyło się, tzn. ziarno zaczęło ponownie wzrastać aż do osiągnięcia drugiej kulminacji, by po jej przekroczeniu znów opadać.

Ten charakterystyczny układ składu mechanicznego profilu lessowego w Grzybowicach powtarzał się konsekwentnie w dalszych badaniach regionalnych, podjętych w ośmiu innych punktach lwowskiego Podola. Gdy zestawiono na rysunku wszystkie pierwsze kulminacje badanych profilów i związano je w izarytmy, okazało się, że średnie wielkości ziarna pyłu lessowego spadają konsekwentnie od północnego zachodu ku południowemu wschodowi. Przyczyną tego zjawiska mógł być tylko wiatr słabnący w wymienionym kierunku. Zestawione w ten sam sposób drugie kulminacje oznaczały kierunek wiatru od zachodu ku wschodowi, zatem logika wskazywała, że wyróżnione dwie kulminacje mogą odpowiadać dwu zlodowaceniom o odmiennych kierunkach wiatru.

3. Analiza chemiczna ryczałtowa i racjonalna (wyciąg w HCl) profilu grzybowickiego scharakteryzowała dokładnie materiał lessowy tego profilu. Tego rodzaju analizy lessów innych miejscowości potwierdziły pod

tym względem jednolitość wszystkich próbek lessowych na Podolu. To samo dotyczy analizy tzw. ciężkich minerałów, które w zakresie jakościowym i ilościowym potwierdziły pogląd, że anemoklastyczny less we wszystkich punktach Podola musi być genetycznie związany z dobrze wymieszanym przez wiatr pyłem lessowym porwanym w atmosferę na jego zapleczu.

4. Rozwiązano zagadnienie natury i genezy lessu karpackiego na tle badań próbek podjętych z 2 odkrywek z tzw. depresji worochciańskiej. Analizy chemiczne, mechaniczne i ciężkich minerałów potwierdziły genetyczny związek tej gliny z lessem podolskim, związanie zaś składu mechanicznego z drugą serią izogranów podolskich uzasadniało wniosek, że materiały z Worochty odpowiadają drugiemu polskiemu zlodowaceniu.

5. W obszarze Krakowa zbadano ustalonymi już metodami próbki lessu z Mogiły oraz Zwierzyńca. Less z ostatniej miejscowości był przedmiotem szczegółowych badań paleolitycznych, przeprowadzonych ostatnio przez L. Sawickiego. Pracy tego autora brak jednak dokumentacji litologicznej, która by mogła walnie przyczynić się do rozwiązania zagadnień stratygraficznych w profilach zwierzynieckich. Badania autora dotyczyły stropu odkrywek lessowych określonych przez Sawickiego jako less młodszy. Wykazały one, że zarówno lessy z Mogiły, jak i Zwierzyńca odpowiadają swoim składem mechanicznym jak i chemicznym analizom lessu podolskiego, prawdopodobnie ich górnym poziomom (drugie zlodowacenie).

6. Ustalone metody badań petrologicznych profilów lessowych oddadzą właściwe usługi wówczas, jeżeli zastosuje się je w pracach nad lessem pierwotnym. Jest zatem rzeczą konieczną, by przed rozpoczęciem tego rodzaju badań ustalić, czy ma się do czynienia z lessem pierwotnym, czy wtórnym. Niepodjęcie tej ważnej pracy na początku badań może doprowadzić do ponownego chaosu. Less — jak wiadomo — jest skałą bardzo „wiotką", łatwo ulegającą erozji, przemieszczaniu, spływom itp. Obraz np. składu mechanicznego tzw. lessu wtórnego jest zupełnie odmienny od lessu pierwotnego. W badaniach regionalnych można jednakże zestawiać porównawczo skład mineralny i strukturę tylko osadów lessu pierwotnego.

Autor daje wkazówki, gdzie należy szukać takich osadów. Są to miejsca, gdzie less występuje na kulminacjach morfologicznych w danym obszarze, bo tylko tak mogły zachować się nie zmienione „ostańce", jako spągowe części pierwotnych pełnych profilów lessowych.

7. Anemoklastyczny less z tytułu swego bardzo drobnego ziarna mógł osadzać się w danym terenie w okresach „ciszy" atmosferycznej, a zasięgi jego rozprzestrzeniania się zarówno w poziomie, jak i w pionie są w zasadzie nieograniczone. Stąd wyznaczanie dzisiejszej granicy jego rozmieszczenia, np. w pionie terenów górzystych, nie może być w żaden sposób dokonane ze względu na łatwość, z jaką w każdym okresie jego pokrywa ulegała zniszczeniu.

8. Jako postulat dalszych badań nad polskim lessem autor wysuwa potrzebę kontynuowania prac przy użyciu wyżej ustalonych metod w szerokim zakresie regionalnym. Dotyczy to przede wszystkim obszarów południowej Polski na przedpolu Karpat. Zbadanie tutaj wystarczająco dużej ilości profilów wymienionej skały, zakonserwowanych w pierwotnym stanie, pozwoliłoby bardziej precyzyjnie ustalić co następuje:

a) ilość pokryw lessowych,

b) stan ich zachowania,

c) uchwycić wtórne zmiany w jego profilach jako dokument klimatycznych interglacjałów,

d) związać z wymienioną skałą postępy kultury ludzkiej.

W wymienionym zakresie byłaby bardzo wskazana współpraca z badaczami ościennych krajów, dysponującymi — zwłaszcza na wschodzie — wielkimi obszarami pokrywy lessowej.

Nazwę lessu należałoby ograniczyć ściśle do materiału anemoklastycznego, zalegającego w pierwotnych, nie skażonych wtórnie profilach. Jest niesłuszną sprawą wyróżnienie np. 2 rodzajów lessów, tj. eolicznego i wodnego (less jeziorny!). Każdy właściwy less jest bowiem pochodzenia anemoklastycznego. Pył lessowy, opadający na powierzchnię ziemi, jeśli dostanie się do środowisk wodnych, jest tego samego pochodzenia. Środowisko wodne zmienia tylko jego strukturę, a nie genezę. Mechanika opadania pyłu lessowego w profilu wodnym jest zasadniczo odmienna od środowiska eolicznego. W wodzie następuje bowiem frakcjonowanie masy lessowej na części o grubszym ziarnie, które opada szybciej na dno zbiornika, i na część ilastą, dłużej unoszącą się w zbiorniku. Less opadający w wodzie zawsze musi być „zwarwowany", na co można znaleźć dokumentację przez konsekwentne zbadanie składu mechanicznego jego profilu.

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A b s t r a c t. Anemoclastic loess is an important historical document not only of Polish diluvium. The dust of this rock, blown by the wind from above the glaciers, was deposited in periglacial zones in secluded places where the strength of the wind dropped to its minimum. Its origin is connected with the barometric gradient caused by the formation of the glacier plateau. It follows logically that the presence of each glacier is connected with the formation on its foreland of loess deposit. In other words the amount of loess depositions corresponds to the amount of glaciation on a given area.

The author began a broad methodical investigation on Polish loess. In the first phase of research the 1928 phenomenon of dust falling which had been carried by east winds from the Azov steppes towards the eastern territories of Poland was used. At that time both the kind of falling matter and its granulometric differentiation were determined according to the distance from its starting place. Characteristic isarythms of the size of the dust grain, called „isograns", were drawn on a special map.

In the regional research of the Podole loess, using the methods already established, a result determining the presence of three kinds of loess in the area was obtained. The measurement of their grain-size variation made it possible to draw on the map isograns determining the diminishing of the average grain in the lower part of the outcrop in the direction from NW towards SE. Isograns of the upper level of loess showed a similar decrease from W to E. These differentiations of isograns could be caused only by the change of the wind direction. Numerous detailed analyses — chemical, microscopic and of heavy minerals — determined exactly the quality of loess material.

In the western part of Poland the Cracow loesses were analysed in the same way. This material appeared to be identical with the loess of Podole. From all the investigations resulted the main conclusion that p r i m a r y loess is characterized by extremely typical grain-size variation which can be determined by microscopic measurements. The quantity of the grain-size variation is illustrated by the „summation" curve shown mathematically by means of appropriate equations. Secondary loesses show in this respect different relations.

INTRODUCTION

Anemoclastic loess is — as is known — an important historical document not only of Polish diluvium. Long lasting disputes concerning its origin, at first based only on its megascopic description or on academic discussions, once caused confusion in the opinions as to its origin (Scheidig (1934), Quiring (1934), Vendel and others). At last, with the increase in the amount of field observation the thesis on the eolian origin of this rock was slowly established. The first to point to it on the basis of long studies in Central Asia was the German scientist Richthofen. The hypothesis was reinforced by the Russian scientist Obrutchev and some others so that at present any controversy about the eolian origin of loess is invalid. Nowadays it is generally accepted that loess material is rock dust blown out from desert centres on their foreland which may sometimes lie at a considerable distance.

The problem of the mechanics of loess sedimentation as an eolian deposit could be solved ultimately only on the basis of analysis of the most precise and various kind performed on the loess matter itself. There is no doubt that each fragment of any rock contains in its mineral and chemical composition and structure the history of its origin. The reading of this history is only a matter of using the correct methods of investigation. The methods in the field of petrography of all rock types have been sufficiently set for a number of years so that they might be applied to all types of materials classified on various tables.

In Poland loess appears — in accordance with its origin — chiefly in the southern areas. No doubt its original cover was fairly uniform. During the interglacial periods erosion and denudation factors managed to destroy it in many places owing to the known „flimsy" structure of loess rock which could not resist denudation.

In Poland this cover really forms only large and small „remnants" which do not always consist from primary loess or have not remained unchanged in its full profiles. If we add that loess sedimentation was several times re-laid in the course of diluvium history, and erosion of their profiles independently of this reached various depths, in the historical analysis of this rock there occurred a new difficulty in distinction, as for example older loess from younger. Therefore in order to solve the problem very precise quantitative and qualitative methods had to be used to determine that in any case we are without doubt dealing with material of primary loess or with a loess of first, second and third sedimentation. Without this approach to the problem it would be difficult to solve the historical geological role of the rock during diluvium.

