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AUTHIGENIC ALBITES OF CIESZYN LIMESTONE AND THEIR TWINNING

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Abstract. Authigenic albite from Cieszyn (Teschen) limestone usually occurs as epitaxial overgrowths on cores from detrial soda-feldspar. It shows, that the prevalent growth twinning is that of X-Carlsbad law. Albite twinned or untwinned grains are quantitatively quite subordinate. Optic properties, especially optic axial angle, refractive indices, as well as X-ray diffractometer data correspond to highly ordered low albites as do other known authigenic soda-feldspars. Both neocrystallized overgrowths and recrystallized (simultaneously carbonitized!) cores are structurally homogeneous. The high content of detrital feldspars in limestones, normally in form of cleavage shreds according to basal pinacoid, is responsible for the absence of completely developed X-Carlsbad fourlings and the dominant crystal habit.

INTRODUCTION

It has long been recognized that low-temperature minerals tend towards chemical purity. Low entropy of solid state favours not only restricted thermal movements of molecules and ions but also a scarceness of chemical diadochy.

A striking example of such interdependence is shown by chemical composition of mineral albite. Both high-temperature (*e.g.* volcanic) albite and metamorphic albite originating in lower temperatures are considered to have been rather chemically impure, displaying substitution of sodium by calcium, potassium, a.o. On the contrary, authigenic albite has practically none of the mentioned substitutors in remarkable quantities though concentration of Ca, K, a.o. elements in marine sediments is much elevated. This fact has some consequences in special physical properties or even peculiar crystal habit and twinning. This is not due to metasomatic replacement process only (compare metamorphic albites) but to specific p-t conditions of environment too. Present knowledge suggests that the metasomatic nature of albite crystal growth is commonplace, without exceptions.

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Several convincing examples of metasomatic mode of albite and quartz growth by replacement of calcareous fossils or pseudo-oolite in Cieszyn limestone has been noted by Peszat (1966) and the present author (see Fig. 1*A*). Further observations indicate that this process took place before the latest compaction phenomena (late diagenetic stage) as revealed by transsections of albite crystals with calcite compactional veinlets (Fig. 1*B*). The appearance of quartz crystals, usually of „Marmaros"-type habit, implies, parallel with albitization, mobilization and reprecipitation of silica in the form of authigenic quartz crystals and sometimes spherulites. There are many signs that these phenomena were not completed, as might be expected, before the dolomitization of limestones. All these reactions were influenced by high partial pressure of carbon dioxide. High chemical activity of this component accelerated leaching or precipitation of carbonate, as well as feldspar. That this relation holds well may be proved by the fact that the only effective feldspar syntheses were run in presence of carbonates and carbon dioxide.

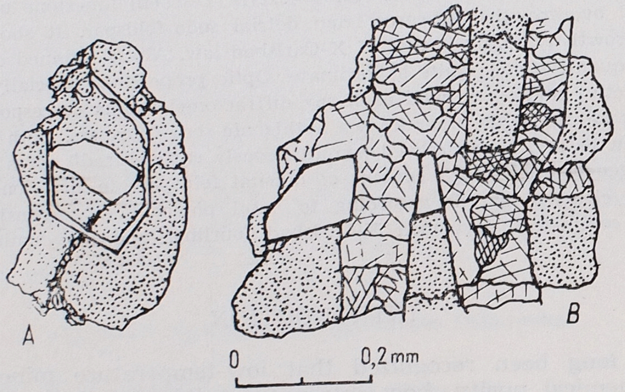

Fig. 1. Quartz crystal forming euhedral perymorph around small detrital quartz nucleus in a micrite of pseudoolite limestone from Lipowa (*A*).
Authigenic albite crystal transsected by late-diagenetic or epigenetic veinlets of coarse- and equigranular calcite in this same limestone (*B*)

The recognition of such source material for authigenic feldspars and secondary quartz excludes the presence of water and clay minerals as unnecessary oversimplifications, in view of abundance of detrital feldspar and quartz grains. Several profiles of Cieszyn (Teschen) limestones (Upper Tithonian-Berriasian) in the area of Cieszyn Silesia reveal constant admixture of terrigenic quartz and feldspar, especially albite. This is regularly true in the case of detritic and silty limestone, products of turbidity flows.

