Bulletin of the Geological Survey of Japan, vol.53 (11/12), p. 795 - 800, 2002

Practical method of determining plagioclase twinning laws under the microscope

Yuhei Takahashi[1]

Yuhei Takahashi (2002) Practical method of determining plagioclase twinning laws under the microscope. *Bull. Geol. Surv. Japan*, vol. 53 (11/12) p.795-800, 5 figs., 1 table.

Abstract: Correspondence between various rock types and frequency of plagioclase twinning laws must be revised with the recent geological background for improving the criteria to discriminate geological settings by plagioclase twinning laws. For this revision, a rapid and reliable method to determine plagioclase twinning law types is necessary. Twinning laws can be recognized in a thin section with the aid of a universal stage. The plagioclase twinning law is determined from the composition plane (CP) and position of the symmetry axis (SA). The CP is determined with cleavages or optical elongation at the diagonal position. Normal, parallel or complex twin types can be understood by optical characters based upon the relationship of SA and CP. Based upon combinations of these characters, we can distinguish most plagioclase twinning laws in natural rocks.

Keywords: plagioclase, twinning law, composition plane, symmetrical axis, twin axis, universal stage

1. Introduction

The twinning law observed in plagioclase is empirically useful for geological and petrological discussion though the correlation between twinning laws and their formation mechanism is hazardous (Smith, 1974). The frequency of various plagioclase twinning laws has become a tool to discriminate different classes of rocks (Gorai, 1951; Suwa, 1956; Tobi, 1962). The discrimination by plagioclase twinning laws has been established during this half century, but it must be revised with the background of new geological and tectonic schemes (Tobi, 1987; Takahashi, 1995). For this revision, a practical and reliable method to identify the plagioclase twinning laws under the microscope will be prepared for people who are not familiar to optical mineralogy.

I have been reviewing and improving the method for identification of plagioclase twinning laws through description and discussion of plagioclase twinning in various rocks. In this paper, I review the practical method to determine twinning laws based on my experience, especially for low temperature type (ordered) oligoclase to andesine plagioclase that is common in granitic rocks and intermediate- to high-grade pelitic metamorphic rocks.

2. Plagioclase twinning in nature

The plagioclase twinning law is characterized by the composition plane (hereinafter CP) and direction of the symmetry axis (hereinafter SA), that is the twin axis. The SA is the same as a two-fold axis. About 20 twinning laws have been defined (*e.g.,* Smith and Brown, 1988), but some are not known in nature or are undistinguishable from other laws.

Tobi (1987) referred to ten twinning laws. Frequent plagioclase twinning laws are albite, albite-Carlsbad, acline and pericline laws. Common but not frequent laws are Carlsbad, Ala A and Baveno laws. Rare laws are Ala B, albite-Ala B and Manebach laws. The Ala B and albite-Ala B twins may not exist in nature.

The albite-Ala B and albite laws become optically identical in oligoclase and andesine compositions (Suwa *et al.*, 1974). Smith (1974) and Tobi (1987) inferred that most (or all) of the albite-Ala B twinning law described in previous reports should be the albite law.

The rhombic section, CP of the pericline twinning law, coincides with (001), CP of acline twinning law, in oligoclase to andesine. Therefore the pericline and acline laws are identical in this composition.

Smith (1974) doubted the Ala A law for the twinning law with CP (001), but Tobi (1987) insisted that the Ala A law is more common than the Manebach law. A thin acline lamella that was found quite near the Ala composition plane should have a Manebach symmetry relation to the opposite Ala individual. Tobi (1987) calls it a "pseudo-Manebach" law.

