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TWIN INTERGROWTH OF PLAGIOCLASES IN GLOMEROPHYRIC ANDESITES OF THE PIENINY MTS. IN POLAND

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Abstract. Plagioclase phenocrysts of volcanic rocks of the Pieniny Mts. are typically high-temperature in character, displaying well developed recurrent zonal structure and fairly complicated twin-glomerophyric aggregations. The latters were the subject of detailed investigations, the results of which are exemplified by means of 8 grains (Fig. 1—8). In general, they from complicated intergrowths consisting of several, or even a dozen of individual crystals. The latters, in turn, consist usually of twin subindividuals, generally intergrown according to Pericline and Albite laws. It was necessary to examine all the possible combinations, the number of which (N_c) depends on the amount (n) of differently oriented subindividuals and is expressed by the equation: $N_c = \frac{n^2 - n}{2}$. The twinning degree $D = \frac{N \times 100}{N_c}\%$ (N — the number of twin relations) characterizes in general geometrical relations observed within glomerophyric plagioclase intergrowths. Another feature of these intergrowths is the presence of numerous twin laws in them. There occur nearly all these found in plagioclases and orthoclase and nearly 20 unknown laws.

The results of these studies of glomerophyric intergrowths of plagioclases can be summarized as follows: 1 — There are no accidental intergrowths in them; 2 — All the intergrowths in question are based on twin laws; 3 — The simple laws display further geometrical relations resulting in complex twin intergrowths; 4 — A complex intergrowth represents a closed cycle of twin transformations and shows higher pseudosymmetry — from trigonal to cubic; 5 — Pseudosymmetric systems can be deduced by appropriate operations of twin triad, producing various types of them; 6 — In glomerophyres consisting of larger amount of individuals, several types of pseudosymmetric systems are formed which, in turn, can originate superior pseudosymmetric systems; 7 — Complex twin (including all the individuals contained in them) explain twinning phenomena in individuals, displaing no direct contacts.

Volcanic rock series occurring in the environs of the Pieniny Mts. in Poland consists of nearly dacitic varieties, amphibole and augite-amphibole andesites including even a basaltic member. All the rocks in question display typical porphyric texture. Euhedral amphibole, augite and plagioclase phenocrysts are embedded in fine to medium-grained matrix. They are up to several milimetres in diameter. Plagioclases are typically high-

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-temperature in character, displaying well developed recurrent zonal structure (Gumowska, 1964), and fairly complicated twin-glomerophyric aggregation. Generally they are quite fresh, thus presenting a very suitable material for complex investigations.

Plagioclase phenocrysts, particularly the larger ones, only rarely occur as individual crystals. In general they form complicated intergrowths consisting of several or even a dozen of individual crystals. The latters, in turn, consist usually of twin subindividuals, generally intergrown according to Pericline and Albite laws.

Individual grains can easily be distinguished because of well developed zonal structure. The anorthite content in these zones ranges from 32 to 60% (for amphibole andesites), whereby the commonest composition is 40 — 47% An corresponding to average anorthite content in phenocrysts under examination (Gumowska, 1964). Very characteristic is regular development of their external crystallographic faces, whilst composition planes within grains are often irregular in shape.

This type of phenocrysts was examined in detal by the present author in order to reveal the spatial relations between individuals contained in them. Detailed investigations by means of universal stage method have shown that these intergrowths show high degree of geometrical regularity.

Preliminary examinations have shown that the majority of individuals, even those displaying no direct intergrowths, exhibits twinning relations. Therefore, it was necessary to examine all the possible combinations, the number of which (N_c) depends on the amount (n) of differently oriented subindividuals or individuals. The relations are expressed by the equation: $N_c = \frac{n^2 - n}{2}$. For the grains studied the number of possible combinations was up to 100.

The value of D was computed from the formula: $D = \frac{N \cdot 100}{N_c}$ (where N is the number of twin relations) determining the twinning degree of a glomerophyre. This degree is often over 50%. Consequently it characterizes in general geometrical relations taking place within glomerophyric plagioclase intergrowths.

Another feature of these intergrowths is the presence of numerous twin laws in them, including those which were not yet described. When comparing them with the number of all the laws known thus far (Burri *et al.*, 1967) we see that of the possible 29 — 14 were found to occur in plagioclases and 9 — in orthoclases. Nearly 20 laws were not indentified in feldspars under examination.

All the distinguished laws can be subdivided into two groups: a — occurring within individuals and connected with the earliest crystallization stage, and b — displaying relations between individuals and thus connected with later crystallization stage. Albite, Pericline, sometimes Carlsbad, Roc Tourné, Manebach and Scopi laws were assigned to the first group, whereas all the remaining to the second one. These are Carlsbad, Roc Tourné, Manebach and Scopi too and less common: Baveno right and left, Estérel, $\perp(100)$, $\perp(1\bar{3}0)$, $\perp(130)$. Moreover, to these group some laws were assigned which were not yet reported to occur in plagioclases: $\perp(1\bar{1}0)$, $\perp(110)$, $\perp(\bar{1}11)$, $\perp(\bar{1}\bar{1}0)$, $[110]$, $[1\bar{1}0]$, $[\bar{1}12]$, $[\bar{1}\bar{1}2]$ and completely

unkown thus far: $\perp(\bar{2}\bar{2}1)$, $\perp(\bar{2}21)$, $\perp(121)$, $\perp(011)$, $\perp(0\bar{1}1)$, $\perp(101)$, $[112]$, $[\bar{0}12]$, $[\bar{1}21]$, $[101]$, $\frac{\perp[010]}{(101)}$, $\frac{\perp[\bar{1}21]}{(101)}$, $\frac{\perp[101]}{(010)}$, $\frac{\perp[\bar{1}10]}{(001)}$, etc.

In order to explain geometrical relations between these laws, some short introduction is necessary.

Plagioclases crystallize in triclinic symmetry but in nature they usually appear as twinned individuals of higher pseudosymmetry. According to the theory of twinning development of minerals (Vardanyantz, 1950), plagioclases can be transformed into pseudo-monoclinic, rhombic, trigonal, hexagonal, tetragonal and pseudo-cubic block. Taking into account weak triclinity of plagioclases and their tendency to regular pseudosymmetry, Burri (1967) considers them to be pseudo-cubic. Consequently he calls different twinning intergrowths as pseudohexaedral, pseudooctahedral, pseudododecahedral and pseudodeltahedral.