The content of clastogenic as compared with epitaxial or completely authigenic albite in these limestone varieties from Żywiec occurrences oscillated between 0.25 per cent (mean) or 2 per cent (maximum) and 2

or 14 per cent, respectively. The last value constituted 90 per cent of insoluble parts. The similar values for samples from Lipowa amounted: 0.6 or 0.8 and 1 or 7 per cent. The influence of contact-metamorphic alterations attributed to teschenite intrusions was discussed elsewhere (Wieser 1971). Some remobilization of feldspar matter was pointed out there. This leads to its full disappearance in nearest neighbourhood of magma body.

MORPHOGENETIC FEATURES

Grain size distribution of albite euhedra from Cieszyn limestone shows an evident approximation of dimensions to the greatest grain sizes of feldspar and quartz detrite. Occasionally they reach 0.27 mm; mean values oscillating between 0.05 and 0.15 mm.

The habit of authigenic albite is quite remarkable. Its platy or tabular shape, with roughly six-sided outlines, is more or less affected by elongation parallel to crystallographic a axis. The anisotropy of crystal growth, expressed in development of some crystallographic faces, is as follows (in diminishing order of prevalence of forms labelled after Dana nomenclature): *c* $\{001\}$, *b* $\{010\}$, *m* $\{110\}$, *M* $\{\bar{1}10\}$, *f* $\{130\}$, *z* $\{\bar{1}30\}$, and *p* $\{\bar{1}11\}$ (Fig. 6). There are also some vicinal or irrational surfaces x (*e.g.*, Fig. 2).

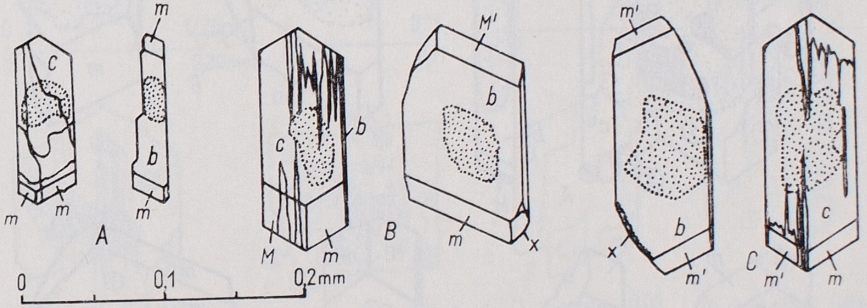

Fig. 2. Predominant shapes and habits of authigenic (epitaxial) albite grains in Cieszyn limestone from Lipowa and Żywiec localities. Doubly positioned crystal sketches display X-Carlsbad (grain *A*) and albite twin-law (grain *B* and *C*) Spotted areas indicate relict (detrital) soda-feldspar nuclei. Faces labelled after Dana nomenclature; x = irrational surfaces

In the identification of faces U-stage techniques of interfacial angles measurements proved to be much helpful. The statistical persistence of occurrence revealed that in 8 to 9 from 10 cases the best developed form was a basal pinacoid. This is justificated in terms of more excellent cleavage after *(001)* than *(010)*, visualized by higher frequency of cleavage shreds, constituting cores of epitaxial albite. These nuclei are well discernable on account of evident pelitization (weathering of primary, clastogenic albites).

The twinning phenomena create another important factor influencing morphogenetic features of authigenic albites or those of only epitaxial ones. This is especially evident considering growth twinning mechanism, which is responsible for the shape of crystals and for minor complications of crystal boundaries, such as concave interfacial angles (Figs 2—4). The presence or absence of twinning in relict cores is not without importance for the kind of twinning law in overgrowths. Untwinned cores seem to be particularly favourable to subsequent formation of X-Carlsbad twins. However, cores twinned after albite rule continue to develop in epitaxial albite without change, though modified in outline.

