Results of Gravimetric Observations on Shuvalovo Lake in Winter 1927 and 1928.

By **R. Numerov.** — (With three Illustrations.)

The question of applying to the study of the geological constitution of the Earth gravity observations with the Eötvös torsion-balance was not seldom subjected to criticism and doubt. The doubts were particularly great with the geologists who were accustumed to see but in drill boring a trustworthy and certain means of investigation*).

This circumstance induced the writer to undertake in winter 1927 and 1928 some experimental investigations on the Shuvalovo Lake near Leningrad, to the purpose of proving the value of the gravitational method of prospecting, the possibility of reconstructing the bottom relief after the data furnished by the gravity survey alone. As control, soundings were carried out — a kind of boring.

In 1927 the work was carried out at the expenses of the Emba-Oil Trust which is always readily supporting the scientific research work, in the just opinion, that applied achievements are possible only with the developement of scientific knowledge. In 1928 the work was continued by the Geological Committee on a larger scale.

Analogous work was performed in 1923 by Dr. Holst on the Titi Lake in Black-Forest [Schwarzwald]**). The results were not very persuasive, in my opinion, because of insufficient accuracy of the variometer constructed by the Institute for Applied Geophysics in Freiburg and, in particular, for want of topographic survey.

The 1st Shuvalovo Lake is situated 15 km north of Leningrad, near the Finland Railway. The lake is lying in a valley and has an area of 1 sq. km. The eastern coast is 15 m high, the western lower. The bottom is covered with sand and silt: its relief (see fig. 1) shows a depression of 13 m in the western and southern portion, in the middle part a sand-bank at about 1 m depth.

The first series of observations was carried out from 9th February to 3rd March 1927. 59 points were secured regularly situated through every 50 m over almost the whole area of the lake. The observations were carried out with large variometer Bamberg-Schweydar No. 92 by V. M. Oseretski with

*) The new physical methods of prospecting are characteristic for yielding indirect evidence on geological constitution, in connection with rock properties, such as different density, different magnetic and electric permeability.

**) Über Gravitationsmessungen mit der Drehwaage auf dem Eise. Zeitschr. f. Geophys. 1.

several collaborators, some of them having for the first time to deal with field work with a torsion-balance.

The second series of observations has performed 13th Dec. 1927/4th March 1928, with little Bamberg variometer No. 533 that yielded 127 stations and 8 control points and later (from No. 169, Table 2) with No. 544 which secured

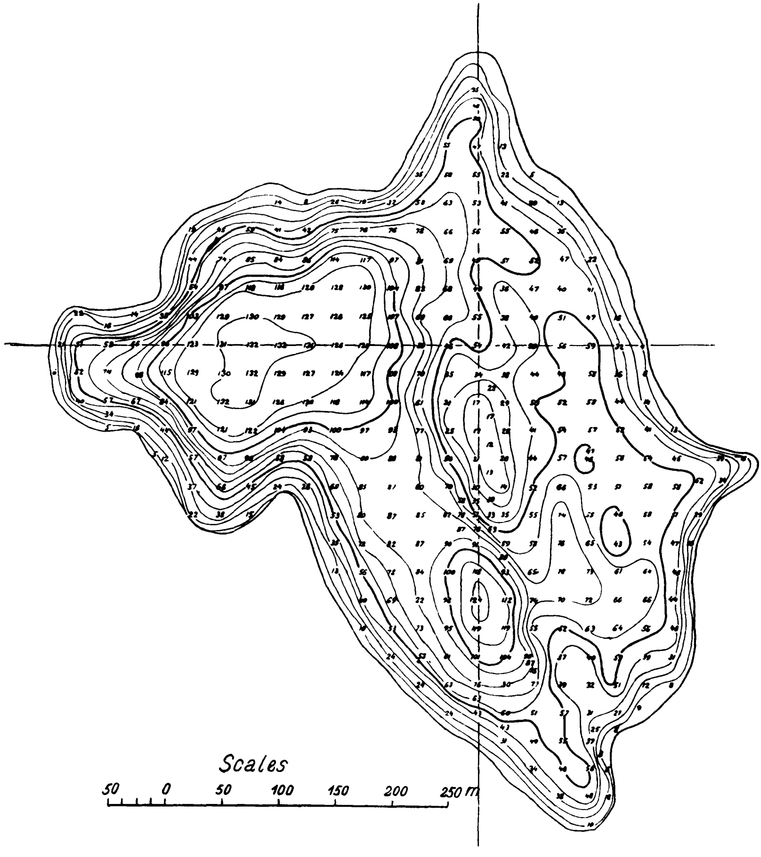

fig. 1. Gravity observations on Shuvalovo Lake 1927–28.
Isobaths in decimeters.

62 stations and 3 control ones. The second series of observations was carried out to the purpose of rendering those of the first series more accurate and complete. In the SE quadrant the topographical survey was repeated through every 25 m, and in some cases even through 12.5 m. On the remaining area of the lake, the survey was executed through every 50 m, the instruments being installed in the intervals between the points of observations of the 1st series of 1927. The observations were carried out by S. I. Alexeiev under collabo-

Table 1. Results of Observations on the Shuvalovo Lake, 9 February — 3 March 1927.