From geometrical point of view, all the systems of symmetry represent spatial arrangement of diad rotation axes. Thus, in monoclinic system there is one diad axis, in rhombic — 3 mutually perpendicular, in trigonal — 3 diads situated in one plane at 60° relative to each other, in tetragonal — 4 axes in one plane at 45°, in hexagonal — 6 axes in one at 30° and in cubic system there occur 6 diads so arranged in space that the axes of the nearest triad are situated 60°, 60° and 90° among each other.

In is easy to demonstrate that by rotating the monoclinic system trough 180° about the axis situated at 60° with its symmetry axis we obtain trigonal system. Similarly, if such axis is situated at 45°, the resulting system displays tetragonal tendency, if at 30° — hexagonal tendency, 90° — orthorhombic system, since, as follows from Euler's theorem, two perpendicular diads create third one, perpendicular to them. Similarly, by rotating orthorhombic system and around a diad, perpendicular to one of its axis and situated at 45° with regard to second one — we obtain tetragonal system and if this angle amounts to 30° — hexagonal one.

Cubic system can be obtained by analogical operations of orthorhombic one around three mutually perpendicular diad axes, which with two diads of the former system are oriented at 60°, 60°, 45° and with the third — at 90°, 45°, and 45°.

These geometric regularities occur in spatial relations between individuals developed in twinned forms or between twinned aggregates. It should be emphasized that from theoretical point of view such relations can exist in all these cases when angular distances between twin axes are the same or close to the above mentioned.

Such is the origin of complex twins of higher order (*i.e.*, displaying higher symmetry than orthorhombic — twin triads) which were found to occur in all the glomerophyric intergrowths of plagioclases under investigation. These twin complex intergrowths display various pseudosymmetry — from trigonal to cubic. They originate by combination of various twin laws which within individual systems of symmetry form their specific types. In general, their stereographic projections differ from ideal model, depending on deviation of twin axes from theoretical ones.

Complex intergrowths are formed by twinning of originally twinned individuals. Consequently, aparat from *essential twin-axes* formed by one pair of subindividuals, there appear *secondary axes* — of the remaining pairs. The latter directions not always correspond to definite crystallographic ones, being often bisectrices between them. Essential and secondary axes form a *coupled system* and subindividuals connected with them — *closed transformation cycles*.

Essential axes are often bisectrices in character. Consequently, pseudosymmetrical systems are often very close to ideal models. Nevertheless, in some cases the situation might be different.

Moreover, complexity of this phenomenon consists in the fact, that individuals (aggregates) participating in these intergrowths not always contain the same number of subindividuals and show either identical or different twinning. Finally, the same individual can participate in more than one complex intergrowth. Sometimes this can lead to the formation of a system showing higher symmetry or even to the origin of two or more systems. If individuals are represented by albite-pericline twins, there always originate two identical systems, displaying slight mutual rotation.

When examining spatial relations in glomerophyric intergrowths, the present author tried often to construct ideal projections, tending to simplify the phenomenon in question and explain the mechanism of formation of a complex intergrowth. Individual types of pseudosymmetry systems were described by means of symbolic formulas proposed by present author.

EXAMPLES OF SOME TYPES OF TRIGONAL, TETRAGONAL, HEXAGONAL AND CUBIC PSEUDOSYMMETRY

A. Pseudotrigonal system is formed by rotation of a twin-pair about the axis, forming with its axis the angle of approx. 60°.

This symmetry is exemplified by a grain presented in Fig. 1*a*, *b* (amphibole andesite of Ścigocki stream — 5/17), in which two similar types were found to occur:

$$Ab \cdot Ab \Big/ \frac{\perp(110)}{b\perp(1\bar{1}0)} \quad L^3 = Z$$

$$P \cdot P \Big/ \frac{\perp(110)}{b\perp(1\bar{1}0)} \quad L^3 \approx Z$$

Above the line in these symbols — direction of essential twin-axis is presented, whilst below — that of secondary one. Bisectrix is denoted by "b".

Subindividual A_1 with B_1 of the albite-pericline AB individuals was intergrown according to the direction $\perp(1\bar{1}0)$. Consequently, two coupled pseudotrigonal intergrowths were formed: one connected with albitic subindividuals and the second — with pericline ones. The degree of twinning $D = 47\%$.

Another examples of this symmetry were formed in pseudocubic system.

B. Pseudotetragonal system is formed by rotation of twin-triads about the axis perpendicular to one of its axes and oriented at 45° with regard to its second one.

The commonest type of this symmetry can be expressed as follows:

$$2 \cdot M : Sc : P \Big/ \frac{\perp(021) : Sc : \perp(0\bar{2}1)^{*}}{b\perp(0\bar{2}1) : Sc : \perp(021)} \quad L^4 = X$$

It is formed by combination of two triads Manebach : Scopie : Pericline ($M : Sc : P$) with essential triad Baveno-r : Scopie : Baveno-l, resulting from a combination of Scopie and Baveno laws. Another similar type:

$$2 \cdot Ab - A : Es : Ab \Big/ \frac{\perp(021) : Es : \perp(0\bar{2}1)^{**}}{b\perp(0\bar{2}1) : Es : \perp(021)} \quad L^4 = X$$

originates by combination of triads of the type: Albite — Ala : Estérel : : Albite ($Ab - A : Es : Ab$). This triad is rotated by 4° about X axis when compared with the triad $M : Sc : P$. Because of their similarity, they can