Based upon the above mentioned review, there are eight plagioclase twinning laws that we need to understand; albite, Carlsbad, albite-Carlsbad, pericline,

[1] Institute of Geoscience, GSJ (Present duty: Adviser of Geological Investigation Center, Mongolia)

acline, Ala A, Manebach and Baveno laws. These twins are classified into three types, normal, parallel and complex twins (Fig. 1) based upon the relationship between CP and SA. The normal twin is defined as the twin whose SA is normal to the CP. The parallel law is the law whose SA is a crystallographic axis lying in the CP. The complex law is the law whose SA lies in the CP normal to a crystallographic axis. The complex law can be thought as a joint operation of the normal and the parallel laws. The above mentioned

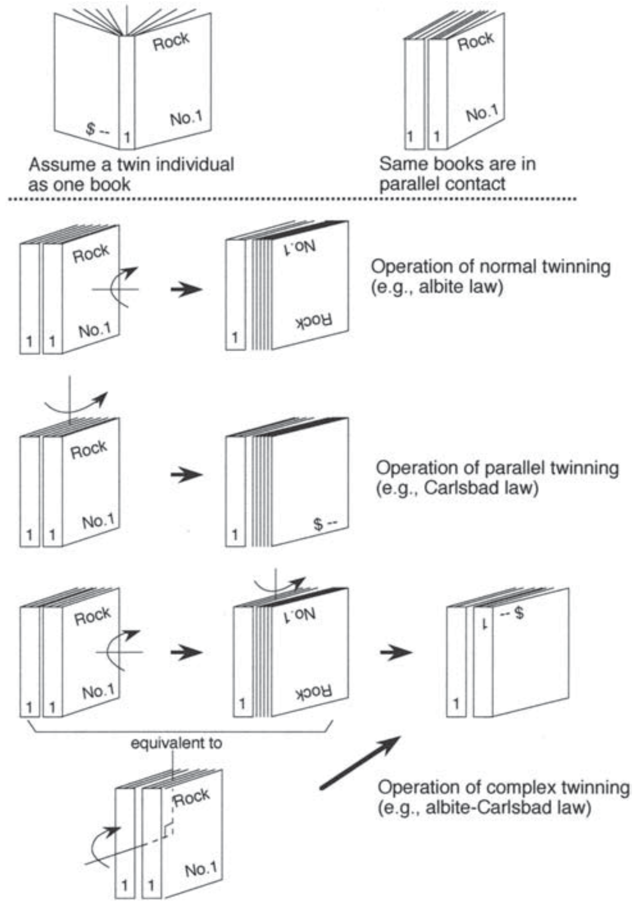

Fig. 1 Concept of twinning types.

Table 1 Plagioclase twinning laws according to composition plane, symmetry axis (twin axis) and type of twinning. Modified from Tobi (1987). Symbol " // " after the name is the law which usually shows lamellar. Bold is the law which occurs frequently. Symbol " * " shows the laws that are often optically identical. Symbol " ** " is the laws which are disputed their frequency in nature.Capitalization for some twins is follows the previous usage, but all the names of the twins should not be capitalized (see 4. Supplement in the text).

composition plane (CP)	normal law	parallel law	symmetry axis (SA)	complex law symmetry axis (SA)
(010) (=cleavage)	**albite** //	Carlsbad	[001]	**albite-Carsbad** normal to [001] in (010)
(001) (=cleavage)	Manebach **	acline* // Ala A**	[010] [100]	
rhombic section		**pericline*** //	[010]	
(021) (diagonal to cleavages)	Baveno			

eight plagioclase twinning laws are summarized in Table 1 based on the definition of the CP and SA.

3. Practical method to determine the plagioclase twinning law

Suwa *et al*. (1974) proposed a reliable method of determining the plagioclase twinning law by using extinction angle variation charts for the CP (010). Takahashi (2001) proposed how to prepare new extinction angle variation charts for any CP based upon Suwa *et al*. (1974). Tobi (1987) briefly showed a rapid method of determining the plagioclase twinning law.

I will review the method to determine the plagioclase twinning law with a little improvement based on my experience. The twinning law can be identified in a thin section with the aid of a universal stage.

