Zeitschrift: Schweizerische mineralogische und petrographische Mitteilungen = Bulletin suisse de minéralogie et pétrographie

Band: 52 (1972)

Heft: 2

Artikel: On a zoned ternary feldspar from Domadalshraun, Iceland

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DOI: https://doi.org/10.5169/seals-40609

On a Zoned Ternary Feldspar from Domadalshraun, Iceland

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With 3 figures and two tables in the text

Abstract

Chemical and optical data are given for a zoned ternary feldspar with high temperature optics, ranging from Or 4 Ab 66 An 30 in the core to Or 18 Ab 75 An 7 in the margin. The optical orientation of the alkali-rich mantle corresponds with the conventional scheme for anorthoclase. Additional data on anorthoclase phenocrysts, microlites and glass within the same rock outline the course of crystallization of this rhyolitic vitrophyre.

In acid volcanic rocks from south-central Iceland the composition of feldspar ranges from oligoclase-andesine to sodic alkali feldspar. The narrow field of ternary feldspars connecting these end members is outlined by some published microprobe analyses (H. SCHWANDER) of phenocrysts, whose optics have been studied by SCHEDLER (1971). Rocks with two feldspar phases have not been considered by this author.

Rhyolitic vitrophyres collected recently from Domadalshraun, 25 km ENE of Hekla, contain phenocrysts of alkali feldspar as well as plagioclase. Minor constituents of these rocks are greenish, alkali – poor calcic clinopyroxene ($2\,V_\gamma$ 52 – 56° · c $\wedge$ [n_γ] 42 – 48°), magnetite and dark brown hornblende ($2\,V_\alpha \sim 60°$, c $\wedge$ [n_γ] 4 – 10°). Sample Isl. 280 shows three generations of feldspar in the colourless glassy matrix:

1. Rare, zoned *plagioclase* phenocrysts with high temperature optics and with resorbed boundaries. The marginal zones have the composition of *ternary feldspar*.

2. Abundant, euhedral to subhedral, slightly zoned *calcic alkali feldspars* which can reach a size of 5 mm and often show square forms. Most of these phenocrysts are simply twinned, exclusively according to laws admitted in the monoclinic system, and the re-entrant angles of Carlsbad twins may be seen. The individuals of these primary twins show secondary multiple twinning after the albite and pericline laws. In sections perpendicular to [100] the

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close-set crosshatched pattern is quite conspicuous, though unequally developed in adjacent domains of one and the same crystal. In other orientations this very dense twinning is invisible and extinctions are apparently homogeneous. In such cases a universal stage analysis of a Carlsbad twin can give either distinctly triclinic optical symmetry, or nearly monoclinic symmetry. Monoclinic symmetry between the indicatrices is clearly the resultant of superposed, submicroscopically twinned invididuals, occurring in equal amounts ("Summenoptik"). The crystals were originally monoclinic and became triclinic during the course of cooling. Locally very diffuse cryptoperthitic domains are visible under the microscope, but the components have not yet been identified by microprobe or X-ray studies. This description and the chemical, optical and X-ray data contained in Tables 1 and 2 fit the term *anorthoclase* as defined by Smith and MacKenzie (1958), and Bambauer (1969).

Diffractometer data of an anorthoclase concentrate ($>90\%$ anorthoclase) are given in Table 1. The powder pattern gives the best fit with data for anorthoclase (Carmichael and MacKenzie, 1964) and for high albite (Donnay and Donnay, 1952), and the lines were indexed according to these references. By dry heating of the feldspar and homogenisation at 850° for 24 hours little change was effected: the values for $2\,\Theta$ are systematically somewhat lower and between $2\,\Theta = 31.20°$ and $31.85°$ the peaks have better resolution (new

