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Mineralogical characteristics of feldspars of the granitoids in Bayankhongor area, central Mongolia

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Yuhei TAKAHATHI, Sambuu OYUNGEREL, Kazuki NAITO and Baljinnyamiin Delgertsogt (1998) Mineralogical characteristics of feldspars of the granitoids in Bayankhongor area, central Mongolia. *Bull. Geol. Surv. Japan*, vol. 49 (8), p. 439–446, 4 figs., 1 table.

Abstract: Feldspars of the granitoids in Bayankhongor area, central Mongolia, were investigated mainly by optical methods. The granitoids in this area are classified into dioritic facies (diorite-granodiorite) and granitic facies (granite in a narrow sense). The optic axial angle of K-feldspar of the rocks of the granitic facies decreases in younger rocks, from Riphean to late Paleozoic, but shows the largest value in Mesozoic. This means that the ordering degree of K-feldspar decreased in the order Riphean, early Paleozoic and late Paleozoic. The highest ordered K-feldspar appears in Mesozoic granites.

In dioritic facies, the frequency of C-twinning of plagioclase increases in order of Riphean (3%), early Paleozoic (22–30%) and late Paleozoic (42–64%). In granitic facies, the frequency of C-twinning is 3% in Riphean, 7% in early Paleozoic, 6 to 65% in late Paleozoic and 4% in Mesozoic.

Thus the frequency increase of plagioclase C-twinning corresponds to decrease of optical axial angle of K-feldspar. It can be inferred that less frequency of the C-twinning in older granitoids may have resulted from a later thermal metamorphic effect.

1. Introduction

Feldspars are most common minerals in crustal rocks, and they give many informations from their crystallographical characteristics. It is well known that the optic angle is strongly dependent on the long-range order of Al, Si in the tetrahedral sites of K-rich feldspars, and in fact $2V_X$ has been used to designate relative structural state (Smith, 1974). Twinning laws of plagioclase have been used in the discussion of geological setting for igneous and metamorphic rocks. For example, the twinning types except albite and pericline twins, especially carlsbad and albite-carlsbad twins (C-twinning), occur in non-metamorphosed igneous rocks but rarely in metamorphosed igneous rocks (Gorai, 1951). In addition, pericline twin is used as indicator of shear stress condition under high temperature (Olsen and Kohlstedt, 1985).

We are currently engaged in the metallogenic map project of the Bayankhongor area, central Mongolia. In order to clarify relationship between granitic activity and metallogeny, characterization for each granitic body should be done based upon many view points. We already pointed out the relationship between granitoids series and some metal deposits in the area (Takahashi, *et al.*, 1998). In this paper, we show optic axial angle of K-feldspar and frequency of twinning law of plagioclase for the granitoids in the area.

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2. Geologic and petrographical background

The Bayankhongor area is geotectonically divided into Baidrag, Bayankhongor, Dzag and Khangay Zones from south to north (Tungalag, 1997). The Baidrag Zone is composed of Archean high-grade metamorphic rocks ranging from amphibolite to granulite facies and Proterozoic metamorphic rocks of greenschist facies. The Bayankhongor Zone is the latest Proterozoic (Vendian) to Cambrian geologic unit. It is composed of psamitic, pelitic and basic schists with calcareous and quartzose rocks. In addition, the ophiolitic rocks such as ultramafic rocks, gabbro, sheeted dike and pillow lava are also exposed. These rocks are sometimes occurred as allochthonous appearance. The Dzag Zone consists mainly of Cambrian to Ordovician sandstone associated with conglomerate and

Keyword: plagioclase, K-feldspar, C-twinning, optic axial angle, granitoid, Mongolia