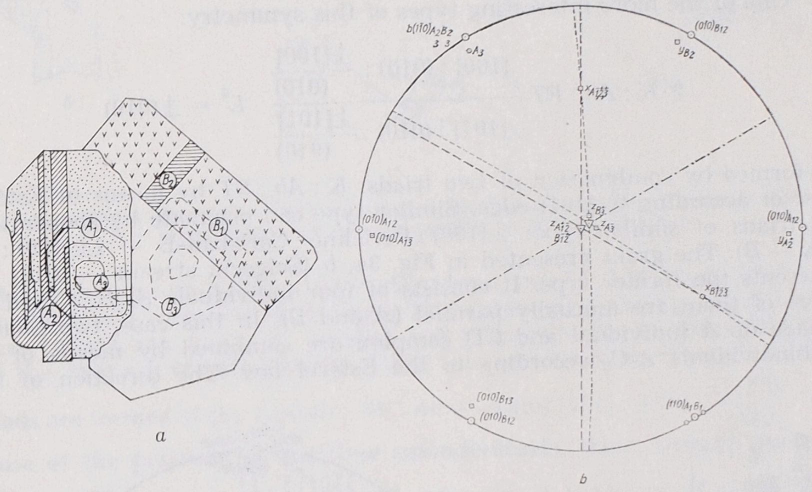


Fig. 1. *a* — plagioclase grain (average — $An_{40.5}$). Hornblende andesite, Ścigocki stream; *b* — stereographic projection $\perp[001]_{A_{1,2} B_{1,2}}$: — — — — twin plane of subindividuals of the same individual, — · — · — · — · twin plane of subindividuals of different individuals, ... twin plane of subindividuals of hypothetical individuals

operate together and a third — intermediate — type of pseudotetragonal system is formed. Another types appear in pseudocubic symmetry.

The grain presented in Fig. 2*a*, *b* (Malinowa quarry — 15/10) illustrates all the three above described cases. It consists of seven individuals *A*, *B*, *C*, *D*, *E*, *F* and *G*. A individual and $B_{1,3}$ E_2 complex form triads of $M : Sc : P$ type, whilst $A_{2,3}$ D_2 and $B_{1,2}$ $E_{1,2}$ complexes — triads of the $Ab : Es : Ab - A$ type. Since some of these individuals appear both in pericline-albite twins, there occur not three but two pseudotetragonal systems (Fig. 2*b*).

* $\sphericalangle(0\bar{2}1)/(021) \approx 90°$ for An_{43}

** For plagioclase An_{43} Scopie = Estérel law $\left(\frac{\perp[010]}{(001)} = [100]\right)$.

Moreover, there occurs here another triad Albite : Carlsbad : Roc Tourné ($Ab : K : RT$) in the complex $A_{1,5}$ $C_{3,4}$ and a special rare type of triad $[1\bar{1}0] : (001) : \frac{\perp[1\bar{1}0]}{(001)}$ formed between G individual and Manebach twin $A_{1,3}$, parallel with $F_{1,2}$ individual. Position of these two triads with regard to tetragonal system resembles the distribution of elements in pseudocubic symmetry. This intergrowth can be considered as a type of superior symmetry resulting from superposition of systems of lower symmetry. Formation of this type of symmetry, the twin relations of which do not result from above presented definitions, is common in glomerophyres under examination. The degree of twinning $D = 39.5\%$.

C. Pseudohexagonal system is formed by rotation of a twin triad about an axis perpendicular to one of its axis and oriented at the angle of 30° with regard to the second one.

One of the more interesting types of this symmetry:

$$2\cdot K : Ab : RT \Big/ \frac{[100] : (010) : \dfrac{\perp[100]}{(010)}}{[101] : (010) : \dfrac{\perp[101]}{(010)}} \qquad L^6 = \perp(010)$$

is formed by combination of two triads: $K : Ab : RT$ by means of Estérel law or according to [101] edge. Similar type can originate by cooperation of triads of similar type: $\perp(100)$: Pericline : Carlsbad-B — ($\perp(100) : P : K — B$). The grain presented in Fig. 3*a*, *b* (Ścigocki stream — 9/18) represents the former type. It consists of four individuals A, B, C and D. Two of them are mutually parallel (A and B). In this case, two double triads of A individual and CD complex are combined by means of its subindividuals A_2C_2 according to the Estérel law. The direction of the

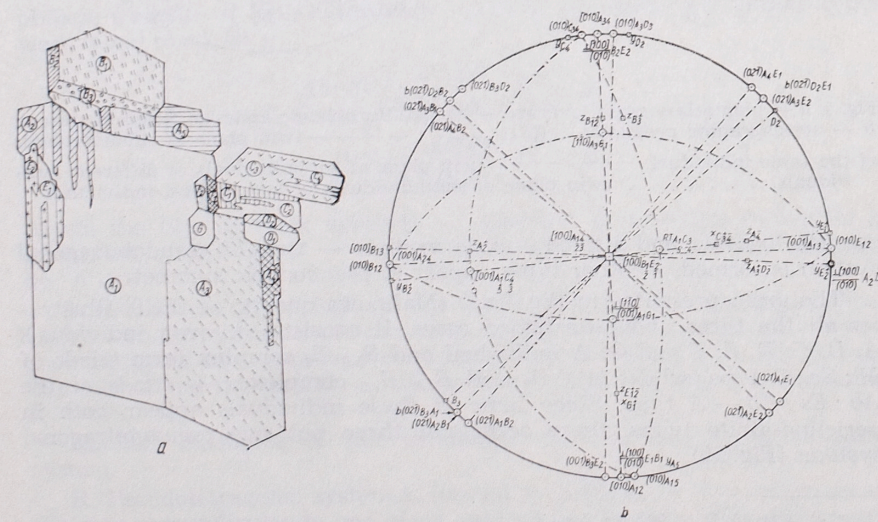


Fig. 2. *a* — plagioclase grain (average — An_{44}). Hornblende andesite, Malinów quarry; *b* — stereographic projection $\perp[100]_{A,\,B,\,E}$