A good field for research of loess cover was the area of Podole bounded in the north by the so called „Podolian border" and in the south by the river Dniestr. The glaciers never moved into this high area, dominating with rising land over the northern depression of the river Bug. This country was then a foreland of glaciation untouched by glacial erosion, and its loess profiles did not suffer such radical destruction as in the north and west, where the continental glaciers moving southwards repeatedly partially or even completely destroyed the deposits over which they moved.

In the whole of Podole loess covered the surface of older prediluvial beds and its thickness often reaches here 30 m (e. g. in Halicz). An important impulse in explaining the origin of the rock in Podole was following accident.

On 29th April 1928 the inhabitants of Lwów witnessed a mysterious and powerful phenomenon of nature. Throughout the day a brownish dust fell on their heads and even caused panic here and there because of the extraordinary solar eclipse. At the beginning two of the professors of the University (Romer and Arctowski) tried to explain the phenomenon in the newspapers by the eruption of a volcano not very far from the town. This of course increased the anxiety. Their opinion was not supported by the investigation of the material in question. An immediate analysis made by K. Smulikowski, assistant at the Chair of Mineralogy at the Lwów Technical College showed in a few hours that the dust matter falling from the air on the area of Podole was brown soil which had been blown by eastern winds and which reached our territories as the result of a powerful hurricane on the Azov steppes. Three important facts were then determined: first, that the matter was of anemoclastic origin, second, that the place it came from was recognized, and third, that the dust settled on Podole at a distance which could be precisely estimated in kilometres from the place where it was picked up by the winds. These very facts appearing as *experimentum crucis* caused the author to explain the mechanics of dust falling and at the same time gave the natural bases for study on loess. A special expedition was organized which collected samples of the dust from 72 places, exactly determining these places topographically; the samples underwent two analyses — mechanical and physicochemical. The former by microscopic measurements determined the average size of dust grains (chiefly of quartz), the latter the quantities of colloidal components (clay) by adsorption of methylene blue. Finally two types of isarythms were drawn. One, called isograns showed distinctly the decrease of dust grains westwards (1 micron per 50 km). It was the expression of logical consequence which proved the decrease in the average grain with the increase in the distance from its starting place. The isarythms of adsorption of methylene blue called isoadsorbents behaved contrary to isograns i. e. the quantity of colloidal components in the blown soil, also in accordance with the logical postulate, increased westwards. The final result of the investigation on dust in Podole in 1928 was that a fairly precise method of investigation of anemoclastic matter was determined which in consequence indicated even the direction of winds (J. Tokarski 1936). No wonder then that the carrying out of the analytical experiment with dust was immediately followed by a regional and quantitative elaboration of the physiography of Podole loess.

PODOLE LOESS

In order to solve rationally the problem of loess it was necessary to collect samples from loess profiles consistently in a uniform way from various places in Podole. It is obvious that the samples had to correspond to primary loess. Because of the fact mentioned above that such loess undoubtedly underwent to a certain degree mechanical and chemical degradation, it was necessary when collecting samples to find places where the degradation was very slight. It was logically deduced that places where loess was to be found in its primary form would appear in morphological culminations of the area. There, though the chances of degradation of loess matter were the greatest, the rock could form „remnants" of the primary deposit. Preliminary field investigation confirmed this opinion. The profiles performed in the culminations, even quite deep ones, sometimes disclosed the primary form of the rock with all its typical characteristics, i. e.: uniform grain, lack of stratification or any addition of sand etc. Only eight such profiles were investigated in detail because of the lack of means.

In order to establish the methods of investigation an 11 metre primary profile of loess in Grzybowice near Lwów was chosen in the preliminary research. The results of the methodical work were as follows:

1. Loess samples collected at 1 metre intervals along profiles were analysed microscopically, mechanically, and chemically.

2. Qualitative microscopic analysis determined their mineral composition in general. Quantitative microscopic analysis showed the mechanical composition of the samples (characterized by the measurements of the greatest diameters of grains which appeared in the field of vision of the microscope) by means of an appropriate summation curve for which the following general equation was determined in the form (Fig. 1):

$$y = A - a \cdot x + B\,(x - 3)^n$$

where $A = 100{,}3$, $a = 14.8$, $B = 3.864$, $n = 1.38$.

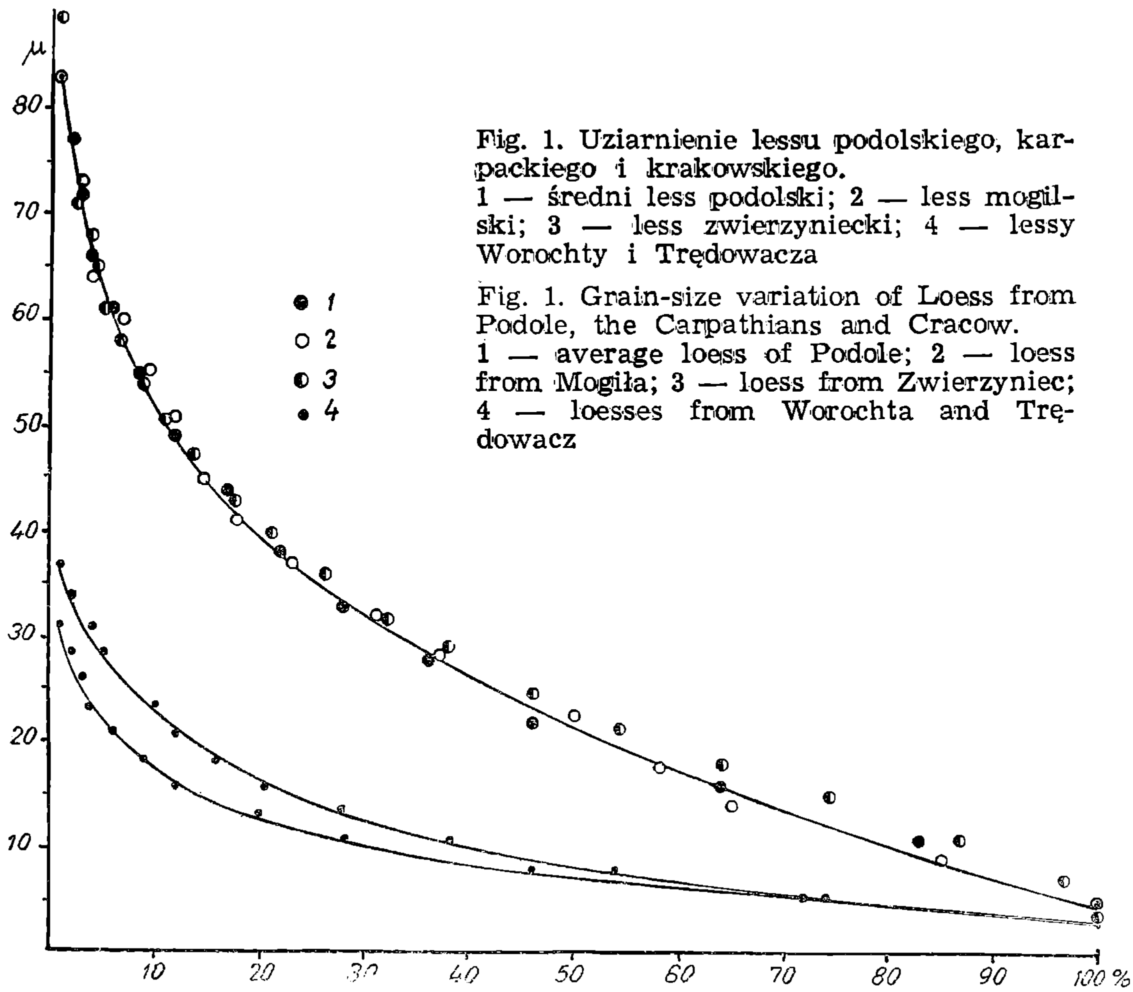

Fig. 1. Uziarnienie lessu podolskiego, karpackiego i krakowskiego.
1 — średni less podolski; 2 — less mogilski; 3 — less zwierzyniecki; 4 — lessy Worochty i Trędowacza

Fig. 1. Grain-size variation of Loess from Podole, the Carpathians and Cracow.
1 — average loess of Podole; 2 — loess from Mogiła; 3 — loess from Zwierzyniec; 4 — loesses from Worochta and Trędowacz

3. Chemical brutto and fractional analyses of ten samples characterized exactly the investigated zones of the rock.

4. The loess of Grzybowice cannot be genetically connected with tertiary sand from the vicinity of Lwów as was shown by comparative analyses.

5. Heavy minerals contained in the loess of Grzybowice analysed in ten zones showed the presence of a great quantity of three most important components: iron and titanium oxides, garnet, and zircon. The quantity relation of these components in the profile was variable. Analytic details of these investigations may be found in the author's paper (J. Tokarski 1935).