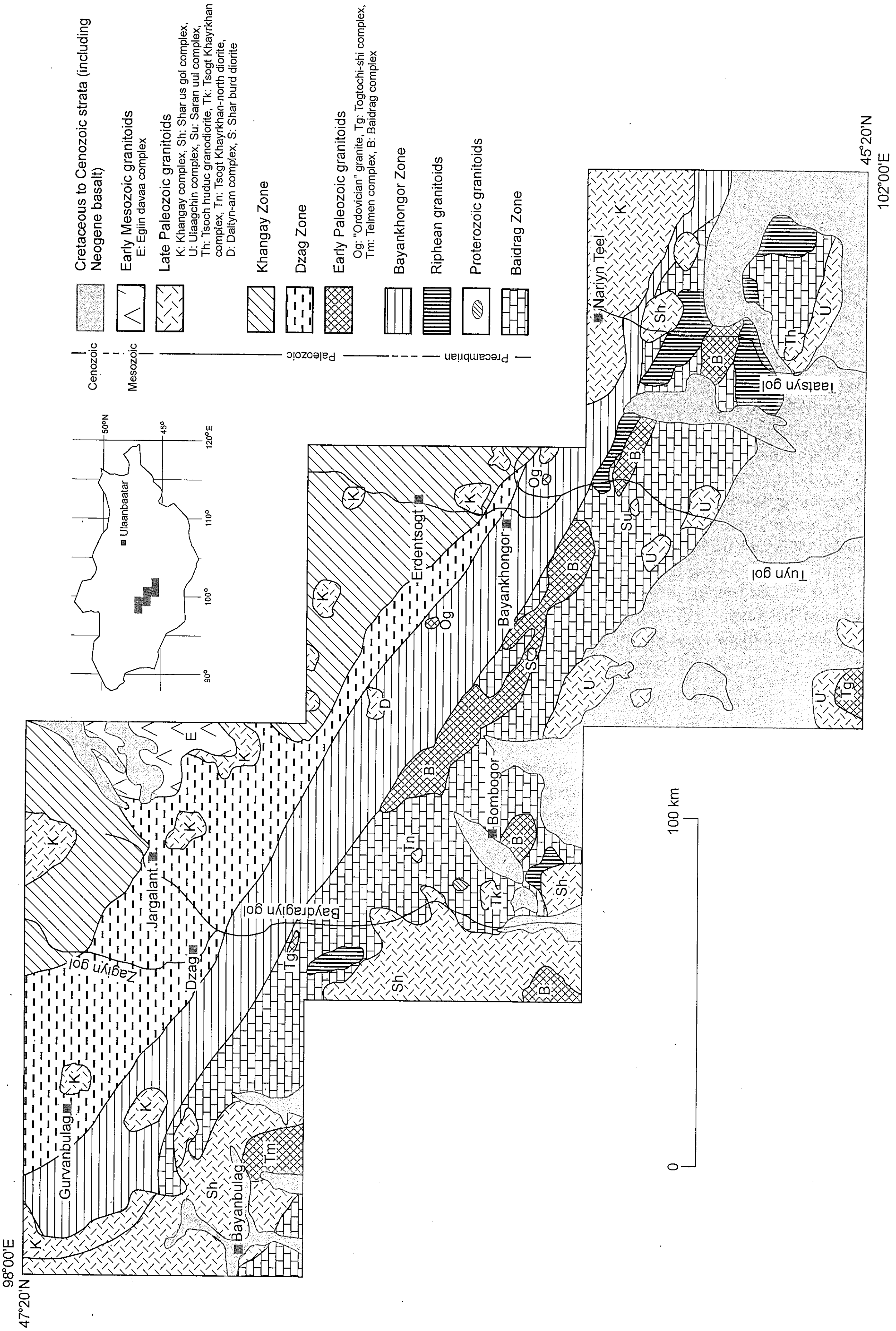

Fig. 1 Geologic map. Cited from Takahashi *et al.* (1998).

mudstone. The Khangay Zone consists of Devonian to Carboniferous turbidite sediments.

Many granitic bodies intruded into these zones. The granitic bodies are variously called after local geographical names in the geologic map sheets in 1 : 200,000 (Bayarsaihan and Henzii, 1990 ; Davaa, 1989 ; Tumurchudur *et al.*, 1990 ; Zabotkin, 1988) and Takahashi *et al.* (1998) as shown in the legend in Fig. 1. In this study, the rocks of dioritic and granitic facies are studied. The rocks of dioritic facies in this study are petrographically diorite, quartz diorite, monzodiorite, quartz monzodiorite and granodiorite in IUGS classification (Streckeisen, 1976). Samples are selected, 1 from Riphean, 2 from early Paleozoic and 6 from late Paleozoic. The rocks of the granitic facies in the study are almost granite in a narrow sense. Samples are selected, 2 from Riphean, 2 from early Paleozoic, 5 from late Paleozoic and 1 from Mesozoic.