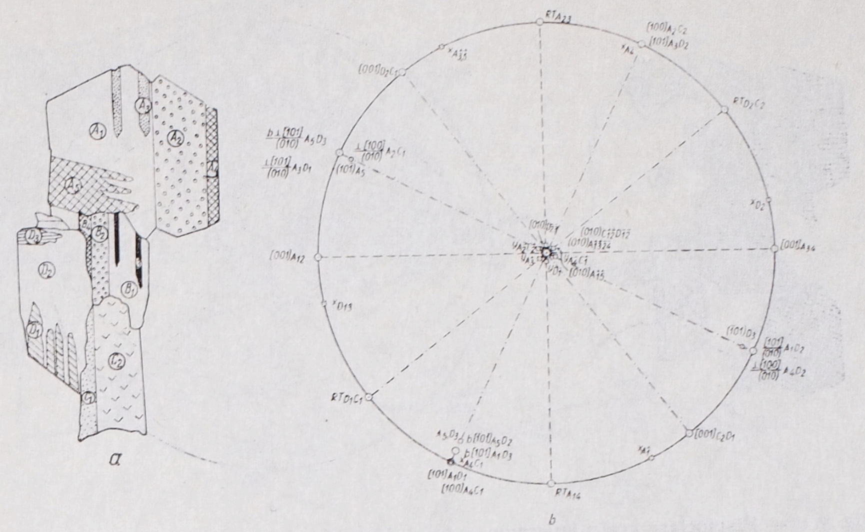


Fig. 3. *a* — plagioclase grain (average — $An_{40.5}$). Hornblende andesite, Ścigocki stream; *b* — stereographic projection parallel to $(010)_{A,\,C,\,D}$ plane

latter is parallel with that of secondary twin axis of [101] edge. Carlsbad subindividuals form correspondingly two subsequent and the same twin-axes, which are mutually parallel and perpendicular to the first pair. All the axes are transformed by Albite law and consequently two double triads are formed of the type $Es : Ab : Ab — A$ and $[101] : (010) : \frac{\perp[101]}{(010)}$. Because of the presence of pericline subindividuals, there appears another triad: $b[101] : b\perp(010) : b\,\frac{\perp[101]}{(010)}$. The degree of twinning $D = 71\%$ and when taking into account Pericline law — $D = 55\%$.

Identical type of pseudohexagonal symmetry occurs in the grain presented in Fig. 4*a*, *b* (Sztolnia stream — 2/9) between bi-individuals $A\,C$ and $D\,E$. Moreover, the new-formed triads: $Ab : Es : Ab — A$ and similar $P : Sc : M$, formed due to the presence of pericline subindividual A_3 and D_3, are twinned with pericline twin $B_{1,2}$ according to Baveno laws and form two subsequent pseudotetragonal systems. L^6 and L^4 are perpendicular. The degree of twinning $D = 46\%$.

Another type of complex twin, displaying hexagonal pseudosymmetry, is represented by the grain illustrated in Fig. 5*a*, *b* (Sztolnia stream — 2/6). It was formed by combination of two triads $Ab : K : RT$ according to $\perp(1\bar{3}0)$:

$$2\cdot Ab : K : RT \Big/ \frac{\perp(1\bar{3}0) : [001] : \perp(110)}{b\perp(130) : [001] : b\perp(1\bar{1}0)}^{*} \qquad L^6 = Z$$

* $\sphericalangle\,(1\bar{3}0)/(110) \approx 90°$; $\sphericalangle\,(130)/(1\bar{1}0) \approx 91°$; $\perp(110) = \frac{\perp[001]}{(1\bar{3}0)}$; $b\perp(1\bar{1}0) = b\,\frac{\perp[001]}{(130)}$;

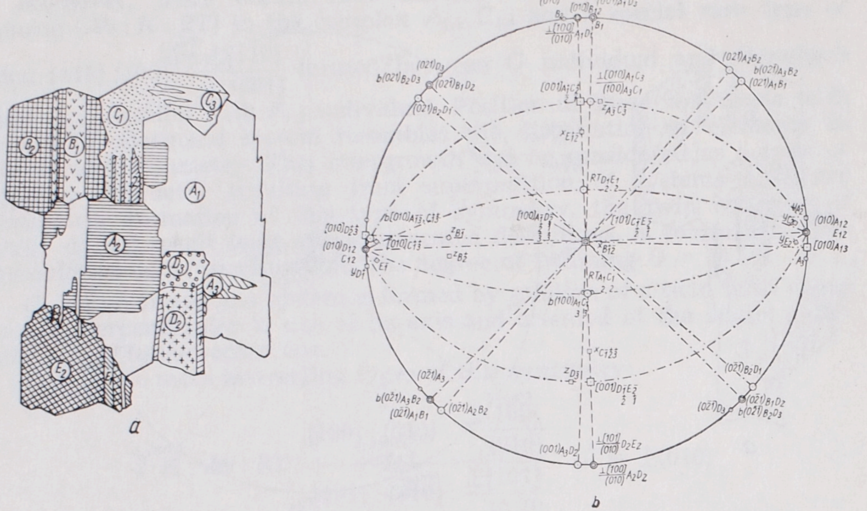


Fig. 4. *a* — Plagioclase grain (average — An_{47}). Hornblende andesite, Sztolnia stream; *b* — stereographic projection $\perp[100]_{A_{1,2}\,D_{1,2}}$

Consequently, two triads are formed: essential $\perp(1\bar{3}0) : [001] : \perp(110)$ and secondary — $b\perp(130) : [001] : b(1\bar{1}0)$.

The grain in question consists of six individuals *A*, *B*, *C*, *D*, *E* and *F*, whereby $E = A$ and $F = B$. One triad in composed of two-individual complex *A* and *B*, the second one — of *D* individual. Pericline twins $C_{1,2}$

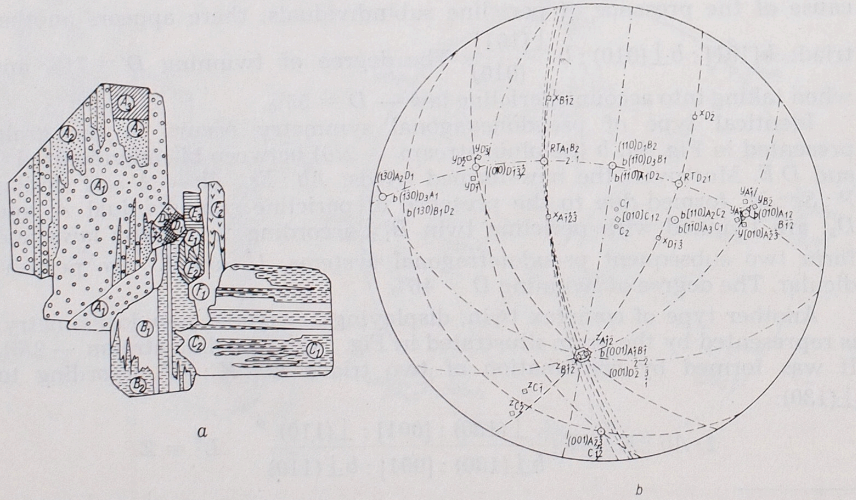
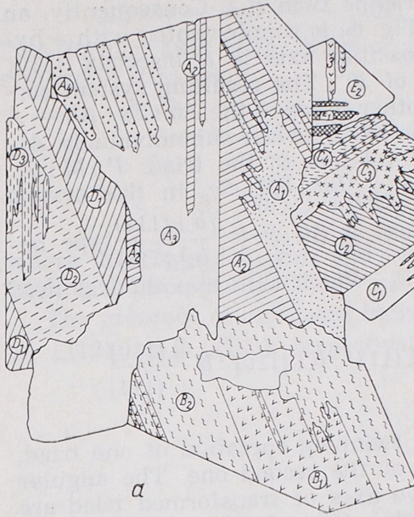


