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A guide to plagioclase twinning, and an urge to further research on its petrological significance*

by *Alex C. Tobi*[1]

Abstract

In plagioclase the most common twins are lamellae according to the albite and acline-pericline laws. Next follows the Carlsbad law. In magmatic rocks its abundance increases with An-content; in medium-grade metamorphic rocks the law is not formed, but in low-grade albite porphyroblasts it occurs subordinate to simple albite twins. The albite-Carlsbad law is caused by the joint occurrence of the two component laws: it is not necessary to give complex laws a separate identity. Next in abundance is the Ala-A law with composition plane (001). It is quite common in some magmatic rocks. The Baveno twin is less frequent, the Manebach law still rarer. The other laws listed in literature are dubious or optically indistinguishable from the laws mentioned.

It is usually possible to determine the twins without cumbersome measurements or constructions in the stereographic net. The universal stage is helpful to identify the composition plane and to determine the type of twinning: normal or parallel-complex.

Further crystallographic research on the causes of formation of the various twinning laws may shed more light on the origin and evolution of rocks.

Keywords: Plagioclase twinning, universal stage, rock formation.

Introduction

The twins occurring in plagioclase have been thoroughly studied for more than a century, and books and papers on the subject fill a long shelf in many earth-science libraries. At first they were studied by goniometry on well-developed crystals, later on in thin sections under the polarizing microscope, and then with single-crystal X-ray diffractometry. It is not always easy to compare results obtained with different methods. Certainly few people will have the patience now to check or amplify goniometric data which were obtained decades ago. As far as the polarizing microscope is concerned, an exhaustive review was published by BURRI, PARKER and WENK (1967). The extensive description of about 30 twinning laws may have stimulated some scientists, but discouraged others. But several laws are not known to exist in nature, or are indistinguishable from other laws. So on p. 86 the authors give a list of ten laws which can be recognized in thin section with the aid of a universal stage. A similar (but not identical!) list is given in the next caption.

The interest petrologists take in the types of twinning in plagioclase is not purely descriptive. As plagioclase is one of the most common rock-forming minerals, they hope that the twins will tell more of the origin and evolution of rocks. To reach this goal interaction of petrology and crystallography is required. The petrologist describes the patterns of twinning in rocks of which the evolution is well-known, the crystallographer tries to establish what caused the various twinning laws under the given circumstances. To make such an inventory it is too cumbersome to identify each twin

* Dedicated to Professor Ernst Niggli on the occasion of his 70th birthday.

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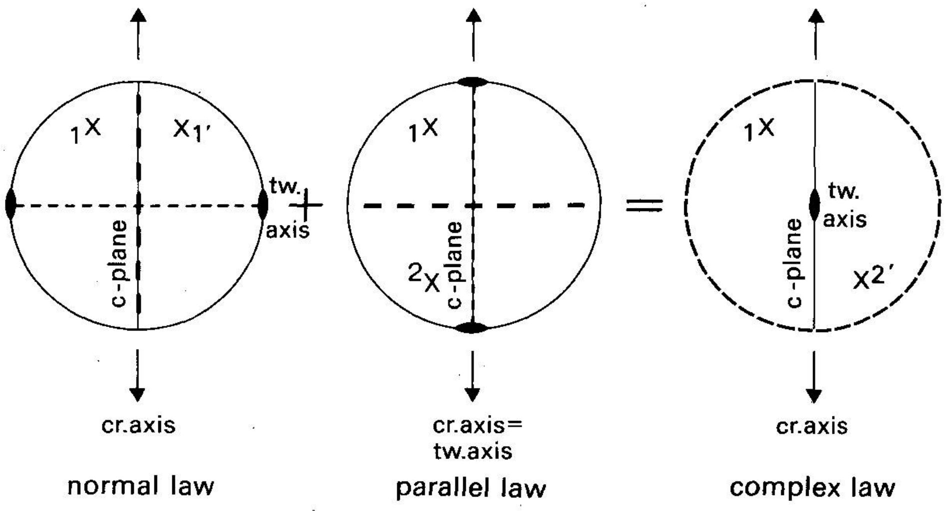

Fig. 1 Stereographic diagram showing the relation between a normal law, a parallel law, and the complex law acquired by their "addition". All diagrams have the composition plane (c-plane) vertical N-S, and the crystallographical axis (cr. axis) chosen as symmetry axis (tw. axis) of the parallel law horizontal N-S. Light dashes: tw. axis; heavy dashes: symmetry plane of twin. The symmetry operation is shown by one pole (x) of the indicatrix: 1-1': normal law; 1-2: parallel law; 1-2' complex law.

by construction in the stereographic net. Therefore, quicker methods of recognition are here reviewed again. Then some characteristic patterns are described, urging further crystallographical research on why they were formed.