Nos.	Co-ordinates x	y	Mean day temperature t^0	$2V_{xy}$	V_Δ	R	λ	V_{xz}	V_{yz}	H meters	$\Delta g.10^5$	ε_1	ε_2
1*	− 4	0	− 3°	−23	+12	26	149°	− 3	−37	5.6	96	−10	− 3
2*	− 2	0		−10	+22	24	168	+ 2	−59	4.9	94	−16	−10
3	0	0	− 2	+29	+24	38	25	+26	+ 3	5.4	100	− 7	− 4
4	+ 2	0		−10	+31	32	171	+27	− 1	1.7	114	−14	− 6
5	+ 4	0		−13	+18	22	162	− 2	−25	2.1	116	−10	− 7
6	+ 6	0	− 8	+29	−11	31	56	−61	−88	5.1	113	+ 4	0
7	+ 8	0		+27	−14	30	59	−16	− 6	11.8	86	+15	0
8	+10	0		+13	−23	26	76	+28	+10	11.9	90	+20	+ 2
9	0	− 2		+ 2	+ 7	8	9	+ 3	− 2	3.9	107	− 9	− 7
10*	0	+ 4	− 8	− 6	− 7	9	109	+10	−17	12.1	66	− 3	− 3
11*	0	+ 6		−12	+20	23	164	− 3	−14	13.1	59	− 4	− 3
12*	0	+ 8		−10	+ 9	14	156	0	− 3	13.2	56	− 7	− 2
13*	0	+10		−38	+21	43	149	−15	+27	12.3	70	+ 2	+11
14*	0	+12	− 6	+21	+114	116	5	−83	+34	6.6	86	−17	+ 4
15*	0	+14		+42	+14	44	36	− 9	+38	5.1	104	− 5	−21
16*	+ 2	+12		−18	+71	73	172	+75	+17	6.7	84	−16	+ 2
17*	+ 2	+ 8		− 6	+12	14	167	+24	− 9	13.1	61	− 3	0
18*	+ 4	+ 8	− 4	−26	− 5	26	129	+76	−40	9.0	85	− 2	+ 4
19*	+ 8	+ 4		+10	−30	31	81	+32	+38	5.6	106	0	0
20*	+ 6	+ 4		+38	−23	44	61	+18	+25	8.0	94	+ 1	0
21*	+ 4	+ 4		+50	−18	52	55	+19	+ 2	9.0	84	− 3	− 3
22*	+ 2	+ 4	− 8	+29	− 3	30	48	+23	−17	11.4	74	+ 1	− 1
23*	0	+ 2		−31	+16	35	149	+ 5	−59	8.9	86	− 1	0
24*	− 2	+ 8		− 4	+ 5	7	163	−29	+10	11.9	64	− 6	+ 2
25*	− 4	+ 8	− 8	−14	−46	48	98	−49	−10	5.9	84	−20	− 1
26*	− 2	+10		+11	−29	31	79	−45	+74	5.4	85	−22	− 1
27*	− 4	+ 4	−12	−10	+53	54	174	−81	−32	7.6	83	−12	− 1
28*	− 4	+ 6		+17	+33	38	14	−66	+27	4.2	81	−33	−14
29*	− 4	+ 2		−64	+12	64	141	−18	−23	7.2	89	− 8	0
30*	− 2	+ 4	−15	−18	+ 7	19	145	− 1	−17	13.0	63	− 1	0
31*	− 6	0		−11	−82	83	94	+ 2	−55	5.4	96	−11	− 1
32*	− 4	− 2		+12	+ 6	14	33	−25	−30	4.4	112	− 1	+ 5
33*	− 4	− 4	−18	+20	−14	25	62	−31	−67	1.0	138	+ 6	+13
34*	− 2	− 4		+21	−24	32	70	−28	−53	4.1	124	+ 9	+10
35	+ 2	− 2		+35	−24	43	62	+ 7	+12	5.0	112	+ 2	0
36	+ 2	− 4	−19	+38	−66	76	75	+ 6	−20	5.8	114	+ 9	+ 3
37	+ 2	− 6		+30	−26	39	66	−29	−58	1.4	134	+ 4	+ 1
38	+ 4	− 6		+39	+ 6	39	40	− 2	−26	5.4	126	+19	+ 7
39	+ 6	− 6		−26	+ 6	26	142	+ 9	+ 1	5.6	130	+24	+10
40	+ 6	− 4	−24	− 9	+ 3	10	44	−13	−56	5.5	118	+11	+ 1
41	+ 6	− 2		−28	+ 6	28	140	−10	+30	5.5	112	+ 5	− 2
42	+12	− 6		−25	+12	28	148	+46	− 9	1.2	148	+17	+ 2
43	+10	− 4		+23	− 4	23	50	+36	− 2	6.3	129	+27	+10
44	+12	− 4		−34	+ 4	34	138	+13	+22	3.2	141	+21	+ 7
45	+12	0	− 8	+ 8	−17	19	77	+50	+ 4	7.6	109	+14	0
46	+14	− 2		+34	−38	51	69	+35	+10	4.9	121	+11	− 5
47*	+10	+ 2		+ 6	− 4	8	64	+30	+26	7.3	99	+ 2	− 6
48*	+ 8	+ 2		+47	−11	48	52	+ 8	+27	8.4	89	− 1	− 9
49	+ 8	− 2	− 3	−42	+49	64	160	− 8	−15	6.5	102	+ 1	−10
50	+ 8	− 4		+17	− 6	18	54	− 4	−41	7.3	114	+ 7	+ 2

Nos.	Co-ordinates x	y	Mean day temperature t^0	$2V_{xy}$	V_{Δ}	R	λ	V_{xz}	V_{yz}	H meters	$\Delta g.10^5$	ε_1	ε_2
51	+8	−6		−37	−46	59	109°	−15	−8	6.4	127	+25	+8
52	+4	−4	−1°	−14	−1	14	133	−2	−24	4.6	115	+3	−4
53	+4	−2		+6	−8	10	71	−5	+38	4.4	113	0	−3
54*	+6	+2		+34	−3	34	48	−15	−8	8.5	91	+1	−4
55*	+4	+2	−1	+64	−20	67	54	−11	−32	8.1	95	+3	+1
56*	+2	+2		+14	−25	29	75	+3	−71	6.1	96	−7	−5
57*	+2	+6	1	+15	+46	49	9	+33	−7	12.0	64	−6	−4
58*	+4	+6		+41	+22	46	31	+50	+20	5.8	89	−16	−9
59*	+2	+10	1	+31	+23	38	27	+46	+44	12.1	69	0	+1

Table 2. Results of Observations on the Shuvalovo Lake
13 December 1927 — 4 March 1928.