After having established the efficiency of the investigation methods on the basis of loess from Grzybowice, the regional investigation of the rock of Podole near Lwów began. The mechanical composition was investigated in eight places at one metre intervals by means of the microscopic method. It soon became evident that on certain zones of investigated profiles which were not of equal thickness characteristic culminations appeared of the size of an average grain; lover culminations showed larger grains in general (with the exception of the profile in Halicz). As the lower zones of the investigated profiles were the oldest and

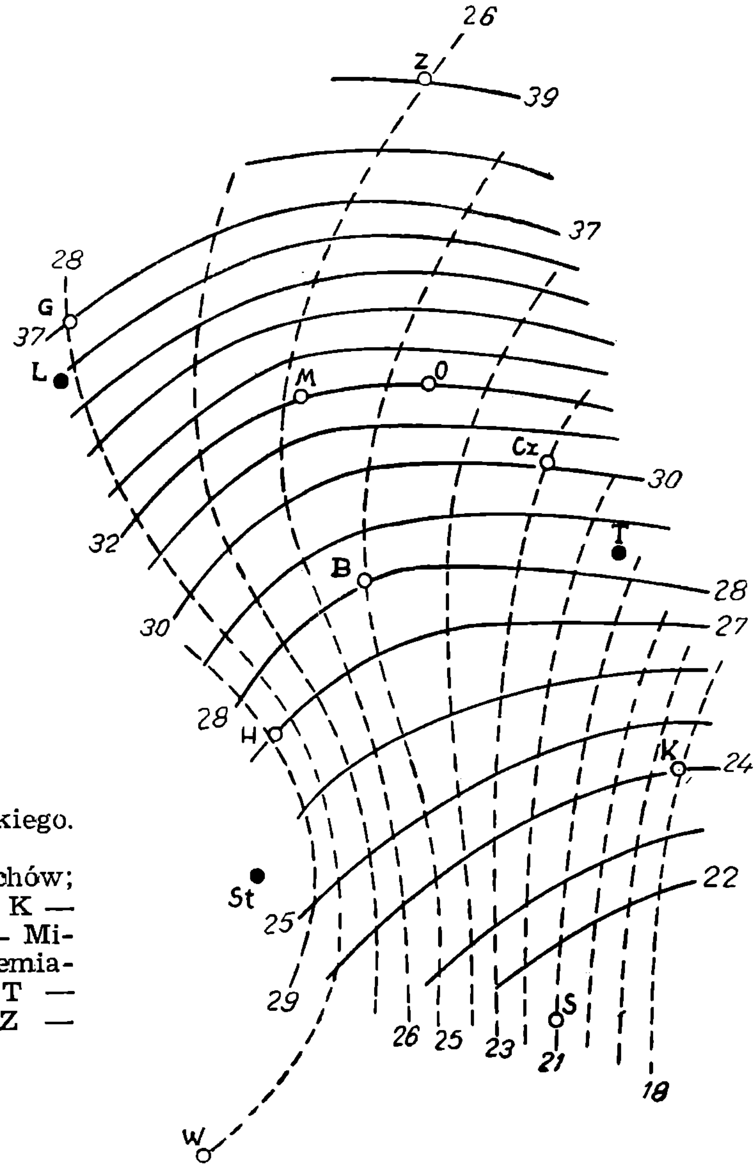

Fig. 2. Izograny lessu podolskiego.
Isograns of Loess of Podole.
B — Brzeżany; Cz — Czerniechów; G — Grzybowice; H — Halicz; K — Kopyczyńce; L — Lwów; M — Mitulin; O — Opaki; S — Siemiakowce; St. — Stanisławów; T — Tarnopol; W — Worochta; Z — Zboryszów

least degraded — which was logical — their culminations were put together into the first picture of isograns. The second culmination was treated in the same way. The third culmination could not be presented consistently by means of a graph of isograns as the corresponding upper zones of loess underwent erosion in most cases. On the included table (Fig. 2) are shown the isograns for the first culmination (from the bottom) and of the second one. The former shows distinctly the decrease of the grain from the NW towards the SE. This extremely characteristic differentiation in the size of loess grain in this direction could be caused, as in the dust grain of 1928, by the winds blowing from the NW and weakening towards the SE. The second culminations assembled in the isograns give a different picture. Here the decrease of the grain appears in the direction from W to E.

The following conclusions result from the entire regional investigation of the Podole loess:

1. The characteristic physiography of the primary loess of Podole was established on the basis of 23 precise chemical analyses of various samples. Besides this the mineral nature of the clayey component isolated in its pure form was precisely analysed, and on the basis of microscopic measurements of the diameters of quartz grain carried out on 114 samples the characteristic dispersion of the size of its quartz components was shown. In the course of research about 9 million planimetric lines were counted in the microscope. The control of the mineral composition was made by means of adsorption of methylene blue. All the various kinds of investigation determined without doubt the mineralogical nature of the loess rock of Podole.

It should be pointed out that these tiring and precise petrographic investigations had no precedent. As anemoclastic material loess of Podole could be formed by the blowing of dust components out of the sands gathered on its hinterland over a large area.

2. The methods used for investigation made it possible to distinguish exactly primary from the secondary loess. Primary loess may be precisely differentiated from the secondary matter (loess-like) already on the basis of microscopic determination of the mechanical composition.

3. The regional investigation of the loess rock in Podole facilitated the exact determination of the direction of diluvial winds. It was modelled on the investigation of the dust fall in 1928.

4. The presence in the loess profiles of Podole of three culminations of the average size of grain confirmed the conclusion concerning the presence of three loesses of Podole parallel to three glaciations.

5. In the investigated eight loess profiles of Podole „fossil soil" was not found. This is quite accidental. These soils, which in the interglacial periods should be formed on the loess cover, were in a certain already cold period destroyed by erosive factors.

The details concerning the research on loess in Podole were monographically elaborated in the PAU publications (J. Tokarski 1936).

All the above mentioned results of the research on loess encouraged without doubt the extending of the investigations to the territories outside Podole. The collection of materials on the territories west of Podole was entrusted to Professor A. Malicki, a co-worker of the Department of Mineralogy and Petrography at the University of Lwów. Professor Malicki collected extensive material from these areas which, though assembled in the laboratories could not be analysed because of the outbreak of the second world war.

The Lwów investigations determined the following important physiographic characteristics of the primary loess:

1. The loess rock contains an extremely characteristic and constant individual mechanical composition which could be shown exactly in the microscopic measurements by means of a summation curve. This was possible because the investigation of the characteristic in this way determined a uniform dispersion of grain size in numerous samples collected in many places in Podole. Thus the statement in a given case whether we are dealing with a sample of primary loess should be made on the basis of determination — an easy one — in the microscope of a sufficient number of grain sizes. All the loesses on which erosive factors have worked lose to a certain extent various fractions (especially the dusty ones), thus giving a different curve of grain dispersion.

2. The chemical composition of the loess of Podole, investigated precisely in 23 samples, showed the following variability in percentages of five main components, calculated into 100:

$$SiO_2 = 81.05 - 89.00,\ Al_2O_3 = 4.37 - 8.65,\ Fe_2O_3 = 1.21 - 4.95,\ CaO = 1.17 - 6.24,\ MgO = 0.64 - 1.75.$$

In the analyses not calculated in 100 K_2O varied from 1.35 to 2.14, $Na_2O = 0.77 - 0.96$. The full average analysis of this loess gave the following figures:

$$SiO_2 = 71.67,\ R_2O_3 = 10.35,\ CaO = 5.73,\ MgO = 1.12,\ K_2O = 1.83,\ Na_2O = 0.84,\ \pm H_2O = 2.74.$$

3. The rational chemical analysis performed on the sample of loess from Grzybowice (zone 1) showed that in hydrochloric acid 5.59% components dissolve in weight percentages, of which:

$$SiO_2 = 1.33,\ Al_2O_3 = 1.54,\ Fe_2O_3 = 2.18,\ CaO = 0.24,\ MgO = 0.30,$$

and in sulphuric acid 2.48%, of which

$$SiO_2 = 0.06,\ Al_2O_3 = 1.56,\ Fe_2O_3 = 1.83,\ CaO = 1.10,\ MgO = 0.13.$$

The alkalis in the amount: $K_2O = 1.31$, $Na_2O = 0.78$ also passed into the solution. As the quantity of components soluble in muriatic acid from any clastic rock throws some light on its genetic relations (hydration and hydrolysis of the primary material) the given results of the rational analysis of loess here characterize this rock.

4. The average size of loess grain in the investigated profiles in Podole consequently decreases from bottom to top though not constantly. The profiles investigated for mechanical composition are divided into sections in which the size of grains increase and after reaching culminations at a certain point consistently decrease. These culminations are extremely characteristic for the primary loesses. When all the investigated profiles of Podole showed the same characteristic in this respect the phenomenon could be caught synthetically by drawing the isarythms of selected culminations. These isarythms — as was mentioned above — were called isograns. From the dispersion of isograns it appeared that the loess culminations in various profiles increase in the lower parts of the profile from NW towards SE and in the upper (culmination 2) from W towards E. The explanation of this phenomenon was based on the pre-

vious investigation of the dispersion of dust grain from the year 1928. The conclusion was that only the wind direction could decide on the regional variability of grain culmination.

The following important conclusion concerning the mechanical composition of loess appears after these considerations. The investigation in Podole established that the average size of grains of the loess rock varies in the c u l m i n a t i o n s from 39 to 18 microns. It is clear that in the course of the given profile most of the averages contain smaller grains. One should bear in mind that one micron is one thousandth of a millimetre. Thus the mass of one grain is very small. We know well that dust can float even in calm air for quite a long time (the eruption of the volcano Krakatau in 1883). The smallest dust will fall on the earth's surface only when, for instance, its electrically active surfaces forced by the humidity of the medium join into bigger or smaller aggregates. If the speed of air current is for instance only 6 cm/sec. loess dust cannot yet fall to the ground. Such „silence" in the air approaches the „absolute". In other words it means that loess dust in the periods of glaciation could fall on the foreland of the glaciers in the regions of almost „absolute silence". The zones of atmospheric „silence" are well known in hot climates, but we have not much knowledge about such conditions of atmosphere in the polar climate. The falls of loess dust are documentary proof that such „silence" in climates which were decided by glaciation are possible.

The problem mentioned above is undoubtedly connected with the interpretation of falls of plant „dust" which when blown out from the centres of phytosociological media had probably to follow the same laws of eolian dynamics as loess dust. The falls of such „dust" were widely considered recently as paleobotanical documents. Here we shall only point out that this organic „dust" has a considerably smaller specific gravity than the loess grains and that they can make use of various means of flying which must have caused the differentiation of their concentration in the places of falling.

PROBLEM OF THE LOESS OF THE CARPATHIANS

As can be seen from the given graphs of isograms in the country by the river Dniestr the culmination of the lower loess reached an average size of 22 microns and those of the upper loess 18 microns. It is quite clear that the line of the Dniestr could not be a drastic southern boundary for the sedimentation of dust in diluvial periods. Rock dusts blown by the northern or western winds certainly passed this boundary moving southwards or eastwards, but the end of their sedimentation cannot now be determined exactly. Thus loess dust undoubtedly settled also in the areas beyond the river Dniestr. The boundary of its range has not yet been determined.

