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Leszek STOCH, Edeltrauda HELIOS-RYBICKA *

ON DISINTEGRATION OF QUARTZ DURING WEATHERING PROCESS OF GRANITIC ROCKS

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Abstract. Changes in microtexture surface of quartz grains and in grain-size distribution of quartz in weathering crust were examined. These phenomena were caused by chemical dissolution of quartz during kaolinization of granitic rocks. Grain-size distribution of quartz in parent granitic rocks was found to be lognormal, truncated on both sides. During weathering, dispersion of grain-size distribution and the mean size of quartz grains are slightly increased.

INTRODUCTION

Dissolution of minerals in water or aqueous solutions play essential role during chemical weathering of rocks. Under definite conditions even comparatively resistant rock-forming minerals are subjected to dissolution processes. Quartz belongs to minerals showing the lowest solubility in water — it amounts to 7 ppm and is the least of all the silica modifications (Wey, Siffert 1961).

No matter of its low solubility, quartz participates in chemical processes connected with weathering. Examinations of chemical and mineral alterations of weathering crust of granites have shown some decrease of quartz content in their upper kaolinitic zone (Petrov 1967). Weathering of siliceous rocks (ferrugineous quartzites of the Magnitogorsk region) results in nearly complete disappearance of quartz constituting approx. 40 per cents of these rocks. Replacement of quartz by kaolinite are observed whereby necessary alumina is introduced by circulating solutions (Carozzi 1960). Corroded quartz grains were observed to occur in kaolinite clays from Jaroszów (Stoch 1962).

Under definite conditions of weathering of igneous rocks, quartz is subjected to superficial sericitization (Carozzi 1960).

Mineralogical examinations of Tertiary weathering crusts formed on

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* Institute of Geology and Mineral Resources, Academy of Mining and Metallurgy, Cracow.

Lower Silesian granites confirmed that during weathering quartz displays some chemical activity manifested by changes of the texture of surface of its grains (Stoch, Sikora 1975; Sikora, Stoch 1972). More detailed study of these changes was the aim of the present paper.

Authors examinations were dealing with the change of form and character of the surface of quartz grains observable by means of polarizing microscope and electron scanning one. Moreover, changes in grain-size distribution of quartz caused by weathering process were studied.

In lower part of weathering zone, where no distinct alterations of quartz are observed, grain-size distribution of this mineral is the same as in parent granitic rock. Grain-size distribution of minerals is determined by conditions of their origin and, in the case of sedimentary rocks, depends of transport of particles. As follows from earlier studies (Stoch, Sikora 1972), grain-size distribution of clay minerals represents their typomorphic feature. Grain-size distribution of quartz in granitic rocks depends on their crystallization conditions and can be one of petrogenetic criteria.

CHARACTERISTICES OF SAMPLES STUDIED

Quartz grains in question occur in primary kaolins formed by weathering of granites in the environs of Bolesławice and Roztoka (Lower Silesia) and in kaolin developed on gneisses in Wyszonowice.

Kaolin from Bolesławice is the product of weathering of binary granite displaying locally strong cataclasis and hydrothermal alterations (Gawroński, Kozydra 1969). Its occurrence is situated in central part of the Strzegom—Sobótka granitic massif. The samples examined were collected from the bore-hole (28A) which penetrated the whole weathering crust up to slightly altered primary rock.

Kaolin from Roztoka is the product of weathering of biotite granite and its occurrence is localized in eastern part of the Strzegom—Sobótka massif. Primary kaolins are accompanied here by secondary ones, representing slides of weathering crusts. However, this displacement could not distinctly influence the size and form of quartz grains. Kaolin from Wyszonowice was formed by weathering of Strzelin biotite gneisses showing oriented structure.

All the examined weathering crusts of granites and gneisses of Lower Silesia display distinct zonality of distribution of main mineral components. The bottom part of profile under study consists of slightly altered primary rock which is overlain by a zone showing increased content of both primary and secondary micas, called kaolinite-mica zone. The uppermost kaolinite zone contains but minute amounts of mica minerals.

MICROSCOPIC CHARACTERISTICS AND FORM OF QUARTZ GRAINS

Quartz content in weathering crusts under examination amounts to 30—60 per cent and increases from bottom to the top. This is connected with decomposition of feldspars and micas during weathering process and with removal of considerable amounts of chemical constituents from primary rock.

In kaolin from Bolesławice, quartz occurs as large sharp-edged grains, up to several milimetres in size. Apart from individual grains, we observe large quartz aggregates displaying mosaic structure as well as small amounts of fine-grained quartz dust. Locally, there occurs fine-grained secondary quartz. Generally, quartz grains show wavy extinction and some of them are strongly cataclized.

More than 80 per cent quartz grains exceed 60 µm in size. The decrease of grain size is accompanied by diminishing of quartz content in it. Consequently, very minute amounts of this mineral occur in fractions below 20 µm. X-ray determinable quartz was found to occur up to the fraction approx. 0.5 µm.

Quartz occurring in kaolin from Roztoka forms individual large grains, much more than 60 µm in diameter and show uniform extinction. Only several per cent of total quartz content is present in fractions below 60 µm. As follows from X-ray data, only very small amounts of quartz are present in fractions 30—2 µm.