Fig. 5. *a* — Plagioclase grain (average — An_{47}). Hornblende andesite, Sztolnia stream; *b* — stereographic projection parallel to the plane of thin section



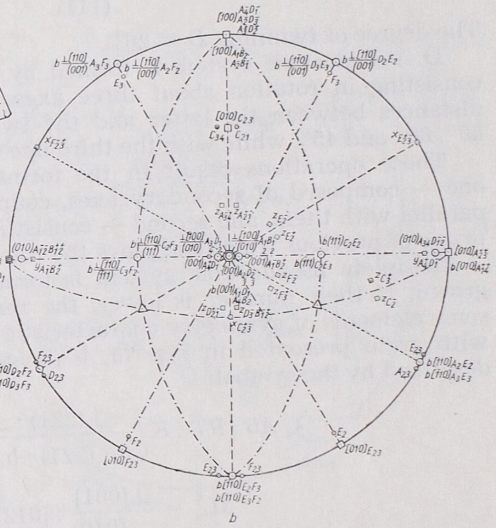


Fig. 6. *a* — Plagioclase grain (average — An_{47}). Hornblende andesite, Sztolnia stream; *b* — stereographic projection parallel to $(001)_{A_{2,3}\,D_{2,3}}$ plane

and $A_{1,3}$ are related by [110] law and form a coupled intergrowth of the type: $2\cdot P \Big/ \frac{[110]}{[1\bar{1}0]}$, $L^6 = \perp(001)$, displaying pseudohexagonal tendency.

Degree of twinning — $D = 40\%$.

Complete pseudohexagonal system is formed by combination of two triads of the type $P : M : Sc$ or $Ab : Ab — A : Es$. The first one according to the symbolic formula:

$$2\cdot P : M : Sc \Bigg/ \frac{[110] : (001) : \dfrac{\perp[110]^{**}}{(001)}}{[1\bar{1}0] : (001) : \dfrac{\perp[1\bar{1}0]}{(001)}} \quad L^6 = \perp(001)$$

is exemplified by the grain presented in Fig. 6*a*, *b* (Sztolnia stream — 1/5), in which a double triad $P : M : Sc$ of $A_{2,3}$ and $D_{2,3}$ subindividuals is

** $\frac{\perp[110]}{(001)} = b\,(\bar{2}21)$; $\frac{\perp[1\bar{1}0]}{(001)} = b\,(\bar{2}\bar{2}1)$.

related not with a triad but with a pericline twin $E_{2,3}$. Consequently, an incomplete system is formed, which in Fig. 6a is supplemented with a hypothetical pericline twin $F_{2,3}$. This essential axis is a bisectrix [110] forming with [010] direction the angle of 30°. The resulting system corresponds to ideal model. Moreover, two other triads of the $Ab : Es : Ab - A$ type occur in this grain. They are observed between subindividuals $A_{1,2}$ $B_{1,2}$ and $A_{3,4}$ $D_{1,2}$ and are symmetrical relative to the triad: $P : M : Sc$. These both triads give a resultant one — $bP : bM : Sc$. In this system there also occurs a pseudotrigonal system of the $P \cdot P \Big/ \frac{b\perp(\bar{1}11)}{b\perp(\bar{1}\bar{1}1)}$ type between pericline subindividuals $C_{2,3}$ and $E_{2,3}$ which with hypothetical twin $F_{2,3}$ form the subsequent triads:

$$b\perp(\bar{1}\bar{1}1) : b\perp[\bar{1}10] : b\,\frac{\perp[\bar{1}10]}{(\bar{1}\bar{1}1)};\quad b\perp(\bar{1}11) : b\perp[110] : b\,\frac{\perp[110]}{(\bar{1}11)}$$

The degree of twinning $D = 26\%$.

D. Pseudocubic system is formed by twinning operation of one triad, consisting in rotation about three axes of the second one. The angular distances between the latter and the two axes of transformed triad are 60°, 60° and 45°, while with the third one 90°, 45° and 45°.

These operations result in the formation of two subsequent triads: one — composed of secondary axes, coupled with transforming ones and parallel with them, and second — consisting of axes, each of which belongs to one of previous triads and plays the role of tetrad axis.

Complete pseudocubic system is formed when four triads are intergrown. If their number is lower, the resulting complex display lack of some elements of symmetry characteristic of cubic system. This is the case with grain presented in Fig. 7a, b (Ścigocki stream — 8/3) and can be described by the symbol:

$$4 \cdot Ab : RT : K \Big/ \frac{\perp(\bar{2}\bar{2}1) : \perp(1\bar{2}1) : [012]}{b\perp(\bar{2}21) : b\perp(121) : b[0\bar{1}2]}\ ^{*}$$

$$3L^4 = \frac{\perp[001]}{(010)} : [012] : b\,[0\bar{2}1]$$

in which four triads are related by the triad laws: $\perp(\bar{2}\bar{2}1) : \perp(1\bar{2}1) : [012]$ (the essential one). The latter is coupled with the triad: $b\perp(\bar{2}21) : b\perp(121) :$ $: b\,[0\bar{1}2]$ (the secondary one) while the four tetrad axes triad is composed of the directions: $RT : [012] : b\,[0\bar{1}2]$.