Opinion has always been divided in Poland in this matter. Some workers thought that loess dust reached the foot of the Carpathian range, others that it penetrated here and there into the gorges of the Carpathian rivers. There are also some who consider that loess did not cover the Carpathian heights and recently an isohypse of 400 m above sea level was determined as the maximal boundary height which it could reach (M. Klimaszewski 1948). However the diluvial formations in the Carpa thians generally have not been elaborated more systematically and in detail. Although many geographical and other papers mention them the correct and proper petrographic method was not used. The result was a new chaos leading to the fact that even the classification of these formations was not logically mad i. e. on a lithological basis. Thus the unsolved problem of the Carpathian loess still remains.

As for the problem of the hypsometry of the appearance of loess, science proved long ago that the sedimentation of loess could even cover heights up to 3.000 m (P. Woldstedt 1929). Thus, logically, it is not possible in any way to determine dogmatically the hypsometric boundary for loess sedimentation when on the one hand the contemporary research on the atmosphere found the presence of inorganic dust on the considerable heights of the troposphere and on the other hand we shall never know to which height reached the dynamics of glacial foens scattering loess on their foreland.

Loess is, as was mentioned above, a very „flimsy" rock liable to erosion (especially in the mountainous area) even under the influence of not very heavy rain.

Were the Carpathian peaks formed during the preglacial period covered with loess during the glaciation? The answer might be yes or no. In any case in the interglacial and postglacial periods there were many opportunities for this „flimsy" rock to be washed out of the peaks and influenced by gravitation factors using the streams of water.

Vegetation preserves the territory from erosion. Whether the determination of the p r e s e n t distribution of loess to a height of 400 m above sea level was caused by the forest or grass land reaching this limit can be solved only by paleobotanical investigation.

Independently of the above still theoretical considerations it should be investigated exactly whether various clays appearing in the Carpathians, often in large areas, have any genetic connection with loess. All statements concerning the appearance of „local clays" i. e. those formed by the weathering of the ground in the area, are denied by the logical understanding of natural phenomena as long as exact data (but not megascopic!) of clay and the stone matter which by weathering could cause its accumulation are not supplied.

With this in mind and the investigation on loess concluded the author took the first opportunity to tackle the problem of the Carpathian clays. Suitable investigations were made in the region of Worochta by the river Prut in the East Carpathians (1930). The distance of this place from the river Dniestr is 80 km in direct line and the average height about 500 m above South Podole. The region of Worochta is situated in the middle region of the flysch Carpathians. The geological ground for the area is from the south beds of Krosno chiefly formed from sandstone and from the north under the diluvial cover largely developed Menilite shales, Hieroglyphic beds and beds of Popiele. The morphology of the area is characterized by gentle inclines and the vast valley of the Prut is here richly covered by diluvial formations. Field observations tell us that the mentioned formations were not — at least not in the latest periods — moved so that probably because of the preponderance of accumulation over denudation they have been preserved quite well in diluvial forms till the present time. „The depression" of Worochta is covered above all by thick layers of clays situated at different heights. Their thickness varies over a not very wide range and does not exceed 3 m.

In order to explain the mineral nature and origin of these clays detailed research was undertaken following the methods established and applied for the research on the Podole loess. For this reason two small shafts were made in suitable places. One was placed on a terrace on the left bank of the river Prut at a height of 800 m above sea level near the local brick works and the other north from the first one, on the right bank of the river at a distance of about 1 km on a gentle slope about 830 m above sea level. Both shafts were about 3 m deep reaching the ground of local flysch sandstone. In the profiles of these diggings samples were collected at intervals of 20 cm which were subjected to petrographic analysis. They looked like clay which was differentiated in the profiles first of all by the colour changing gradually from grey at the bottom to yellow at the top. From the bottom third dcm towards the top the clay acquired an appearance similar to loess. All the samples were composed of pelite and, like the whole profile, contained no foreign additions. The samples underwent a quantitative mechanical analysis, microscopic investigation and at the same time detailed chemical investigation.

The results of mechanical and microscopic investigations on these samples are as follows :

Introductory microscopic investigations aiming at determining the mechanical composition of the clay on the basis of the measurements of the greatest diameters of its main element i. e. quartz, showed that the investigated material is not directly suitable for such a type of measurement. The reason was the presence of a too large amount of clayey substance which in thick layers covered the sand grains. They were then separated by means of sedimentation in a Schultze-Harkort apparatus, the remaining part composed of pure quartz grains being investigated in the normal way by the microscope.

In order to compare clays from Worochta with loess of Podole an identical separation was carried out on 7 samples of Podole loess. From the obtained figures it could be seen that the average quantity of sand in the clays from Worochta amounted to 45% after rejecting the upper zones of outcrops again well covered with clay. The figure corresponds to the average content of sand in the loesses of southern Podole. Loess of south ern Podole contained on the average 64% of sand. It should be mentioned that analogical calculations carried out for northern Podole (Zboryszów, Grzybowice, Czerniechów and Halicz) also showed 64% of quartz.

Thus we reach the important — in my opinion — conclusion that the relation of the contents of sand to the clayey components in the material from Worochta corresponds to the loesses of Podole.

As it was mentioned above the sandy remains of the samples from Worochta were investigated by means of the microscope in order to find the dispersion of the grain size. By means of these measurements in 14 levels the following averages were set as follows:

Fractions %	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Worochta	28	26	18	8	8	3	3	2	1	1	1	1	—	—
Trędowacz	26	20	16	10	8	5	3	12	4	1	1	2	1	1

The figures given on the graph (Fig. 1) show the dispersion of the grain for the loesses from Worochta in the shape of the summation curve. This curve appears on the graph below the upper one which illustrates the dispersion of the average loess of Podole. The lack of coincidence of the two curves may be explained in a simple way. The curve of the Podole loess was the average of all the measurements taken in various places in Podole taking into consideration all the outcrops. If instead of this curve for the average grain we presented the graphs for individual samples, we would doubtless obtain the whole range of curves, some of which would be placed above the average curve and some below it. Thus for example one of the zones of loess at Trędowacz on the border of Podole gave in the zones of quartz grains a number of figures placed in the second zone, below the mentioned profile from Worochta. The suitable curve for Trędowacz was also placed on figure 1, where it closely approaches the loess from Worochta. Nothing prevents us from connecting the investigated clays of the area of Worochta with the Podole loess on the basis of the similarity of their mechanical composition. At any rate it was proved that the mechanical composition of clay from Worochta is very near that of some of the zones of Podole loesses. In other works dealing with hydroclastic material, that is carried by water the author (J. Tokarski 1935), showed that the picture of grain-size variation of the material is basically different from anemoclastic loess.

In order to compare closely the Podole loess with clay from Worochta a number of chemical analyses of Carpathian clay were made. They are shown on the included Table No. 1.

Table 1

Clays from Worochta
weight perc.

Level / Components	Outcrop I			Outcrop II			average weight %
	1	6	11	2	6	11	
SiO_2	50.40	58.35	69.84	58.27	67.17	67.46	61.83
TiO_2	0.55	0.72	0.64	0.95	0.61	0.70	0.70
Al_2O_3	16.03	18.35	12.89	18.63	15.45	15.60	16.15
Fe_2O_3 *	6.02	7.18	5.41	7.64	6.12	6.46	6.47
[FeO]	[2.70]	[2.10]		[3.22]	[1.60]	[1.55]	[2.23]
MnO	0.20	0.25	0.10	trace	0.20	trace	0.18
CaO	5.85	1.24	0.62	0.51	0.51	0.58	1.55
MgO	4.77	2.26	1.10	2.42	1.80	1.39	2.29
Na_2O	1.33	0.86	1.04	1.56	1.90	0.98	1.27
K_2O	3.50	3.78	1.98	3.60	2.77	2.50	3.02
$+ H_2O$	3.45	5.25		4.12	3.08	4.24	3.88
CO_2	8.44	2.05	6.30	2.50	0.50	0.92	2.92
P_2O_5	0.19	0.33		0.19	0.25	trace	0.24
Total	100.73	100.62	99.92	100.39	100.36	100.90	100.50

* Values of FeO included in Fe_2O_3.

As can be seen from the figures given, the clays from Worochta both in individual samples and in the average contents of oxides differ sometimes considerably from the Podole loess. This is especially true of the three chief components i. e. SiO_2, Al_2O_3 and CaO. They show less silica and lime but much more of alumina. This fact agrees with the results of mechanical analysis which showed much less sand in Worochta and with the topological placement of material in its basin (80 km from the southern boundary of Podole).

In order to compare closely the above mentioned clays with Podole loess an additional chemical analysis was performed on the clayey substance separated from loess from the region of Czerniechów. It showed the following chemical composition:

%% $SiO_2 = 61.4$, $Al_2O_3 = 16.0$, $Fe_2O_3 = 7.0$, $MgO = 1.8$, $CaO = 2.2$.

The above analysis approaches very nearly the average analysis of clays from Worochta. It is difficult to accept this fact as accidental. The close genetic connection between the material from Worochta and loess of Podole comes to mind.

Loess from Czerniechów was shown by the following chemical data:

$$SiO_2 = 67.1,\ Al_2O_3 = 7.7,\ Fe_2O_3 = 3.4,\ MgO = 1.2,\ CaO = 8.3,\ CO_2 = 6.5.$$

We see in Czerniechów a marked surplus of SiO_2 and CaO in relation to the clay from Worochta besides a considerable lack of Al_2O_3. These differences could be caused by the addition to the primary clayey substance of material from Czerniechów i. e. calcium carbonate and sand. In fact when we take the clay from Worochta as a basis and add to it 70 weight parts of sand, 15 weight parts of CaO and 11.7 of CO_2 then after the percentage calculation we obtain the following figures:

$$SiO_2 = 67.2,\ Al_2O_3 = 8.1,\ Fe_2O_3 = 3.2,\ MgO = 1.1,\ CaO = 8.4,\ K_2O = 1.6,\ Na_2O = 0.6,\ H_2O = 1.5,\ CO_2 = 8.0.$$

The analysis of this „synthetic" loess composed of the Carpathian clay with the addition of sand and calcium carbonate is practically identical with the results obtained from the real analysis of loess from Czerniechów. With the above data in mind we may freely consider the relationship between the clays from Worochta and the loess of Podole as logical.