It is noteworthy, that the secondary growth twinning favours the development of fourlings, more frequently after X-Carlsbad than albite twin-law. Correct determination of these twins was completed only in last years. Some authors misinterpreted these even as Roc Tourné fourlings (Fig. 5). It must be said, however, that the distinction between X-Carlsbad and albite twins cannot be accomplished without difficulties. It is due to the existence of marginal differences in lattice orientation of corresponding subindividuals. Füchtbauer (1948) paid special attention to the displacement of lateral faces, which depends on the kind of the twin-seam forming faces. But the interfacial angle varying between 50′; 35,5′; 12,5′ is visible only if {*100*}, {*110*} and {*130*} forms, respectively, contact with each other (as {*100*} in Fig. 5*D*). This is, unfortunately, not noticeable in the case of authigenic albites from Cieszyn limestone. Belonging to incompletely developed fourlings they are devoid of central twin-seams (compare composition surfaces on Figs 2—4) as was also recorded by Füchtbauer (1948, Fig. 2, 4, a.o.) and many other workers.

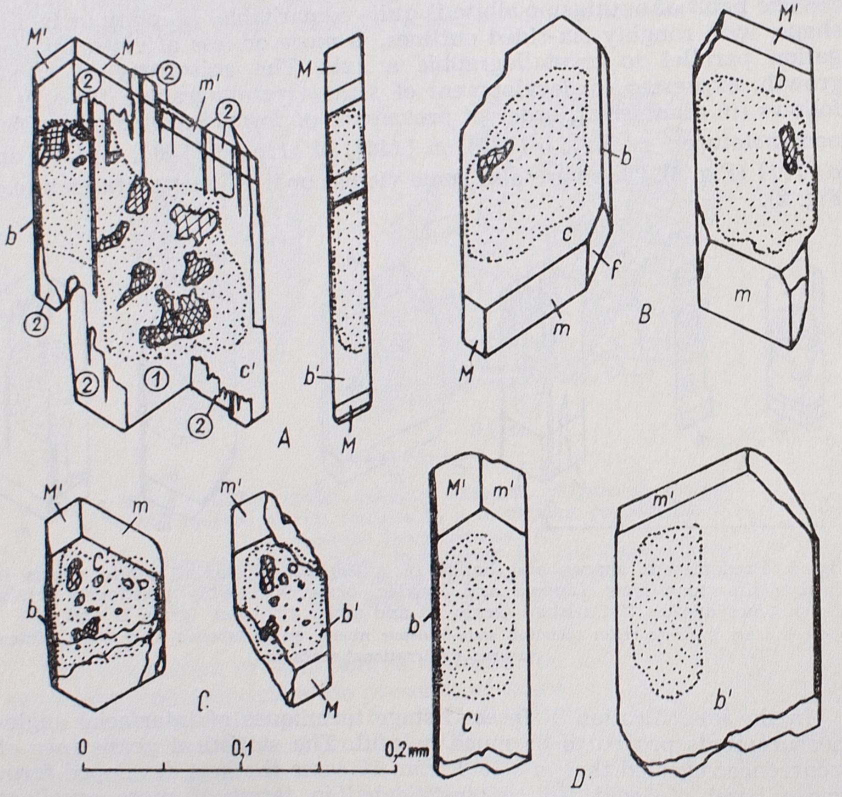

Fig. 3. Aberrant shapes and habits of authigenic albite grains from the same occurrences. The only twinned grain (*A*) shows albite- and possibly X-Carlsbad rule of twinning

Dottes areas — detrital nuclei locally carbonitized (grains *A — C*). Faces labelled after Dana nomenclature