3. K-feldspar

The K-feldspar in the rocks of the granitic facies is recognized as microcline or orthoclase in general appearance under microscope. Microcline is common in Riphean and Mesozoic granites, and it shows microcline structure. Orthoclase is occured in early Paleozoic and late Paleozoic granites. It shows perthite structures (mostly, strings or rods types in Fig. 152 of Deer *et al.*, 1992). Both microcline and orthoclase are observed in "Ordovician" Granite.

To know characteristics of K-feldspar quantitatively, optic axial angle of K-feldspar is measured. Results are shown in Fig. 2. The optic axial angle (2 Vx) is 64°-78° in Riphean granites, 58°-69° in Baidrag Complex (abbreviation in Figs ; B), 54°-59° in Daltynam Complex (D), 60°-65° in Ulaagchin Complex (U), 48°-62° in Khangay Complex (K), 54°-63° in Shar us gol Complex (Sh) and 82°-85° in Egiin davaa Complex (E). In summary, the optic axial angle of K-feldspar decreases in younging order from Riphean to late Paleozoic, but shows the largest value in Mesozoic.

For K-rich alkali feldspars, the optic axial angle 2 Vx provides a precise estimate of the total Al content of the T_1 tetrahedral sites. According to Su *et al.* (1984), for monoclinic varieties with the optic axial plane (OAP) perpendicular to (010) and triclinic varieties with the OAP nearly perpendicular to (010),

$$\text{Total Al in } T_1 \text{ sites} = 0.665 + 0.711 \sin^2 Vx.$$

The value for the rocks of the granitic facies in the Bayankhongor area is estimated 0.86 to 0.95 in Riphean, 0.83 to 0.90 in early Paleozoic, 0.78 to 0.87 in late Paleozoic and 0.97 to 0.99 in Mesozoic. In the other words, the ordering degree of K-feldspar is decreasing in order of Riphean, early Paleozoic and late Paleozoic. The highest ordered K-feldspar appears in Mesozoic. These are supported by tricrinisity of K-feldspar with use of XRD for some samples (Naito, 1998 in press). For example, the triclinisity $(12.5 \times (d_{131} - d_{1\bar{3}1}))$ is 0.82 for Riphean Granite and 0.0 for Ulaagchin Complex in late Paleozoic. The former is defined as microcline and the latter as orthoclase.