Short review of twinning in plagioclase

The twinning laws of plagioclase are characterized by their composition plane (CP) and by the position of their (two-fold) symmetry axis (SA). As the crystal lattice has a centre of symmetry, a SA automatically implies a symmetry plane (SP) perpendicular to it. Depending on the relation between the CP and the SA, three types of twinning are distinguished.

In the *normal* twin the SA is situated normal to the CP, which thus becomes the mirror plane of the twin. The best known example is the albite law with CP (010). In the *parallel* law the SA is a crystallographical axis lying in the CP. The best-known example is the Carlsbad law with CP (010) and SA [001]. In the *complex* law the SA lies in the CP normal to a crystallographical axis. The complex law can be thought to have originated from the joint operation of a normal and a parallel law (Fig. 1). As we will see in a later section, there are reasons to believe that this is exactly what actually happens, and why the law was called "complex". A review of relevant laws of twinning is given in the table below.

Tab. 1 Plagioclase twins arranged according to composition plane and type of twinning. // after name: usually lamellar; italics: frequent; between brackets: rare, with "?": perhaps non-existent.

composition plane (CP)	normal law	parallel and complex laws	twin axis (SA)
(010) (= cleavage)	*albite //*	Carlsbad (Ala B?) *albite-Carlsbad* (albite-Ala B?)	[001] [100] ⊥ [001] in (010) ⊥ [100] in (010)
(001) (= cleavage)	(Manebach)	*acline //* Ala A	[010] [100]
// [010] ± (001) (rhombic section)		*pericline //*	[010]
(021) ±45° w. cleav.	Baveno		

Note that the lamellar twins are normal twins if the CP is (010), parallel twins if the CP is (001) or the rhombic section. Note also that no complex laws are indicated for the CP (001), because the axes [010] and [100] are so nearly perpendicular that Manebach-acline would be optically indistinguishable from Ala A, and Manebach-Ala from acline (Fig. 2). As there is some controversy on the subject, I will recur to this point in a more detailed discussion on twins with CP (001). Combinations of twins with different CP's should not be called complex twins. The laws listed cover at least 99.9 per cent of the twins which can be proved optically to exist in natural rocks.

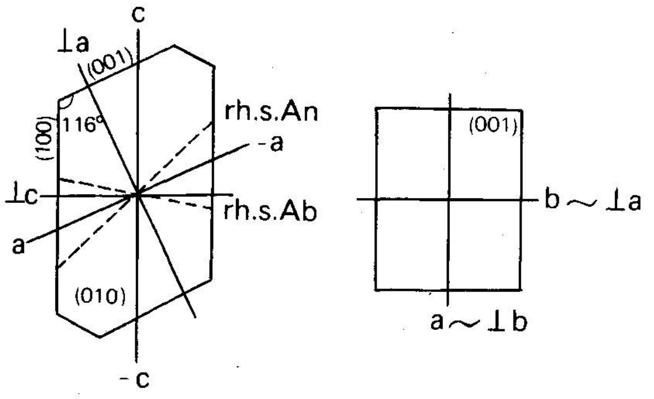

Fig. 2 Position of the symmetry axes of the parallel and complex laws in the planes (010) and (001), and variation of the rhombic section (rh. s.) for low plagioclase.