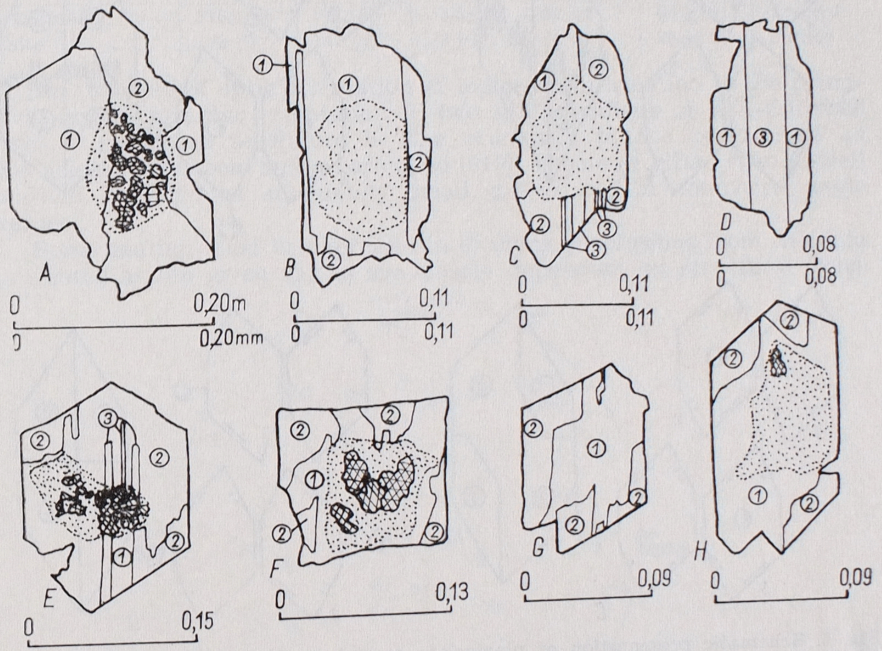

Fig. 4. Intersections (of thin slides) of X-Carlsbad (*A — C, E — H*) and albite law twins (*C — E*) of authigenic albite grains

Further explanations as in Figs 2 and 3

Likewise, here and there observable furrows (reentrants) on the lateral faces (*010*), produced usually by {*130*} forms and being connected with fully developed fourlings, are absent in here investigated examples too. As might be supposed, the composition surfaces in X-Carlsbad twins remember more the penetration twins than contact ones, developed as, *e.g.*, albite lamellae (Figs 2—4).

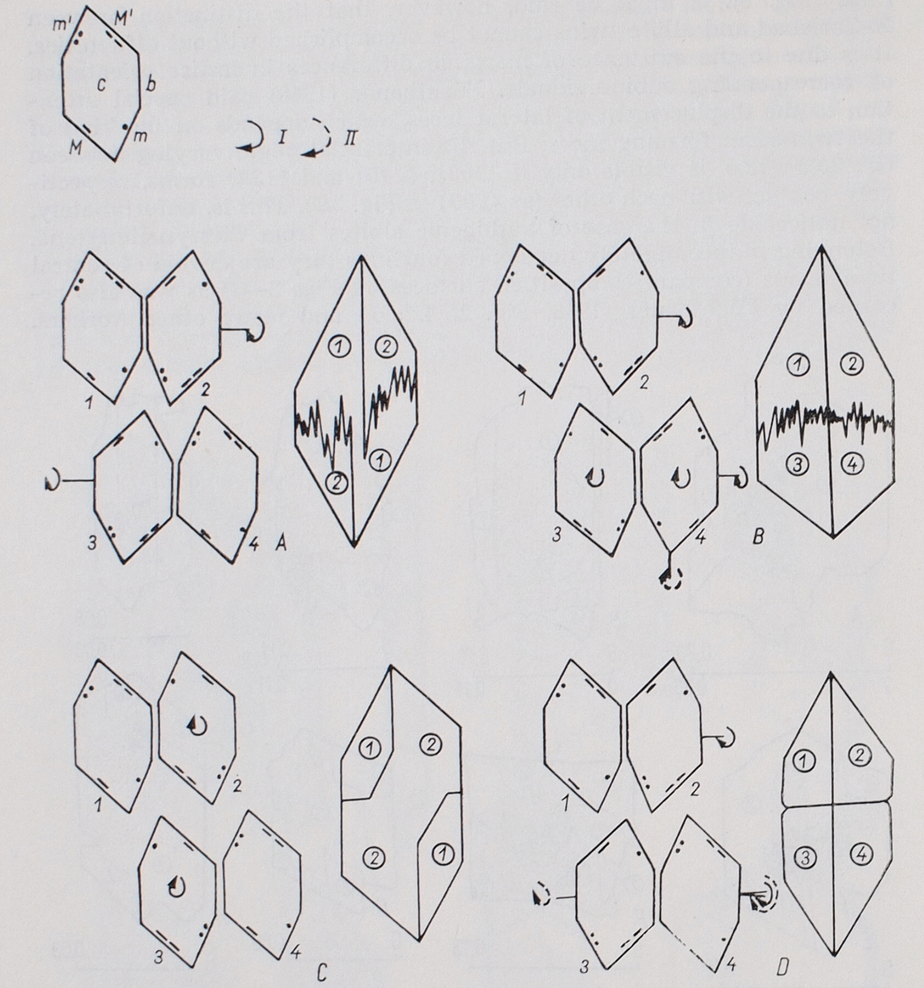

Fig. 5. Schematic presentation of plagioclase crystal fourlings twinned after albite (*A*), Roc Tourné (*B*), Carlsbad (*C*), and X-Carlsbad (*D*) twin laws and their origin
Note the rectilinear composition surfaces and parallelity of net planes in opposite quadrants of Carlsbad twins. Numbers denote the sequence of twinning operations and those in circles — subindividuals with separate lattice orientation; I — rotation, II — second kind rotation