The solution of the problem of the Carpathian loess may be approached in a different way. The above mentioned fact of the surplus of clayey substance in the clay of Worochta compared to Podole loess would be explained by means of deluvial phenomena. If for example we suppose that the profiles of loess from Worochta were probably originally considerably higher and the processes of podsolization took away gravitationally not only the parts, soluble in water, but also the clayey colloids towards the bottom parts, we must consider that the greater amount of clayey material in these bottom parts is secondary, caused by the iluvial and deluvial processes. The opposite of the above given computations could be checked if we had removed from, for instance, clay from Worochta suitable quantities of clayey substance then such a formation would have been equal to the mineral composition of loess from Czerniechów.

Marian Łomnicki, a geologist from Podole, to whom we are indebted for the excellent pages of „The Geological Atlas of Galicia", differentiated two types of clay in Podole i. e. that from slopes and that from the tops. Unfortunately these were only morphological differences without any detailed lithological proof.

Bricks cannot be made out of loess clay because it is too „lean" (too much sand and too little clay). Łomnicki „slope" clay is „lean" loess and „top" clay, usually of small thickness is distinctly clayey and has been used in brickmaking for many years. This is proved by the existence of a great many brick works in the vicinity of Lwów, on the hills and their neighbourhood, which for centuries have been the basis of this branch of the ceramic industry. These brick clays developed secondarily out of loess, which in the bottom part of the profiles, in a secondary way, accumulated a larger number of clayey colloids thus causing the passing of loess into a kind of loam.

The average analysis of heavy minerals separated out of two profiles from Worochta compared with a similar analysis of ten samples of loess from Grzybowice, gave pictures which were similar in the preponderant elements i. e. non-transparent minerals, iron oxides, garnet, zircon and rutile (Table 2). Moreover in the clay from Worochta there is a great percentage of tourmaline and in that from Grzybowice a great percentage of staurolite. It should be noted that in the lists of heavy minerals determined in the two profiles from Worochta some of the items greatly vary, e. g. in the percentages of garnet, zircon, rutile and tourmaline. This fact lowers the value of the calculated averages from these profiles. However, taking into consideration that among the loesses of Podole the investigated heavy minerals vary both in grain size and quality, we may state very generally that the average contents of heavy minerals in Worochta may correspond to the loesses of Podole.

If some compositions of heavy minerals — as was presented in another paper (Tokarski 1947) — appearing in flysch layers from Inoceramian beds to those of Polanica recall some loesses, it should be considered as accidental.

Table 2

Heavy Minerals

Sample / Minerals	Worochta — average of 2	Grzybowice — average of 10
Non-transparent	48	36
Garnet	11	38
Zircon	17	13
Rutile	10	4
Disthene	—	1
Sillimanite	—	1
Tourmaline	8	1
Hornblende	1	1
Biotite	—	1
Staurolite	1	4
Andalusite	1	—
Muscovite	3	—

In the author's opinion the comparison of the analysis of heavy minerals contained in the clay from Worochta with the loesses of Podole did not prove but also not disprove the existence of a genetic connection between the two formations.

One important problem remains to be discussed, namely the connection of material from Worochta with isograns of Podole loess. This, however, is not an easy matter to be solved, chiefly because of the lack of more details on the general data on the stratigraphy of Carpathian diluvium. The Eastern Carpathians had their own glaciations and this differentiates them chiefly from the, in this respect, „free" Podole. Comparative material is here isograns of Podole for two periods presented on Fig. 1. The average quartz grain of the clay from Worochta was computed for 28 microns. It corresponds to two isograns, i. e. Brzeżany (first culmination) and Grzybowice (second culmination). It remains to decide with which Podole loess it would be more logical to connect the clay of Worochta. However, the connection of the isogran of Worochta with that of Brzeżany would be unnatural because the line in Podole goes more or less in the direction W to E and at a great distance from Worochta. It would be unnatural to „curve" the isogran line of the first culmination of Podole in the SE direction. It would blurr the very consistent picture of the course of the mentioned isarythms in Podole. The connection, however, of the point of Worochta with the isograns of Grzybowice of the second culmination does not change anything in its general direction; on the contrary it will extend this isarythm consistently southwards.

We would problably have obtained the same result if we had connected the point of Worochta with the third culminations of Podole. However, as was mentioned above, we had not enough Podole material for that.

If the first glaciation of the Eastern Carpathians had a vast extent, the corresponding loess could not be formed in the Worochta basin in that period. It was, however, possible in the second or third glacial period when the glaciation did not cover the place. In the at that time free Carpathian basins loess of the western origin settled blown probably by a much greater difference in the barometric potential in comparison with possible, certainly slight, Carpathian glaciations.

It is clear that the above theses require confirmation. This could be obtained if by means of methods of investigation of loess, already tried, a sufficient number of samples of loam were analysed, not only from the Eastern but also from the Western Carpathians.

LOESSES FROM THE CRACOW REGION

After having finished the investigation on the loess of Podole and of the Carpathians a systematic regional investigation on the loess in southern Poland was to have begun, applying the method already tested. Unfortunately the research could not be carried out because of the outbreak of the war in 1939. The same topic was resumed in 1950 in quite different conditions of work at the Jagellonian University, when the author came to work in Cracow. At the beginning the research was limited to a number of samples of loess from the nearest vicinity of Cracow.

Only C. Kuźniar (1912) investigated at one time and only incidentally the loess rock of the province of Cracow. He analysed petrographically incidental samples from Witkowice, Dobczyce and Kopań. In this paper the results of investigation of the loess sample are given; it was taken from the artificially uncovered profile in the vicinity of Mogiła near Cracow, at a depth of about 250 cm (Tokarski, Oleksynowa 1951). The following results in weight percentages were obtained by chemical analysis of the rock:

$$SiO_2 = 73.16,\ Al_2O_3 = 7.66,\ Fe_2O_3 = 3.47,\ CaO = 5.36,\ MgO = 1.36,$$
$$K_2O = 2.30,\ Na_2O = 0.60,\ CO_2 = 3.90,\ \pm\ H_2O = 2.39.$$

The analysis is practically identical with the average of the loess of Podole presented above.

The analyses of Podole were limited to the determining of chemical composition of the loess rock either on brutto chemical analyses or on fractional analyses i. e. performed on extracts in hydrochloric and sulphuric acid. But the detailed mineral composition was not then determined. Such determination was made for the first time in the analysis of loess from Mogiła. The basis for the stechiometric calculations was the acceptance of the existence in loess of the following components: quartz, montmorillonite, kaolin, calcite, sericite and limonite. The presence of these minerals was determined approximately qualitativ by means of the microscope. The quantitative determination of these components by the microscope was impossible except in the case of quartz, because the clayey part of colloidal nature came in size beyond the possibility of determination. At this stage the computations of molecular percentages of chemical analysis into mineral components were made, accepting their theoretic formulae. From these computations it appeared that the investigated loess was composed in weight percentages from: montmorillonite — 7.29, kaolin — 9.07, calcite — 8.88, sericite (connecting the whole amount of potassium shown analytically) — 5.11, limonite — 4.06, quartz — 64.75, the components adsorbed by colloids — 2.17. The calculation of the mineral compositions of loess made for these computations was in accordance with the stechiometric computations made in petrographic research.

In the meantime a new method of determining the mineral composition of soils and clastic rocks was determined on the basis of weight thermoanalysis (J. Tokarski 1951). This new quantitative analysis consisted in the definition of loesses by weight in different temperatures of samples containing such components as: sand, humus, carbonates, montmorillonite and kaolinite, as the result of dehydration, ignition and dissociation. Agreement between the chemical computations, thermal and microscopic analyses of loess from Mogiła is shown on the following table:

Weight Percentages	Chemical analysis	Thermal analysis	Microscopic analysis
Sand	66	75	67
Montmorillonite	7	7	—
Kaolinite	9	9	—
Sericite	5	—	11
Clay	—	—	11
Calcite	9	9	11
Limonite	4	—	—
Total	100	100	100

It can be seen on the above table to what extent thermoanalysis may help in the regional investigation of loess.

From the results of the investigation of loess from Mogiła it appeared that this rock does not differ very much from the loess of Podole in its chemical composition. Especially striking is the similarity in mechanical composition of loess from Mogiła to the average Podole loess. This can be seen on Fig. 1 where the identity of the dispersion of the grain size of the investigated rocks is most distinctly shown. It should be stated that the loesses of Cracow and Podole appearing in places very distant from each other, must be considered genetically as identical.

The second subject for investigation was the profile of loess rock artificially uncovered in the vicinity of Zwierzyniec near Cracow. It is the site known today for the paleolithic findings discovered here in numerous places and recently elaborated carefully by L. Sawicki (1952). He gives in his work a detailed description of outcrops and workings of loess, carried out in this place. All the topographic details of this outcrop were so exactly described by the author that there is no need to repeat them here. However in the paper there are no exact data concerning the lithological nature of loess formations. The definitions given by the author, such as clay, silt, quartz sand, sandy compact formation etc., are not sufficient today, as was pointed out in the previous chapters of the present paper.

Bearing in mind the exact lithological characterization of loess as a diluvial document, the appropriate research was carried out in the Department of Petrography at the Academy of Mining and Metallurgy in Cracow, which could make possible a comparison between the Cracow rock and the loess in Podole and the Eastern Carpathians. In order to do this the samples collected from the Zwierzyniec profile were investigated; by means of the microscope the mechanical composition was studied in various zones, some general chemical and rational analyses were performed, and finally a weight thermal analysis was made. The results are given below.

The outcrop at Zwierzyniec is situated in the south-west part of Cracow, on the east slope of a hill 236 m above sea level in the fork of the rivers Vistula and Rudawa. At the bottom of the loess layer there are Jurassic limestone. The length of the outcrop uncovered by the archeological diggings carried out in 1948 (L. Sawicki) is 32 m and its wall runs in the direction N to S. The thickness of the profile where the samples were collected is 9.5 m (Plate XX, Figs 5 and 6). Samples for analyses were taken from the profile of the outcrop at intervals of 1 m except points 2, 9 a and 9 b, where the intervals were smaller.