The recognition of plagioclase twins

A quantitative study of plagioclase twins should be made by using thin sections. A sound determination should be based on crystals orientated perpendicular to the CP. Although a certain number of crystals with this orientation will usually be present, it is advisable to equip the microscope with a universal stage. Orient the CP vertical and "N–S", perpendicular to the control axis of the stage. In this position a normal twin will be invisible because the individuals have equal illumination (it will become visible on insertion of the gypsum plate). On turning on the control axis the twin will remain invisible. Sometimes, the orientation has to be adjusted slightly, because the CP may deviate from the ideal plane, even if it appears as a straight line (this is a wide-spread cause of error in constructions on the stereographic net, see Tobi (1965). If we are dealing with a parallel or complex law, its individuals will have different illumination. However, two special positions may now be reached if the control axis is turned. If the illumination becomes equal, it means that the SA is now horizontal N–S (and the SP vertical E–W). If the twin remains invisible even after insertion of the gypsum plate, the SA coincides with the microscope axis.

Having made the choice between normal and parallel or complex twinning, we proceed with determination of the CP. Turn the CP to NE position by rotating the microscope stage over 45° (a normal twin will again show equal illumination). If we now turn on the control axis, the CP will have negative elongation (subtraction in both individuals with the gypsum plate) if it is (010), varying elongation if it is (001). If the An-content is above 70% the distinction becomes less clear. Note that in the section normal to [100] acline lamellae can only be distinguished from albite lamellae in this way, because the SP is vertical in this orientation.

If lamellar twins are present, it will usually be easy to identify the other laws as well. A simple twin, consisting of two individuals only, may sometimes give problems. The Baveno twin is usually easily recognized because of the oblique position of the CP with regard to cleavages and crystal outline. The main CP's (010) and (001) will be treated in separate sections.

TWINS WITH CP (010)

The main (perhaps the only) twins with CP (010) are the albite and Carlsbad laws, and their combination albite-Carlsbad. All these are most typically represented in magmatic rocks, e.g. phenocrysts of andesites and basalts. Generally the (normal) albite law is lamellar, the Carlsbad law simple (rarely it may show a few lamellae). In the 0 and 45° positions of the microscope stage only the Carlsbad twin is visible. Usually both Carlsbad individuals will have albite lamellae, so that four extinction positions can be distinguished. (If one of the Carlsbad individuals is oriented normal to [100], this is the ideal section to determine the

An-content, if necessary zone for zone; see TOBI and KROLL, 1975). In this way, the albite-Carlsbad law is also realized.

This type of twinning, where the SA lies in the CP perpendicular to a crystallographical axis, has traditionally been called a "complex law" in English. SMITH (1974) prefers a translation of the German term: "edge-normal law", because "complex" would suggest "difficult", "complicated", information he thought to be less relevant. I think, however, that the term was chosen because the albite and Carlsbad laws also occur separately in these crystals: in *that* sense the twinning is "complex".

If only adjoining twin individuals are considered, the Carlsbad law is at least ten times more frequent than the albite-Carlsbad law. All this points to the fact that the complex law is an *addition law* caused by the subsequent operation of a normal and a parallel law.

As indicated in the table, the Ala-B and albite-Ala B laws are considered rare, even dubious. The existence of the parallel Ala-B law has never been established definitely. There are a number of reports on the occurrence of lamellar albite-Ala B twinning in magmatic as well as metamorphic rocks, but these are generally erroneous. Many authors used measured cleavages and CP's to determine the indicatrix orientation of the twin individuals. The errors obtained with this procedure are too large: depending on the direction of the aberration it may lead to the assumption of different composition of twin individuals, or to an erroneous determination of the twinning law (TOBI, 1965). Instead, SA's constructed in the stereographic net should be used as crystallographical reference directions. Moreover, most cases were reported in plagioclase with about 30% An. At this composition n_x almost coincides with [100], so that the Ala twin becomes optically invisible. Consequently, the albite-Ala and albite laws become optically identical. If one does not realize that, chance governs the outcome of constructions in the stereographic net: there are always two solutions for the SA if two corresponding indicatrix axes coincide. Finally, these "albite-Ala B" twins are often described as consisting of a lamellar alternation of two sets of individuals only, which means that the separate albite and Ala-B laws would not be represented. This situation has never been reported for the albite-Carlsbad twin, the only complex law which could be definitely proved so far.