Nos.	Co-ordinates x	y	Mean day temperature t^0	$2V_{xy}$	V_{Δ}	R	λ	V_{xz}	V_{yz}	H meters	$\Delta g.10^5$	ε_1	ε_2
1	0	0	−13°	+28	+21	35	26°	+27	+2	5.4	100	−6	+1
2	+1	0	−13	+5	+16	17	8	+34	+7	3.4	108	−7	−1
3	+2	0	−13	−8	+30	31	172	+26	−2	1.7	115	−8	−2
4	+3	0		0	+20	20	180	−7	−34	1.7	118	−5	0
5	+5	0	−13	−6	+29	30	174	−31	−40	3.0	111	−6	−4
6	+4	0		−18	+17	25	156	−11	−25	2.1	116	−5	−1
7	+6	0	−16	+35	−12	37	54	−52	−76	5.1	101	−7	−7
8	+7	0		+53	−12	54	51	−34	−40	9.1	90	0	−3
9	+8	0		+32	−21	38	62	−14	−8	11.8	84	+7	+1
10	+9	0	−8	+24	−23	34	67	+8	+6	12.4	83	+8	+1
11	+10	0		+11	−25	28	78	+28	+12	11.9	88	+11	+3
12	+11	0		+3	−25	26	87	+33	+8	10.1	96	+11	+2
13	+12	0	−7	+11	−16	19	72	+56	+8	7.6	107	+11	+2
14	+13	0		+24	−21	32	65	+75	+22	4.2	123	+11	+3
15	+14	−1		+37	−30	48	65	+51	+31	3.1	133	+16	+7
16	0	−1	−4	+29	+41	50	17	+6	−18	4.2	102	−10	−3
17	+1	−1		+46	+33	57	27	+21	+14	3.8	105	−8	−3
18	+2	−1		+7	+14	16	13	+11	+6	2.9	109	−9	−4
19	+3	−1	−8	+17	−4	17	52	+4	+7	2.8	111	−7	−3
20	+4	−1		+4	+20	20	5	+18	+43	2.0	114	−8	−5
21	+5	−1	−7	−31	+46	56	163	−14	+6	1.4	114	−10	−8
22	+6	−1		−20	+42	47	167	−25	−6	3.4	109	−6	−6
23	+7	−1		−38	+42	56	159	−46	−49	5.8	100	−4	−7
24	+8	−1	−5	−1	+10	10	176	−24	−64	9.3	91	+2	−3
25	+9	−1		+12	−5	13	57	+6	−50	11.2	89	+9	+1
26	+10	−1		+26	−25	36	67	+20	−38	11.9	92	+15	+6
27	+11	−1		+26	−31	40	70	+36	−19	10.4	99	+15	+6
28	+12	−1	−17	+32	−28	43	66	+43	−7	8.0	109	+15	+5
29	+13	−1		+45	−36	58	64	+50	+13	6.0	120	+16	+7
30	+15	−2	−11	+29	−37	47	71	+33	+27	3.4	134	+19	+7
31	+16	−3		+29	−23	37	64	+49	+41	3.8	136	+23	+9
32	+15	−4	−16	+52	−113	124	78	−20	−48	5.6	130	+25	+10
33	+16	−4	−9	+60	−61	89	68	+33	−10	4.8	132	+23	+8
34	+15	−3		+62	−37	72	61	+18	+10	4.8	128	+19	+6
35	+14	−3	−8	+44	−44	62	68	+12	−13	5.5	124	+18	+6
36	+14	−4		−3	−76	76	91	−21	−65	3.7	130	+16	+4
37	+13	−4		−64	−25	69	124	+14	−20	3.1	129	+12	+1
38	+13	−3	−6	+36	−44	57	70	−11	−46	5.7	120	+15	+4
39	+13	−2		+51	−41	65	64	+30	−11	5.1	116	+8	−2
40	+12	−2		+56	−26	62	58	+17	−46	7.3	106	+8	−2

Nos.	Co-ordinates x	Co-ordinates y	Mean day temperature t^0	$2\,V_{xy}$	V_Δ	R	λ	V_{xz}	V_{yz}	H meters	$\Delta g \cdot 10^5$	ε_1	ε_2
41	+11	− 2	− 9°	+20	−20	28	68°	+13	−67	9.0	102	+12	+ 2
42	+11	− 3		−13	−34	36	101	−20	−40	3.7	114	0	− 8
43	+12	− 3		− 1	− 2	2	101	− 6	−69	3.9	120	+ 7	− 2
44	+12	− 4	− 5	−33	2	33	133	+14	+19	3.2	126	+10	0
45	+12	− 5		−33	−60	66	105	+29	−44	5.1	129	+21	+10
46	+12	− 6		−17	−11	20	118	+56	−18	1.2	137	+12	+ 1
47	+11	− 6	− 4	− 1	− 4	4	98	+44	−31	3.9	124	+11	0
48	+11	− 5		−23	−25	34	111	+28	−29	5.3	118	+11	+ 1
49	+11	− 4		− 9	+ 2	9	142	+40	+27	4.0	118	+ 5	− 4
50	+10	− 6	− 6	−10	− 9	13	112	+34	−19	5.6	113	+ 8	− 3
51	+10	− 5		− 3	+ 1	3	56	+21	−14	6.4	111	+ 9	− 1
52	+10	− 4		+11	+ 9	14	26	+35	+ 4	6.3	111	+ 9	0
53	+10	− 3	− 5	−41	+57	71	123	+32	− 6	5.2	112	+ 5	− 3
54	+10	− 2		− 8	+ 8	12	156	+ 6	−65	5.5	102	− 4	− 1
55	+14	− 2		+24	−48	53	76	+40	+11	4.9	126	+17	+ 6
56	+ 9	− 2	− 3	−45	+38	59	155	−12	−56	7.4	100	+ 3	− 4
57	+ 9	− 3		−17	+30	34	166	+26	+ 9	7.0	105	+ 6	− 1
58	+ 9	− 4		+16	+ 7	18	34	+16	− 8	7.2	104	+ 6	− 2
59	+ 9	− 5	− 2	− 7	+18	19	170	+ 7	−13	6.6	107	+ 6	− 3
60	+ 9	− 6		− 8	−62	63	94	−16	+ 2	6.6	108	+ 7	− 3
61	+ 8	− 6		−26	−46	53	105	−20	− 8	6.4	112	+10	+ 2
62	+ 8	− 5	−10	+ 2	+16	16	93	−20	−21	6.1	108	+ 5	− 2
63	+ 8	− 4		+18	0	18	45	− 6	−40	7.3	102	+ 4	− 3
64	+ 8	− 3	− 5	−10	− 3	11	127	+14	+ 2	7.8	99	+ 4	− 3
65	+ 8	− 2		−59	+48	76	154	− 6	−13	6.5	100	− 1	− 6
66	+ 7	− 2		−51	+30	59	150	− 5	+18	5.8	100	− 4	− 8
67	+ 7	− 3		−13	−24	28	104	+ 8	+ 1	7.6	94	− 2	− 7
68	+ 7	− 4	− 3	− 1	+ 4	4	176	− 3	−50	6.5	101	0	− 6
69	+ 7	− 5	1	−21	+21	30	157	−10	−31	4.3	111	0	− 6
70	+ 7	− 6	1	−31	−32	44	112	− 7	0	5.4	115	+ 9	+ 2
71	+ 6	− 6		−25	− 8	26	126	+10	− 1	5.6	115	+10	+ 4
72	+ 5	− 6	0	+ 6	+18	19	9	− 4	− 1	5.8	114	+10	+ 5
73	+ 6	− 5		−26	+15	30	150	+ 3	14	4.8	112	+ 3	− 1
74	+ 6	− 4		− 9	+ 3	10	144	−13	−56	5.5	103	− 3	− 7
75	+ 6	− 3	1	− 9	−40	41	97	− 6	− 4	7.4	94	− 3	− 7
76	+ 6	− 2		−31	+12	34	146	−12	+45	5.5	99	− 7	− 9
77	+ 5	− 3	− 5	+ 3	−53	53	88	−15	− 7	6.6	96	− 5	− 7
78	+ 4	− 3		+ 2	−45	45	89	−16	−13	5.7	100	− 5	− 6
79	+ 4	− 4	−11	−17	+ 5	18	142	+ 5	−16	4.6	108	− 2	− 3
80	+ 5	− 4		−24	− 5	24	129	− 4	−42	5.5	107	+ 1	− 1
81	+ 5	− 5		− 2	+ 9	9	172	+ 7	− 3	5.1	112	+ 4	+ 1
82	+ 4	− 5	−19	+26	−20	33	64	− 3	− 5	5.8	111	+ 7	+ 4
83	+ 4	− 6		+41	+14	43	36	− 9	−20	5.4	117	+11	+ 8
84	+ 5	− 7	−22	−21	+31	37	163	− 6	−10	5.8	116	+12	+ 6
85	+ 6	− 7		−64	−27	70	124	+21	−28	5.1	118	+10	+ 4
86	+10	− 7	−15	+48	−48	67	68	+11	−62	4.8	126	+17	+ 6
87	+ 3	− 6		+41	− 3	41	47	−21	−42	4.1	121	+ 9	+ 8
88	+ 3	− 5		+41	−14	22	54	−12	−31	5.2	113	+ 6	+ 5
89	+ 3	− 4	−17	+15	−13	20	66	+ 5	− 7	5.7	107	+ 2	+ 2
90	+ 3	− 3	−14	+10	+12	16	20	− 2	−16	5.4	103	− 3	− 3