The investigated loess corresponds to Sawicki's upper zone and is separated by sand lenses from the lower zone of the rock investigated by means of drilling.

The investigation of the mechanical composition of loess samples by means of the microscope showed that the average grain sizes of samples from 1 — 9 b ranged from 19 to 31. The variations in the profiles from Grzybowice were from 23 to 37.

Assembled below are the comparative figures which characterize the average size of loess grain in 11 zones of Zwierzyniec and 10 zones of Grzybowice.

It can be seen from the figures given that the fluctuations in the average in the two investigated places are similar. Calculated averages from the averages of the whole profile at Zwierzyniec gave the figure 26, and for Grzybowice 28. If an exceptionally large culmination equal to 37 microns was calculated (zone 2) for the profile of Grzybowice, a new average for 9 points would also amount to 26 microns. These calculations show that the loesses from Zwierzyniec and Grzybowice taken as a whole are almost identical in their grain-size variation.

Samples Aver. in microns	1	2	3	4	5	6	7	8	9	9a	9b	average
Zwierzyniec	29	27	24	22	27	19	26	21	30	31	24	26
Grzybowice	28	37	27	28	27	28	28	25	25	23	—	28

The graph of the summation curve for the average loess of Zwierzyniec was also made on Fig. 1 where the loess from Mogiła and the average ones from Podole are shown. The graph showed that the same curve of dispersion had to be accepted for the loess from Zwierzyniec.

The problem of grain-size variation of the two profiles was developed more widely by assembling summation curves for all the zones from Grzybowice and Zwierzyniec. These are shown on Fig. 3. From the course of the curves may be seen the considerable similarity of the mechanical composition in the two investigated profiles.

The analysis of the heavy minerals of the zones of Zwierzyniec brought the results presented on Table 3. For the sake of comparison the respective figures for Grzybowice horizons are given. The following conclusions may be drawn from these figures:

1. The list of heavy minerals found in the two places are similar.

2. Percentages of the contents of heavy minerals in the levels from Zwierzyniec range from 0.04 to 0.3, their concentration towards the lower part of the profile being distinctive.

3. In the two loess series the number of non-transparent minerals, garnet and zircon, are predominant. Rutile is here the fourth. On this heavy mineral the analysis of loesses from Grzybowice ends, the remaining minerals appearing only in small quantities. An exception is staurolite which ranges from 3 to 5% in Grzybowice. Disthene, sillimanite, tourmaline, hornblende, biotite, staurolite and andalusite appear in the zones of Zwierzyniec in larger quantities than in Grzybowice. Thus for instance percentages of andalusite range at Zwierzyniec from 7 to 4% whereas in the loess from Grzybowice this mineral was not found at all.

4. The variability of the quantity relations in the two profiles is of the same kind. Since the dominant heavy minerals in both investigated series are the non-transparent minerals, garnet and zircon, rutile keeping a middle place, it can be etablished on the basis of this analysis that the two loess formations, i. e. from Grzybowice and Zwierzyniec, are very similar in this respect.

Chemical „brutto" and rational analyses were performed on the samples collected from zones 3 and 8 of the profile from Zwierzyniec. The figures are assembled on Table 4. For comparison similar analyses made as averages from 10 zones of the Grzybowice profile were also included on this table. The following conclusions follow from the figures given:

Table 3

Analyses of Heavy Minerals

Level Minerals	Zwierzyniec												Grzybowice		
	1	2	3	4	5	6	7	8	9	9a	9b	10	2	5	7
%%	007	007	004	0.2	0.1	0.1	0.1	0.2	0.3	0.1	0.1	0.2			
Non-transparent	34	31	30	33	39	36	39	40	47	36	42	47	43	37	36
Garnet	13	12	15	18	16	14	18	12	11	10	7	4	28	30	36
Zircon	20	23	20	20	21	26	25	18	16	28	20	24	17	19	15
Rutile	6	4	3	3	4	3	4	4	6	8	4	7	3	4	4
Disthene	2	6	5	4	3	2	2	4	2	1	4	4	1	1	—
Sillimanite	—	1	tr	tr	tr	tr	—	—	—	—	tr	tr	1	1	1
Tourmaline	7	6	8	3	3	2	2	3	4	5	5	2	1	2	1
Hornblende	3	3	3	5	4	5	1	4	4	2	3	3	tr	tr	3
Biotite	9	5	7	5	2	5	1	5	2	1	3	1	2	1	1
Staurolite	2	3	3	2	2	1	2	3	2	3	5	2	4	5	3
Andalusite	4	6	6	7	6	6	6	7	6	6	7	6	—	—	—
Glauconite	—	—	tr	—	—	tr	—	—	—	—	—	—			

Table 4

Chemical Analyses of Loesses

Sample Weight %%	Zwierzyniec 3		Zwierzyniec 8		Grzybowice average of 10	
	„brutto" analysis	rational analysis	„brutto" analysis	rational analysis	„brutto" analysis	rational analysis
SiO_2	73.58	0.10	74.42	0.13	77.54	1.33
Al_2O_3	7.26	1.40	9.19	4.00	6.40	1.54
Fe_2O_3	2.92	2.68	3.33	2.83	3.02	2.18
CaO	4.90	3.87	1.89	1.62	4.10	0.24
MnO	—	—	—	—	0.04	—
MgO	1.05	0.95	1.11	0.91	1.19	0.30
Na_2O	1.69	—	1.15	—	0.87	—
K_2O	2.52	0.54	3.41	0.34	1.74	—
P_2O_2	—	—	—	—	0.38	—
Ignition loss	4.95		3.70			
$-H_2O$	1.05		1.87		1.54	
CO_2	—		—		3.18	
Total	99.92	9.54	100.07	9.83	100.00	5.59

1. In the loess from Grzybowice there are larger percentages of contents of SiO_2 and smaller of Al_2O_3 and $Na_2O + K_2O$. The figures defining percentages of Fe_2O_3 and MgO in the two formations are very similar. The percentage of CaO in Zwierzyniec 3 is larger, in Zwierzyniec 8 smaller in relation to the average of Grzybowice. Smaller or greater

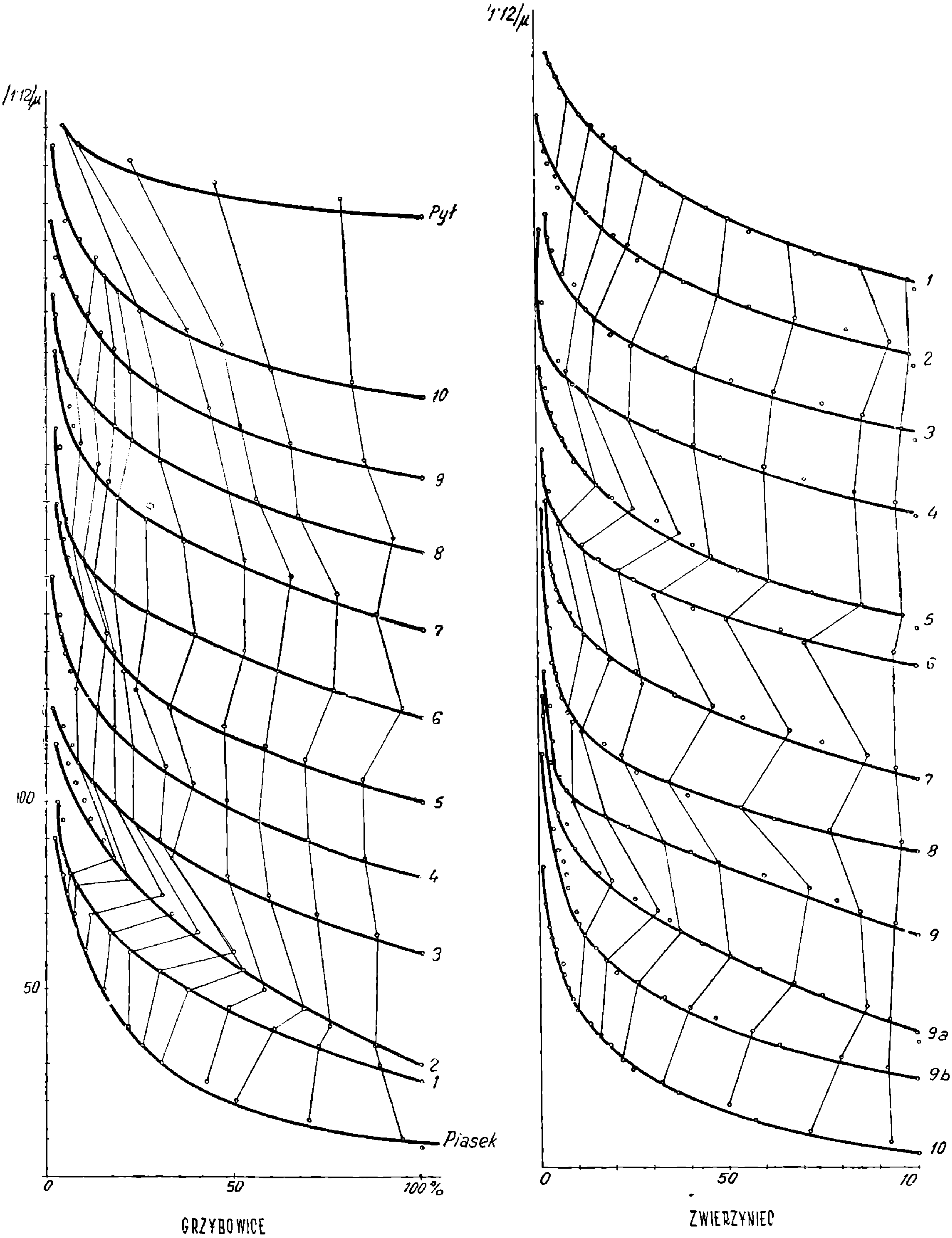

Fig. 3. Krzywe rozsiewu ziarn lessu
Fig. 3. Curves of Loess Grain Dispersion

differences in the two formations should of course be explained by the differences in the stages of their secondary degradation (podsolization). Thus nothing prevents the acceptance of the fact that „brutto" analyses of the two loess formations compared here are similar within the limits of their variability.