TWINS WITH CP (001) OR RHOMBIC SECTION

It will appear that there is still more controversy about the twins with CP (001). As was stated before, we have omitted the complex laws here because the axes [100] and [010] are so nearly perpendicular that the parallel and complex laws can not be distinguished optically. But this lead is not chosen by other authors. BURRI, PARKER and WENK (1967) think that the "acline law" should in reality be Manebach-Ala, because it would be incongruous to suppose that a twin with SA [010] could have an arbitrary choice between the CP's (001) and rhombic section. I do not quite see their point. For one thing, why not? A preference for either acline or pericline lamellae could well be caused by different conditions during their formation. For another, the authors do not raise the same point for the Ala law, which, according to them, would also have the choice between two CP's. There are considerations pleading against their proposal. The normal Manebach law is very rare, the parallel Ala law is somewhat more common. Both laws appear to be restricted to magmatic rocks, and both form simple twins only. Then why should their complex law Manebach-Ala be abundant in magmatic as well as metamorphic rocks, and why should these twins be dominantly lamellar? A comparative study has shown that acline and pericline twins are about equally abundant on an average; occasionally wedge-shaped lamellae occur that are bounded by (001) on one side, and by the rhombic section on the other! So they are probably the same law, the choice of CP being governed by differences in the conditions of formation. SMITH (1974, p. 315) reaches a similar conclusion on somewhat different grounds.

The pericline law is optically characterized by the (usually small) angle between (001) and the CP. In low plagioclase, the rhombic section coincides with (001) at about 40 An, so that the acline and pericline laws are identical at that composition. On the solidus of high plagioclase, this coincidence continues over the whole range from 0 to 70% An (SMITH, 1974, p. 320). If the crystal later passes to the low-temperature form or changes its composition, the conditions of formation of the twin are "frozen" by the orientation of the CP. The name "Manebach-pericline" is not warranted for a complex law because the CP's of the components are different.

SMITH (1974) treats plagioclase twinning elaborately in his treatise on feldspars. He acknowledges my remarks on the improbability of lamellar albite-Ala B twinning, and then proceeds to doubt the Ala law altogether. But in fact there is little reason to do so. Many Ala twins show no other laws with CP (001) in the same grain. If we disregard twinning on (010), they are just simple twins, occasionally with some narrow acline or pericline lamellae at some distance from the Ala CP. As was already stated above, it seems unreasonable to consider such an Ala twin as Manebach-acline, as (in adjoining individuals) the simple Manebach law must be at least a hundred times rarer than Ala (in fact I have seen Manebach only a few times). In one case a very thin acline lamella was found quite near to the Ala CP (Fig. 3). It is interesting to reflect that this lamella should have a Manebach symmetry relation to the opposite Ala individual. It is easy to check that with symmetrical extinction or construction in the stereographic net. But I do not think it is true: we are again dealing with an "addition law", this time caused by the subsequent operation of two parallel laws, Acline and Ala. I propose to call it a "pseudo-Manebach" law. In this particular crystal this conjecture can be proved by studying the somewhat broader lamella some distance above the Ala CP. It happens to be a pericline twin, with rhombic section clearly differing from (001). Obviously participation in a Manebach twin is ruled out for this individual, but it still has the same indicatrix orientation as the acline lamella, and symmetrical extinction in the zone normal to (001) with the opposite Ala individual.

Fig. 3 Microphotograph of a typical simple Ala-A twin with transverse albite-law lamellae cutting straight through the composition plane (CP). Note the almost equal extinction positions of the Ala individuals: in a section exactly normal to [100] the twin would be invisible. A thin acline lamella very close to the Ala CP (right, enlarged in (b), and a somewhat broader pericline lamella (left, some distance above this CP) both form a "pseudo-Manebach law" with the opposite Ala individual. Crossed polars. Width of photograph (a) 1.5 mm.

WENK (1979) also comes to the defence of the Ala law in a paper on plagioclase fourlings twinned according to the albite, Ala and albite-Ala laws. I agree with most of his statements, but object against two of them. Firstly, we are dealing here with simple Ala-A twins crossed by transverse albite lamellae. In these combinations the complex albite-Ala law is not realized because the component laws do not have the same CP, so it does not follow from his observations—as he says—that my statement on the non-existence of lamellar albite-Ala B twins is incorrect. The combinations he describes are regularly found in some rocks, and are very easily recognized, because *the Ala twin is the only twin where transverse twin lamellae cut straight through the composition plane.* This brings me to my second remark: the statement that "the fourling is readily recognized in sections perpendicular to [100]" is incorrect. On the contrary, *any twin* is optically invisible in the section normal to its SA (even if the gypsum plate is inserted). If this section happens to be normal to [100], it identifies [100] as the SA, and no further measurements or constructions are needed for its determination. In that orientation Wenk's fourling will only show the albite lamellae. If the stage is slightly tilted from that position the Ala twin will appear by small differences in extinction angle.