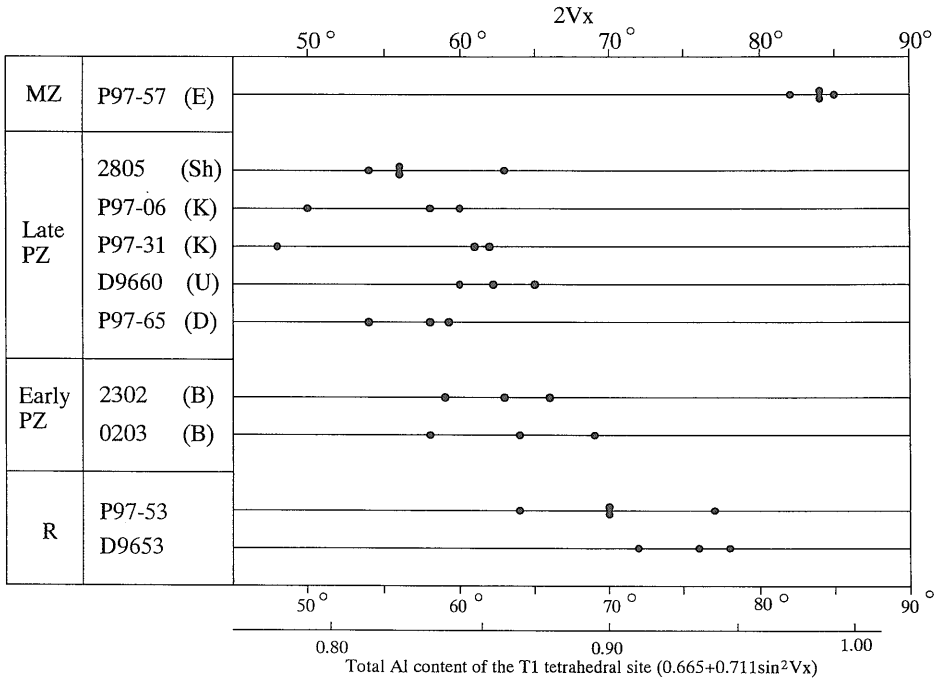

Fig. 2 Optic axial angle of K-feldspar of the granitic facies. Abbreviations: R, Riphean; PZ, Paleozoic; MZ, Mesozoic (The same in Figs. 3 and 4). Abbreviations within parenthesis are shown in Fig. 1. (The same in Figs. 3 and 4 and Table 1).

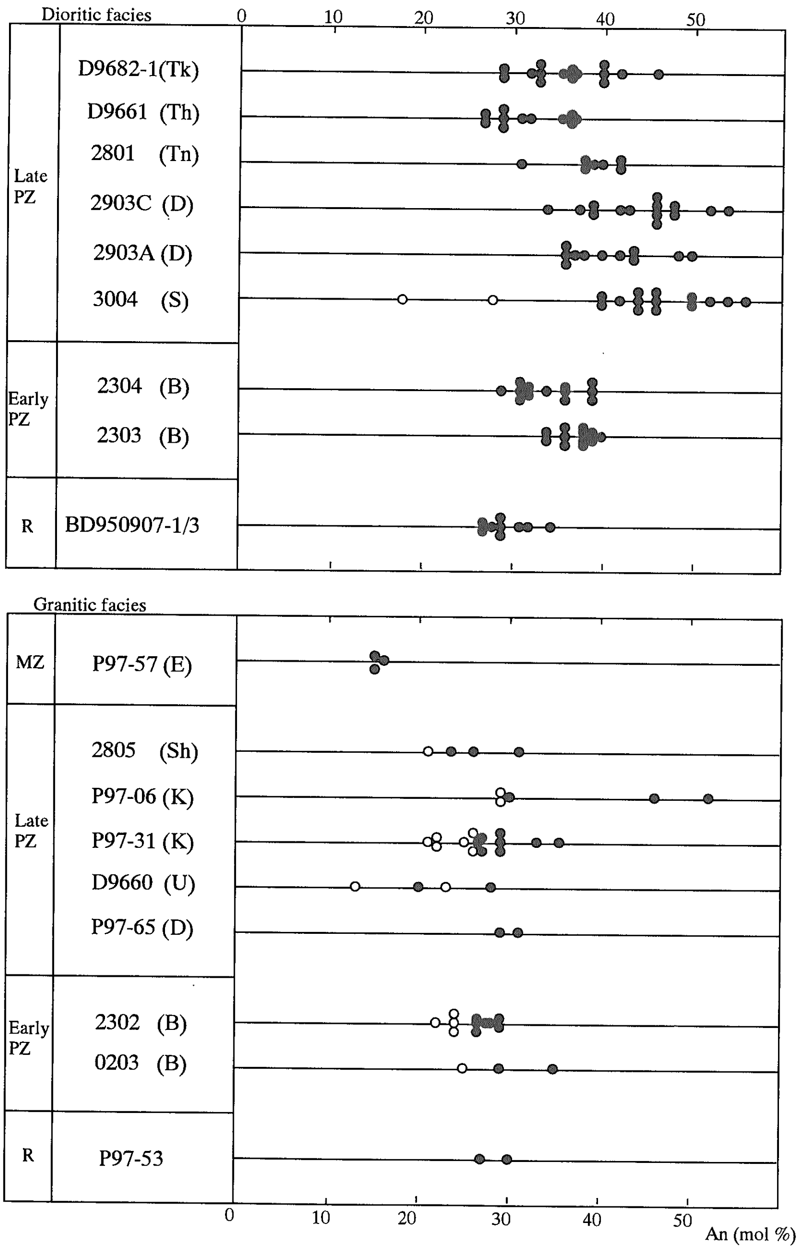

Fig. 3 Anorthite content of plagioclase (mol%). Open circle shows rim of grain.