2. Similar differences appear in the analyses of the extracts of HCl acid. The loesses from Zwierzyniec passed over to acid percentages nearly twice as high as those from Grzybowice. The only serious difference in these rational analyses was the low contents of CaO in the average loess from Grzybowice.

3. The mineral contents of loess from Zwierzyniec was also determined by means of a new weight thermoanalysis. The results of the analysis carried out on 10 samples are shown on Table 5. It appeared that the percentages of the main minerals contained in loess samples from 1 to 9 b vary as follows: montmorillonite 2.1 — 5.9, humus 0.2 — 2.5, kaolinite 1.0 — 10.4, calcite 0.5 — 7.3 and sand 79.9 — 95.9. It was observed that various percentages of the mentioned components appear in the profile zones without any distinctive consequence. However the fact that montmorillonite appears in two zones with a distinct increase in the content seems to be characteristic i. e. zone 2 (5.9), zone 8 (5.4). Humus appears in large quantity (2.5%) only in zone 8. The analysis given on Table 5 refers to the level of sand.

Table 5

Thermal Analysis of Loess „Zwierzyniec"

	% of losses in				% of minerals				
Level	150°	400°	550°	900°	M	H	K	C	S
1	0.53	0.60	0.81	0.43	3.6	1.0	4.9	1.4	81.1
2	0.72	0.14	1.28	2.45	5.9	0.2	9.0	5.0	79.9
3	0.42	0.51	1.49	2.73	2.8	0.8	10.4	5.6	80.4
4	0.42	0.53	1.23	3.43	2.8	0.9	8.3	7.3	80.7
5	0.40	0.74	1.52	2.57	2.3	1.2	10.3	5.2	81.0
6	0.38	0.79	1.11	2.95	2.1	1.3	7.1	6.1	83.4
7	0.56	0.80	1.26	2.35	3.5	1.3	8.0	4.3	82.9
8	0.90	1.51	1.00	1.25	5.4	2.5	4.6	1.7	85.8
9	0.78	1.04	0.65	0.56	5.0	1.7	2.7	0.2	90.4
9a	0.42	0.57	0.48	0.47	2.7	0.6	2.4	0.5	93.2
9b	0.29	0.60	0.28	0.38	2.6	1.0	1.0	0.5	95.9
10	0.12	0.50	0.04	0.18	0.3	0.9	—	—	98.8
Fossil Soils:									
2	0.49	0.22	0.53	0.48	3.8	0.3	3.5	0.7	91.7
4	1.12	0.55	1.05	1.08	8.6	0.8	6.7	1.5	82.4

M — montmorillonite
H — humus
K — Kaolinite
C — calcite
S — sand

Besides the mentioned surplus of montmorillonite the greatest percentages of kaolinite cumulate in zones 3 and 5. Calcite ranges in the zones 2 — 7 from 7.3 to 4.3. In the lower zones and in the first upper one there is very little calcite.

These variabilities of mineral composition in the zones of the profile from Zwierzyniec are normal. They were doubtless caused by the secondary phenomena which the loess profile underwent during long periods, e. g. interglacial periods.

Two samples taken from the zones determined by L. Sawicki as „fossil soil" also underwent thermal analysis. The results of this analysis are shown on Table 5 in the last two rows of figures. It appeared that in these zones the percentages of humus range from 0.3 to 0.8, but in the loess zones these percentages are generally higher. It should be stressed that the percentage of montmorillonite in these soils is comparatively high, reaching 8.6%. Thus it is doubtful whether these two zones of darker colour may be called fossil soil. It may be accepted with equal probability that they are some kind of illuvial zones which, containing a larger amount of montmorillonite or organic and mineral components strongly adsorbing also organic kathions, acquired because of this a darker colour than their surroundings. These components could accumulate also in a secondary manner in the mentioned zones during the process of podsolization of the primary loess.

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translated by M. Filippi

Kraków, May, 1960

OBJAŚNIENIE TABLIC
EXPLANATIONS OF PLATES

Tablica XVIII
Plate XVIII

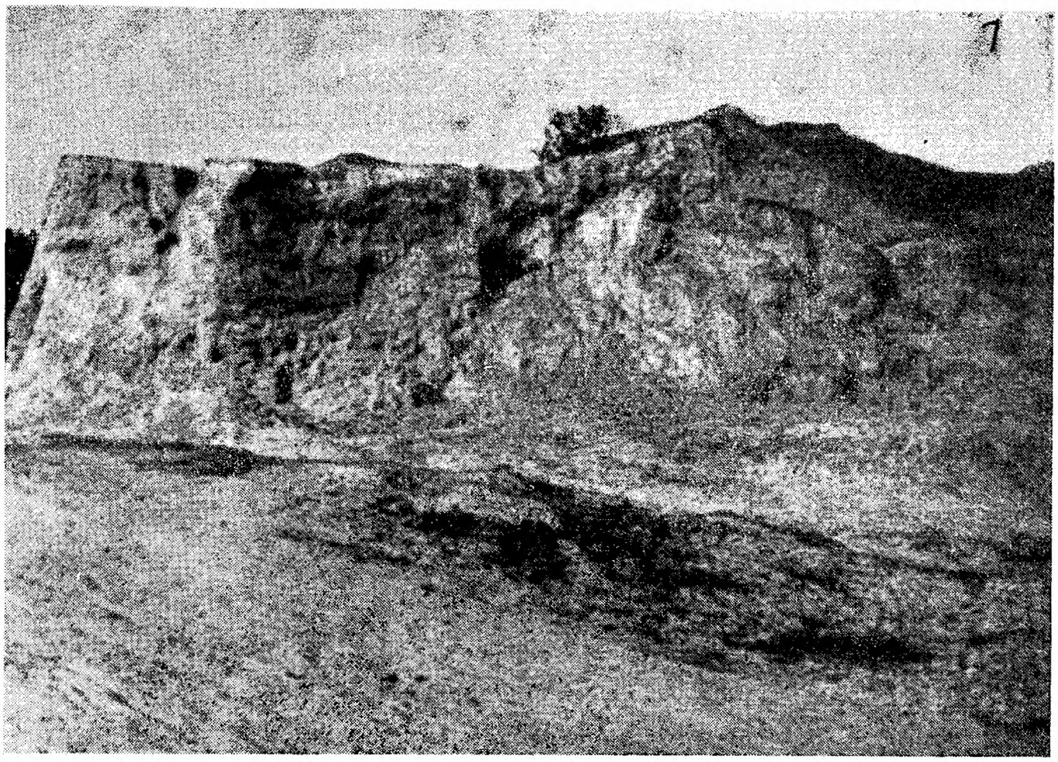
Fig. 1. Profil pierwotnego lessu w Grzybowicach.
Fig. 2. Profil wtórnego lessu w Grzybowicach.
Fig. 1. Profile of the primary loess at Grzybowice
Fig. 2. Profile of the secondary loess at Grzybowice.

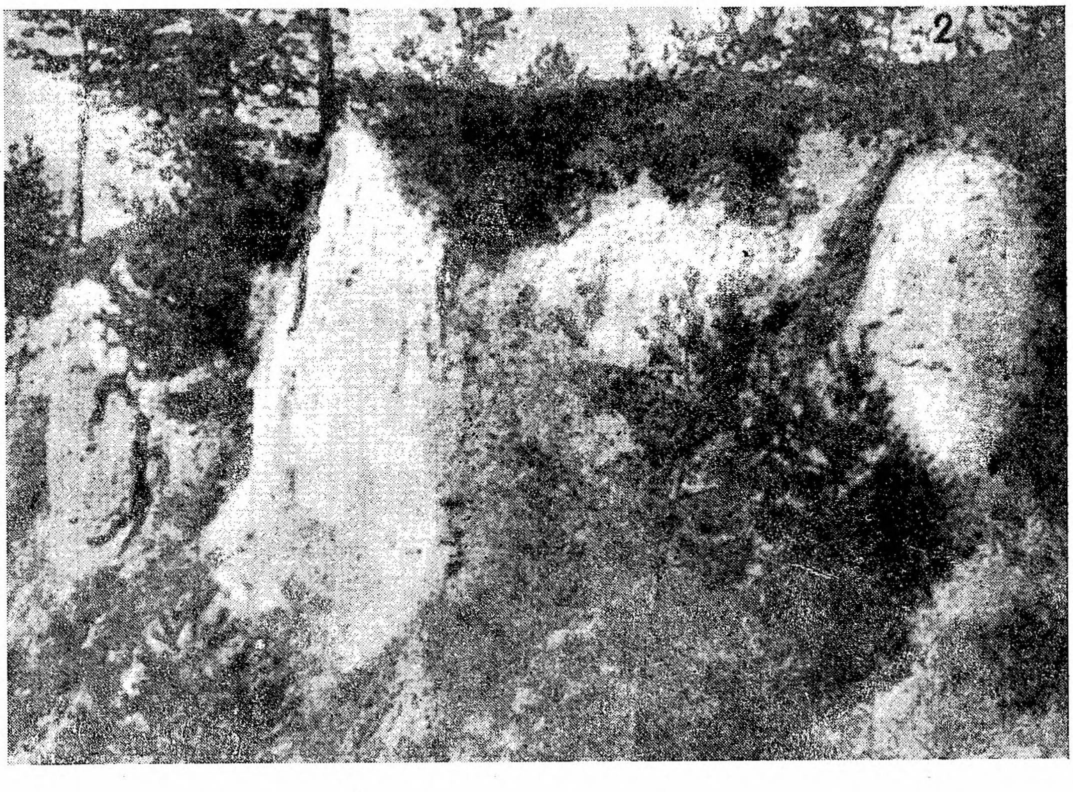
Tablica XIX
Plate XIX

Fig. 3. Preparat mikroskopowy lessu grzybowickiego $\pm 60\times$
Fig. 4. Preparat mikroskopowy ciężkich minerałów z lessu grzybowickiego $\pm 60\times$
Fig. 3. Microscopic preparation of heavy minerals from Grzybowice $\pm 60\times$
Fig. 4. Microscopic preparation of heavy minerals from loess from Grzybowice $\pm 60\times$

