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Labradorite from Surtsey (Iceland)

By Hans-Rudolf Wenk (Zürich and Basel)

With 1 figure in the text

Abstract. Some optical, chemical and X-ray data of the volcanic labradorite (65% An) from the island of Surtsey (Iceland) are given. The investigations include some structural results and a new determination of the lattice parameters.

Surtsey, the new volcanic island south of Iceland was formed in november 1963 by a submarine eruption. Except the pacific volcanoes, it is actually the only place at which a volcanoe of Hawaiian magma type is active. During an excursion to Iceland in 1964 the author — although not beeing able to enter Surtsey — received some specimens of plagioclase crystals from the coastal sands, ejected by the primary ash eruption phase¹). The crystals have a light honey-yellow colour and are extremely clear. They are up to 5 cms long, very homogeneous and show almost no inclusions.

The material made worth an investigation first to get a check point for the new migration curves (BURRI, PARKER, WENK, 1966) of the high temperature (volcanic) plagioclase series, secondly to make this unique material known to the investigators of plagioclase in crystallography and petrology. Some chemical, optical and X-ray data, published in the regional literature of Iceland (E. WENK, H. SCHWANDER, H. R. WENK, 1966) are repeated here (mainly because of some curiosities in icelandic printing) and new information is added.

The orientation of the optical indicatrix in a twin complex (albite-, Carlsbad-, and Roc Tourné-laws) is represented by the Eulerian I position angles ϕ 51.8°, θ 35.2°, ψ 25.8°, 2 V_y 82° determined by U-stage method. From this other position angles have been calculated:

¹) We are obliged to Dr. Sigvaldarson (Reykjavik), who gave us these crystals.

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Euler I	ϕ	51.8°	θ	35.2°	ψ	25.8°	2 V,	, 82	2°		
Euler II	R	120.2°	Ι	75.5°	\mathbf{L}_{α}	57.6°	LA	8.6	6°		
Euler III	D	21.2°	N	58.7°	\mathbf{K}_{α}	72.9°					
Goldschmidt (φ, ρ)	[n _o] 231.8	°	35.2°	[n _β]	120.2	° 75	.5°	$[n_{\gamma}]$	21.2°	58.7°
	A	212.4	0	81.7°	B	350.19	21	.9°			
Becke (λ, φ^*)	[n_] 20.8	°	29.0°	[n _β]	-29.19	°-73	.3°	$[n_{\gamma}]$	52.8°-	-30.8°
	Α	-56.6	°	74.8°	B	21.6°	3	.9°	-		

The data are compared with the migration curves for volcanic plagioclases in BURRI, PARKER, WENK 1966. From this an anorthite content of 66 mole percent can be deduced²).

The refraction index in cleveage flakes (001) is 1.562-1.563, which corresponds to 64-66% An (see BURRI, PARKER, WENK, 1966). The refraction index of labradorite glass is 1.543, corresponding to 67% An in the diagram of SCHAIRER, SMITH and CHAYES (1956).

The following chemical analyses have been made by H. SCHWANDER (see E. WENK, H. SCHWANDER, H. R. WENK, 1965) with a JEOL JXA-3A microprobe and a JACO spectrograph:

	Or	$\mathbf{A}\mathbf{b}$	\mathbf{An}
microprobe	0.6	33.8	65.6
spectrograph	1.2	33.6	65.2

X-ray studies were expected to supply some information on the structure of volcanic labradorites.

d-values taken form powder photographs (see Table I), indexed using trial values from COLE, SØRUM and TAYLOR (1953), served as input to refine the lattice parameters by least squares (Table II).

Of special importance are the 2ϑ angle difference values for the characterization of the structure:

SMITH, J. R. and YODER, H. S. (1956): 2ϑ (131) -2ϑ (1 $\overline{3}1$) $= 2.045^{\circ}$ SMITH, J. V. and GAY, P. (1958): 2ϑ (131) $+2\vartheta$ (220) -4ϑ (1 $\overline{3}1$) $= 1.005^{\circ}$ 2ϑ (1 $\overline{1}1$) -2ϑ (20 $\overline{1}$) $= 0.790^{\circ}$

In the diagrams of SMITH and YODER (1956) and SMITH and GAY (1958) the values fall into the field of volcanic plagioclases, but they differ distinctly from the curves for heated and synthetic feldspars. This fact indicates, that considerable time may have passed since the growth of the crystals in the magma. The lack of zonar structures also indicates that an excellent state of equilibrium was reached during the subvolcanic

²) All chemical data are in mole percent.