OPTICAL PROPERTIES

Another approach toward the solution of the problem of identification of the growth twinning is based on optical parameters. These comprise specially the optic orientation of indicatrix in each subindividual,

including optic axes angles. The angles between mentioned optic vectors (Köhler's angles) were utilized by Kastner and Waldbaum (1968), as well as by Fisher (1968) as a mean in identification of X-Carlsbad twin-law. Comparison of those, comprising limits of error, with those of albite twin-law are tabulated below:

Twin-law	α/α′	β/β′	γ/γ′	A/A′	B/B′	Source
X-Carlsbad . . .	177,5±1°	147,5±1°	33±1°	82±1°	84±1°	Kastner,
albite	178±1°	146,5±1°	33±1°	83±1°	85±1°	Waldbaum (1968)
X-Carlsbad . . .	177°	146,5°	33°	82°	86°	Fisher
albite	178,5°	147°	33°	82,5°	85°	(1968)
X-Carlsbad . . .	176,5±1°	146,25±1°	33,5±1°	82±1°	86±1°	present
albite	178±1°	147±1°	33±1°	82±1°	86±1°	author

An example of optic orientation of indicatrix in relation to the primitive, crystallographic orientation in two subindividuals of a X-Carlsbad twin is presented in Figure 6. The proximity of the position of an X-Carlsbad twin pole and a normal to *(010)* = pole of albite twin is well marked. It explains adequately small differences in compared angle values.

Some caution must be exercised in drawing conclusions from the data presented as the given values are clearly dependent on structural (tem-

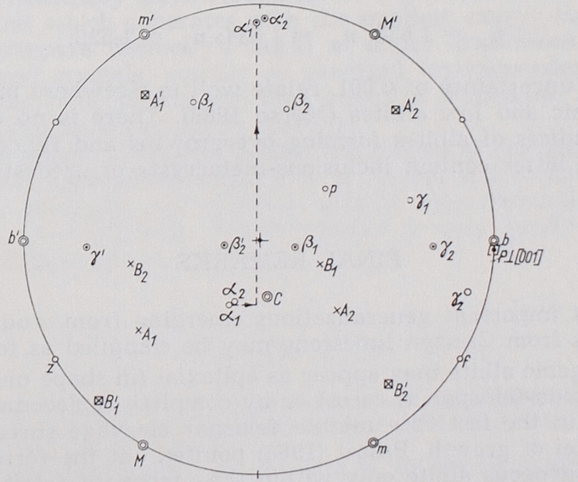

Fig. 6. Stereographic projection (upper hemisphere) showing original and shifted position of indicatrix and optic axes A, B, versus geometric primitive orientation of albite crystal (Żywiec)
The relative size of circular symbols for crystallographic faces is shown in order of their prominence in all examined grains. The proximity of pole of X-Carlsbad twin and axis b, normal to the albite-twin composition surface, is very evident

perature) state of plagioclase. Whether this relation should be attributed only to geometric (twinning) transformations or to structural state is a matter of X-ray examinations. These show unexpected uniformity of lattice dimensions in recently investigated authigenic albite overgrowths, as well as in the detritic albite relicts.

The following X-ray data *: $2\Theta(131) — 2\Theta(1\bar{3}1) = 1.10$ and $2\Theta(\bar{2}41) — 2\Theta(\bar{2}\bar{4}1) = 1.75$ correspond well with those of acid members of the low plagioclase series (Bambauer *et al.* 1962, Figs. 5, 6), namely almost pure or pure albite with highest Al/Si-ordering. It is not a surprising fact as the albite neo- and recrystallization took place slowly and in the presence of water, acting as an efficient catalyst.