Nos.	Co-ordinates x	Co-ordinates y	Mean day temperature t^0	$2V_{xy}$	V_Δ	R	λ	V_{xz}	V_{yz}	H meters	$\Delta g.10^5$	ε_1	ε_2
91	+ 5	− 2		+ 8	−17	19	78°	− 4	+43	5.2	101	− 6	− 7
92	+ 3	− 2		+13	−11	17	65	− 1	+47	4.1	105	− 7	− 5
93	+ 4	− 2	−12°	−11	−15	18	108	−10	+47	4.4	103	− 8	− 7
94	+ 2	− 2		+49	−19	53	56	+10	+ 8	5.0	105	− 3	0
95	+ 2	− 3		+10	−25	27	79	+ 4	−10	5.2	105	− 2	0
96	+ 2	− 4	−21	+17	−43	46	79	+ 6	−24	5.8	108	+ 4	+ 4
97	+ 2	− 5	1	+35	−16	42	55	− 8	−44	4.4	116	+ 5	+ 6
98	+ 1	− 4	2	+24	−52	57	78	+ 2	−31	5.8	107	+ 3	+ 4
99	+ 1	− 5		+20	−30	36	73	0	−50	3.6	117	+ 3	+ 5
100	0	− 5		+18	−12	22	62	− 8	−57	3.2	118	+ 2	+ 5
101	0	− 4	− 2	−20	−29	35	107	+10	−39	5.9	106	+ 2	+ 5
102	0	− 3	− 5	+25	−28	37	69	+ 8	+20	5.6	103	− 2	+ 2
103	+ 1	− 3		−10	−15	18	107	+ 6	+11	4.8	105	− 4	− 1
104	+ 1	− 2	− 5	+20	+ 6	21	37	− 8	−15	4.4	105	− 6	− 1
105	0	− 2		+ 9	+14	16	107	+ 1	− 2	3.9	105	− 8	− 2
106	0	+ 1		− 8	+40	41	174	+36	−30	4.6	98	−12	− 4
107	+ 1	+ 1	− 6	+ 8	− 1	8	49	+15	−28	3.5	105	−10	− 2
108	+ 2	+ 1	−11	− 4	+17	17	173	+14	−32	3.1	109	− 8	− 1
109	+ 1.5	− 0.5		+22	+ 7	23	36	+23	−16	2.8	113	− 5	+ 1
110	+ 2.5	− 0.5		+ 7	+22	23	9	+17	+23	1.7	117	− 6	− 1
111	+ 3	+ 1	−13	−14	+13	19	157	−12	−45	2.5	108	−11	− 6
112	+ 4.5	− 0.5		−23	+23	33	157	− 6	−31	1.3	117	− 8	− 5
113	+ 3.5	− 0.5		−32	+49	58	164	− 1	+ 9	1.2	119	− 6	− 2
114	+ 4	+ 1	−14	−22	− 3	22	131	−31	−82	5.0	103	− 3	− 2
115	+ 5	+ 1	− 8	+59	−36	67	61	−19	−48	7.0	98	− 1	0
116	+ 6	+ 1		+62	−21	66	54	−18	−13	8.2	91	− 3	− 3
117	+ 7	+ 1		+54	−14	56	52	− 5	+ 7	9.0	86	− 4	− 6
118	+ 8	+ 1	− 2	+41	− 7	41	50	− 2	+19	10.0	86	+ 1	− 3
119	+7.5	− 0.5	− 1	+24	− 3	24	49	−40	−47		90		
120	+ 6	− 0.5	1	−23	+16	28	153	−38	−40	3.3	110	− 6	− 5
121	+ 6.5	− 0.5		−11	+11	15	157	−63	−62	5.3	103	− 4	− 5
122	+ 6.5	0		+48	−14	50	53	−48	−58	7.8	95	0	− 2
123	+ 5.5	0	− 6	+ 1	+14	14	2	−38	−69	3.5	106	− 9	− 7
124	+ 5.5	− 0.5	−13	− 3	+24	24	176	−20	−29	3.0	114	− 3	− 2
125	+ 5.5	+ 0.5		+42	−30	52	63	−41	−58	6.8	98	− 2	− 2
126	+ 6	+ 0.5		+61	−32	68	59	−33	−50	7.8	93	− 2	− 3
127	+ 6.5	+ 0.5		+62	−31	68	59	−18	−30	8.7	90	− 1	− 3
128	+ 9	+ 1	−14	+24	+ 1	24	44	+15	+30	9.8	88	+ 2	− 3
129	+10	+ 1		+58	+ 3	58	44	+39	+18	9.5	93	+ 5	− 1
130	+11	+ 1		+20	−11	23	59	+31	+40	8.1	102	+ 8	+ 1
131	+12	+ 1	−11	− 2	−15	15	94	+52	+40	6.3	112	+10	+ 3
132	+13	+ 1		−34	−32	46	113	+75	+35	2.4	130	+10	+ 4
133	+12	+ 2		−22	+ 6	23	142	+58	+42	2.4	123	+ 3	− 1
134	+11	+ 2		+23	− 4	24	50	+44	45	5.8	111	+ 7	+ 2
135	+ 9	+ 2	−13	+20	+ 4	20	40	+15	+30	8.2	95	+ 1	− 2
136	+ 7	+ 2		+56	− 3	56	46	+13	− 1	8.7	90	− 1	− 3
137	+ 5	+ 2		+58	−29	64	58	− 9	−13	8.0	92	− 2	− 1
138	+ 3	+ 3	−13	+56	−26	61	58	− 2	−14	9.3	84	− 5	− 1
139	+ 7	+ 3	−17	+30	−12	32	56	+11	+10	8.2	92	− 2	− 2
140	+ 8	+ 3	− 7	+23	−17	28	63	+19	+17	7.2	97	− 1	− 2