Tablica XX
Plate XX

Fig. 5—6 Odkrywki lessu na Zwierzyńcu
Fig. 5—6 Outcrops of loess at Zwierzyniec





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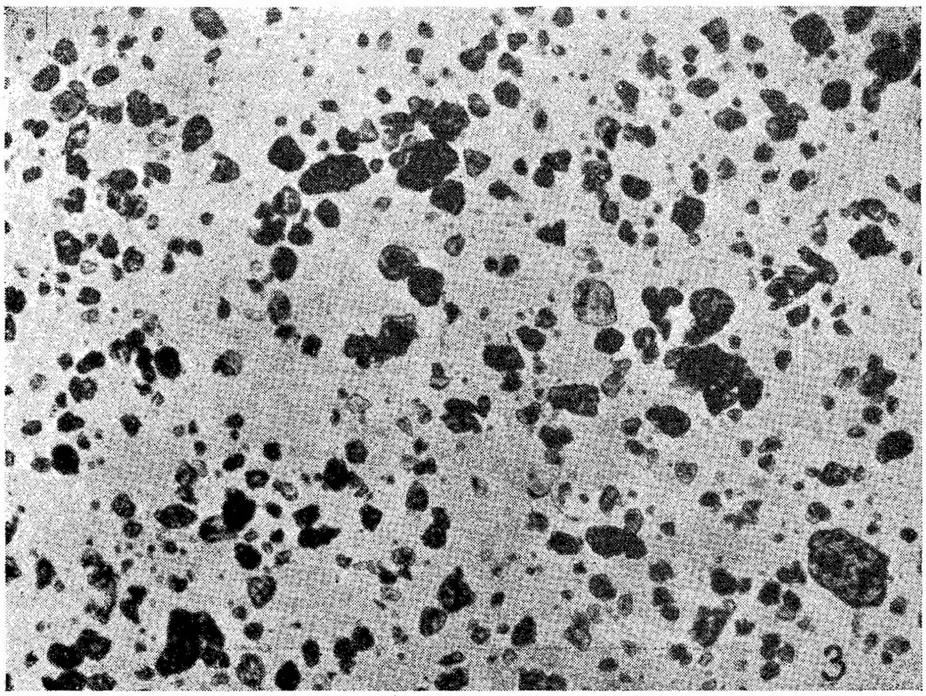

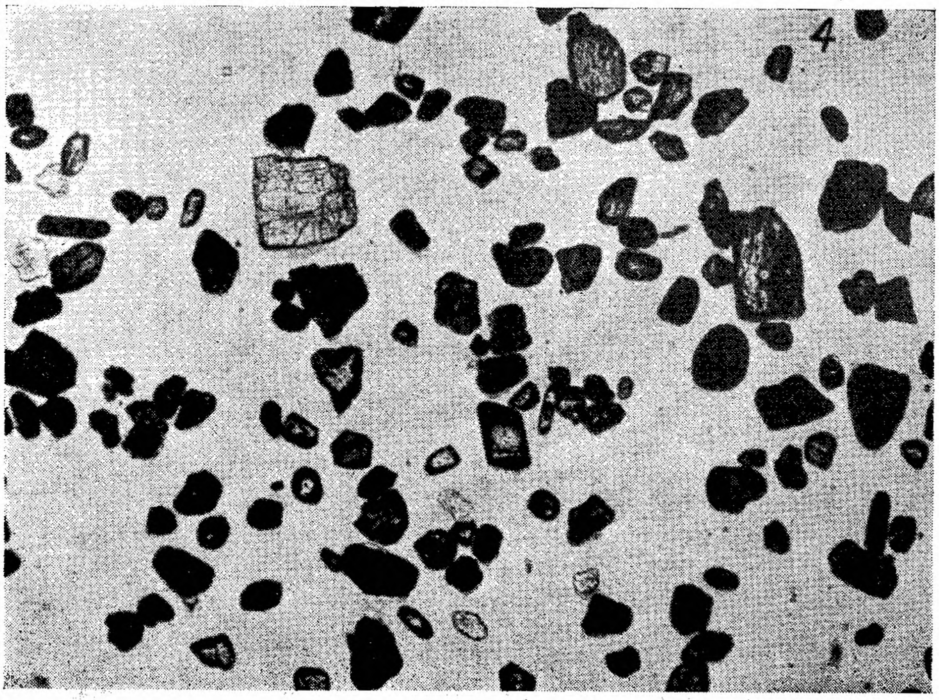

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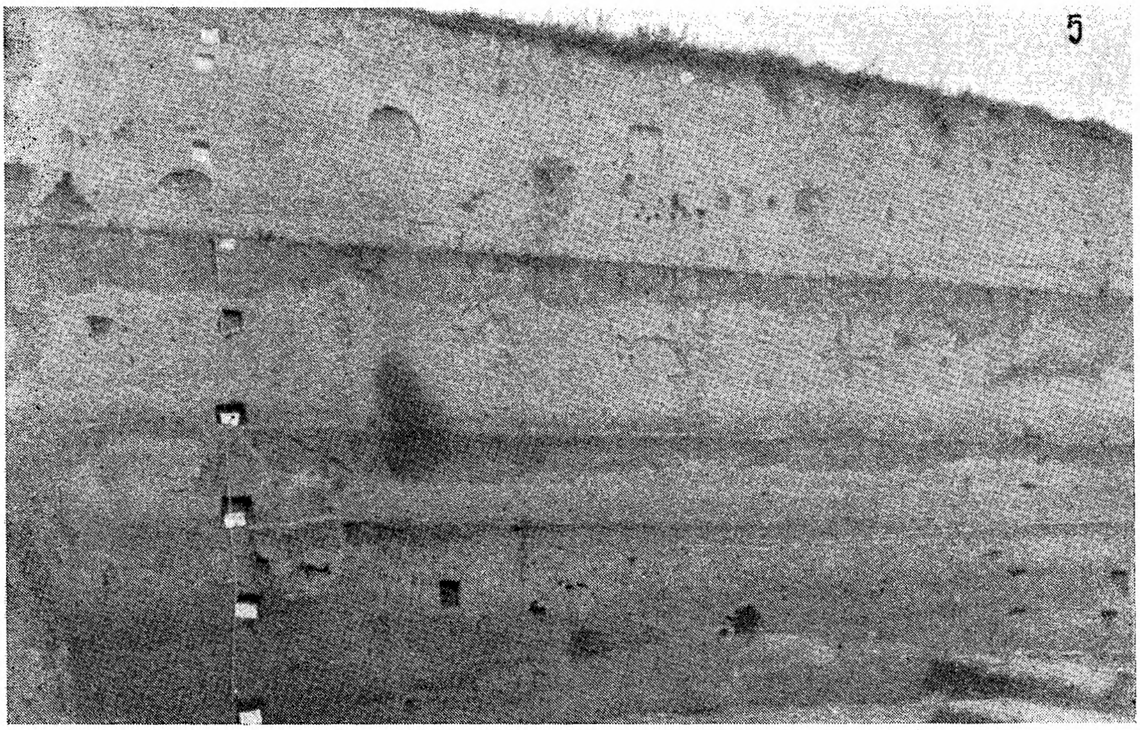

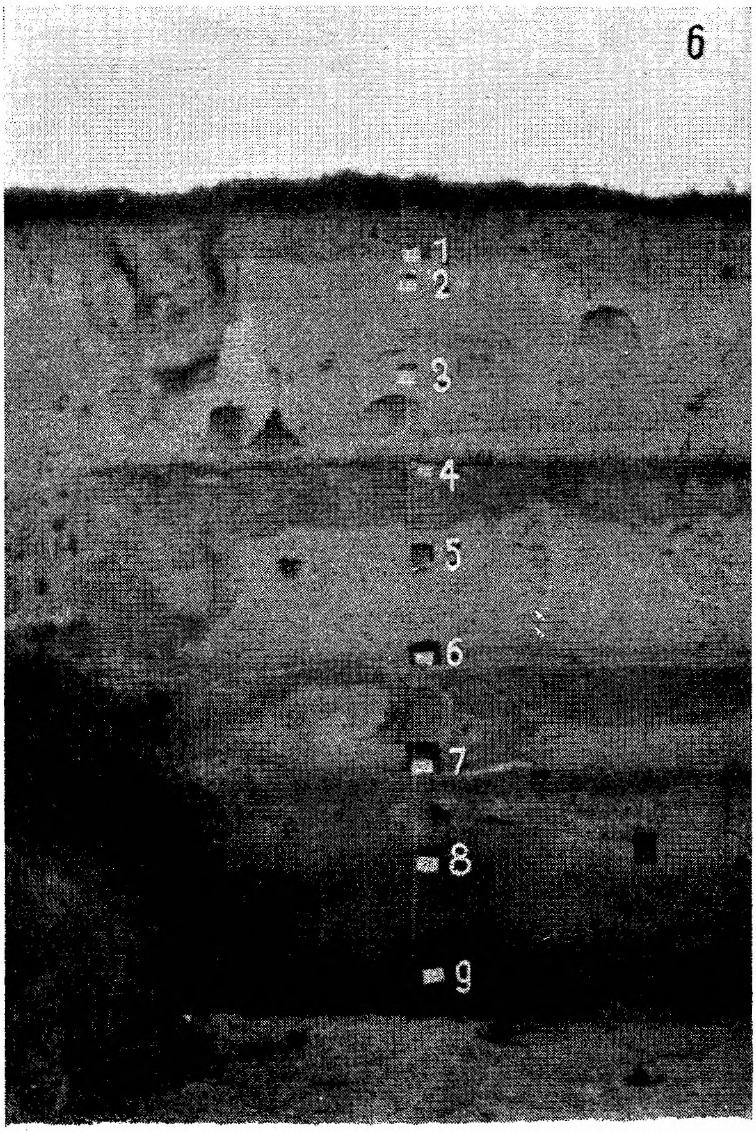

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