4. Plagioclase

4.1 Anorthite contents and ordering degree

Anorthite content of plagioclase can be optically estimated. In this study, a-normal method (Suwa *et al.*, 1974) and Köhler angle method (Uruno, 1963) were used (Fig. 3). The latter method gives not only anorthite content but also ordering degree. The ordering degree of plagioclase is 0.8 to 1.1 for the granitoids in the area. These values mean ordered plagioclase (low-temerature type).

In dioritic facies, anorthite content is around 30 mol% in Riphean and 30 to 40 mol% in early Paleozoic (dioritic facies of Baidrag Complex). In late Paleozoic, Shar burd diorite shows 40 to 55 mol%. Daltyn-am Complex shows 35 to 55 mol%. In Tsogt Khayrkhan-north Diorite, Tsohiokudag Granodiorite and Tsogt Khayrkhan Complex, anorthite contents of plagioclase are mostly 30 to 40 mol% though showing a little difference in each body.

In granitic facies, anorthite content of plagioclase is mostly 20 to 35 mol%. However, plagioclase of the Khangay Granite (sp. no. P 97-06) sometimes shows around 50 mol% in anorthite content. In Mesozoic granite, anorthite contents of plagioclase is around 15 mol%.

4.2 Twinning laws

Plagioclase twinning laws are determined by optical method using a universal stage (Takahashi, 1995).

Table 1 Frequency of twinning laws of plagioclase.

Dioritic facies

Age	Riphean	Early Paleozoic		Late Paleozoic					
Abbr in Fig.1		B	B	S	D	D	Tn	Th	Tk
Sp.no.	BD9509 07-1/3	2303	2304	3004	2903A	2903C	2801	D9661	D9682-1
Carlsbad				1					
Ab-Ca	1	11	12	28	33	21	28	19	22
Ab-Ca-Pe		1	3	5			2		
Albite	23	32	28	12	17	28	20	4	28
Ab-Pe	5	6	6	4				17	
Pericline	1		1			1			
Total	30	50	50	50	50	50	50	40	50

Granitic facies

Age	Riphean	Early Paleozoic		Late Paleozoic					Mesozoic
Abbr in Fig.1		B	B	D	U	K	K	Sh	E
Sp.no.	P97-53	0203	2302	P97-65	D9660	P97-31	P97-06	2805	P97-57
Ab-Ca	1	2	1	2	3	26	25	4	1
Ab-Ca-Pe			1				1		
Albite	38	28	24	25	44	23	10	20	21
Ab-Pe	1		2	3	3	1	4	1	2
Pericline			2						1
Total	40	30	30	30	50	50	40	25	25

Abbreviation: Ab-Ca; albite-carlsbad, Ab-Ca-Pe; albite-carlsbad twinning overlapped by pericline twinning, Ab-Pe; albite-pericline

That is, the twinning laws are determined by measuring the extinction angle in the zone perpendicular to the composition plane and using the diagram of Suwa *et al.*(1974) and Suwa (1977). Plagioclase twinning data of the granitoids in the area are shown in Table 1 and Fig. 4.

Dioritic facies : Plagioclase twins in the dioritic rock in Riphean are mostly albite twin, followed by albite-pericline. In dioritic facies of Baidrag Complex (B, early Paleozoic), plagioclase twinning is mostly albite twin, followed by albite-carlsbad and albite-pericline twins. Plagioclase twinning of Shar burd diorite (S) is mostly albite-carlsbad and albite laws, followed by albite-carlsbad law with pericline law and pericline law. Carlsbad twinning is also identified as minor. Plagioclase twinning of the Daltyn-am Complex (D), Tsogt Khayrkhan Complex (Tk) and Tsogt Khayrkhan-north Diorite (Tn) is albite-carlsbad and albite twinning laws with minor of pericline twinning. Plagioclase twinning of Tsoch huduc Granodiorite (Th) is mostly albite-carlsbad and pericline laws, followed by albite law.

