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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 phase[1]). 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_γ 82° determined by U-stage method. From this other position angles have been calculated:

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

Euler I	ϕ	51.8°	θ	35.2°	ψ	25.8°	$2V_\gamma$	82°		
Euler II	R	120.2°	I	75.5°	L_α	57.6°	L_A	8.6°		
Euler III	D	21.2°	N	58.7°	K_α	72.9°				
Goldschmidt (φ, ρ)	$[n_\alpha]$	231.8°	35.2°	$[n_\beta]$	120.2°	75.5°	$[n_\gamma]$	21.2°	58.7°	
	A	212.4°	81.7°	B	350.1°	21.9°				
Becke (λ, φ^*)	$[n_\alpha]$	20.8°	29.0°	$[n_\beta]$	−29.1°	−73.3°	$[n_\gamma]$	52.8°	−30.8°	
	A	−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 deduced[2]).

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	Ab	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): $2\vartheta(131) - 2\vartheta(1\bar{3}1) = 2.045°$

SMITH, J. V. and GAY, P. (1958): $2\vartheta(131) + 2\vartheta(220) - 4\vartheta(1\bar{3}1) = 1.005°$

$2\vartheta(1\bar{1}1) - 2\vartheta(20\bar{1}) = 0.790°$

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.

Table I. *Powder data for Surtsey labradorite*

2 ϑ	dobs	dcalc	Irel	hkl	2 ϑ	dobs	dcalc	Irel	hkl
13.585 ± 0.005	6.513		ms	$1\bar{1}0$	35.740	2.510	2.509	s	$\bar{2}41$
15.180	5.832	5.828	mw	$11\bar{1}$	36.445	2.464		w	
18.865	4.700	4.695	ms	$0\bar{2}1$	36.765	2.443		w	
21.930	4.050	4.046	s	$20\bar{1}$	37.145	2.419		mw	
22.720	3.910	3.909	ms	$1\bar{1}1$	37.680	2.386		w	
23.595	3.767	3.764	vs	$111, 1\bar{3}0$	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	$13\bar{1}$	38.995	2.309		w	
25.595	3.477	3.475	mw	$11\bar{2}$	39.420	2.285		w	
25.950	3.431	3.430	w	$22\bar{1}$	39.710	2.269		w	
26.430	3.369	3.365	ms	$\bar{1}12$	40.395	2.231		w	
26.590	3.351		vw		40.500	2.225		vw	
27.495	3.241	3.243	s	$2\bar{2}0$	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		ms	
27.990	3.185	3.185	vs	002	42.980	2.103		ms	
28.425	3.137	3.139	s	220	43.170	2.094		w	
29.465	3.029	3.031	ms	$1\bar{3}1$	44.785	2.023		w	
30.235	2.953	2.953	s	$04\bar{1}$	44.935	2.016		w	
30.410	2.937	2.940	s	$02\bar{2}$	45.590	1.989		mw	
30.185	2.911		w	$22\bar{2}$?	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	$2\bar{2}2$	46.755	1.942		w	
33.790	2.650	2.651	mw	$\bar{1}32$	47.050	1.932		mw	
35.230	2.546		vw		47.135	1.927		mw	
35.625	2.518	2.520	s	$24\bar{1}$					

Table II. *Lattice parameters for Surtsey labradorite*

a	8.186 Å ± 0.007	a*	0.13604 Å^{-1} ± 0.00009
b	12.871 Å ± 0.007	b*	0.07790 Å^{-1} ± 0.00004
c	7.109 Å ± 0.005	c*	0.15696 Å^{-1} ± 0.00008
α	93.57° ± 0.04	α^*	85.84° ± 0.04
β	116.03° ± 0.05	β^*	63.89° ± 0.05
γ	90.37° ± 0.04	γ^*	87.84° ± 0.04
V	671 Å^3 ± 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.