3.1 Determination of the composition plane (CP)

We orient the CP vertical along the N-S direction, perpendicular to the E-W axis of the stage (the control axis) (Fig. 2a, b). We turn the CP to the NW position by rotating the microscope stage over 45° (Fig. 2c). If we turn on the E-W axis and both individuals along the CP show length fast with the gypsum plate, the CP is (010) as shown in Fig. 2d and cases 1 and 2 of Fig. 3. If the individuals along the CP vary in elongation, the CP is (001) or rhombic section as shown in Fig. 2d and cases 3 and 4 of Fig. 3. The rhombic section is identical to (001) in oligoclase and andesine as mentioned before.

If the An content is above 70 mol % (bytownite and anorthite), the above easy method is not applicable, but the CP must be determined from each crystallographic axis orientation. If the CP shows an oblique

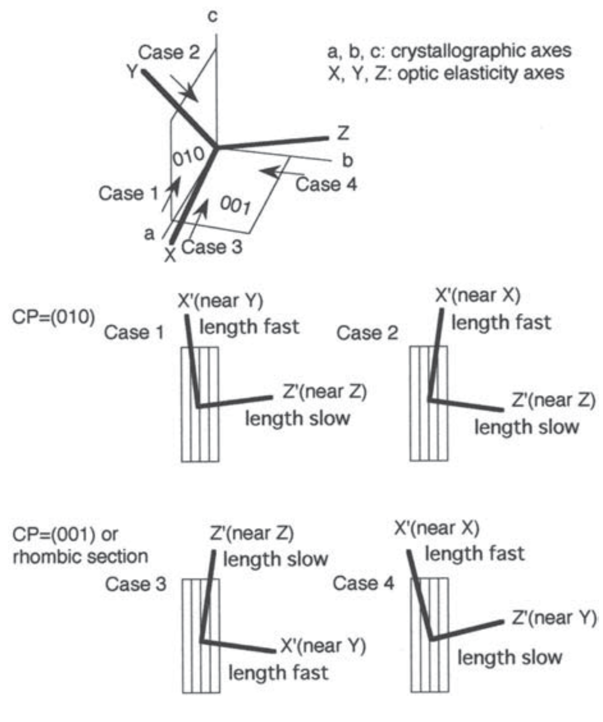

Fig. 3 Idealized orientation for understanding the relationship between the composition planes and elongation.For the optic elasticity axes, instead of X, Y and Z, α, β and γ are often used, respectively.