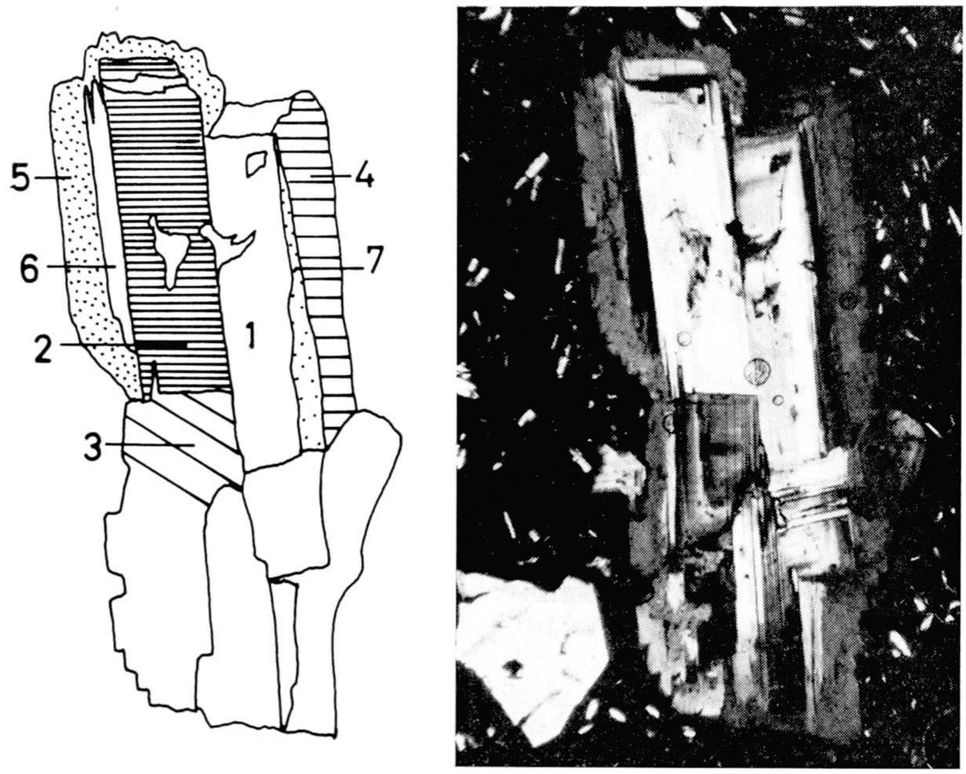

Fig. 1. Zoned phenocryst of ternary feldspar in rhyolitic vitrophyre from Domadalshraun, south central Iceland. For data of the different individuals see Table 2. Twin laws: 1/2 Carlsbad, 2/3 acline, 1/6 and 4/5 Roc Tourné, 2/6 albite. Vergr. ~35×.

line at 31.41°?). Moreover, line 19 is stronger than line 18 for the heated feldspar.

The small differences between the diagrams of the tempered and the unheated feldspar, and the single $(20\bar{1})$ peak suggest the alkali feldspar to be highly disordered and in an initial state of unmixing. Doubling of the peaks (111) and (131) indicates triclinic symmetry. From the relative position of these lines ($2\,\Theta_{h\bar{k}l} > 2\,\Theta_{hkl}$), there follows $\alpha^* < 90°$; this result is confirmed by optical universal stage studies.

According to TUTTLE and BOWEN (1958) the position of the line $(20\bar{1})$ gives good information on the composition of homogeneous alkali feldspars. From $2\,\Theta_{20\bar{1}} - 2\,\Theta_{10\bar{1}0}$ quartz $= 1{,}004$ (resp. 0,989 for the heated feldspar) an Or-content of 14% (resp. 15%) is derived. This is a mean value for several anorthoclase crystals, but it compares well with the point analyses of the microprobe.

3. Scaly microlites of sodic alkali feldspar, often twinned and with refractive indices similar to the above mentioned anorthoclase phenocrysts. Optical study not possible.