Nos.	Co-ordinates		Mean day temperature t^0	$2\,V_{xy}$	V_Δ	R	λ	V_{xz}	V_{yz}	H meters	$\Delta g \cdot 10^5$	ε_1	ε_2
	x	y											
141	+9	+3		+44	−3	44	47°	+34	+7	6.9	100	+1	−1
142	+10	+3		+26	+5	26	40	+43	+50	5.3	111	+4	+2
143	+7	+5	−10°	+22	−6	23	53	+40	+68	3.5	112	−3	+1
144	+5	+5		+58	−14	60	52	+30	+36	6.8	95	−5	0
145	+5	+3	−10	+16	−21	26	71	+16	−18	8.6	87	−5	−3
146	+4	+3		+48	−31	57	61	+8	−16	8.8	88	−3	0
147	+6	+3		+46	−23	51	58	+11	−10	8.7	89	−2	−2
148	+5	+7		+11	+26	28	11	+59	−30	2.4	107	−13	−4
149	+6	+9	−7	−39	−49	62	109	+46	−13	3.8	108	−5	+3
150	+5	+9		−47	−62	78	109	+64	−12	6.6	97	−4	+5
151	+5	+10		−40	−25	47	119	+36	+62	3.7	103	−11	0
152	+4	+10		−25	−13	28	121	+48	+74	5.7	92	−13	−2
153	+25	+13	−4	−28	+12	30	147	+78	+25	3.4	101	−14	+2
154	+3	+11		+3	+19	20	5	+68	+49	4.4	94	−17	−3
155	+3	+9		−3	−15	15	96	+38	+13	12.1	70	−6	+2
156	+3	+7		−4	+37	19	176	+63	−30	10.4	77	−7	0
157	+3	+5	−8	+44	−1	44	46	+32	+5	10.0	82	−3	+2
158	+1	+3	−10	−6	−14	16	102	+18	−35	9.8	80	−6	0
159	+1	+5	−8	+14	+12	18	24	+8	−8	12.4	68	−7	0
160	+1	+9		−14	+17	22	160	+17	−8	13.0	57	−15	−5
161	+1	+7		+12	+36	38	9	0	+9	12.9	64	−8	0
162	+1	+11		+8	+81	82	3	+7	+42	11.5	71	−8	+5
163	+1	+13	−10	+12	+63	65	6	+18	+36	7.2	91	−7	+9
164	+1	+14		+5	+20	21	7	+18	+75	5.2	106	−1	+17
165	−1	+9		−22	+2	22	138	−14	+15	12.9	60	−12	0
166	−1	+7	−7	−16	+28	32	166	−10	−10	12.9	60	−12	−2
167	−1	+5		−31	+9	33	143	+7	−19	12.5	66	−8	+1
168	−1	+3		−10	−5	11	120	0	−50	10.7	73	−9	−1
169	−1	+1		+4	+22	22	6	+14	−19	6.6	92	−9	0
170	−1	−1		+1	+25	25	1	+2	−18	3.8	102	−11	−3
171	−1	−3	−6	+31	−35	47	69	+5	−6	5.1	105	−3	+3
172	−1	−5		−3	−20	21	95	−8	−69	1.6	120	−3	+2
173	−3	−4		+25	−6	25	52	−25	−51	2.1	120	−1	+7
174	−2	−2		+26	−2	26	48	+9	+19	4.7	104	−5	+2
175	−5	−3	−3	+18	−23	30	71	−26	−38	1.3	122	−3	+9
176	−3	−1		−12	+16	20	172	+36	−19	5.1	99	−9	+1
177	−7	−1		+21	−18	27	65	−3	−73	1.3	111	−14	+3
178	−84	0		−9	−68	69	94	−35	−39	4.8	106	−3	+14
179	−7	+1		−66	−81	104	110	−6	+25	5.5	98	−8	+8
180	−5	+2		−91	−8	92	132	−35	+3	5.8	91	−13	+1
181	−5	0	−6	−5	−1	6	129	−36	−20	5.3			
182	−3	+1		−34	−2	34	134	+10	−37	6.9	88	−11	−1
183	−2	+2		−25	+25	35	158	+15	−24	8.2	82	−12	−2
184	−3	+3		−46	+43	63	156	−16	−24	9.7	75	−12	−1
185	−3	+5		−43	+28	51	152	−34	+14	11.4	72	−7	+5
186	−2	+6	−15	−26	+42	49	164	−39	+19	12.0	69	−7	+4
187	−3	+7		+13	+34	37	10	−62	−16	8.4	76	−17	−2
188	−3	+9		+38	−25	46	62	−39	+31	7.4	80	−17	0
189	−1	+11	−15	−16	+31	36	166	−56	+65	3.8	90	−23	−5

Table 3.
Additional depths of the Shuvalovo Lake according to 1928 mesurings.