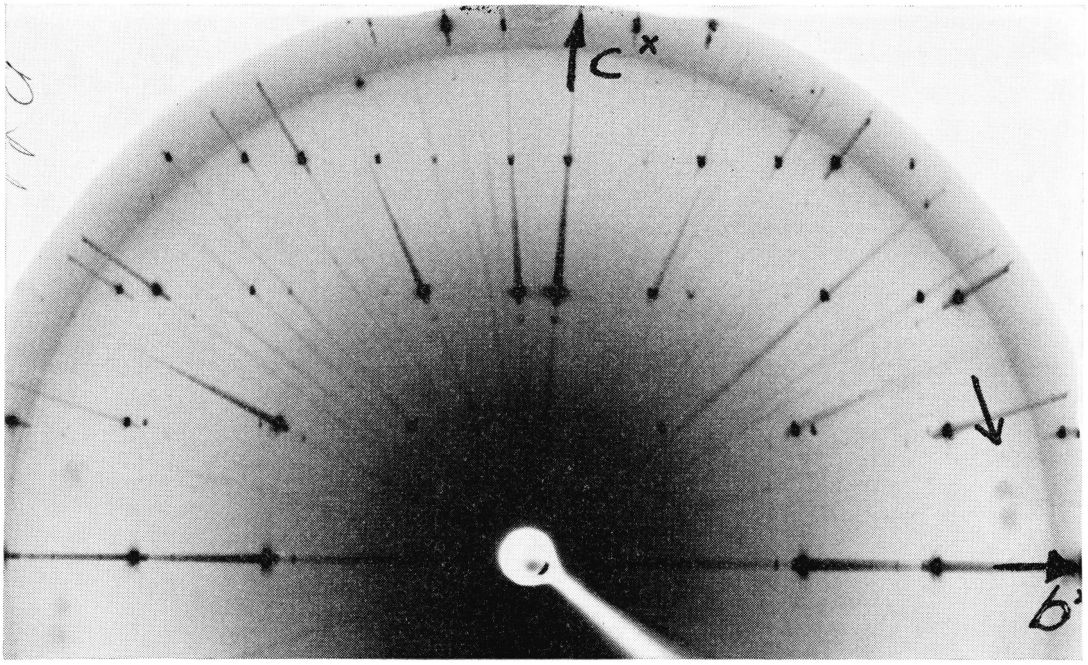

Fig. 1. Precession a-photograph of Surtsey-labradorite. Very diffuse and week b-split reflections (marked by arrow).

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New X-ray Data for Wenkite[1])

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 PAPAGEORGAKIS (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 mineral[3]). 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 $\bar{6}$2m, P $\bar{6}$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-

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[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.