The twin represented in Fig. 1 is of special interest and was studied in detail. Its oligoclase-andesine core is surrounded by potassian oligoclase and ternary feldspar with a slightly resorbed boundary and is again mantled by anorthoclase. Table 2 gives information on the chemical and optical data of this phenocryst, of other feldspars and of the glass from the same rock sample Isl. 280. As is shown also by Fig. 2, this crystal covers almost the whole compositional range of phenocrysts known from South Iceland. It proves, combined with the data on microlites, anorthoclase phenocrysts, glass and the mother rock, potassium enrichment in the melt during the course of crystallisation. The feldspar series clearly avoids the albite corner.

The phenocryst of Fig. 1 is twinned according to laws (albite, Carlsbad, Roc Tourné and acline) which favour an exact optical study. It serves as a test case for establishing the relative optical orientations of high-temperature plagioclase and sodic alkali feldspar. The composition plane (010) is common to all individuals and zones of the twin-stock, except for individual 3. The twin axes X, Y, Z constructed from the individuals of the homogeneous central plagioclase core and from those of the alkali feldspar rim agree very well, and the (001) cleavages of the individuals concur and change in accordance with the twin-law; (001) of individuals 5 and 6 clearly coincide. Measurements in the strongly zoned and narrow intermediate lamellae are less reliable. If the position of the rectangular crystallographic coordinates $X = \frac{\perp 001}{(010)}$, Y = pole (010), Z = [001] is taken as a base, with the normal to (001) in the positive quadrangle, optic orientations result as shown in Fig. 3. The optics of the alkali-rich marginal zones (Or 17.4 to 18.1, Ab 74.4 to 75.4, An 8.2 to 6.1)