Kaolin from Wyszonowice contains 35—50 weight per cent of quartz. Generally, it occurs here as aggregates of grains of different sizes. Quartz in fractions below 60 µm is developed as individual grains originated from disintegration of aggregates. The smallest quartz grains are approx. 2 µm in diameter. The amount of fine-grained quartz (less than 30 µm in diameter) does not exceed 10 per cent of its total content in the rock.

Microscopic examinations of samples from various weathering zones in question have shown that weathering is accompanied by some disintegration of quartz aggregates and increase of finer grains content. Some larger individual quartz grains are also subjected to disintegration process, the intensity of which increases toward the upper part of weathering crust. Because of lack of any stronger mechanical forces that would cause disintegration of compact quartz aggregates, this phenomenon should be attributed to chemical processes operating there.

As follows from microscopic examinations of thin sections, the initial stage of this process consists in broadening and cracking of intergranular boundaries and cracks in aggregates which become more pronounced. Fissures within quartz grains are also enlarged. This process resembles deepening of intergranular boundaries resulted from chemical etching of polished surfaces procedure used sometimes during microscope examinations (Phot. 1). This phenomenon is particularly well observed in kaolin from Wyszonowice, being best pronounced in upper part of weathering crust i.e. in kaolinite zone.

It is supposed that the process in question is caused by aggressive activity of circulating solutions. Disolution of quartz begins from the surfaces of grains resulting in gradual decrease of binding forces uniting them in aggregates. New minerals begin to crystallize in fissures thus formed. In the zone of slightly altered granite and in the kaolinite-mica zone of weathering crust in Bolesławice crystallization of sericite in fissures among quartz grains is observed. Sometimes these fissures are filled with siderite (Phot. 2) and in upper parts of weathering zones coarse crystalline aggregates of columnar kaolinite are also observed (Phot. 3). Crystalization of new minerals in fissures is wedging apart the grains forming a given aggregate.

Similar mechanism operates in kaolin from Roztoka, where destruction of larger uniform quartz grains consists in separation of fine fragments from them.

In the vicinity of weathering feldspars, formation of sericite at the surfaces of quartz grains is observed. The latters are sometimes surrounded by sericite rims, thought kaolinite is the main mineral of weathering zone. The formation of sericite at the surface of quartz may be interpreted, similarly as sericitization of feldspars, as the case of incongruent dissolution of quartz.

In order to confirm an active role of quartz in chemical processes taking place during weathering, the surface of grains of this mineral were examined by means of electron scanning microscope. As follows from these observations, there are numerous cavities at the surface of quartz grains which can be connected with chemical corrosion. These are particularly well developed in quartz grains occurring in lower part of weathering crust enriched in mica. Generally these cavities can be observed using electron scanning microscope (Phot. 4) but some of them can be detected by means of petrographic microscope too.

Considerable amount of secondary mica in weathering zone indicates that the environment was alkaline, favouring dissolution of silica. Another type of quartz surface, also possibly connected with chemical corrosion, is presented in Phot. 5.

In lower part of weathering crust we observe the formation of traces of etching. Their origin can be explained by local increase of pH at the contact of quartz grains with those of decomposing feldspars or micas.

In the course of further weathering, gradual smoothing of quartz surface is observed. This process is distinct in upper part of weathering crust. In this zone we observe e.g. diminishing or even disappearance of cavities formed after weathered intergrowths of feldspars in quartz grains. In this part of weathering crust, chemical processes were slightly different in character. Dissolution took place under the influence of acidic atmospheric waters infiltrating into the rock and causing its desilification. This process is exemplified by quartz from kaolin of Roztoka. Its surface is presented in Phot. 6. The presented grain was situated in a zone of advanced weathering manifested by trace amounts of feldspars and micas preserved.

Dissolution of silica in weathering crust is locally accompanied by its precipitation on surfaces of quartz grains (Phot. 7 and 8). The coexistance of two reverse processes of dissolution and precipitation of silica in the same zone is possible due to local differences in physico-chemical character of the environment conditioned by the presence of weathering minerals (feldspars, micas). On the other hand, equalization of concentrations of chemical components during weathering processes proceeds by means of diffusion processes which, in general, are very slow.

GRAIN-SIZE DISTRIBUTION OF QUARTZ IN PRIMARY KAOLINS

Dissolution processes of quartz grains and disintegration of its aggregates and course grains are reflected in grain-size distributions of this mineral. These curves are often used in examinations of sedimentation processes and abrasion of grains constituting sedimentary rocks. These data can also be useful in the analysis of disintegration of minerals during weathering of granitic rocks.

As already mentioned, the coarser fractions of kaolins in question consist practically exclusively of quartz grains whilst those below 20 μm are so poor in it that its content can be neglected. Consequently, grain-size distribution of kaolin fractions above 20 μm corresponds practically to that of quartz contained in it. This distribution in the range above 63 μm was determined by sieve analysis of the samples purified from clay substance by rinsing with distilled water alkalized with ammonia. The content of fractions below 63 μm was determined by means of sedimentation balance.

Fragments of cumulative grain-size distribution curves thus obtained for kaolins, corresponding to those of quartz contained in them, are presented in Figure 1. The curves are denoted by numbers, increasing with depth of sampling sites.

As follows from these data, the amount of fine-grained quartz increases toward the upper part of weathering crust. This phenomenon is particularly well observed in kaolins from Bolesławice and Roztoka.