Conclusion implying the completely ordered state (I.I = intermediacy index = 100) combined with virtually pure composition of soda-feldspar is supported by some optical properties. Optic axes angles ($2V_\gamma$), measured by the present author, varied between 84,5° and 85,5°; mean = 85° with uncertainty of 0,5°. Shutov and Muraviev (1966) give the mean values of 87° and 88°, whereas Füchtbauer (1956) — 85° to 91° for all specimens of authigenic albites published until now. The last mentioned author compares these values with those for spilite albites = 79 ÷ 88° and low albites = 76 ÷ 80° (corresponding to Kastner's and Waldbaum's albites from pegmatites and metamorphic rocks with $2V_\gamma = 75 \div 82°$).

Chemical purity of authigenic albites may be also deduced from indices of refraction. They were determined by the immersion and spindle stage method at 20°C in Na light. The following mean values are:

$$n_\gamma = 1{,}538;\ n_\beta = 1{,}534;\ n_\alpha = 1{,}529.$$

All with uncertainty of 0,001, relate well to elsewhere published data for authigenic and low albites (Morse 1968). There is no difference in refractive indices of albites forming overgrowths and relict cores, especially if the latter contain inclusions-metacrysts of „redestributed" calcite.

FINAL REMARKS

The most important generalizations emerging from studies of authigenic albites from Cieszyn limestone may be compiled as follows:

1. Authigenic albite may appear as epitaxial (in shape of overgrowths on detrital soda-feldspar as cores) or by complete replacement of carbonates. Also in the last case minute feldspar cleavage shreds were serving as nuclei of growth. Peszat (1966) pointed out the formation of coreless, homogeneous albite only within the carbonate detrite grains.

2. The shape of plagioclase cleavage shreds determines the habit of albite neocrysts. Therefore, it is tabular, especially according to basal pinacoid.

* Determined with Rigaku-Denki X-ray diffractometer, CuK_{α_1} radiation, Ni-filtered.

3. There are many signs indicating the mechanism of growth by replacement of carbonate matter. The advanced roundness of cores in epitaxial albites induces some „incorporation" (resorption) of clastogenic by authigenic feldspar. This is readily convincing when cores are rich in calcite poikilitic metacrysts (bimetasomatic phenomena). It should be noted that there is no difference in optic properties between such neo- and recrystallized albite.

4. The only rules of twinning in growing albites are represented by albite and X-Carlsbad laws. The albite twins were partly formed as prolongations of albite lamellae in detrital cores, if present. The X-Carlsbad twins were recognized as generating only in overgrowths in association of or without albite twins. Untwinned crystals are rather exceptional.

5. The identification of twinning laws in authigenic albites is simple in completely developed fourlings. In other examples very indicative is the shape and orientation of composition surfaces, as well as angles between optic vectors in each subindividual.

6. The subindividuals of X-Carlsbad twins are regularly oriented so that the opposite quadrants are of the same lattice orientation, corresponding more to the example *C* than *D* on Fig. 5. The composition surfaces, though irrational, tend to approximate (*100*) if between adjacent subindividuals and (*010*)-in albite twins only.

7. It seems that Donnelly's (1967) assumption regarding twinned crystal growth as „a kinetic process, in which the resulting forms reflect more rapid rather than more stable directions of growths" is more valid than that advocated by Kern (1961). According to Kern the most favoured twin is that which generates with the smallest energy increase. Such arguments (compare Donnelly's work) as larger dimensions of twinned than untwinned crystals, equally as genetical interdependence of twinning with rapidity of growth and high viscosity of medium, may also be postulated basing on investigated material.

8. The examined authigenic albites are indeed of common parentage. This judgement arises from uniformity of optical and structural properties between neocrysts and between detrital core forming plagioclase, more or less recrystallized. Potash-feldspar is only rarely covered by thin overgrowths of albite.