The grain, presented in Fig. 7a, consists of four individuals A, B, C and D displaying the following twin relations: A individual, similarly as the B one, is twinned according to triad $Ab : RT : K$, whereby A with B and $C_{3,4}$ with D are related by Baveno laws. B and $C_{3,4}$ are pericline twins and form a triad according to bisectrices of the directions $P : \perp(100) : K - B$. Consequently, the subindividuals 1, 2 and 3 of both triads $Ab : RT : K$ occur in the position expressed by the following laws:

$\perp(\bar{2}\bar{2}1) - A_1D_1$, $b - (2\bar{2}\bar{1}) - A_2D_2$, and $b\perp(121) - A_3D_3$.

Two former axes with those of the Baveno laws form pseudotrigonal systems of the type:

$$1)\ \perp(0\bar{2}1)\cdot\perp(0\bar{2}1) \Big/ \frac{b\perp(100)}{\perp(\bar{2}\bar{2}1)} \qquad L^3 = [012]$$

$$2)\ \perp(021)\cdot\perp(021) \Big/ \frac{b\perp(100)}{b\perp(2\bar{2}\bar{1})} \qquad L^3 = b\,[0\bar{1}2]$$

where the Baveno-l twins and two Baveno-r ones were transformed according to the axis $b\perp(100)$.

The presence of one more individual twinned with A_1 or A_2 according to $\perp(1\bar{2}1)$ or $b\perp(121)$, respectively, would supplement the system thus

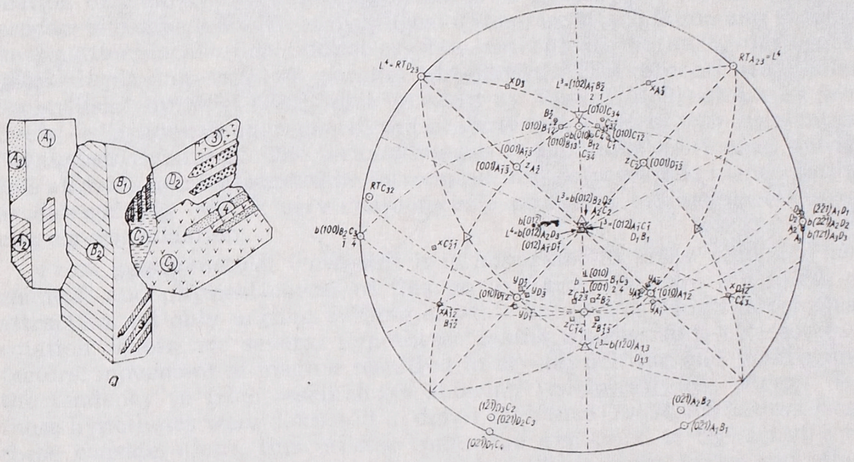


Fig. 7. a — Plagioclase grain (average — $An_{40.5}$). Hornblende andesite, Ścigocki stream; b — stereographic projection (ideal) $\perp[012]_{A_1C_4B_1D_1}$

formed in lacking axes — one diad and two triads. The twinning degree of this grain is $D = 38\%$.

Similar type can originate by incorporating triads: $P : \perp(100) : K - B$.

Another two types showing cubic pseudosymmetry can be formed by transformation of triads $P : Sc : M$ or $Ab : Es : Ab - A$ according to the formula:

$$4 \cdot P : Sc : M \text{ or } 4 \cdot Ab : Es : Ab - A \Big/ \frac{\perp(0\bar{2}1) : b\perp(110) : b\perp(\bar{1}11)^{*}}{b\perp(021) : b\perp(1\bar{1}0) : b\perp(11\bar{1})}$$

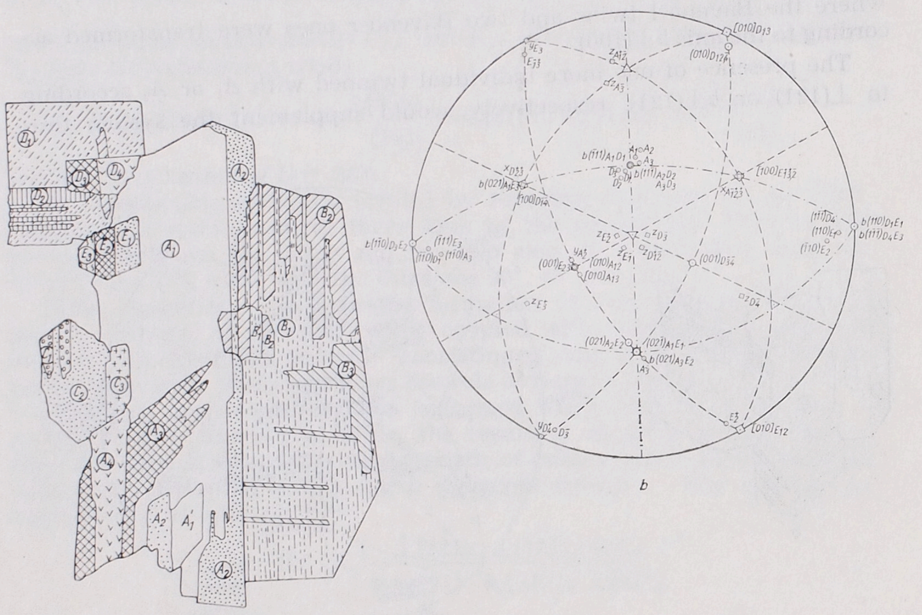
$$3L^4 = \perp(021) : b\perp(0\bar{2}1) : [100]$$

* $\sphericalangle (\bar{2}\bar{2}1)/(1\bar{2}1) = 90°$; $\perp(1\bar{2}1) = \frac{\perp[012]}{(\bar{2}\bar{2}1)}$; $\perp(\bar{2}\bar{2}1) = \frac{\perp[012]}{(1\bar{2}1)}$; $\sphericalangle (\bar{2}21)/(121) = 87°$;

$b\perp(121) = \frac{b\perp[012]}{(\bar{2}21)}$; $\perp(\bar{2}21) = \frac{b\perp[0\bar{1}2]}{(121)}$.

* These laws of both the triads (essential and secondary) can also be described by appropriate directions of normal, parallel and complex laws.