Grain-size distribution curves of quartz are, in the majority of cases examined, bi-modal in type (Fig. 2). We may distinguish in them the

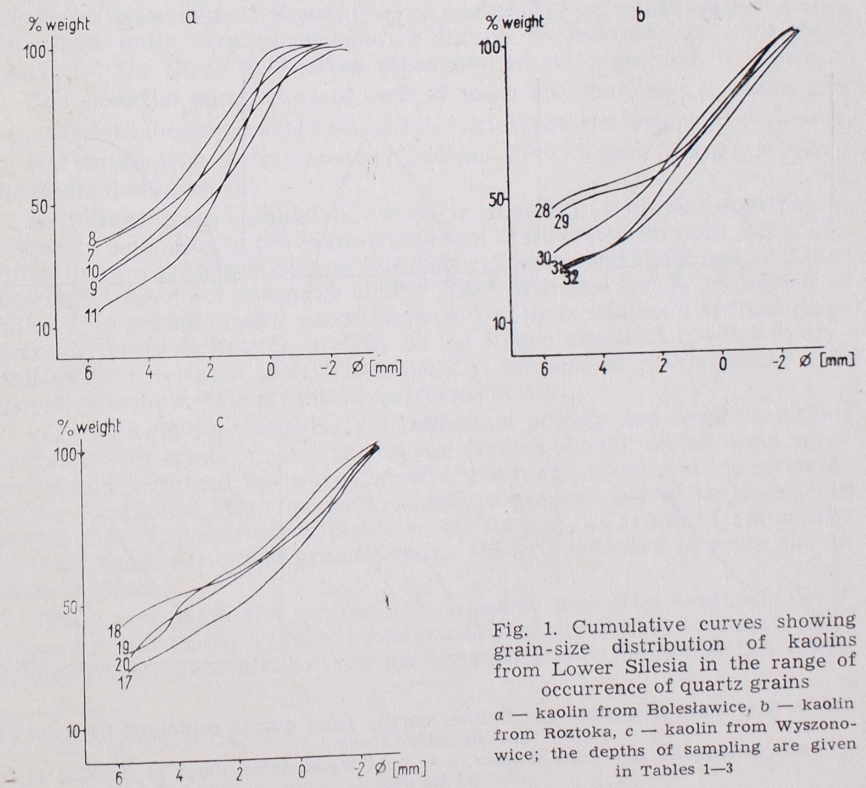

Fig. 1. Cumulative curves showing grain-size distribution of kaolins from Lower Silesia in the range of occurrence of quartz grains

a — kaolin from Bolesławice, *b* — kaolin from Roztoka, *c* — kaolin from Wyszonowice; the depths of sampling are given in Tables 1—3