Characteristic patterns of plagioclase twinning

Gorai (1951) was one of the first to study the distribution of the various twinning laws over different classes of rocks. To facilitate recognition and quantitative treatment, only two groups of twins were distinguished. The albite, acline and pericline laws, which usually occur in lamellar form, were called A-twins, all other laws (alone or combined with A-twins) were called C-twins. If the twins are classified without the aid of the universal stage, it is often difficult to recognize simple twins consisting of two individuals only. His suggestion that A-twins should have symmetrical and C-twins asymmetrical extinctions is incorrect for the CP (001). But the result of the quantitative survey was still convincing and interesting. Metamorphic rocks contained only A-twins (with a higher proportion of untwinned grains for the thermometamorphic rocks). In magmatic rocks, the relative amount of C-twins increased with the An-content of the plagioclase.

Later, a somewhat more detailed classification was proposed by Tobi (1961, 1962). It includes not only the distinction of A- and C-twins, but also of their CP's. In *magmatic* rocks, there is a clear dominance of twins with CP (010). Not only is the Carlsbad law by far the most frequent C-twin, but also are albite lamellae more frequent than acline-pericline lamellae. Some trondhjemites and spilites are aberrant in that Ala twins are more frequent than Carlsbad twins. Characteristic sections are elongated according to (010) with lamellar albite twins and a simple transverse Ala-A twin. An appreciable amount of Ala-A twins may also occur in some gabbros, e.g. in one of the rings of the Ardnamurchan intrusive complex, Scotland (Fig. 3). But such observations may only be used descriptively as part of the "fingerprint" of a given rock, until we know more of the underlying cause of the various types of twinning.

Taking into consideration the CP of the twins is also useful for the study of metamorphic rocks. In such a study one should first establish whether a given plagioclase twin is a frozen relict of an earlier stage, or has indeed grown as a blast during the metamorphic stage that is being studied. For instance, larger plagioclase crystals in an amphibolite are often not porphyroblasts, but phenocrysts of the original basalt. Their An-content may be higher than that of the recrystallized plagioclase in the matrix, or, if their composition was changed during metamorphism, the change may be apparent from clouds of clinozoisite and rutile (their outlines often still show the zoning). But even then most of their twins, just as the crystal outlines, will be relicts of the magmatic stage, i.e. they will be C-twins with A-lamellae. If we concentrate on the matrix, the crystals commonly form a kind of mosaic structure; they are clear and contain only (lamellar) A-twins. If the metamorphism is a Barrovian (almandine-)amphibolite facies (higher pressure), acline-pericline twins dominate over albite twins (usually 2:1 or more). Other rock compositions in the same facies (e.g. micaschists) will provide the same pattern of plagioclase twinning. If it concerns a lower-pressure amphibolite facies (characterized by andalusite or cordierite in appropriate compositions), the maximum An-content in the matrix will be higher, and albite twins will clearly dominate over acline-pericline twins. This means an approach towards magmatic conditions, where twins with CP (010) are much more frequent than those with CP (001) or rhombic section.

In pelitic schists metamorphosed in the greenschist facies, prophyroblasts of albite are commonly found. Characteristically they show simple twins, so that they are easily distinguished from eventual magmatic relics. Before 1959 these twins were attributed to the albite law by some authors, to the Carlsbad law by others, often without proof for either of these possibilities. Later (Tobi, 1959, 1961, 1962) it appeared that both laws may indeed be found (the albite law most commonly), including the occasional presence of the complex albite-Carlsbad law. In this case the other laws are sometimes realized by the occurrence of a central lamella between the main individuals of the simple twin (Fig. 4). Such a central lamella is often wedge-shaped, because the Carlsbad CP is usually somewhat less regular than the albite CP. Note that twins with CP (001) or rhombic sections do not occur in these porphyroblasts. Other types of twins in greenschist-facies rocks are generally magmatic or higher-grade metamorphic relics, or signify a transition to the amphibolite facies.