Co-ordinates		H	Co-ordinates		H	Co-ordinates		H	Co-ordinates		H
x	y	meters	x	y	meters	x	y	meters	x	y	meters
+12.5	0	6.2	0	+ 9	13.1	+ 2	+ 5	11.8	−1	− 4	4.7
+ 7.5	− 1	8.9	0	+ 7	13.2	+ 2	+ 3	10.0	−2	− 3	4.9
+13.5	− 1	4.3	0	+ 5	12.6	+ 3	+ 2	7.7	−3	− 3	4.7
+ 3.8	− 4	4.7	0	+ 3	10.8	+ 3	+ 4	9.7	−3	− 2	5.2
0	− 6	0.4	−1	0	5.5	+ 3	+ 6	9.3	−3	0	4.9
+ 1	− 6	0.8	−1	− 2	4.0	+ 3	+ 8	12.2	−3	+ 2	8.1
+ 2	− 6	1.4	−2	− 1	3.8	+ 3	+10	9.7	−3	+ 4	11.7
+ 3	− 7	1.3	−2	+ 1	6.8	+ 3	+12	1.9	−4	− 1	5.4
+ 4	− 7	4.5	−2	+ 3	10.4	− 3	+ 6	8.6	−4	− 3	3.4
+ 7	− 7	4.7	−2	+ 5	12.8	− 3	+ 8	8.4	−5	− 2	2.9
+ 8	− 7	4.6	−2	+ 7	11.6	− 3	+10	4.4	−5	− 1	4.1
+ 9	− 7	4.4	−2	+ 9	9.7	− 4	+ 9	4.5	−5	+ 1	6.2
+11	− 6.9	3.1	−2.5	+10	4.6	− 4	+ 7	4.1	−5	+ 3	3.2
+12	− 7	0.8	−1	+10	10.3	− 4	+ 5	7.5	−5	+ 4	2.8
+12.8	− 5.8	0.9	−1	+ 8	13.0	− 4	+ 3	7.6	−5	+ 5	2.8
+12.8	− 5	3.4	−1	+ 6	12.7	− 4	+ 1	6.6	−5	+ 6	0.8
+13.6	− 5	0.8	−1	+ 4	12.5	+ 4	+11.4	0.5	−5	+ 7	1.4
+13.6	− 4.2	2.5	−1	+ 2	6.9	+ 4	+11	1.2	−6	+ 1	5.8
+ 4	− 8.6	3.9	+1	+ 2	7.0	+ 4	+ 9	9.7	−6	− 1	2.2
+ 4	− 9.4	1.6	+1	+ 4	11.7	+ 4	+ 7	5.8	−6	− 2	0.5
+ 4.8	− 8.6	3.4	+1	+ 6	12.7	+ 4	+ 5	7.8	−7	0	4.7
+ 4.8	− 7.8	5.2	+1	+ 8	13.2	+ 5	+ 4	8.5	−8	0	5.0
+ 6	− 7.8	2.9	+1	+10	12.9	+ 5	+ 6	2.6	−9	0	3.4
+ 7	− 7.6	1.6	+1	+12	8.8	+ 5	+ 8	4.5	−1	+12	1.4
+ 8.5	− 2.5	6.8	+1	+15	0.5	+ 6	+10	2.2	−0.8	+13	1.6
+ 6.4	+ 1	8.7	+2	+14	4.0	+ 6	+ 8	1.6	−1	+14	2.2
+ 6.9	+ 1	9.0	+2	+13	5.7	+ 7	+ 4	7.2	−6	+ 2	3.5
0	+14.6	2.1	+2	+11	8.4	+ 8	+ 5	1.3			
0	+13	5.8	+2	+ 9	13.2	+ 9	+ 4	4.0			
0	+11	9.8	+2	+ 7	12.8	+10	+ 4	1.0			

ration of some members of the Geological Committee and a number of other workers for the first time dealing with the work of a torsion-balance.

The instruments were mounted upon three bricks symmetrically laid on ice. The pavilion was installed on slides and hand-driven from station to station. To that purpose special sledges were constructed. Three stations in average were secured every day, yet on some days, when instruments were running accurately, four or even five stations were obtained. In spite of low temperature reaching — 32° C, the Bamberg variometers worked quite satisfactorily.

The observations of central and coastal points were not corrected for the topographic effect, and the normal influence of the terrestral ellipsoid was accepted as

$$\frac{\partial^2 V}{\partial x \partial z} = -7.1; \quad \frac{\partial^2 V}{\partial x^2} - \frac{\partial^2 V}{\partial y^2} = -2.6.$$

The results of the first and the second series of observations are given in Tables 1 and 2. Vertical columns contain the numbers of stations, the rectangular co-ordinates x, y (unit $= 25$ m), the positive axes x and y being directed southward and westward, the mean day temperature, the anomalous gradient values: $2V_{xy} = 2\frac{\partial^2 V}{\partial x \partial z}$; $V_{\Delta} = \frac{\partial^2 V}{\partial x^2} - \frac{\partial^2 V}{\partial y^2}$; R; λ; $V_{xz} = \frac{\partial^2 V}{\partial x \partial z}$; $V_{yz} = \frac{\partial^2 V}{\partial y \partial z}$

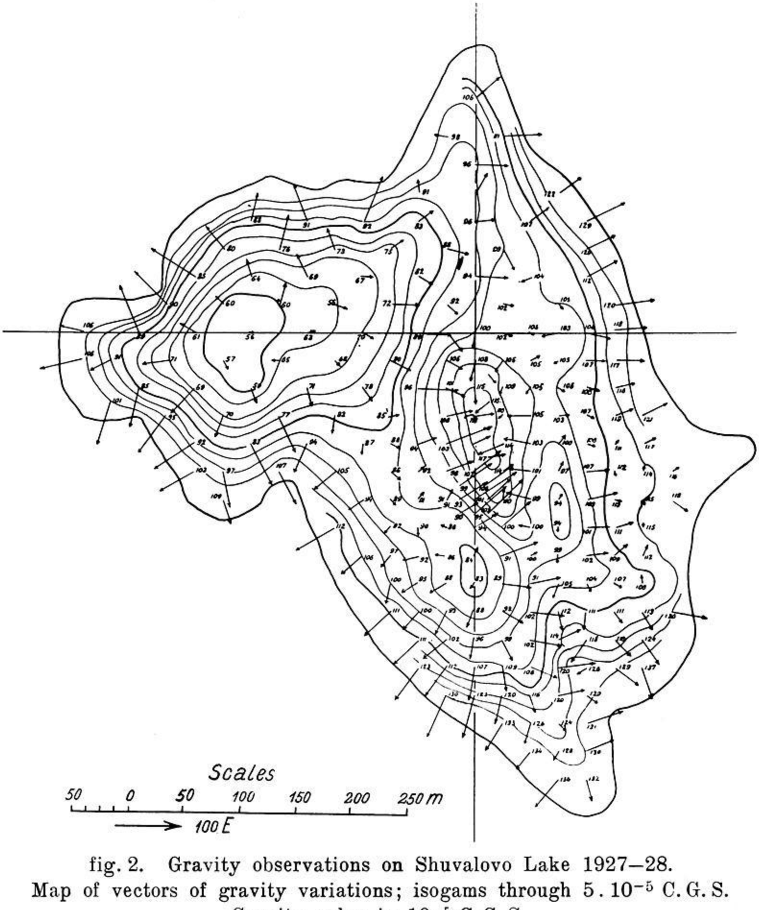

fig. 2. Gravity observations on Shuvalovo Lake 1927—28.
Map of vectors of gravity variations; isogams through $5 . 10^{-5}$ C. G. S.
Gravity value in 10^{-5} C. G. S.

in 10^{-9} (C. G. S.); the depth H in meters; the gravity anomaly Δg in units 10^{-5} cm sec^{-2}, and finally the residual errors of ε_1 and ε_2 for solution of con ditional equations (see p. 287).