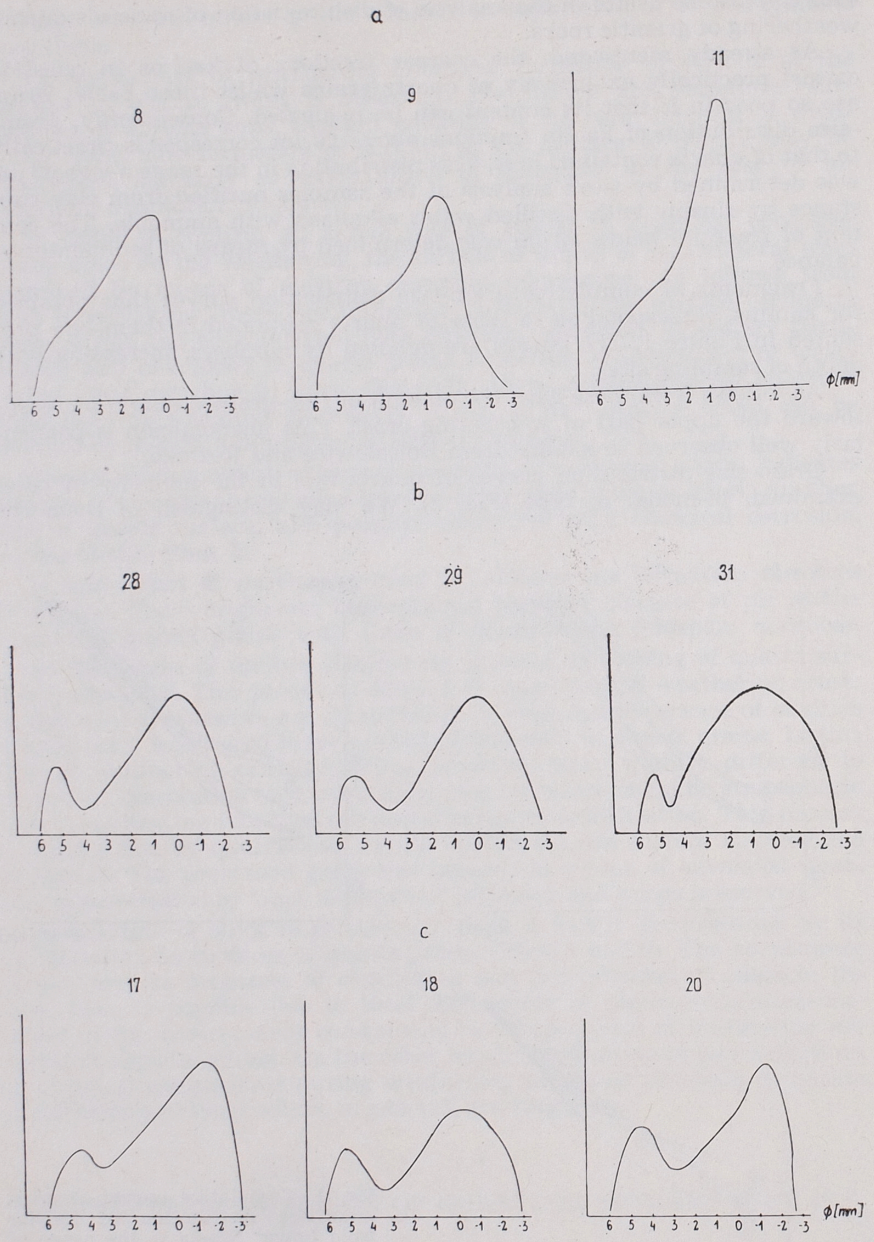

Fig. 2. Grain-size frequency distribution curves from quartz contained in some of kaolins under study

a — from Bolesławice, *b* — from Roztoka, *c* — from Wyszonowice, depth of sampling as in Tables 1—3

main population consisting of coarser grains and less abundant subordinate one represented by fine-grained quartz. The latter consists essentially of grains originated from disintegration of larger grains or of their aggregates. Percentual content of this population increases toward the top of weathering crust i.e. with development of this process.

Gradually advancing disintegration of quartz grains is also manifested by increasing asymmetry of distribution curve of the main population due to broadening of its finer fraction part. This phenomenon is well observed in grain-size distribution curves for quartz in kaolins from Bolesławice (Fig. 2*a*).

Bi-modal grain-size distribution curves of quartz for kaolins from Roztoka and Wyszonowice were separated into its two component unimodal ones by means of graphical method proposed by Hald (1952). This procedure was also applied by Spencer (1963) in his study of grain-size distributions of clastic sediments. Using this method it was possible to obtain corrected grain-size distributions of the main population which was subsequently examined more in detail. It was found that grain-size frequency distribution of main population is lognormal in type and this hypothesis was verified by means Kolmogorov test at the confidence level 0.95 (Zieliński 1972).

Corrected grain-size distributions for main populations of quartz were presented in the system of coordinates: probability per cents against grain-size in Φ units. Typical cumulative curves of grain-size distribution of quartz for the three weathering zones studied are presented in Figure 3.

The essential parameters of each of these distributions i.e.: mean size $\bar{X}_p$, standard deviation σ, skewness $\sqrt{b_1}$ kurtosis b_2, coefficient of skewness S_k and coefficient of kurtosis K (Griffiths 1967) * were computed using the method of moments.

As follows from cumulative curves in question, grain-size distribution of quartz belonging to the main population is truncated on both sides. The upper limit of grain size of quartz is 6000 μm whilst the lower one — 20 μm and these limits are distinctly sharp. Their existence can be explained as follows: In granitic rocks quartz forms either by crystallization from magma or by recrystallization process. In the former case it is the last to crystallize from residual melt. Consequently, the size of still available free spaces determines upper limit of quartz grain size.

As follows from theory of crystallization process and from conditions of stability of crystal nuclei, the crystal formed should exceed some minimal size determined by properties of a given substance and by crystallization conditions. Finer grains gradually disappear and at their expense larger ones of more than critical size are formed. As follows from results of these examinations of granitic rocks, the critical value of grain size in them is 20 μm.

Changes in grain-size composition of quartz caused by weathering processes are illustrated by distribution parameters presented in Tables 1—3. Though it is rather difficult to find precise relations between the values

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* $b_1 = \frac{m_3}{\sigma^3}$; $b_2 = \frac{m_4}{\sigma_4}$; $S_k = \frac{\sqrt{b_1}}{2}$; $K = b_2 - 3$

where: m_3 and m_4 are moments of a given distribution.

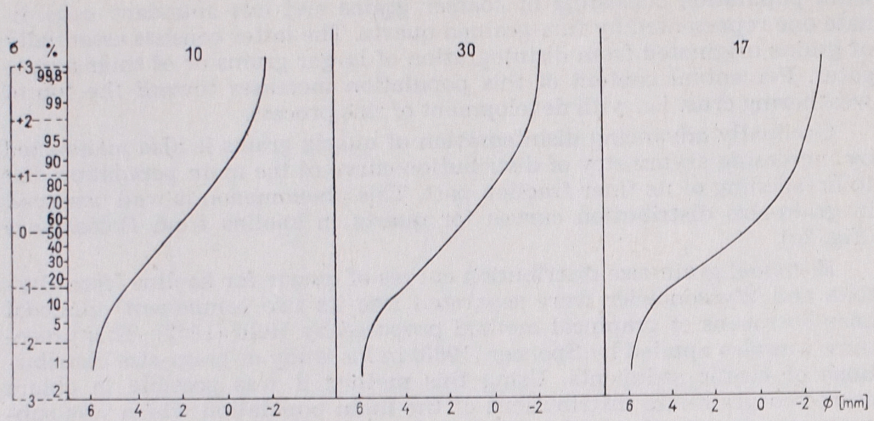

Fig. 3. Grain-size cumulative curves drown on probability per cent ordinate against Φ of main population of quartz grains of some of kaolins under study
10 — kaolin from Bolesławice, *30* — kaolin from Roztoka, *17* — kaolin from Wyszonowice