Labradorite from Surtsey (Iceland)

15.922									
2 8	dobs	deale	Irel	hkl	2 9	dobs	dcalc	Irel	\mathbf{hkl}
13.585 ± 0.0	005 6.513		\mathbf{ms}	110	35.740	2.510	2.509	S	241
15.180	5.832	5.828	mw	111	36.445	2.464		w	
18.865	4.700	4.695	\mathbf{ms}	$0\overline{2}1$	36.765	2.443		w	
21.930	4.050	4.046	s	201	37.145	2.419		mw	
22.720	3.910	3.909	ms	111	37.680	2.386		w	
23.595	3.767	3.764	VS	111,130	37.900	2.373		w	
24.405	3.644	3.639	s	130	38.215	2.354		vw	
24.495	3.631	3.626	s	131	38.995	2.309		w	
25.595	3.477	3.475	mw	$11\overline{2}$	39.420	2.285		w	
25.950	3.431	3.430	w	$22\overline{1}$	39.710	2.269		w	
26.430	3.369	3.365	ms	Ĩ12	40.395	2.231		w	
26.590	3.351		vw		40.500	2.225		vw	
27.495	3.241	3.243	s	$2\overline{2}0$	41.790	2.160		w	
27.750	3.213		vs?		42.155	2.142		ms	
27.815	3.205	3.209	vs	040	42.375	2.131		\mathbf{ms}	
27.990	3.185	3.185	vs	002	42.980	2.103		\mathbf{ms}	
28.425	3.137	3.139	8	220	43.170	2.094		w	
29.465	3.029	3.031	ms	131	44.785	2.023		w	
30.235	2.953	2.953	8	041	44.935	2.016		w	
30.410	2.937	2.940	s	$02\overline{2}$	45.590	1.989		$\mathbf{m}\mathbf{w}$	
30.185	2.911		w	222?	46.125	1.967		w	
31.510	2.837	2.837	s	131	46.475	1.953		w	
31.730	2.818	2.822	w	$2\overline{2}\overline{2}$	46.755	1.942		w	
33.790	2.650	2.651	mw	132	47.050	1.932		$\mathbf{m}\mathbf{w}$	
35.230	2.546		vw		47.135	1.927		mw	
35.625	2.518	2.520	8	241					

Table I. Powder data for Surtsey labradorite

Table II. Lattice parameters for Surtsey labradorite

a	$8.186 ~\AA~\pm~0.007$	a* 0.13604 Å ⁻¹ \pm 0.00009
b	12.871 Å \pm 0.007	b* 0.07790 Å ⁻¹ \pm 0.00004
\mathbf{c}	$7.109~\AA~\pm~0.005$	c* 0.15696 Å ⁻¹ \pm 0.00008
α	$93.57^{\circ} \pm 0.04$	α^* 85.84° \pm 0.04
β	$116.03^{\circ} \pm 0.05$	β^* 63.89° ± 0.05
γ	$\mathbf{90.37^\circ}~\pm~0.04$	γ^* 87.84° \pm 0.04
V	$671 \text{ \AA}^3 \pm 1.2$	

phase. In strongly exposed precession b photographs (Fig. 1) no diffuse c-type reflections but very diffuse b split type reflections only for a few indices (the same which show strong b splits in low state plagioclases) could be observed. The meaning of diffuse b-type reflections is discussed by MEGAW (1962). Therefore this crystal is better ordered (with respect to Si/Al, LAVES and GOLDSMITH, 1954) than a synthetic crystal grown rapidly at the same temperature. Although the origin makes probable something like high albite structure (following GAY, 1953, 1956), intermediate conditions cant be exluded.

The example of Surtsey labradorite proves that structural facts can become very useful indicators in petrologic research.