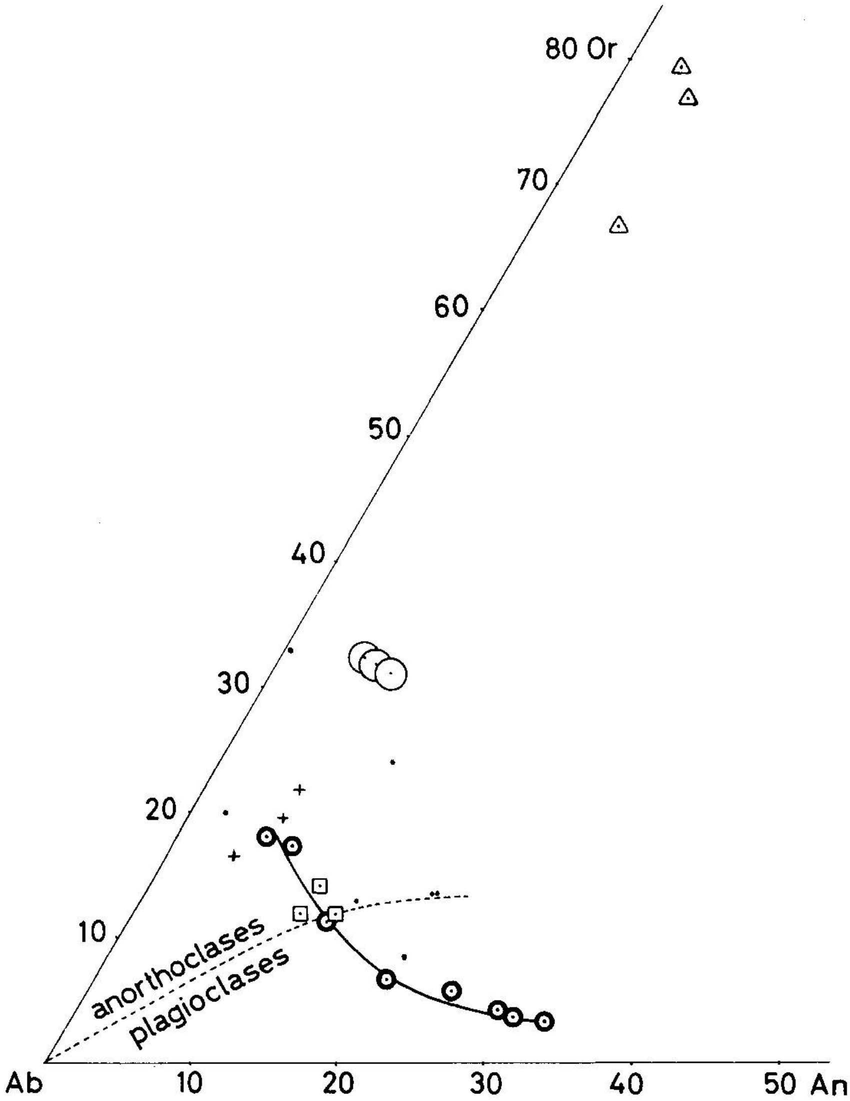

Fig. 2. Or-Ab-An diagram, showing the compositions of different zones of feldspar in Fig. 1 (open circles connected by line), of anorthoclase phenocrysts (squares), of microlites (crosses) and of glass (triangles) of rhyolitic vitrophyre Isl. 280. Dots represent south-icelandic feldspar data from Schedler 1971. Large circles indicate rock composition of three vitrophyres from Domadalshraun.

agree with the conventional scheme for "anorthoclase", e.g. with Fig. 230 in Tröger (1959, part 1). The new orientation for microcline, established by Laves (1951) for well ordered potassian feldspar is not to be extended to disordered sodium-rich alkali feldspars, as was done by Marfunin (1966).

If the Euler angles II of the anorthoclase forming the external zone (mean values 4 and 5 in Table 2) are compared with Plate II of Burri–Parker–Wenk (1967), it becomes evident that triclinic high-temperature alkali feldspars with An 6–8 could be misinterpreted as high-temperature oligoclase: on the high-curves for R An 14 is read, for I An 14, for L_α An 15 and for L_A An 14! However, the corresponding optic axial angle and the refractive indices do not agree; they fit pure high-albite fairly well. The anorthoclase margin of the twin

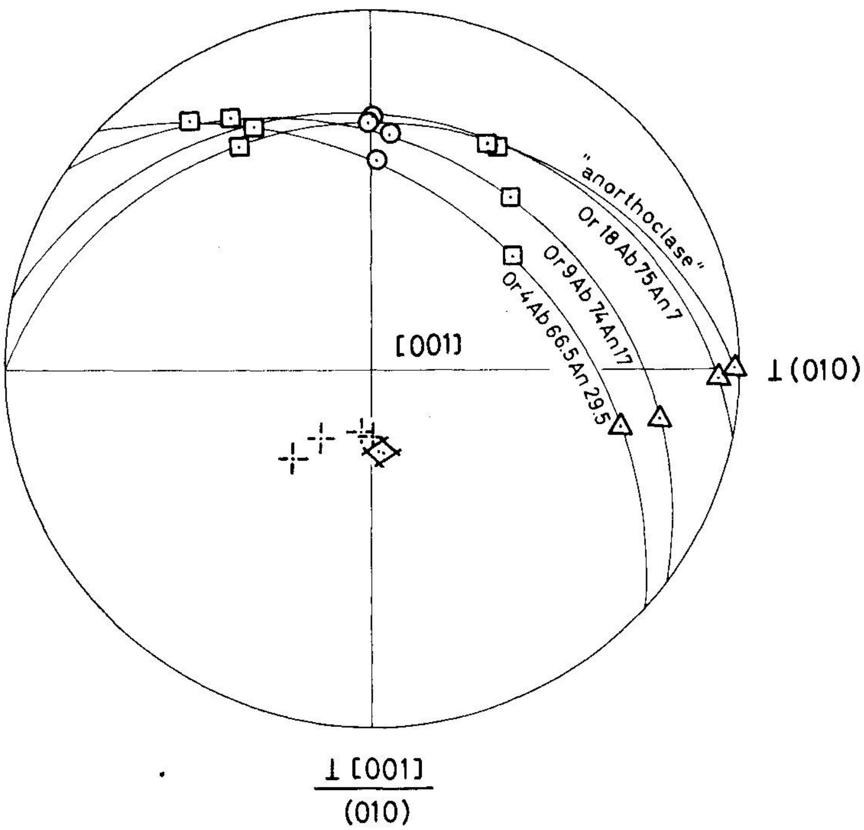

Fig. 3. Stereographic projection perpendicular to [001] of the chief optic directions in different zones of the twin stock shown in Fig. 1, and of anorthoclase phenocryst with nearly monoclinic optical symmetry, due to superposed submicroscopic twin lamellae occurring in equal amounts.