From comparison of observations of the 1 st and 2 nd series, secured with different instruments at a year's distance at 23 common points, the mean error of one gradient V_{xz} and V_{yz} proved to be equal to $\varepsilon = \pm 2 . 10^{-9}$.

In Table 3 are given supplementary measurings of H (in meters) at points where no gravimetric observations were executed, in order to secure more accurate drawing of isobaths.

The gravity anomaly Δg is obtained by means of numerical integrating of gradients V_{xz} and V_{yz}, the mark at the point with co-ordinates $x = y = 0$

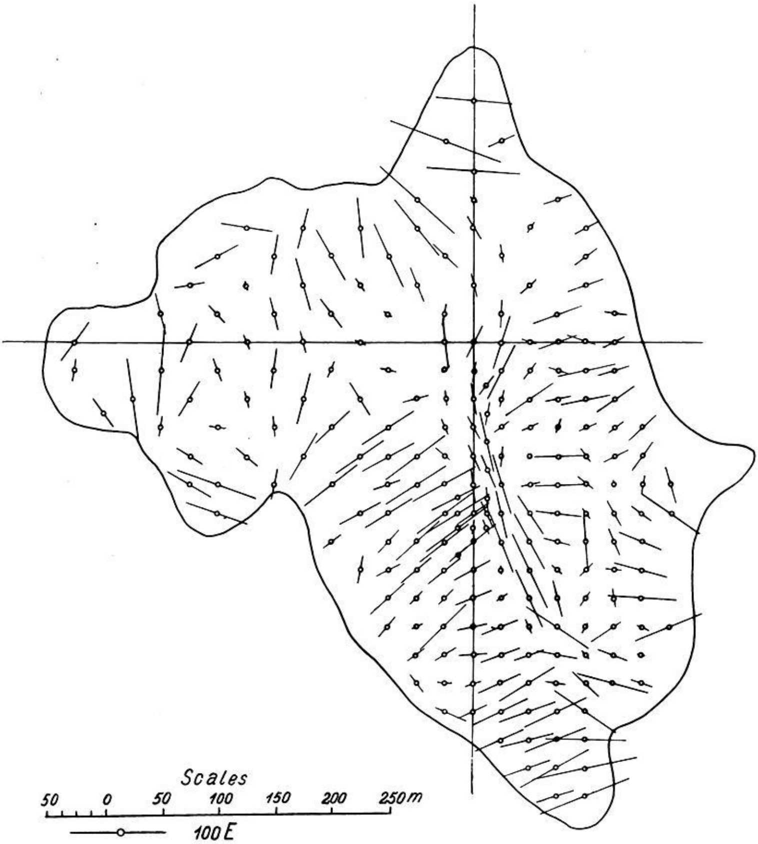

fig. 3. Gravity observations on Shuvalovo Lake 1927–28.
Map of curvature gradients.

being conditionally accepted as equal to $\Delta g = 100 . 10^{-5}\,\mathrm{cm\,sec}^{-2}$. Integrating was performed by contours, passing from one point to another with equal distribution of errors on closing single contours.

In fig. 1 are given the horizontals of the lake bottom (isobaths) through every 1 m with depth marks in decimeters. In fig. 2 is shown the plan of vectors of gravity variations in the 2 nd series with 35 complementary points of the 1 st series, marked in the 1st table with asterisk. Isogams (lines of equal anomaly) are drawn through every 5.10^{-5} cm sec^{-2}. Finally, in fig. 3 gradients of curvature R and λ are given, computed after formulae:

$$R\cos 2\lambda = \frac{\partial^2 V}{\partial x^2} - \frac{\partial^2 V}{\partial y^2},$$

$$R\sin 2\lambda = 2\frac{\partial^2 V}{\partial x \partial y}.$$

The graphic representation of the results of the 1 st series of observations (1927) shows in general lines the same picture as that obtained from the total of observations of both series.

Comparing the maps of isogams with that of depths we state their almost complete identity. The place of greatest depth ($h = 13.2$) possesses the minimum gravity value $\Delta g = 56.10^{-5}$; on the contrary, at the sand-bank in the centre of the lake ($h = 1.2$) the maximum anomaly $\Delta g = 137.10^{-5}$ is observed. But for the eastern part, where the coastal effect appears, isogams and isobaths are well corresponding.

In order to compare the anomalies of Δg with depth h, we may approximately put that

$$\Delta g = a + bh + cx + dy \quad \dots\dots\dots\dots \quad (1)$$

The coefficient a depends upon the accepted mark Δg. Coefficient b can be drawn from theoretical considerations. In fact, the horizontal layer with density δ and thickness h of infinite strike calls forth at an arbitrary point the gravity

$$\Delta g = 2k^2\pi\delta h \quad \dots\dots\dots\dots \quad (2)$$

where $k^2 = 667.10^{-10}$ is the attraction constant. Thus the coefficient b can be computed from the formula

$$b = 2k^2\pi\delta = 42\delta.10^{-8}\,(\text{C. G. S.}) \quad \dots\dots\dots \quad (3)$$

if the difference of densities δ of the layer and the environing masses is known. The coefficients c and d determine the effect of "deep geology" and yield a systematic linear variation of gravity over the whole area of the lake, proportional to co-ordinates.

In order to determine the coefficients a, b, c, d, we composed 59 and 189 conditional equations of the form (1) from the numerical data of Tables 1 and 2.

The normal equations for observations of the 1 st series of 1927 have the following appearance:

$$\left.\begin{aligned} 59\,a + 411.6\,b + 172\,c + 98\,d &= 5\,805 \\ 411.6\,a + 3495.58\,b + 1154.4\,c + 1200.4\,d &= 3\,695.7 \\ 172\,a + 1154.4\,b + 1864\,c - 252\,d &= 19\,558 \\ 98\,a + 1200.4\,b - 252\,c + 1724\,d &= 4\,320 \end{aligned}\right\} \quad \dots \quad (4)$$

and for the second series of 1927/28:

$$\left.\begin{array}{rl} 187\ a + 1128.5\ b + 999\ c - 55\ d = & 19\,331 \\ 1128.5\,a + 8282.85\,b + 5990.4\,c + 487.0\,d = & 109\,998.5 \\ 999\ a + 5990.4\ b + 10\,024\ c - 1574\ d = & 110\,130 \\ -52\ a + 487.0\ b - 1\,574\ c + 3562\ d = & -13\,290 \end{array}\right\} \quad . . (5)$$