Acknowledgements: Thanks are due to Prof. E. Wenk (Basel) for kind help, to Dr. H. U. Nissen (Zürich) for useful discussions and to the computer centers of the ETH (Zürich) and the University of Basle for the assistance in using their machines.



Fig. 1. Precession a-photograph of Surtsey-labradorite. Very diffuse and week b-split reflections (marked by arrow).

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New X-ray Data for Wenkite¹)

By Hans-Rudolf Wenk (Zürich and Basel)²)

Abstract. X-ray data for the new barium-silicate Wenkite are given. For the first time there is a list of d-values and more accurate lattice constants obtained by least squares refinement.

In the course of a structure determination of the new barium silicate wenkite from Candoglia (Northern Italy), described first by PAPAGEOR-GAKIS (1959, 1962), a more accurate list of d-values and lattice constants refined by least squares method (BURNHAM, 1962) have been obtained.

The data given by PAPAGEORGAKIS prove wenkite to be a new mineral³). However the chemical formula postulated by him,

 $(OH)_5 (SO_4)_2 Ba_{4.5} Ca_{4.4} Al_9 Si_{12} O_{42},$

can be shown by microprobe analysis to be somewhat inaccurate. Although all the elements found by PAPAGEORGAKIS are present, the weight proportions are different, mainly because of the fine intergrouth with quartz. The mineral seems to be chemically very homogeneous. An exact quantitative analysis is expected shortly.

From precession photographs the hexagonal Laue group 6/mmm can be found; no extinction laws could be detected, therefore the five space groups P 6/mmm, P 6mm, P $\overline{6}2m$, P $\overline{6}m2$ and P 622 are possible. There is so far no reason to give preference to P 6/mmm as suggested by PAPAGEORGAKIS. It is hoped that an unarbitrary determination of the space group will be possible from HARKER-sections of PATTERSON-syn-

¹) The name wenkite is given in honour of E. Wenk (Basel) and is not related to the author.

²) Institut für Kristallographie und Petrographie der Eidg. Techn. Hochschule, Zürich, Switzerland.

³) A notice on wenkite was given by FLEISCHER (1963). The name of the mineral was recently accepted by IMA.

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Table I. Powder data for wenkite, crystal I*), taken with a Jagodzinski type powder camera. Relative intensities obtained with a Zeiss photometer. Si-calibration. Cu-radiation