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ALBITY AUTIGENICZNE Z WAPIENI CIESZYŃSKICH I ICH ZBLIŹNIACZENIA

Streszczenie

W wapieniach cieszyńskich z okolic Żywca stwierdzono występowanie autigenicznego albitu najczęściej w postaci epitaktycznych zrostów na detrytycznych skaleniach sodowych. Odłupki powstałe wzdłuż płaszczyzn łupliwości zgodnych z dwuścianem podstawowym były nie tylko zalążkami neokrystalizacji, lecz również decydowały o ogólnym pokroju i habitusie ziarn. Panującym zbliźniaczeniem u neokryształów jest typowo wzrostowe zbliźniaczenie X-karlsbadzkie. Wielka liczba okruchów będących zalążkami spowodowała, iż zbliźniaczone kryształy nie są wykształcone w postaci kompletnych czworaków. Rozpoznanie bliźniaków X-karlsbadzkich w tym przypadku ułatwia przebieg i kształt szwu bliźniaczego oraz orientacja optyczna indykatrysy.

Dane optyczne neokryształów, szczególnie kąty osi optycznych oraz dane rentgenograficzne, odpowiadają — podobnie jak i znanych albitów autigenicznych o najwyższym stopniu uporządkowania, niskotemperaturowym, czystym skaleniom sodowym. Identyczność tych cech zarówno w narosłych neokryształach, jak i w rekrystalizowanych reliktowych jądrach (szczególnie przy równoczesnej ich karbonatyzacji) wskazują na pełną, strukturalną i chemiczną homogenizację skaleni. Wzrost albitu autigenicznego odbywał się przez metasomatyczne zastąpienie osadu wapiennego, głównie turbidytowego, w późnodiagenetycznym okresie, a więc po jego solidyfikacji, lecz przed powstaniem strzałki kalcytowej.

OBJAŚNIENIA FIGUR

Fig. 1. Kryształ kwarcu tworzący euhedralną perymorfozę wokół małego ziarna detrytycznego kwarcu jako zalążka w mikrycie wapienia pseudooolitowego z Lipowej (*A*). Kryształ autigenicznego albitu przecięty późnodiagenetycznymi lub epigenetycznymi żyłkami grubo- i równoziarnistego kalcytu w tymże wapieniu (*B*)

Fig. 2. Przeważające postacie i habitusy autigenicznych (epitaktycznych) ziarn albitu w wapieniu cieszyńskim z występowań w Lipowej i Żywcu. Rysunki kryształów w dwu położeniach ujawniają X-karlsbadzkie (ziarno *A*) i albitowe zbliźniaczenie (ziarna *B* i *C*)

Zakropkowane pola — jądra reliktowego (detrytycznego) skalenia sodowego. Oznaczenia ścian według nomenklatury Dany; *x* — powierzchnie irracjonalne

Fig. 3. Aberrantne postacie i habitusy autigenicznych ziarn albitu z tych samych wystąpień. Jedynie zbliźniaczone ziarno (*A*) wykazuje albitowe i przypuszczalnie X-karlsbadzkie zbliźniaczenie
Zakropkowane pola — detrytyczne jądra lokalnie skarbonatyzowane (ziarna *A* — *C*). Oznaczenia ścian według nomenklatury Dany

Fig. 4. Płytki cienkie bliźniaków X-karlsbadzkich (*A* — *C*, *E* — *H*) i albitowych (*C* — *E*) ziarn autigenicznych albitu
Pozostałe objaśnienia zob. fig. 2 i 3

Fig. 5. Schematyczne ujęcie czworaków kryształów plagioklazów zbliźniaczonych według prawa albitowego (*A*), Roc Tourné (*B*), karlsbadzkiego (*C*) i X-karlsbadzkiego (*D*) oraz ich geneza
Zwraca uwagę prostoliniowość szwów bliźniaczych i równoległość płaszczyzn sieciowych w naprzeciwległych kwadrantach bliźniaka karlsbadzkiego. Cyfry wskazują kolejność operacji bliźniaczych, a zawarte w kółkach — subindywidua o oddzielnej orientacji sieci przestrzennej; *I* — prosta operacja symetryczna, *II* — złożona operacja symetryczna

Fig. 6. Projekcja stereograficzna (półkula górna) ukazująca pierwotne i reorientowane położenie indykatrysy i osi optycznych *A*, *B* względem wyjściowej orientacji geometrycznej kryształu albitu (Żywiec)
Względna wielkość kołowych symboli dla ścian krystalograficznych jest przedstawiona według ich ważności u wszystkich badanych ziarn. Bliskość bieguna bliźniaka X-karlsbadzkiego i osi *b*, normalnej płaszczyzny bliźniaczej bliźniaka albitowego, jest dobrze widoczna.