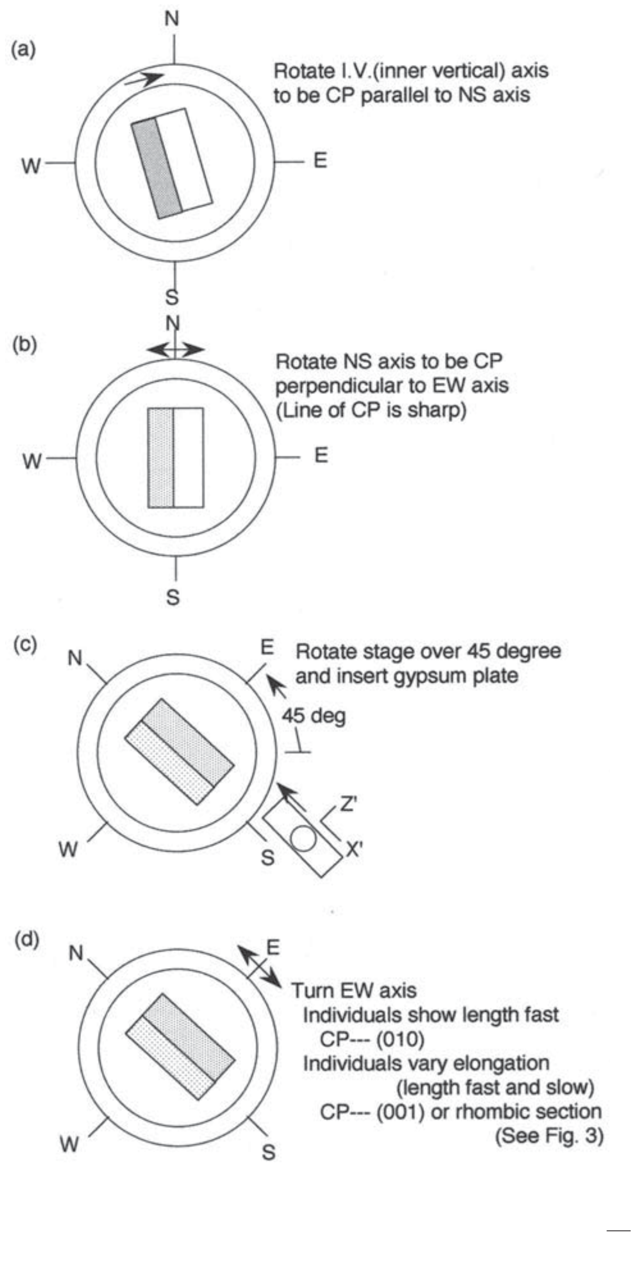

Fig. 2 Illustration for the way to determine the composition plane.

position with regard to cleavages and crystal outline, it is (021), and the twinning law is directly recognized as the Baveno twin (Fig. 4).

3.2 Determining the type of twinning

We orient the CP vertical along the N-S direction, perpendicular to the E-W axis of the stage, which is the same as the first step in determining the CP (Fig. 2a, b).

In a normal twin at this position, the individuals show equal illumination and twinning is invisible. The individuals show a symmetrical extinction in any position around the E-W axis. In a parallel or complex law, its individuals generally show a different retardation. When the individuals show equal retardation rotating around the E-W axis, the SA is horizontal to the N-S direction at this position.

In natural plagioclase, the complex twin is the only albite-Carlsbad twinning law as mentioned before (Table 1). This law is easily distinguished from other laws with three or four different illuminations in one position.

3.3 Systematic method for determining the plagioclase twinning laws

The method to determine the plagioclase twinning laws is summarized though some laws were already referred. First, we determine the composition plane according to 3.1. Second, we decide the type of twinning, normal or not, from 3.2. Whether the twinning is lamellar or not (simple twin) is also additional information. When the CP is (021), diagonal to cleavages, the twinning law is Baveno twin as mentioned above (Fig. 4).

When the CP is (010) and SA shows a normal twin, the twinning law is albite twin, which mostly appears as lamellar. When the twin axis (SA) shows a parallel twin, the twinning law is Carlsbad twin. This twin occurs as a simple twin. Extinction angle variation charts (Suwa *et al.*, 1974) are helpful for confirming the twinning law. In the case of a Carlsbad twin, the extinction positions of twinned individuals are on the same side against the vertical hair between the position of straight extinction in one crystal and the position of straight extinction in another twinned crystal (for the case the angle of the two positions is less than 90^{o} though only two ways are applicable) in andesine to labradorite. The concept of using the extinction angle variation charts is shown in Fig. 5. When plagioclase shows three or four different illuminations, twinning is the complex twin and twinning law is the albite-Carlsbad twin.

Lamellar twinning is the pericline law for the CP rhombic section and acline law for the CP (001). The SA is the b-axis in both twinning laws and rhombic section and (001) are identical in oligoclase and andesine. Therefore these laws are not optically distinguished. We describe “pericline (acline) twin” or “pericline twin” with the understanding that it includes the acline law.

When the CP is (001) and twinning is simple, the twinning law is Manebach twin for a normal twin and Ala A twin for a parallel twin. The controversy over which law is dominant in nature remains (Smith, 1974; Tobi, 1987). I cannot resolve this argument. Therefore we describe a simple twin of CP (001) as “Manebach twin” with the understanding that it may be a Ala A twin.

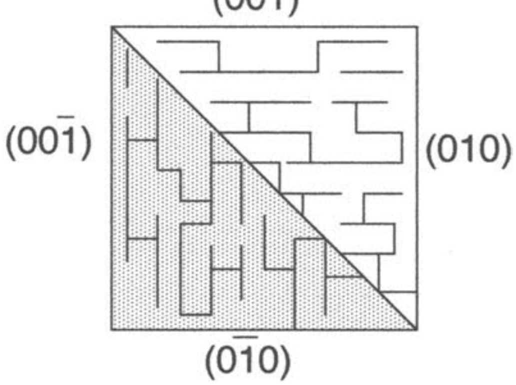

Fig. 4 Baveno twin in relation to cleavages, simplified from Fig. 44 of Emmons (1943).