<u>ክ ነ ነ</u>	TNTENSTTV	0.9/078	DIORN	DOATO	RESIDI	UALS OF D
	10	11 095	7 47100	T ACLEO	(UDB-CALU)	(UDS-CALC)/SIGHA
	40	13 100	6 75946	7.40100 6 75585	.00972	.00013
1 Ô 1	10	14.070	6 28905	6 29130		
$\hat{2}$ $\hat{0}$ $\hat{0}$	5	15.140	5.84690	5.85073	00384	00009
1 1 1	25	17.700	5.00659	5.00804	00145	00005
201	35	19.263	4.60374	4.60410	00036	00001
210	15	20.058	4.42303	4.42274	.00029	.00001
2 1 1	50	23.343	3.80749	3.80460	.00289	.00016
002	40	23.808	3.73416	3.73075	.00341	.00019
102	70	25.125	3.54133	3.55446	01313	00083
3 U I 9 9 0	100	20.140	3.43809	3.40008	.00141	.00009
310	75	20.340	3.31900	3.31192	.00174	.00012
202	60	28.328	3.14778	3.14565	.00213	00003
$\bar{2}$ $\bar{2}$ $\bar{1}$	40	28.980	3.07842	3.07727	.00115	.00010
311	45	29.990	2.97701	2.97608	.00093	.00008
$2\ 1\ 2$	60	31.330	2.85267	2.85168	.00099	.00010
401	30	32.850	2.72406	2.72353	.00053	.00006
302	65	33.190	2.69693	2.69605	.00088	.00010
320	90	33.343	2.68490	2.68450	.00040	.00004
229	20	33.303	2.02021	2.92999	.00022	.00003
003	40 5	36 068	2.30431	2.30402	00049	.00000
3 1 2	40	36.663	2.44903	2.44859	.00044	.000012
4 1 1	25	37.180	2.41615	2.41592	.00024	.00003
5 0 0	35	38.435	2.34010	2.34029	00020	00003
$1 \ 1 \ 3$	10	38.520	2.33513	2.33402	.00111	.00017
042	10	39.098	2.30193	2.30205	00012	00002
203	20	39.318	2.28955	2.28893	.00062	.00010
501	10	40.015	2.25127	2.25195	00068	00011
3 2 2	30	40.000	2.23281	2.23303	00022	00004
1 2 3	5	41.605	2.16883	2 16788	00095	00017
$\overline{3}$ $\overline{3}$ $\overline{1}$	>5	41.865	2.15596	2.15590	.00006	.00001
421	35	42.608	2.12007	2.12021	00015	00003
303	45	43.088	2.09756	2.09710	.00046	.00009
223	5	45.225	2.00328	2.00283	.00046	.00009
502	10	45.728	1.98241	1.98251	00011	00002
513	15	45.930	1.97410	1.97412	.00004	.00001
403	5	47.965	1 89504	1 89488	00035	
$\hat{0}$ $\hat{0}$ $\hat{4}$	25	48.758	1.86606	1.86537	.00069	.00017
4 3 1	15	48.840	1.86312	1.86280	.00032	.00008
$2\ 3\ 3$	35	49.935	1.82480	1.82447	.00033	.00008
521	5	50.165	1.81697	1.81731	00034	00009
160	5	51.150	1.78427	1.78446	00019	00005
599	10	52.705	1.73523	1.73552	00029	00008
	20	04.770 54 858	1.07440	1.07442	.00003	.00001
4 2 3	10	55.550	1.65291	1 65261	00029	000019
4 4 1	5	55.748	1.64750	1.64729	.00022	.00007
224	25	56.355	1.63119	1.63293	00175	00057
134	5	56.880	1.61737	1.61726	.00011	.00004
612	10	57.185	1.60947	1.60979	00032	00011
603	30	60.343	1.53257	1.53470	00213	00081
3 3 Z	25	60.648	1.52559	1.52550	.00009	.00003
800	10	63 528	1 46908	1.02000	.00009	.00003
0 5 4	5	63,730	1.45904	1.45870	.00034	.00015
163	5	64.175	1.44999	1.44989	.00010	.00004
	5	64.335	1.44677			
	5	67.415	1.38796			
	15	69.498	1.35137			
	Э	70.770	1.33016			
		76 225	1.20000			
		79,195	1.20845			
		87.625	1.11260			
		89.395	1.09510			

*) As the error in the lattice parameters is slightly higher for crystal II (see Table II), and the deviations $d_{obs} - d_{calc}$ not so regular distributed, the values for crystal I are probably more accurate.

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Table II. Powder data for wenkite, crystal II, taken with a Jagodzinskitype powder camera. Si-calibration. Cu-radiation