Granitic facies : In the granitic facies except Khangay and Shar us gol Complexes (K and Sh), albite twinning is the most common law and the other laws are less than 10% in frequency. Plagioclase twinning of the Khangay Complex are mostly albite-carlsbad and albite laws, followed by pericline law. Plagioclase twinning of Shar us gol Complex is mostly albite law, followed by albite-carlsbad law.

Frequency of C-twinning : As mentioned in first chapter, C-twins, which are defined for all the twinning types except the albite and pericline twins, and pericline twin are sometimes diagnostic for discussing geological setting. In following, the frequency of C-twinning is discussed.

In the dioritic facies, the frequency of C-twinning is 3% in Riphean, 22 and 30% in early Paleozoic and 42 to 64% in late Paleozoic. It is concluded that the frequency increases in order of Riphean, early Paleozoic and late Paleozoic. On basis of geological setting of the rocks and empirical rule of twinning laws (Gorai, 1951), it is inferred that less frequency of the C-twinning in older masses resulted from later thermal metamorphosed effects.

In the granitic facies, the frequency of C-twinning is 3% in Riphean, 7% in early Paleozoic, 6 to 65% in late Paleozoic and 4% in Mesozoic. In late Paleozoic, the frequency is low (about 6%) in granitic facies of Daltyn-am and Ulaagchin Complexes and high (52 and 65%) in Khangay Complex. The frequency shows intermediate value (16%) in Shar us gol Complex. Thus the frequency roughly decreases in order of Riphean, early Paleozoic, and late Paleozoic, though the values