Table 1

Grain-size distribution parameters for quartz of kaolin from Bolesławice (bore-hole 28A)

Sample	Depth m	$\bar{X}$	σ	$\sqrt{b_1}$	S_k	b_2	K
7	31,0—34,4	2,4	3,96	—0,27	—0,14	2,41	—0,59
8	34,4—40,0	2,0	3,27	—0,44	—0,22	2,30	—0,70
9	40,0—46,0	1,5	3,93	—0,37	—0,18	2,26	—0,74
10	46,0—47,2	2,1	3,68	—0,16	—0,08	2,11	—0,89
11	47,2—54,4	1,7	2,25	—0,62	—0,31	2,51	—0,49

Table 2

Grain-size distribution parameters for quartz of kaolin from Roztoka

Sample	Depth m	$\bar{X}$	σ	$\sqrt{b_1}$	S_k	b_2	K
28	10,1—19,6	0,5	3,14	—0,37	—0,18	2,45	—0,55
29	19,6—23,6	0,2	3,03	—0,31	—0,15	2,35	—0,65
30	23,6—25,2	1,2	3,50	—0,01	—0,01	2,17	—0,83
31	25,2—27,0	0,8	3,60	—0,14	—0,07	2,13	—0,87
32	27,0—31,0	0,7	3,10	—0,08	—0,04	2,35	—0,65

Table 3

Grain-size distribution parameters for quartz of kaolin from Wyszonowice (bore-hole 16W)

Sample	Depth m	$\bar{X}$	σ	$\sqrt{b_1}$	S_k	b_2	K
17	11,7—17,0	—0,1	3,54	—0,45	—0,22	2,24	—0,76
18	17,0—22,1	0,1	2,97	—0,17	—0,08	2,21	—0,79
19	22,1—24,4	0,1	2,89	—0,10	—0,05	1,97	—1,03
20	24,4—27,0	—0,3	2,87	—0,46	—0,23	2,15	—0,35

of these parameters and the depth (since grain-size distribution of quartz is also influenced by local structural and textural variations of rocks) but some distinct tendencies are observed. First of all there is a distinct increase of mean size of quartz grains and of standard deviation of their frequency distributions. Moreover, when passing from the bottom to the top, we observe initially a decrease and then an increase of skewness and assymmetry of frequency distribution curve of grain-size. This is illustrated by changes in values of $\sqrt{b_1}$, b_2 and S_k parameters. Simultaneously, some negligible diminishing of peakedness of distribution curve takes place.

These statistical data confirm the thesis that during weathering process quartz grains are subjected to alterations which influence grain-size destribution of this mineral. The observed changes can be explained by distruction and disintegration of grains into smaller ones. This refers, first of all, to grains of medium size. Simultaneously, the amount of finest grains slightly diminishes. This can be due to dissolution phenomena. Consequently, the upper part of distribution curve is rendering more sharp and its extremal point is moved slightly to the right. Simultaneously, the part of curve corresponding to finer fractions become more diffuse and dispersion of grain-size increases.

As follows from the obtained data, grain-size distribution of quartz in granitic rock under investigation is lognormal in type. This can be a one of the causes of lognormal distribution of grain-size of this mineral generally observed in sedimentary rocks. In this case weathering, segregation of grains, abrasion phenomena during erosion and transport of weathered material probably only modify the grain-size distribution of quartz in sediments.

The present authors examinations have shown that quartz participates in chemical processes taking place in weathering crusts of igneous rocks. Its partial dissolution results in desintegration of larger grains and their aggregates as well as in polishing and smoothing of quartz grain surfaces.

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Leszek STOCH, Edeltrauda HELIOS RYBICKA

O DEZINTEGRACJI KWARCU W PROCESIE WIETRZENIA SKAŁ GRANITOWYCH

Streszczenie

Prześledzono zjawiska dezintegracji kwarcu w procesie kaolinizacji skał granitowych Dolnego Śląska. Pod działaniem roztworów krążących w zwietrzelinie następuje korozja chemiczna ziarn kwarcu. W pierwszym etapie zaznacza się ona poszerzaniem granic międzyziarnowych w agregatach ziarn oraz pęknięć w pojedynczych ziarnach (fot. 1). Następnie obserwuje się dezintegrację ziarn i ich agregatów którą przyspiesza krystalizacja nowych minerałów (kaolinit, syderyt) w szczelinach międzyziarnowych (fot. 2 i 3). Badania morfologii powierzchni ziarn kwarcu wykazały, że w dolnej strefie zwietrzeliny (strefa kaolinitowo-mikowa) gdzie panowało środowisko alkaliczne obserwuje się korozję jamistą (fot. 4, 5). W strefach stropowych natomiast rozpuszczanie chemiczne powoduje wygładzenie powierzchni (fot. 6). Lokalnie w czasie wietrzenia miało miejsce również wytrącanie się krzemionki (fot. 7 i 8).