h k l	2 v (OBS)	D (OBS)	D (CALC)	RESIDU. (OBS-CALC)	ALS OF D (OBS-CALC)/SIGMA
001	11.760	7.51869	7.46487	.05382	.00074
1 1 0	13.025	6.79118	6.75727	.03390	.00057
1 0 1	14.000	6.32033	6.29370	.02663	.00052
200	15.065	5.87584	5.85197	.02387	.00054
1 1 1	17.635	5.02490	5.00964	.01525	.00047
	19.220	4.01394	4.00049	00985	.00039
210	23 338	3.80829	3.80564	.00265	.00014
õ õ ž	23.805	3.73463	3.73244	.00219	.00012
$1 0 \overline{2}$	25.008	3.55763	3.55599	.00164	.00010
301	25.775	3.45348	3.45759	00411	00027
2 2 0	26.350	3.37941	3.37864	.00077	.00005
3 1 0	27.458	3.24550	3.24609	00059	
202	20.020	3.14/10	3.14000	00007	.00001
	29.995	2.97652	2.97682	00030	00003
	31.320	2.85355	2.85268	.00087	.00009
401	32.830	2.72567	2.72419	.00148	.00016
302	33.173	2.69827	2.69696	.00131	.00014
3 2 0	33.323	2.68647	2.68507	.00140	.00016
1 4 0	35.105	2.55407	2.55401	.00006	.00001
231	35.493	2.52703	2.02009	00124	.00016
	36 045	2 48959	2.48829	.00130	.00017
312	36.643	2.45032	2.44936	.00096	.00013
$\tilde{4}$ $\tilde{1}$ $\tilde{1}$	37.163	2.41722	2.41649	.00073	.00010
500	38.410	2.34156	2.34079	.00077	.00012
$1\ 1\ 3$	38.515	2.33542	2.33501	.00041	.00006
042	39.073	2.30334	2.30275	.00060	.00009
023	39.300	2.29000	2.20900		00004
501	40 343	2.23372	2.23355	.00016	.00003
3 2 2	41.385	2.17985	2.17966	.00019	.00003
2 1 3	41.580	2.17008	2.16874	.00134	.00023
3 3 1	41.850	2.15670	2.15640	.00030	.00005
4 2 1	42.595	2.12068	2.12070	00002	00000
303	45.078	2.09802	2.09790	00014	.00003
4 4 3 5 0 2	45 713	1 98302	1.98307	00004	00001
3 1 3	45.903	1.97526	1.97483	.00042	.00009
600	46.513	1.95076	1.95066	.00011	.00002
043	47.950	1.89560	1.89554	.00006	.00001
0 0 4	48.740	1.86671	1.86622	.00049	.00012
3 4 1	48.828	1.80300	1.80322	00055	00003
102	49.155	1 82490	1.82509	00019	00005
521	50.138	1.81789	1.81772	.00017	.00004
611	52.683	1.73590	1.73591	00000	00000
053	53.730	1.70452	1.70495	00043	00013
5 2 2	54.760	1.67487	1.67485	.00002	.00001
700	54.855	1.67219	1.07199		00011
000 192	55 545	1.65304	1.65314	00010	00003
4 4 1	55.750	1.64745	1.64765	00021	00007
$\hat{2} \ \hat{2} \ \hat{4}$	56.345	1.63145	1.63358	00213	00070
$6\ 1\ 2$	57.163	1.61004	1.61020	00016	00006
4 4 2	60.095	1.53830	1.53902	00072	00027
603	60.343	1.53257	1.53516		
702	63 550	1.02011	1.04000	.00011	.00001
	64 165	1.45019			
	64.360	1.44627			
	67.425	1.38778			
	68.660	1.36580			
	69.002	1.35986			
	10.418	1.20840			
	76.685	1.24162			
	79.235	1.20794			
	87.220	1.11672			
	87.505	1.11382			

theses⁴). So far no powder data for wenkite have been published. A list of d- and 2 ϑ -values for two different crystals is given in Table I and II. The observed values are compared with calculated data obtained using the lattice constants refined by least squares.

About 60 safely indexed lines were taken as input for the least squares refinement in order to get more accurate lattice parameters. The obtained values are listed below (Table III) and compared with the data given by PAPAGEORGAKIS.

Table III. Lattice parameters of wenkite

	Crystal I	Crystal II	PAPAGEORGAKIS
			(1962)
\mathbf{a}_0	$13.511_7 \pm 0.001_3 ~{ m \AA}$	$13.514_6 \pm 0.001_9 \ \mathrm{\AA}$	$13.528 \pm 0.003 \; { m \AA}$
\mathbf{c}_{0}	$7.461_5 \pm 0.001_1 ~{ m \AA}$	$7.464_9 \pm 0.001_7 ~{ m \AA}$	7.471 ± 0.002 Å
v	$1179.7_1 \pm 0.2_2 ~{ m \AA}^3$	$1180.7_4 \pm 0.3_2 ~{ m \AA^3}$	1184.033 Å ³
a^*	$0.08545_9 \pm 0.00000_8 \ { m \AA^{-1}}$	$0.08544_1 \pm 0.00001_2 \ { m \AA^{-1}}$	
c*	$0.13402_1 \pm 0.00002_0 \ { m \AA}^{-1}$	$0.13396_1 \pm 0.00003_0 \ { m \AA}^{-1}$	

More detailed structural and chemical data will be given along with a crystal structure analysis which is now in progress.

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4) From HARKER-concentrations the two space-groups $P\overline{6}2m$ and $P\overline{6}m2$ can be deduced, of which $P\overline{6}2m$ is more probable.

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