4. Supplement

Now most natural twinning laws for plagioclase can be identified. If you cannot determine the twinning law type, you should check with a classical method (Emmons, 1943) or describe only as “unspecified”.

I add a comment that a pericline twin often overlaps other twinning laws, for example, albite twin and albite-Carlsbad twin. In case of the former, I describe it as a albite-pericline twin, but this does not mean a complex twin. In the latter, I describe it as the albite-Carlsbad twin with an overlapping of the pericline twin.

Capitalization for some twins, *e.g.*, Carlsbad twin, has been used, but Bates (1988) chose not to capitalize once-proper names that are no longer identified with the person or place from which they were derived. He recommends carlsbad twin instead of Carlsbad twin. It is recommended that all the names of the twinning laws should not be capitalized.

Acknowledgements: Professor K. Suwa is appreciated for helpful advice and suggestions for the first version of the manuscript. I am grateful to an anonymous reviewer for offering constructive comments.

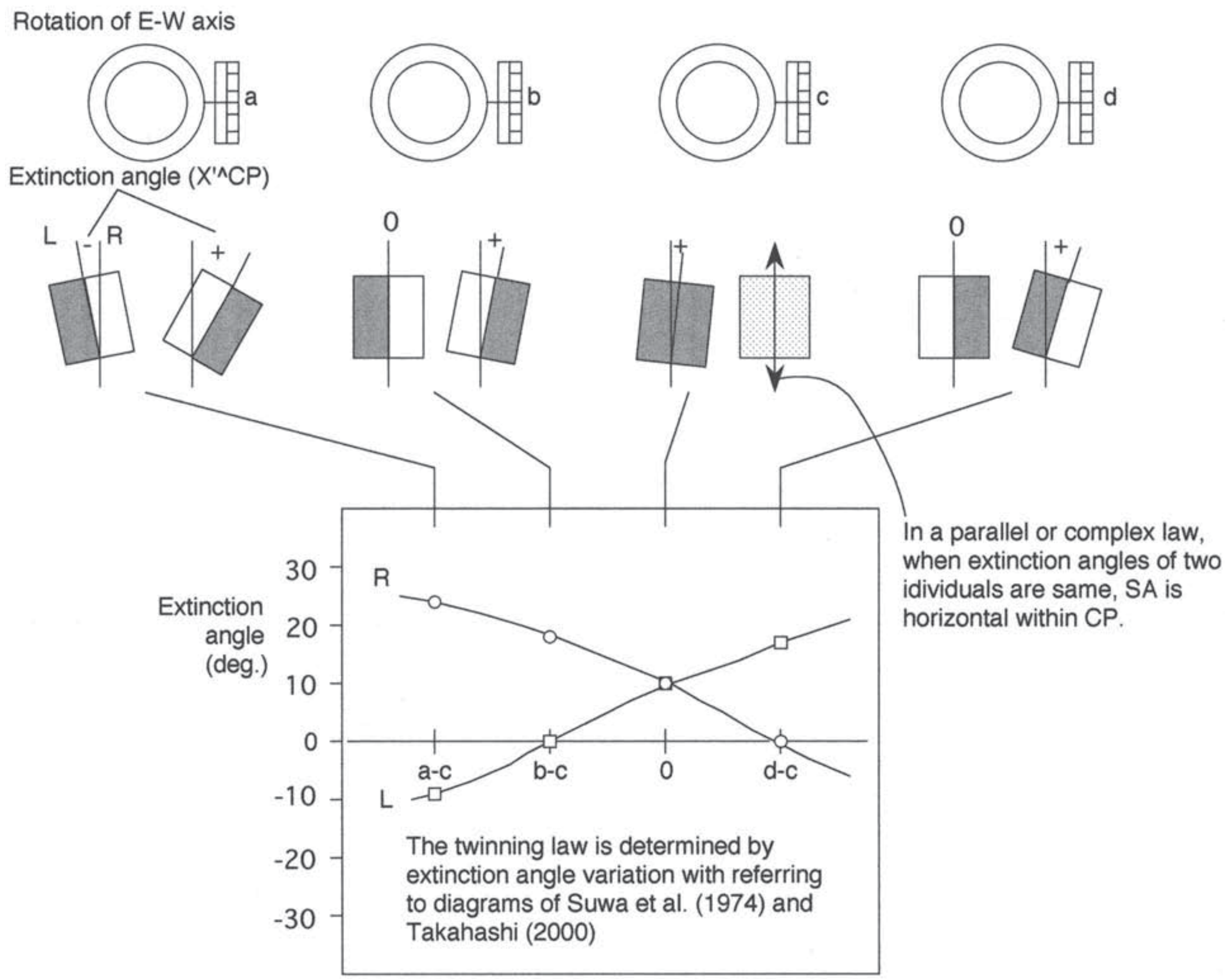

Fig. 5 The method for determining the plagioclase twinning law based upon the variation of extinction angles.

References

Bates, R.L. (1988) *WRITING in earth science*. American Geological Institute, 50p.

Emmons, R.C. (1943) *The Universal Stage*. Geol. Soc. Amer. Mem., 8, 205p.

Gorai, M. (1951) Petrological studies on plagioclase twins. *Amer. Mineral.*, **36**, 884-901.

Smith, J.V. (1974) *Feldspar Minerals 2 (Chemical and Textural Properties)*. Springer-Verlag, 690p.

Smith, J.V. and Brown, W.L. (1988) *Feldspar Minerals (vol. 1) second revised and extended ed*. Springer-Verlag, 828p.