Wykonano analizę statystyczną zmienności rozkładu uziarnienia kwarcu na różnych poziomach pokrywy zwietrzelinowej. Wykazała ona, że kwarc z badanych skał granitowych wykazuje log-normalny rozkład uziarnienia dwustronnie obcięty (fig. 3). W miarę postępu wietrzenia średnia wielkość ziarn wykazuje tendencję wzrostu. Równocześnie zwiększa się odchylenie standardowe. Wraz z przejściem od spągu ku stropowi początkowo maleje a następnie zwiększa się skośność i asymetria krzywej rozkładu wielkości ziarn a zarazem rośnie nieco jej spłaszczenie. Wskazują na to odpowiednie zmiany wartości parametrów statystycznych takich jak miara skośności $\sqrt{b_1}$, spłaszczenia b_2, współczynnik asymetrii S_k i spłaszczenie K (tab. 1—3). Jak się przypuszcza jest to rezultat rozpuszczania ziarn drobnych oraz dezintegracji ziarn dużych w wyniku działania wspomnianych czynników chemicznych.

OBJAŚNIENIE FIGUR

Fig. 1. Krzywe kumulacyjne składu ziarnowego kaolinów z Dolnego Śląska w zakresie występowania ziarn kwarcu
a — kaolin z Bolesławic, *b* — kaolin z Roztoki, *c* — kaolin z Wyszonowic; głębokości z których pochodzą próbki podane są w tabelach 1—3

Fig. 2. Krzywe rozkładu ziarn kwarcu niektórych z badanych kaolinitów:
a — kaolin z Bolesławic, *b* — kaolin z Roztoki, *c* — kaolin z Wyszonowic; głębokości pobrania próbek podane są w tabelach 1—3

Fig. 3. Krzywe kumulacyjne składu ziarnowego w układzie prawdopodobieństwo — Φ głównej populacji ziarn kwarcu niektórych z badanych kaolinów
10 — kaolin z Bolesławic, *30* — kaolin z Roztoki, *17* — kaolin z Wyszonowic

OBJAŚNIENIE FOTOGRAFII

Fot. 1. Wytrawione w czasie wietrzenia granice międzyziarnowe i pęknięcia ziarn kwarcu. Kaolin Wyszonowice

Fot. 2. Krystalizacja syderytu rozklinowująca agregat kwarcu. Kaolin Bolesławice

Fot. 3. Krystalizacja kaolinitu rozklinowująca agregat ziarn kwarcu. Kaolin Bolesławice

Fot. 4. Powierzchnia ziarna kwarcu ze strefy kaolinitowej z kaolinu z Bolesławic. Mikroskop elektronowy scanningowy, pow. × 1000

Fot. 5. Powierzchnia ziarna kwarcu ze strefy kaolinitowo-mikowej, z kaolinu z Bolesławic. Mikroskop elektronowy scanningowy, pow. × 3000

Fot. 6. Wygładzona powierzchnia ziarna kwarcu z kaolinitu z Roztoki. Mikroskop elektronowy scanningowy, pow. × 3000

Fot. 7, 8. Krzemionka wytrącona na powierzchni ziarn kwarcu z kaolinu z Bolesławic. Mikroskop scanningowy, pow. × 3000

Лешек СТОХ, Эдельтрауда ГЕЛИОС РЫБИЦКА

О ДЕЗИНТЕГРАЦИИ КВАРЦА В ПРОЦЕССЕ ВЫВЕТРИВАНИЯ ГРАНИТОВ

Резюме

Прослежен процесс дезинтеграции кварца при каолинизации гранитных пород Нижней Силезии. Под влиянием растворов, циркулирующих в коре выветривания, происходит химическая коррозия кварца. В первой стадии она проявляется в виде увеличения пространств между зернами и трещин в зернах кварца (фото 1). Далее происходит дезинтеграция зерен и их агрегатов, ускоряемая кристаллизацией новых минералов (каолинит, сидерит) в межзерновых трещинах (фото 2, 3). Из наблюдений морфологии поверхности кварца следует, что в ниженей зоне коры выветривания (каолинит-слюдяная зона), характеризующейся щелочной средой, происходила ячеистая коррозия (фото 4, 5), а в верхней зоне — сглаживание поверхности в результате химического растворения (фото 6). Местами во время выветривания происходило выпадение кремнезёма (фото 7, 8).

Был произведен статистический анализ распределения гранулометрического состава кварца в разных горизонтах коры выветривания.

Кварц в исследованных породах характеризуется логнормальным, двусторонне усеченным распределением (фиг. 3). По мере развития процесса выветривания наблюдается возрастание средней величины зерен, одновременно же увеличивается стандартное отклонение. В направлении снизу вверх вначале уменьшается, а потом возрастает наклон и асимметрия кривой распределения величины зерен, в то же время эта кривая все более выравнивается. Это выявляется в соответствующих изменениях величины статистических параметров, как величина асимметрии $\sqrt{b_1}$, эксцесса b_2, коэффициент асимметрии S_k и эксцесса K (табл. 1—3). Предполагается, что это происходит в результате растворения мелких и дезинтеграции крупных зерен кварца под влиянием упомянутых химических факторов.