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

h	k	l	INTENSITY	2ϑ (OBS)	D (OBS)	D (CALC)	RESIDUALS OF D (OBS–CALC)	(OBS–CALC)/SIGMA
0	0	1	40	11.835	7.47122	7.46150	.00972	.00013
1	1	0	30	13.100	6.75246	6.75585	—.00338	—.00006
1	0	1	10	14.070	6.28905	6.29130	—.00225	—.00004
2	0	0	5	15.140	5.84690	5.85073	—.00384	—.00009
1	1	1	25	17.700	5.00659	5.00804	—.00145	—.00005
2	0	1	35	19.263	4.60374	4.60410	—.00036	—.00001
2	1	0	15	20.058	4.42303	4.42274	.00029	.00001
2	1	1	50	23.343	3.80749	3.80460	.00289	.00016
0	0	2	40	23.808	3.73416	3.73075	.00341	.00019
1	0	2	70	25.125	3.54133	3.55446	—.01313	—.00083
3	0	1	100	25.740	3.45809	3.45668	.00141	.00009
2	2	0	80	26.348	3.37966	3.37792	.00174	.00012
3	1	0	75	27.448	3.24666	3.24540	.00126	.00009
2	0	2	60	28.328	3.14778	3.14565	.00213	.00017
2	2	1	40	28.980	3.07842	3.07727	.00115	.00010
3	1	1	45	29.990	2.97701	2.97608	.00093	.00008
2	1	2	60	31.330	2.85267	2.85168	.00099	.00010
4	0	1	30	32.850	2.72406	2.72353	.00053	.00006
3	0	2	65	33.190	2.69693	2.69605	.00088	.00010
3	2	0	90	33.343	2.68490	2.68450	.00040	.00004
3	2	1	5	35.505	2.52621	2.52599	.00022	.00003
2	2	2	20	35.823	2.50451	2.50402	.00049	.00006
0	0	3	5	36.068	2.48805	2.48717	.00089	.00012
3	1	2	40	36.663	2.44903	2.44859	.00044	.00006
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
0	4	2	10	39.098	2.30193	2.30205	—.00012	—.00002
2	0	3	20	39.318	2.28955	2.28893	.00062	.00010
3	3	0	10	40.015	2.25127	2.25195	—.00068	—.00011
5	0	1	80	40.360	2.23281	2.23303	—.00022	—.00004
3	2	2	30	41.393	2.17945	2.17902	.00043	.00007
1	2	3	5	41.605	2.16883	2.16788	.00095	.00017
3	3	1	>5	41.865	2.15596	2.15590	.00006	.00001
4	2	1	35	42.608	2.12007	2.12021	—.00015	—.00003
3	0	3	45	43.088	2.09756	2.09710	.00046	.00009
2	2	3	5	45.225	2.00328	2.00283	.00046	.00009
5	0	2	10	45.728	1.98241	1.98251	—.00011	—.00002
3	1	3	15	45.930	1.97416	1.97412	.00004	.00001
6	0	0	5	46.540	1.94969	1.95024	—.00055	—.00012
4	0	3	5	47.965	1.89504	1.89488	.00017	.00004
0	0	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
5	2	1	5	50.165	1.81697	1.81731	—.00034	—.00009
1	6	0	5	51.150	1.78427	1.78446	—.00019	—.00005
6	1	1	10	52.705	1.73523	1.73552	—.00029	—.00008
5	2	2	25	54.775	1.67445	1.67442	.00003	.00001
7	0	0	20	54.858	1.67211	1.67164	.00047	.00015
4	2	3	10	55.550	1.65291	1.65261	.00029	.00009
4	4	1	5	55.748	1.64750	1.64729	.00022	.00007
2	2	4	25	56.355	1.63119	1.63293	—.00175	—.00057
1	3	4	5	56.880	1.61737	1.61726	.00011	.00004
6	1	2	10	57.185	1.60947	1.60979	—.00032	—.00011
6	0	3	30	60.343	1.53257	1.53470	—.00213	—.00081
5	3	2	25	60.648	1.52559	1.52550	.00009	.00003
7	0	2		60.648	1.52559	1.52550	.00009	.00003
8	0	0	10	63.538	1.46298	1.46268	.00030	.00013
0	5	4	5	63.730	1.45904	1.45870	.00034	.00015
1	6	3	5	64.175	1.44999	1.44989	.00010	.00004
			5	64.335	1.44677			
			5	67.415	1.38796			
			15	69.498	1.35137			
			5	70.770	1.33016			
				75.450	1.25885			
				76.385	1.24575			
				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.