stock described is clearly triclinic. Only the careful consideration of all optical evidence, of morphology and twinning and of X-ray and chemical data can lead to a safe diagnosis.

In our experience such ternary feldspars are quite common in Iceland, and their problems puzzled us for some time until this test case of an alkali-mantled plagioclase was found. Only the microprobe can settle the case and affords the best method for the exact determination of ternary feldspars. But a petrographer has to make his diagnosis mainly in the mm- to cm-domain, and the polarizing microscope is still the most powerful tool for the rough determination of a mineral and for the recognition of problems which are worth of closer study. Therefore, a better understanding of the optically and structurally ill-known series of ternary feldspars from volcanic rocks is highly desirable. We feel that many members of this series have been overlooked in the past.

This note gives a first result of a cooperative investigation in progress on acid Icelandic volcanic rocks and their feldspars. Financial help by the Friedlaender Foundation of Volcanology in Zürich for the field trip in summer 1971 is gratefully acknowledged.

Table 1. *Powder data for anorthoclase Isl. 280 (2Θ: 10°–52°)*

Recorded on an Norelco diffractometer with Ni-filtered Cu-K_α radiation ($\bar{\lambda}$ = 1.5418 Å); scanning speed, 0.25° 2Θ/min; receiving slit: 0.1; chart scale: 1° per 4 cm; time constant: 1; internal standard: quartz; max. error: ± 0.02°

No.	$2\Theta_{Cu}$				d Å	J	hkl	remarks
1	13.75		(13.72)		6.44	11		
2	13.89		(13.88)		6.375	4		
3	15.20		(15.18)		5.828	3		
4	15.60		(15.57)		5.680	4		
5	21.88		(12.865)		4.062	25	$20\bar{1}$	
6	22.88		(22.83)		3.887	14	$1\bar{1}1$	
7	23.56 }		(23.53)		3.760	17	111	
8	23.68 }		(23.655)		3.757	23		
9	24.28		(24.26)		3.665	12		
10	24.52		(24.51)		3.630	6		
.11	25.66		(25.605)		3.472	8		M(M)
12	26.28		(26.25)		3.3915	8		M(M)
13	27.68		(27.65)		3.223	100	040	
14	27.995		(27.95)		3.186	85	002	
15	28.23 }		(28.21) }		3.161	10		
		28.26		(28.25)	3.575			
16	28.28 }		(28.27) }		3.155	12	220	
17	29.68		(29.65)		3.010	12	$1\bar{3}1$	
18	30.40 }		(30.34)		2.905	13		b(b)
19	30.55 }		(30.56)		2.926	11		b(b)
20	31.21 }		(31.21)		2.866	8	131?	(b)
21	31.28 }		(31.41)		2.8595	8		bM
22	31.87		(31.80)		2.807	5		bM(bM)
23	33.49		(33.45)		2.6751	4		(bM)
24	35.49 }		(35.48)		2.5292 }	12		Mb(s.b., M)
25	35.58 }				2.5237 }			Mb
26	36.56		(36.54)		2.458	2		
27	~37.13		(37.13)		2.4295	2		bM(bM)
28	42.06		(41.99)		2.1482	10		bM(bM)
29	42.65		(42.57)		2.1200	8		bM(bM)
30	49.74?		(49.73)		1.8330	4		b(b)
31	50.56 } ?		(50.45)		1.8052	4		b(b)
32	50.75 }		(50.58)		1.7988	2		b(b)
33	51.30 }		(51.275)		1.7808	6		b(b)
34	51.435 }		(51.41)		1.7765	7		

b: broad or diffuse line
M: average of diffuse line
In brackets: data for heated feldspar