ОБЪЯСНЕНИЯ К ФИГУРАМ

Фиг. 1. Кумулятивные кривые гранулометрического состава каолинов Нижней Силезии в отношении распространения зерен кварца

a — каолин месторождения Болеславице, *b* — каолин месторождения Розтока, *c* — каолин месторождения Вышоновице; глубина взятия образцов указана в таблицах 1—3

Фиг. 2. Кривые распределения зерен кварца в некоторых образцах каолина

a — каолин месторождения Болеславице, *b* — каолин месторождения Розтока, *c* — каолин месторождения Вышоновице; глубина взятия образцов указана в таблицах 1—3

Фиг. 3. Кумулятивные кривые гранулометрического состава в системе: вероятность — единицех Ф

10 — каолин месторождения Болеславице, *30* — каолин месторождения Розтока, *17* — каолин месторождения Вышоновице

ОБЪЯСНЕНИЯ К ФОТОСНИМКАМ

Фото 1. Межзерновые границы и трещины в зернах кварца, разъеденные при выветривании. Каолин месторождения Вышоновице

Фото 2. Кристаллизация сидерита, разрушающая агрегат кварца. Каолин месторождения Болеславице

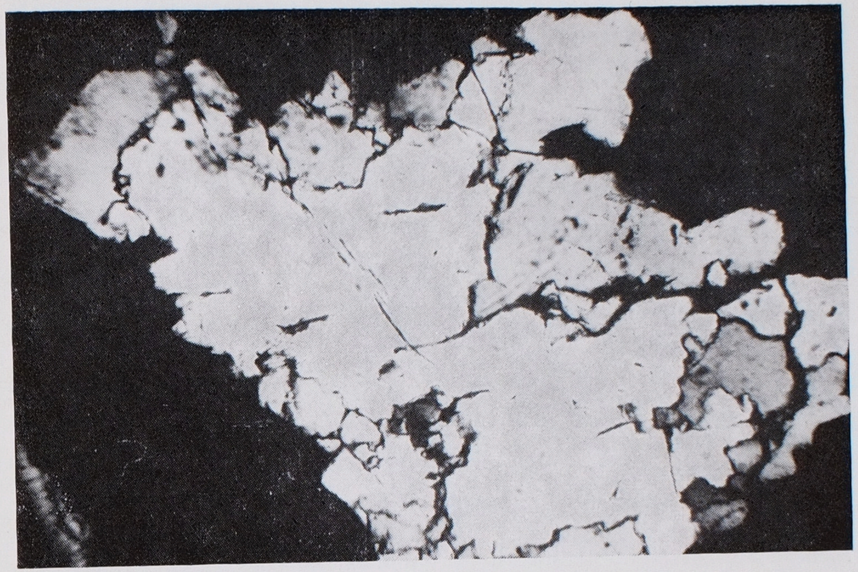
Фото 3. Кристаллизация каолинита, разрушающая агрегат кварца. Каолин месторождения Болеславице

Фото 4. Поверхность кварцевого зерна из каолинитовой зоны месторождения Болеславице. Электронный сканинг-микроскоп, увел. × 1000

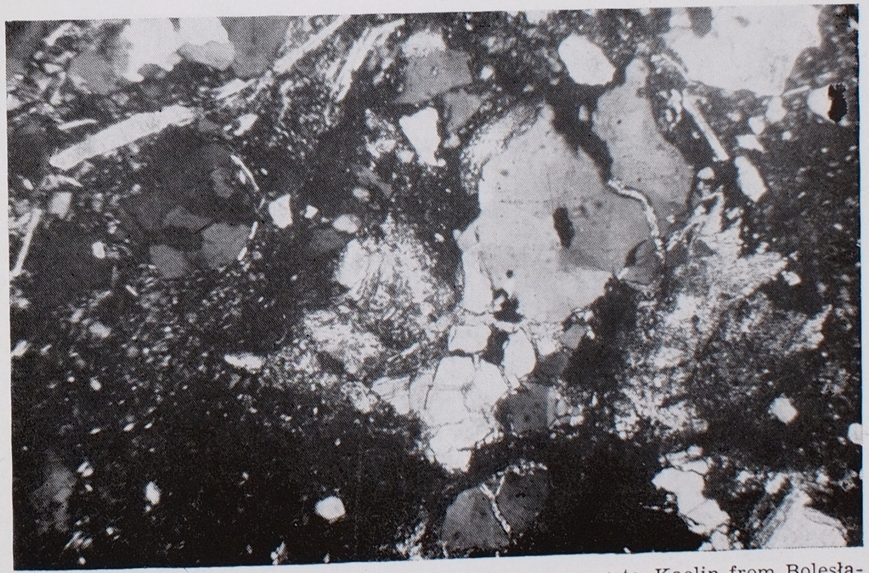
Фото 5. Поверхность кварцевого зерна из каолинит-слюдяной зоны месторождения Болеславице. Электронный сканинг-микроскоп, увел. × 3000

Фото 6. Сглаженная поверхность кварцевого зерна из каолина месторождения Розтока. Электронный сканирующий-микроскоп, увел. × 3000

Фото 7, 8. Кремнезём, образовавшийся на поверхность кварцевого зерна в каолине месторождения Болеславице. Электронный сканирующий-микроскоп, увел. × 3000



Phot. 1. Intergranular boundaries and fissures in quartz grains etched during weathering. Kaolin from Wyszonowice, Crossed nicols. ×160



Phot. 2. Crystallization of siderite wedging a quartz aggregate. Kaolin from Bolesławice. Crossed nicols × 160