Тадеуш ВИЗЕР

АУТИГЕННЫЕ АЛЬБИТЫ ИЗ ЦЕШИНСКИХ ИЗВЕСТНЯКОВ И ИХ ДВОЙНИКИ

Резюме

В цешинских известняках, распространенных в районе местности Живец, наблюдался аутигенный альбит, чаще всего в виде эпитаксических срастаний на обломках натриевого полевого шпата. Обломки согласные со спайностью по основному пинакоиду не только являлись центрами неокристаллизации, но определяли также общий габитус кристаллов. Господствующим видом двойникового срастания новообразованных кристаллов являются типичные двойники роста по X-карлсбадскому закону. В связи с большим количеством обломков, послуживших центрами кристаллизации, процесс срастания не развился до образования совершенных четверников. Определение X-карлсбадских двойников в данном случае основывается на положении и форме двойникового шва и оптической ориентировке индикатрисы.

Оптические константы, в особенности углы оптических осей, и рентгенографические данные исследованных альбитов, как и других аутигенных альбитов, отвечают наиболее упорядоченным, низкотемпературным, чистым натриевым полевым шпатам. Совпадение этих признаков как в новоразвитых кристаллах, так и в перекристаллизованных, реликтовых ядрах (особенно при их одновременной карбонатизации), свидетельствует о полной — структурной и химической — гомогенизации шпатов. Рост аутигенного альбита совершался путем метасоматического замеще-

ния известкового осадка, главным образом турбидитового, в позднедиагенетическую стадию, следовательно после его солидификации, но до образования кальцитовой „стрелки".

ОБЪЯСНЕНИЯ К ФИГУРАМ

Фиг. 1. Кристалл кварца, образующий идиоморфный периморфоз вокруг маленького обломочного зерна кварца, представляющего центр кристаллизации в микрите псевдо-оолитового известняка в обнажении Липова (*A*). Кристалл аутигенного альбита, пересеченный позднедиагенетическими или эпигенетическими прожилками крупнозернистого и равнозернистого кальцита в том же известняке (*B*)

Фиг. 2. Преобладающие виды и габитусы аутигенных (эпитаксических) кристаллов альбита в цешинском известняке, по обнажениям Липова и Живец. Рисунки кристаллов в двух положениях показывают двойникование по X-карлсбадскому (зерно *A*) и альбитовому (зерна *B* и *C*) законам

Пунктирные поля — ядра реликтового (обломочного) натриевого полевого шпата. Обозначения граней по номенклатуре Дана; *x* — иррациональные поверхности

Фиг. 3. Аберрантные виды и габитусы аутигенных кристаллов альбита из обнажений, перечисленных в фигуре 2. Единственное двойникованное зерно (*A*) проявляет альбитовое и, вероятно, X-карлсбадское двойникование

Пунктирные поля — обломочные ядра, местами карбонатизированные (зерна *A* — *C*). Обозначения граней по номенклатуре Дана

Фиг. 4. Шлифы X-карлсбадских (*A* — *C*, *E* — *H*) и альбитовых (*C* — *E*) двойников аутигенного альбита

Объяснения как к фигуре 2 и 3

Фиг. 5. Схемы плагиоклазовых четверников, двойникованных по альбитовому (*A*), Рок-Тюрне (*B*), карлсбадскому (*C*) и X-карлсбадскому (*D*) законам, и их генезис

Отмечаются прямолинейные двойниковые швы и параллельные плоскости решеток в противоположных квадрантах карлсбадского двойника. Цифры показывают последовательность операций двойникования, цифры в кружках обозначают субиндивиды с другой ориентировкой пространственной решетки; *I* — простая симметрическая операция, *II* — сложная симметрическая операция

Фиг. 6. Стереографическая проекция (верхнее полушарие), изображающая первичное и измененное положение индикатрисы и оптических осей *A*, *B* по отношению к исходной геометрической ориентировке кристалла Альбита (Живец)

Величина круговых знаков кристаллографических граней показана соответственно их значению во всех исследованных зернах. Близость полюса X-карлсбадского двойника и оси *b* — нормальной двойниковой плоскости альбитового двойника не вызывает сомнений