A peculiar type of twinning is found in "authigenic albite" occurring in weakly metamorphic (up to greenschist facies) limestones or dolomites from various localities. It was first dis-

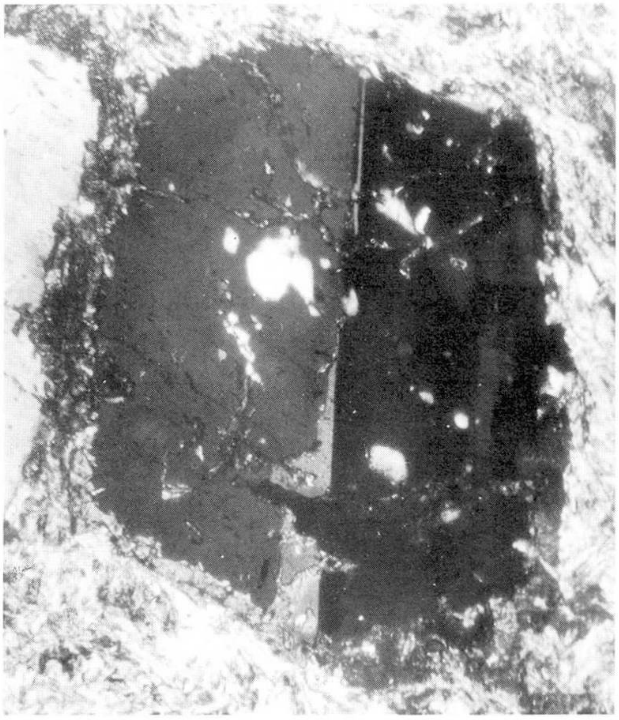

Fig. 4 Microphotograph of a simple albite-Carlsbad twin in an albite porphyroblast grown in the greenschist facies. Note the small difference in extinction position. In the upper part a thin albite twin lamella lies just in the right individual. The broader one below forms an albite twin with the right- and a Carlsbad twin with the left-hand side individual. The Carlsbad position plane is more irregular than that of the albite twin. Crossed polars. Width of photograph 1.5 mm.

covered at Roc Tourné (France) and described in detail by Rose (1865). Many descriptions from the same or other localities followed later, many of them conflicting or at least confusing. A clear review has been given by Smith (1974). Rose's work is treated there mainly on p. 327 and Figures 17–26 (of which the lettering should be changed into a–c–e–f in the upper and b–d–f–h in the lower row!). But it is perhaps easier to focus on their appearance with crossed polars under the polarizing microscope. The simplest and most common form is a quadruplet consisting of two albite-twin individuals which interpenetrate each other crosswise (Fig. 5). The crystals are plates on (010) with a central groove in the middle roughly parallel to (100). In thin section the groove appears as a constriction of the outer surface of the crystal. Within the crystal the plane (100) is not represented: the part of the CP transverse to (010) is always irregular. Usually one of the twin individuals is continuous by the presence of a transverse bridge connecting the two halves. This bridge cuts the other twin individual into two separate parts. Clear-cut as this may seem, there are many other interpretations in literature, most of them reviewed by Smith. Although the albite and Carlsbad symmetry operations are very similar in pure albite, the albite law may be recognized by the reflection of the (001) cleavages, or by the coinciding n_x axes: if n_x of one individual is made parallel to the control axis, the whole twin will remain dark while turning on this axis. In the Carlsbad twin the angle between the n_x axes is about 7°. The "X-Carlsbad" twin construed by others is very improbable because the "X-law" (normal law on (100)) has never been found separately, because (100) is never realized as a CP, and because it would be optically indistinguishable