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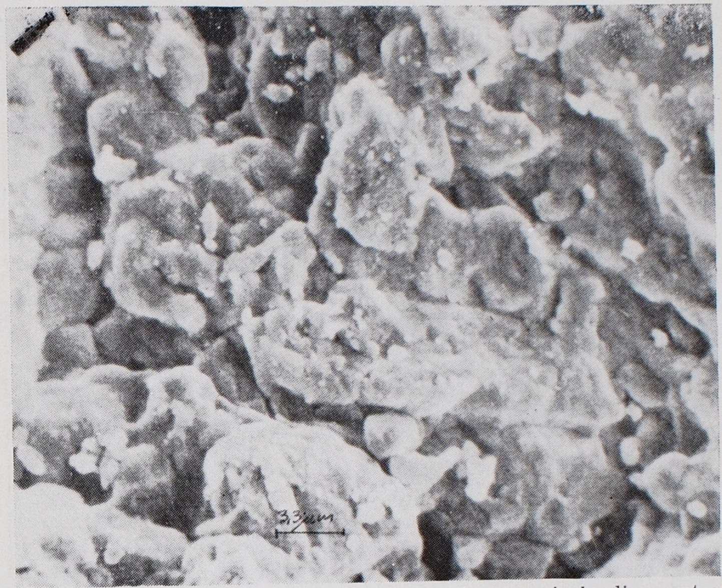
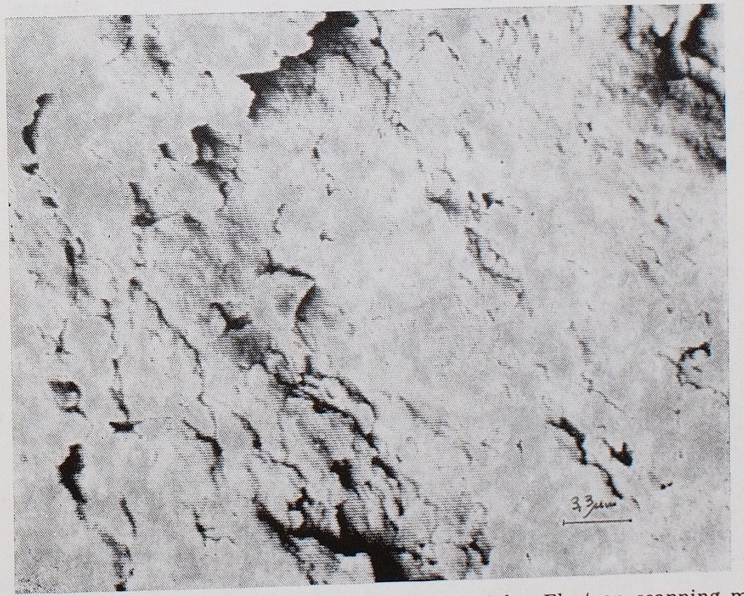
Phot. 3. Crystallization of kaolinite wedging apart an aggregate of quartz grains. Kaolin from Bolesławice. Crossed nicols. × 160

Phot. 4. Surface of a quartz grain from kaolinite zone of kaolin crust in Bolesławice. Electron scanning microscope. × 1000

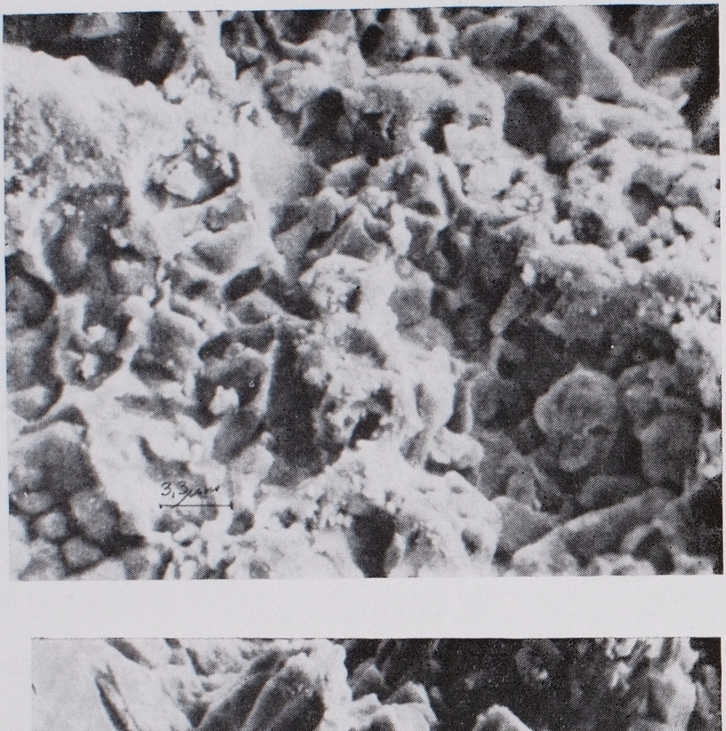


Phot. 5. Surface of a quartz grain from kaolinite-mica zone in kaolin crust of Bolesławice. Electron scanning microscope. × 3000



Phot. 6. Smoothed quartz surface from kaolin of Roztoka. Electron scanning microscope. × 3000

PLATE IV



Phot. 7, 8. Silica precipitated on the surface of quartz grains in kaolin from Bolesławice. Electron scanning microscope, × 3000

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