The former is represented by the grain presented in Fig. 8*a*, *b* (Ścigocki stream — 8/15). It consists of a large bi-individual crystal *A* and *B* related according to the triad *Ab* : *K* : *RT*. Parallel triad of the same type is formed by *C* individual. Pseudocubic system consists of *A*, *D* and *E* individuals, where *A* is an albite-pericline twin, *D* — similarly to *E* — a *P* : *Sc* : *M* triad and simultaneously an albite twin. Since in this example two triads are accompanied by a pericline twin ($A_{1,3}$), the resultant system shows all the elements of symmetry, but does not contain a complete



a *b*

Fig. 8. *a* — Plagioclase grain (average — $An_{40.5}$). Hornblende andesite, Ścigocki stream; *b* — stereographic projection $\perp\simeq[001]_{D_{1,2}\,E_{1,2}}$

amount of subindividuals. Another incomplete system, partly superposing with the first one, was formed between albite twins, showing triadic relation with Scopie — Estérel law. Degree of twinning — *D* = 37%.

The results of these studies of glomerophyric intergrowths of plagioclases can be summarized as follows:

1. There are no accidental intergrowths in these plagioclases.
2. All the intergrowths in question are based on twin laws.
3. Simple twin laws display further geometrical relations resulting in complex twin intergrowths.
4. A complex intergrowths:
   a) represents a closed cycle of twin transformations,
   b) shows higher pseudosymmetry.
5. Pseudosymmetric systems can be deduced by appropriate operations of twin triads, producing various types of them.

6. In glomerophyres composed of larger amount of individuals, several types of pseudosymmetric systems are formed which in turn can originate superior pseudosymmetric systems.
7. Complex twins (including all the individuals contained in them) explain the phenomena of twin relations between individuals, showing no direct contacts.

Apart from purely morphological results of this study, some observations were carried out on the occurrence of various types of intergrowths under consideration in different types of andesites. The obtained data, which are, unquestionably, of petrogenetic significance, clearly show that there are essential differences in the character of feldspar intergrowths in individual varieties of andesites. This refers even to rocks displaying similar petrographic character and in which feldspars are very close in composition.

Closing these consideration, let us consider some problems of the formation of glomerophyric intergrowths. It is generally accepted that this process is connected with early stages of magma consolidation and consists in the attachment of individual crystals, drifting in the melt, into aggregates displaying twin or parallel orientation. This process was called "synneusis" by Vogt (1921) and recently by Vance (1969) whilst its products — "synneusis aggregates" and in particular cases of twin orientation "synneusis twinning". The term synneusis is generally overlooked but, in this author's opinion, should be introduced into petrographic nomenclature as determining one of very characteristic processes taking place during magma consolidation.

From petrogenetical viewpoint it is important to know what are mechanical and physical causes of this process and what are the forces of attraction not only uniting drifting crystals but also causing their mutual rotation. There are several hypotheses taking into account at least two factors: movement of magma resulting in crystal drifting and joining and the tendency to from assemblages showing the lowest free energy. All these hypotheses were discussed in detail by Vance (1969). As follows from these considerations, this process cannot be explained if the activity of long range forces is not taken into account. Short range forces and other factors are not sufficient to interprete the phenomenon under consideration. In Vance's opinion, long range attraction forces are electrostatic in character. This problem is discussed more in detail in another paper of the present writer dealing with further observations on oriented assemblages of plagioclase grains in igneous rock (Gumowska-Wdowiak, 1974).

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Zofia GUMOWSKA-WDOWIAK *

ZROSTY BLIŹNIACZE W GLOMEROFIRACH PLAGIOKLAZOWYCH ANDEZYTÓW OKOLIC PIENIN

Streszczenie

Fenokryształy plagioklazów skał wulkanicznych okolic Pienin wykazują charakter typowo wysokotemperaturowy, cechuje je pięknie rozwinięta rekurencyjna budowa pasowa (Gumowska, 1964) oraz odznaczają się bardzo złożoną budową bliźniaczo-glomerofirową. Stała się ona przedmiotem szczegółowych studiów, których rezultaty zostały przedstawione na przykładzie ziarn, fig. 1—8. Ziarna glomerofirów stanowią zrost kilku, czasem kilkunastu osobników, które z kolei są złożone z subindywiduów bliźniaczych, najczęściej według praw: peryklinowego i albitowego. Badane były wszystkie możliwe kombinacje, których liczba (L_c) dla różnie zorientowanych subindywiduów (n) wyraża się zależnością: $N_c = \frac{n^2 - n}{2}$

Stopień zbliźniaczenia zaś: $D = \frac{N \cdot 100\%}{N_c}$ (N — liczba zależności bliźniaczych) charakteryzuje najogólniej zależności geometryczne dla badanego glomerofiru. Drugą cechą badanych zrostów jest występowanie mnogości praw bliźniaczych, w ich liczbie — prawie wszystkie znane dla plagioklazów i ortoklazu oraz około 20 dotąd nie opisanych.

Rezultaty przeprowadzonych badań zrostów glomerofirowych plagioklazów można sformułować następująco: 1 — nie występują w nich zrosty przypadkowe, 2 — wszystkie zrosty zachodzą według praw bliźniaczych, 3 — pomiędzy prawami zachodzą dalsze związki geometryczne, tworzące złożone zrosty bliźniacze, 4 — złożony zrost stanowi zamknięty cykl przekształceń i wykazuje wyższą pseudosymetrię od trygonalnej do regularnej włącznie (fig. 1b—8b), 5 — poszczególne układy pseudosymetrii dają się wyprowadzić przez odpowiednie przekształcenia triad bliźniaczych; zależnie od rodzaju triad — powstają różne typy, 6 — w glomerofirach o większej liczbie osobników powstaje kilka różnych układów pseudosymetryczych, które mogą tworzyć nadrzędne układy o wyższej pseudosymetrii, 7 — zrosty złożone wyjaśniają zjawisko związków bliźniaczych pomiędzy niestykającymi się ze sobą osobnikami.