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

h k l	2ϑ(OBS)	D(OBS)	D(CALC)	RESIDUALS OF D (OBS–CALC)	(OBS–CALC)/SIGMA
0 0 1	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
2 0 0	15.065	5.87584	5.85197	.02387	.00054
1 1 1	17.635	5.02490	5.00964	.01525	.00047
2 0 1	19.220	4.61394	4.60549	.00845	.00031
2 1 0	20.010	4.43353	4.42367	.00985	.00039
2 1 1	23.338	3.80829	3.80564	.00265	.00014
0 0 2	23.805	3.73463	3.73244	.00219	.00012
1 0 2	25.008	3.55763	3.55599	.00164	.00010
3 0 1	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	—.00004
2 0 2	28.328	3.14778	3.14685	.00092	.00007
2 2 1	28.983	3.07811	3.07804	.00007	.00001
3 1 1	29.995	2.97652	2.97682	—.00030	—.00003
2 1 2	31.320	2.85355	2.85268	.00087	.00009
4 0 1	32.830	2.72567	2.72419	.00148	.00016
3 0 2	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
2 3 1	35.493	2.52703	2.52659	.00044	.00006
2 2 2	35.800	2.50606	2.50482	.00124	.00016
0 0 3	36.045	2.48959	2.48829	.00130	.00017
3 1 2	36.643	2.45032	2.44936	.00096	.00013
4 1 1	37.163	2.41722	2.41649	.00073	.00010
5 0 0	38.410	2.34156	2.34079	.00077	.00012
1 1 3	38.515	2.33542	2.33501	.00041	.00006
0 4 2	39.073	2.30334	2.30275	.00060	.00009
0 2 3	39.300	2.29056	2.28988	.00068	.00011
3 3 0	39.998	2.25218	2.25242	—.00024	—.00004
5 0 1	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
3 0 3	43.078	2.09802	2.09790	.00012	.00002
2 2 3	45.215	2.00370	2.00356	.00014	.00003
5 0 2	45.713	1.98302	1.98307	—.00004	—.00001
3 1 3	45.903	1.97526	1.97483	.00042	.00009
6 0 0	46.513	1.95076	1.95066	.00011	.00002
0 4 3	47.950	1.89560	1.89554	.00006	.00001
0 0 4	48.740	1.86671	1.86622	.00049	.00012
3 4 1	48.828	1.86355	1.86322	.00033	.00008
1 5 2	49.735	1.83167	1.83159	.00008	.00002
2 3 3	49.932	1.82490	1.82509	—.00019	—.00005
5 2 1	50.138	1.81789	1.81772	.00017	.00004
6 1 1	52.683	1.73590	1.73591	—.00000	—.00000
0 5 3	53.730	1.70452	1.70495	—.00043	—.00013
5 2 2	54.760	1.67487	1.67485	.00002	.00001
7 0 0	54.855	1.67219	1.67199	.00020	.00006
3 3 3	54.950	1.66953	1.66988	—.00036	—.00011
4 2 3	55.545	1.65304	1.65314	—.00010	—.00003
4 4 1	55.750	1.64745	1.64765	—.00021	—.00007
2 2 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
6 0 3	60.343	1.53257	1.53516	—.00259	—.00098
7 0 2	60.640	1.52577	1.52589	—.00011	—.00004
	63.550	1.46274			
	64.165	1.45019			
	64.360	1.44627			
	67.425	1.38778			
	68.660	1.36580			
	69.002	1.35986			
	75.478	1.25845			
	76.405	1.24548			
	76.685	1.24162			
	79.235	1.20794			
	87.220	1.11672			
	87.505	1.11382			

theses[4]). 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)
a_0	$13.511_7 \pm 0.001_3$ Å	$13.514_6 \pm 0.001_9$ Å	13.528 ± 0.003 Å
c_0	$7.461_5 \pm 0.001_1$ Å	$7.464_9 \pm 0.001_7$ Å	7.471 ± 0.002 Å
V	$1179.7_1 \pm 0.2_2$ Å^3	$1180.7_4 \pm 0.3_2$ Å^3	1184.033 Å^3
a*	$0.08545_9 \pm 0.00000_8$ Å^{-1}	$0.08544_1 \pm 0.00001_2$ Å^{-1}	
c*	$0.13402_1 \pm 0.00002_0$ Å^{-1}	$0.13396_1 \pm 0.00003_0$ Å^{-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 $P\bar{6}2m$ and $P\bar{6}m2$ can be deduced, of which $P\bar{6}2m$ is more probable.