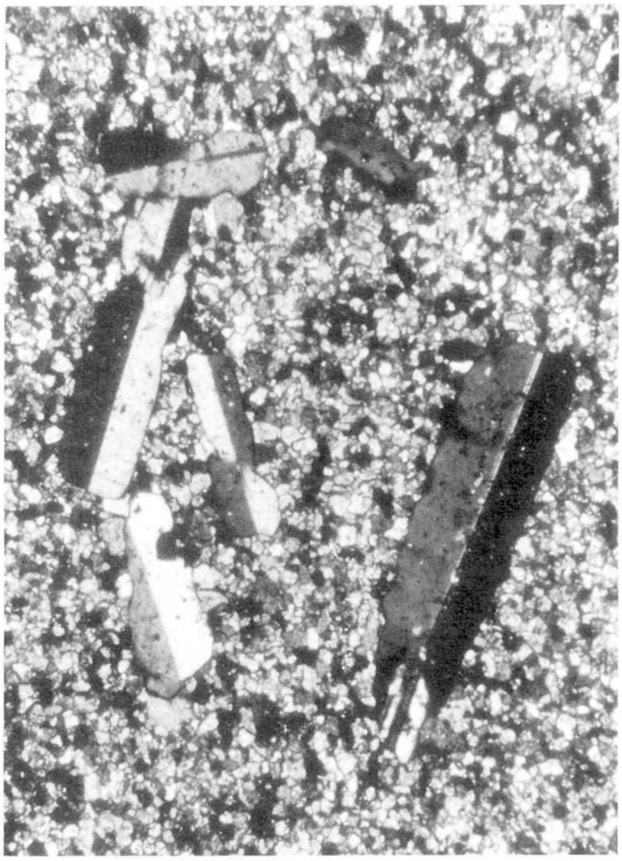

Fig. 5 Authigenic albite porphyroblasts in the Roc Tourné dolomite. The smaller crystal in the middle is the typical albite-law quadruplet. The darker individual is continuous by the occurrence of a transverse bridge which cuts the lighter individual in two parts. The large crystal to the right is mainly an albite-Carlsbad twin with a central lamella comparable to figure 4. The other crystals are mainly albite twins. Crossed polars. Width of photograph: 10 mm.

from the albite law. Neither can the albite-Carlsbad law be present in the simple quadruplet. Unlike the quadruplet, this law causes only a slight displacement of the indicatrix, so that the individuals are distinguished only with difficulty. As the quadruplet is the characteristic twin of Roc Tourné, it is erroneous to name the albite-Carlsbad law after this locality (as BURRI, PARKER and WENK, 1967 have done). However, this does not mean that Carlsbad (and by implication albite-Carlsbad) twinning is completely absent in these rocks. Occasionally the same type of twin is found as described from the greenschist-facies metapelites. They may occur combined with the quadruplets in the same crystal, but these combinations are usually less regular than follows from the descriptions of Rose: the Carlsbad law seldom takes part in the cross-wise penetration. The albite-law quadruplet seems to be a rather unique phenomenon: generally the Carlsbad CP is less regular than that of the albite law.

The cause of plagioclase twinning

Comparatively little is known of the conditions leading to the formation of the various types of twinning in plagioclase (see review in SMITH, 1974). Some general rules have been established, however. *Simple twins* are usually *growth twins* and considered to be due to a "nucleation error" during initial growth of the crystal. This term is perhaps not quite appropriate because it suggests accidental occurrence. The specific and systematic occurrence of a certain law in a given rock suggests that this particular twin represents the energetically most favourable way for the crystal to grow under the given circumstances. Well-known examples are the systematically twinned plagioclase phenocrysts in basic volcanics, and, among the alkali feldspars, megacrysts in granites (in both cases the Carlsbad law is usually favoured). GORAI'S C-twins are mostly growth twins formed in magmatic rocks. Being primary twins, they will often have formed in the high-temperature form, even if the crystal is now low plagioclase. No crystallographic research seems to have been done on the other part of GORAI'S rule: the increase in frequency of these twins with increasing An-content. As in magmatic rocks crystallization temperature and An-content are mutually dependent, it is not known which factor should be most important. It is also intriguing why in some rocks (see preceding section) the role of dominant C-twin should be taken over by the Ala twin. What could steer the change? Again, it is interesting to reflect on the different frequencies of the Ala and Manebach laws. In monoclinic feldspars both laws coincide. When they separate in triclinic feldspar, why should the parallel law be favoured above the normal law?

In a solid environment growth twins should form at lower temperature than while forming from a melt (SMITH, 1974). Yet it should be significant that they are *not* formed during amphibolite-facies metamorphism. Then, if the temperature becomes still lower, they suddenly recur as Carlsbad and simple albite twins in greenschist-facies rocks and authigenic albite. Could it be due to the fact that metastable crystallization is rather common in low-grade metamorphic rocks? After all, the structure of authigenic feldspar is often intermediate between the low- and the high-temperature form.