SPIS FIGUR

Fig. 1. *a* — ziarno plagioklazu (przeciętny skład $An_{40,5}$) z andezytu amfibolowego, Potok Ścigocki; *b* — rzut stereograficzny $\perp[001]_{A_{1,2}\,B_{1,2}}$: linia ———— płaszczyzna bliźniacza subindywiduów tego samego osobnika, linia —·—·—· płaszczyzna bliźniacza subindywiduów różnych osobników, linia . . . . . . płaszczyzna bliźniacza hipotetycznych subindywiduów

Fig. 2. *a* — ziarno plagioklazu (przeciętny skład — An_{44}) z andezytu amfibolowego, kamieniołom Malinów; *b* — rzut stereograficzny $\perp[100]_{A,\,B,\,E}$
Fig. 3. *a* — ziarno plagioklazu (przeciętny skład — $An_{40,5}$) z andezytu amfibolowego, Potok Ścigocki; *b* — rzut stereograficzny w płaszczyźnie $(010)_{A,\,C,\,D}$
Fig. 4. *a* — ziarno plagioklazu (przeciętny skład — An_{47}) z andezytu amfibolowego, Potok Sztolnia; *b* — rzut stereograficzny $\perp[100]_{A_{1,2}\,D_{1,2}}$
Fig. 5. *a* — ziarno plagioklazu (przeciętny skład — An_{47}) z andezytu amfibolowego, Potok Sztolnia; *b* — rzut stereograficzny w płaszczyźnie szlifu
Fig. 6. *a* — ziarno plagioklazu (przeciętny skład — An_{47}) z andezytu amfibolowego, Potok Sztolnia; *b* — rzut stereograficzny w płaszczyźnie $(001)_{A_{2,3}\,D_{2,3}}$
Fig. 7. *a* — ziarno plagioklazu (przeciętny skład — $An_{40,5}$) z andezytu amfibolowego; Potok Ścigocki; *b* — rzut stereograficzny (idealny) $\perp[012]_{A_1C_4B_1D_1}$
Fig. 8. *a* — ziarno plagioklazu (przeciętny skład — $An_{40,5}$) z andezytu amfibolowego; Potok Ścigocki; *b* — rzut stereograficzny $\perp \simeq [001]_{D_{1,2}\,E_{1,2}}$

Зофия ГУМОВСКА-ВДОВИАК

ДВОЙНИКОВЫЕ СРАСТАНИЯ В ПЛАГИОКЛАЗОВЫХ ГЛОМЕРОФИРАХ АНДЕЗИТОВ РАЙОНА ПЬЕНИН

Резюме

Фенокристаллы плагиоклазов вулканических пород окрестностей Пьенин характеризуются признаками типичных высокотемпературных минералов, с прекрасно развитым рекуррентным зональным строением (Гумовска, 1964) и очень сложной двойниково-гломерофировой структурой. Эта структура была предметом детального исследования, результаты которого представлены на примерах (фиг. 1 — 8). Гломерофировые зерна представляют агрегат нескольких индивидов, которые, в свою очередь, состоят из двойникованных субиндивидов, чаще всего по периклиновому или альбитовому законам. Исследовались все возможные комбинации, количество которых (N_c) в различно ориентированных субиндивидах (n) определяется выражением: $N_c = \frac{n^2 - n}{2}$. Степень двойникования $D = \frac{N \cdot 100\%}{N_c}$ (N — число двойниковых зависимостей) характеризует в самых общих чертах геометрические условия в изучаемом гломерофире. Следующим признаком изученных агрегатов является множество законов двойникования, в том числе почти все законы известные по плагиоклазам и ортоклазу и около 20 до сих пор не описанных законов.

Результаты проведенных наблюдений гломерофировых срастаний плагиоклазов можно выразить в виде следующих заключений: 1 — случайных срастаний нет, 2 — все срастания совершаются согласно двойниковым законам, 3 — закономерности подлежат дальнейшим геометрическим связям, образующим сложные двойниковые срастания, 4 — сложное срастание образует замкнутый цикл видоизменений и обладает псевдосимметрией высшей степени от тригональной по гексагональную включительно (фиг. 1b — 8b), 5 — отдельные системы псевдосимметрии

можно определить путем соответствующего преобразования двойниковых триад; в зависимости от вида триад образуются разные типы, 6 — в гломерофирах с большим числом индивидов возникает несколько разных систем псевдосимметрии, которые могут давать системы псевдосимметрии высшего порядка, 7 — сложные срастания объясняют явление двойниконых связей между индивидами не соприкасающимися друг с другом.

ОБЪЯСНЕНИЯ К ФИГУРАМ

Фиг. 1. *a* — зерно плагиоклаза (средний состав — $An_{40,5}$) из амфиболового андезита, ручей Сцигоцки; *b* — стереографическая проекция $\perp[001]_{A_{1,2}\,B_{1,2}}$: линия — — — — — — двойниковая плоскость субиндивидов одного индивида, линия —·—·—·—·— двойниковая плоскость субиндивидов разных индивидов, линия ..... двойниковая плоскость гипотетических субиндивидов

Фиг. 2. *a* — зерно плагиоклаза (средний состав — An_{44}) из амфиболового андезита, карьер Малинув; *b* — стереографическая проекция $\perp[100]_{A,\,B,\,E}$

Фиг. 3. *a* — зерно плагиоклаза (средний состав — $An_{40,5}$) из амфиболового андезита, ручей Сцигоцки; *b* — стереографическая проекция в плоскости $(010)_{A,\,C,\,D}$

Фиг. 4. *a* — зерно плагиоклаза (средний состав An_{47}) из амфиболового андезита карьея Малинова; *b* — стереографическая проекция $\perp[100]_{A_{1,2}\,D_{1,2}}$

Фиг. 5. *a* — зерно плагиоклаза (средний состав — An_{47}) из амфиболового андезита, ручей Штольня; *b* — стереографическая проекция в плоскости шлифа

Фиг. 6. *a* — зерно плагиоклаза (средний состав — An_{47}) из амфиболового андезита, ручей Штольня; *b* — стереографическая проекция в плоскости $(001)_{A_{2,3}\,D_{2,3}}$

Фиг. 7. *a* — зерно плагиоклаза (средний состав — $An_{40,5}$) из амфиболового андезита, ручей Сцигоцки; *b* — стереографическая (идеальная) проекция $\perp[0\,12]_{A_1C_4B_1D_1}$

Фиг. 8. *a* — зерно плагиоклаза (средний состав — $An_{40,5}$) из амфиболового андезита, ручей Сцигоцки *b* — стереографическая проекция $\perp\simeq[001]_{D_{1,2}\,E_{1,2}}$