Table 2. *Chemical* (microprobe, H. S.) *and optical data* (optic axial angles, Euler angles II and refractive indices) *for feldspars and glass of vitrophyre Isl. 280*

Feldspar of figure 1	Or	Ab	An	$2V_\alpha$	R	I	L_α	α^*	Optical analyst
oligoclase-andesine core									
individual 1	4.3	66.8	28.8	83°	132.5°	37°	55°	87°	
individual 2	3.8	66.1	30.1	82°	132.5°	37°	55.5°	86°	
mean values 1/2	4.0	66.5	29.5	82.5°	132.5°	37°	55°	86.5°	E.W.
individual 1				84°	132.5°	37°	52°	87°	
individual 2				82°	132.5°	37.5°	52.5°	87.5°	
mean values 1/2				83°	132.5°	37°	52°	87°	R.W.

	Or	Ab	An	$2V_\alpha$	R	I	L_α	α^*	Optical analyst
"inclusion" in individual 1	5.9	69.2	24.9						
individual 3	3.4	64.2	32.4	83.5°	129°	37.5°	57°	88°	E.W.
individual 3				83°	131°	38.5°	56°	86°	R.W.
mean values 3[1])				83°	130°	38°	56.5°	87°	
transitional zones									
individual 6	11.4	75.0	13.6	63°	123°	28°	65°	86°	
individual 7[1])	6.6	73.4	20.0	70°	129.5°	27°	58°	85°	
mean values 6/7[1])	9.0	74.2	16.8	66.5°	126°	27.5°	61.5°	85.5°	E.W.
anorthoclase margin									
individual 4	18.1	75.8	6.1	49.5°	100.5°	17.5°	82°	87.5°	
individual 5	17.4	74.4	8.2	50°	99.5°	22°	81°	89°	
mean values 4/5	17.7	75.1	7.2	50°	100°	20°	81.5°	88°	E.W.
individual 4 (second measurement)				49.5°	103°	20.5°	82.5°		
individual 5				50°	99.5°	19.5°	78°		
mean values 4/5				50°	101°	20°	80°		E.W.
individual 4				52.5°	112.5°	20.5°	71°	88°	
individual 5				51°	108°	20°	73°	89.5°	
mean values 4/5				51.5°	110°	20°	72°	88.5°	R.W.
means E.W. and R.W.[2])	17.7	75.1	7.2	50.5°	104°	20°	78°		
Anorthoclase phenocrysts									
submicroscopically twinned crystals	12.0	76.2	11.7						
	14.3	73.8	11.9	56°	91°	21°	89.5°	88°	E.W.
	11.8	74.2	14.0						
data from grain mounts (spindle stage)					n_α	n_β	n_γ		
grain 1					1.528	1.534	1.538		
grain 2				53°	1.529	1.536	1.538		
grain 3				54°	1.529	1.537	1.540		
grain 4				51°	1.529	1.535	1.539		R.W.
Microlites	16.5	78.7[3]	4.8	±1°	±0.002				
	19.5	73.9	6.6						
	21.7	71.5	6.8						
Glass	66.6	27.4	5.9						
	76.8	17.6	5.6		n=1.494±0.002				
	79.4	16.8	3.8						
Rocks Domadalshraun									
Isl. 245[4])	32.4	61.6	6.0						
Isl. 302[5])	32.3	61.8	5.9						
BÄCKSTRÖM	31.3	60.3	8.4						

[1]) Data less reliable.
[2]) The two optical operators made their measurements in different parts of individuals 4 and 5.
[3]) Ab by difference.
[4]) Analyses by courtesy of W. STERN, full data will be published later.
Data for glass and rock composition are recalculated to Or+Ab+An=100 mol%.

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Manuscript received 31th May 1972.