During the crystallization of volcanic rocks, twins consisting of two or a few individuals may also be caused by small phenocrysts of plagioclase floating together in the melt *(synneusis)*. If this twin formed in a somewhat later stage of crystallization, this origin may be indicated by the zoning being centered in the middle of the individuals rather than in the centre of the crystal as a whole. In this case the zone bordering the CP reveals the stage in which the twin was formed. Even if crystals grow quite unhampered, their crystal faces will be somewhat irregular by stepwise growth. It is therefore to be expected that twins originated in this way could show deviations from the ideal symmetry operation. Contrary to current comments in literature, it is possible to establish these deviations by careful measuring on the universal stage. If the "individuals" of the synneusis twin each contain albite lamellae, the SA within each of the synneusis individuals can be constructed independently. Their angle gives the amount of tilt caused by the misfit, and the approximate position of its rotation axis.

We now turn to the *lamellar twins* belonging to the albite and acline-pericline laws. Some are also considered as *growth twins*, although their formation is obviously not restricted to the nucleation stage. A primary origin is indicated where the lamellae end bluntly within the

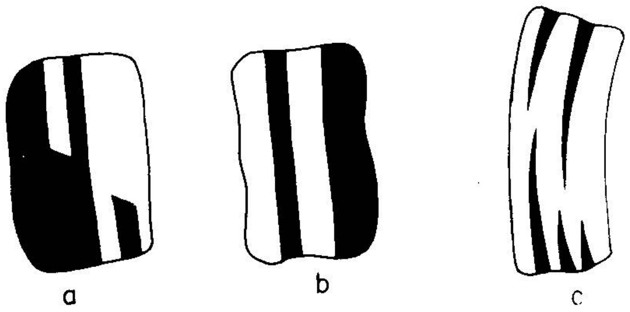

Fig. 6 Microscopical evidence for the mechanism of lamellar twinning.
(a): a blunt ending within the crystal points to growth twinning;
(b): the origin of straight lamellae is uncertain; however, higher alteration in one set of lamellae points to mechanical twinning;
(c): lamellae tapering out within the crystal point to mechanical origin; this is especially clear if the crystal faces are bent.

crystal: a later origin would create a "room problem" (Fig. 6). Such blunt ends are comparatively rare, they are e.g. occasionally found in the albite porphyroblasts discussed above.

Mechanical or *glide twinning* seems to be the most common origin of lamellar twinning in plagioclase. In magmatic rocks such lamellae may be caused by stress within the crystals on cooling. In (dynamo)metamorphic rocks they are mainly caused by deformation of the rock, and often occur associated with bent crystal faces. The lamellae often taper out if they end within the crystal (Fig. 6). If they are running straight through the crystal, their mechanical origin may be betrayed by one set of lamellae being more altered than the other. The higher alteration must be caused by lattice imperfections in the "new" set of lamellae caused by the mechanical twinning. According to Borg (in SMITH 1974, p. 348) synthetic studies suggest that mechanical albite and acline-pericline twins should develop in about equal numbers. However, the lamellar twins described above from the higher-pressure amphibolite facies are usually of mechanical origin, and their preference for the CP (001) and rhombic section still awaits explanation. The scarcity of lamellar twins in plagioclase grown under low-grade metamorphic conditions probably indicates that these conditions are below the temperature threshold where mechanical twins begin to form. Moreover, in (low) pure albite the ordering of the lattice precludes the origin of mechanical twinning (LAVES, 1965). The strong preference for the CP (010) in such rocks is another fact that still awaits explanation.

Finally, lamellar twins may form as *transformation twins*. The only occurrence known in plagioclase is the "chessboard albite" often found in albite replacing potassium feldspar. It is caused by the higher triclinicity of the albite lattice compared to the crystal it replaces.

These genetic considerations are not yet sufficient to explain the differences in the characteristic patterns of twinning found in natural rocks. If more becomes known of their underlying crystallographic causes, these patterns will no longer be only descriptive fingerprints: they will enlarge our understanding of the origin and evolution of the rocks in which they are found.

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