Suwa, K. (1956) Plagioclase twinning in Ryoke metamorphic rocks from the Mitsue-mura area, Kii peninsula, central Japan. *Jour. Earth Sci., Nagoya Univ.*, **4**, 91-122.

Suwa, K., Mizutani, S. and Tsuzuki, Y. (1974) Proposed optical method of determining the twinning laws of plagioclase. *Mem. Geol. Soc. Japan*, no. 11, 167-250.

Takahashi, Y. (1995) Petrological revision and geological application for plagioclase twinning method. *Bull. Geol. Surv. Japan*, **46**, 527-536. (in Japanese with English abstract)

Takahashi, Y. (2000) Variation curves of extinction angle for determining the laws of plagioclase twinning with composition planes of rhombic section and (001). *Bull. Geol. Surv. Japan*, **51**, 309-315. (in Japanese with English abstract)

Takahashi, Y. (2001) Drawing method for variation curves of extinction angle using spread sheet-type calculation soft wear. *Japan. Mag. Mineral. Petrol. Sci.*, **30**, 247-249. (in Japanese with English abstract)

Tobi, A.C. (1962) Characteristic patterns of plagioclase twinning. *Norsk geol. Tidsskr.*, 42-2, 264-271.

Tobi, A.C. (1987) A guide to plagioclase twinning, and an urge to further research on its petrological significance. *Schweiz. Mineral. Petrogr. Mitt.*, **67**, 127-136.

Received August 22, 2002
Accepted December 17, 2002

Bulletin of the Geological Survey of Japan, vol.53(11/12), 2002

鏡下における実用的な斜長石双晶決定法

高橋裕平

要　旨

天然の岩石には多様な斜長石双晶形式が出現するが，その意味の理解には最近の地質学的な解析の結果を加味した再検討が必要である．そのためには，迅速で信頼性の高い斜長石双晶決定法が要求される．そこで小論ではその方法を整理した．双晶決定には自在回転台を利用する．双晶は接合面と対称軸の位置関係から定義できるので，まず接合面を劈開あるいは対角位での光学的な伸長性から決定する．次に垂直双晶か平行双晶か複合双晶かを，対称軸と接合面の関係に基づく光学的な特性から決定する．これらの結果を組み合わせることで，天然に産するほとんどの斜長石双晶形式を同定できる．