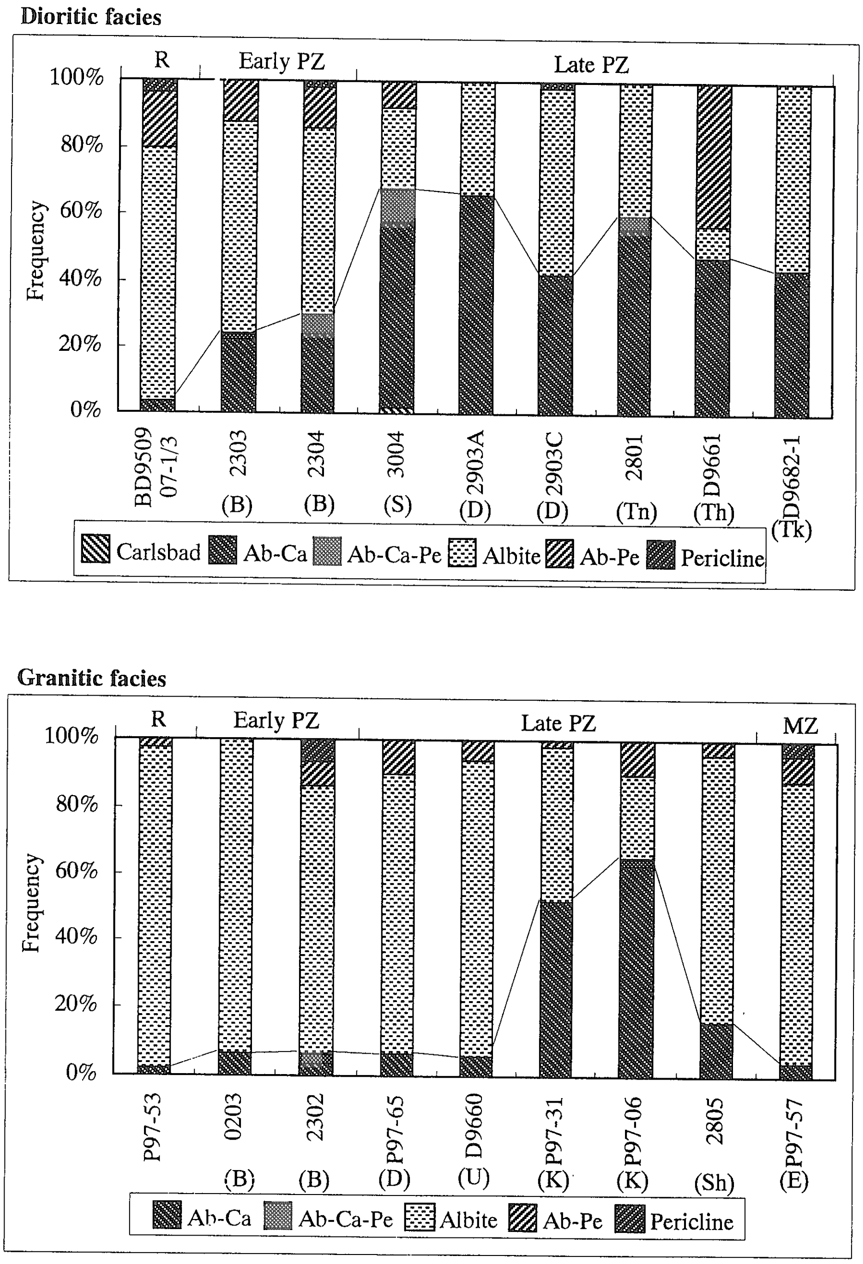

Fig. 4 Frequency of twinning laws of plagioclase. Area under solid line means C-twinning.

of late Paleozoic granites are variable. From these observations it can be inferred that less frequency of the C-twinning in older masses might be resulted from later thermal metamorphoic effects as same as in the dioritic facies. However, the frequency in Mesozoic granitoids shows small value, the reason for which is left to be further studied in detail, for example, in view point of intrusive history within Mesozoic granitoids with reexamining their isotopic ages.

5. Summary and conclusion

The results can be summarized as follows. The optic axial angle of K-feldspar in the rocks of the granitic facies decreases in younging order from Riphean to late Paleozoic, but shows the largest value in Mesozoic. The total Al content of the T_1 tetrahedral sites is estimated 0.86 to 0.95 in Riphean, 0.83 to 0.90 in early Paleozoic, 0.78 to 0.87 in late Paleozoic and 0.97 to 0.99 in Mesozoic. In the other words, the ordering degree of K-feldspar is decreasing in order of Riphean, early Paleozoic and late Paleozoic. The highest ordered K-feldspar appears in Mesozoic. In the dioritic facies, the frequency of C-twinning of plagioclase increases in order of Riphean, early Paleozoic and late Paleozoic. In the granitic facies, the frequency of C-twinning is 3% in Riphean, 7% in early Paleozoic, 6 to 65% in late Paleozoic and 4% in Mesozoic. At least, from Riphean to late Paleozoic, the frequency of C-twinning increases in younging order.

It is concluded that the frequency increase of plagioclase C-twinning corresponds to decrease of optic axial angle of K-feldspar in the granitoids in the area. It is inferred that less frequency of the C-twinning in older granitoids resulted from later thermal metamorphosed effect.

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モンゴル国中央部バヤンホンゴル地域花崗岩類の長石類の鉱物学的性質

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要　旨

モンゴル国中央部バヤンホンゴル地域の花崗岩類中の長石類について主に光学的手法を用いて鉱物学的な性質を調べた．本地域の花崗岩類は，閃緑岩相（閃緑岩-花崗閃緑岩）と花崗岩相（狭義の花崗岩）に分けられる．花崗岩相のカリ長石の光軸角は原生代リフェアンから古生代後期にかけて順に小さくなり，中生代の花崗岩相でもっとも大きい．すなわち，カリ長石の秩序度が，リフェアン，古生代前期，古生代後期の順に小さくなるが，中生代でもっとも秩序度が高くなる．

閃緑岩相の斜長石中のC双晶の頻度は，リフェアンで3%，古生代前期で22-30%，古生代後期で42-64%と時代が若くなる順に増加する．花崗岩相での頻度は，リフェアンで3%，古生代前期で7%，古生代後期で6-65%，中生代で4%と，古生代後期までは時代が若くなる順に増加するが，中生代で小さな値となる．

以上のことから本地域においては，カリ長石の秩序度が減少すると斜長石のC双晶の頻度が大きくなるという対応が認められた．また，より古い時代の花崗岩類中の斜長石のC双晶の頻度が低く，その原因は後の熱変成作用の影響であると考えられる．