On solving the equations let us consider two cases:

1 st case: $c = d = 0$ (linear variations of Δg neglected)

1927 $a = 138 \pm 4$; $b = -5.67 \pm 0.49$; $\sum \varepsilon^2 = 8\,553$; $\varepsilon_1 = \pm 12.2$

1927/28 $a = 131 \pm 2$; $b = -4.52 \pm 0.21$; $\sum \varepsilon^2 = 15\,116$; $\varepsilon_1 = \pm\ 9.0$

2nd case:

1927 $a = 127 \pm 2$; $b = -4.27 \pm 0.27$; $c = +1.16 \pm 0.15$;
$d = -1.60 \pm 0.18$; $\sum \varepsilon^2 = 1742$; $\varepsilon_2 = 5.6$

1927/28 $a = 121 \pm 0.8$; $b = -4.01 \pm 0.1$; $c = +1.18 \pm 0.07$;
$d = -0.90 \pm 0.08$; $\sum \varepsilon^2 = 3458$; $\varepsilon_2 = 4.3$

The residual errors ε_1 and ε_2 are given for both cases in the latter columns of Tables 1 and 2. The mean error of unit weight is equal to $\varepsilon_1 = \pm 12.2$ and $\varepsilon_2 = \pm 5.6$ for the 1 st series; $\varepsilon_1 = \pm 9.0$, $\varepsilon_2 = \pm 4.3$ for the second series. On the ground of the above values the average errors of unknown quantities are computed by means of common formulae of the least square method.

In the first place we have to note that the introduction of the members $cx + dy$ into the equations considerably improved the result of the representation and the sum of squares of residual errors fell from 8553 to 1742 for the year 1927, and from 15 116 to 3458 in 1927/28. Thus, undoubtedly, a general variation of gravity occurs and must be taken into consideration if we intend to study the distribution of gravity over a given area in relation to local effects.

Confronting the obtained value of the coefficient $b = -4.1$ for h expressed in meters and of Δg in 10^{-5} cm sec^{-2}, with the theoretical value [see Formula (3)], we can calculate the density difference δ of water and the lake bottom. In fact, we have

according to observations of 1927 $\delta = \frac{4.1}{4.2} = 0.97$,

„ „ „ „ 1927/28 $\delta = \frac{4.3}{4.2} = 1.03$.

i. e. a value for density difference, near to reality. This confirms the correctness of the theoretical Formula (3) and, consequently, in cases where the density difference of two rocks is known, we are enabled, on the ground of approximate formula

$$\Delta h = h - h_0 = \frac{\Delta g - \Delta g_0}{42\,\delta}\, 10^8 \text{ (C. G. S.)} \quad . . . . . . (6)$$

to determine the differences of depths in dependence of the difference of gravity anomaly at two points.

In the table below, the difference Δh (in meters) is shown after the argument of density δ, putting the difference of gravity anomalies $\Delta g - \Delta g_0 = 0.001 \,\mathrm{cm\,sec}^{-2}$.

Table 4.

δ	Δh (meters)	δ	Δh (meters)
0.0	—	0.6	40
0.1	238	0.7	34
0.2	119	0.8	30
0.3	79	0.9	26
0.4	60	1.0	24
0.5	48	2.0	12

The general variation of gravity on the area of the Shuvalovo Lake, on the ground of coefficients c and d, will be equal:

according to data of the 1 st series, to $\dfrac{\Delta g}{\Delta S} = 1.16 \cos\alpha - 1.60 \sin\alpha$

Δg in $10^{-5}\,\mathrm{cm\,sec}^{-2}$,

" " " " " 2 nd " " $\dfrac{\Delta g}{\Delta S} = 1.18 \cos\alpha - 0.90 \sin\alpha$

ΔS in 25 mm

in the direction of azimuth α. This variation is reaching its maximum value of $0.0008\,\mathrm{cm\,sec}^{-2}$ to 1 km in the direction of azimuth $\alpha = 306^0$ (SO) according to observations of 1927 and of $0.0006\,\mathrm{cm\,sec}^{-2}$ to 1 km in the direction $\alpha = 323^0$ according to observations of 1927/28.

If we know the coefficients a, b, c, d, we can, by means of equation (1) determine the depths at points where the gravity anomaly Δg is known. The mean quadratic error of determination will be equal to $\varepsilon_1/b = \pm 2$ m or $\varepsilon_2/b = \pm 1$ m.

Thus, taking into account the general variation of gravity we double the accuracy of determination of the lake bottom.

The representation of the gravity anomaly in the form of Formula (1) is possible only in case of one contact surface (bottom of the lake) dividing the rocks of different densities. In the case of several contact surfaces situated at different depths, we get a summary idea and no interpretation, theoretically spoken, is possible.

The equations (1) and (3) in the case of several surfaces of divide can be written down as follows:

$$\left.\begin{aligned} \Delta g &= a + 2\pi k^2 h\delta + cx + dy, \\ h\delta &= h'\delta' + h''\delta'' + \cdots \end{aligned}\right\} \quad \ldots\ldots\ldots \quad (7)$$

where

is the mean effect of all layers, which may be secured as the result of gravimetrical observations. It is natural that in order to find the h' sought for one layer, we must on the ground of Formula (7) know δ', h'' and δ'' a. s. o. for all other layers. Only in the particular case of two surfaces, resting unconformably, when the effect of the deep layer calls forth a linear variation of gravity, we may try to interprete the results after having excluded the effect of "deep geology" *).

The residual errors of ε_3 when solving the conditional equations (1), are far from being occasional. Should they be represented graphically, it would be seen, that near the coasts we have mainly positive values and in the centre of the lake, above the depression, a group of negative values. Such systematic alternation of signs is observed over the whole area of the lake and depends on the one hand, upon integrating system, unestimated coastal effect, and finally and mainly, upon more complicate effect of the underground relief upon Δg than a simple proportional dependency on depth h.

In possession of the underground relief in the first approximation, we can go over to the second approximation and compute the effect of the relief $\overline{\Delta g}$ according to formulae like those we are using when estimating the effect of topographic masses upon the variometer observations**).

The variation of difference $\sigma = \Delta g - \overline{\Delta g}$ from some mean value will indicate what correction of $\Delta h = -\sigma/b$ is to be introduced into the preliminary values of depths h.

Vorträge, gehalten auf der Tagung der Deutschen Geophysikalischen Gesellschaft,

Dresden, 3. bis 5. Oktober 1929.

Zur Erforschung der ersten 100 km Erdkruste.

Von **J. Koenigsberger.** — (Mit einer Abbildung.)

§ 1. Die gewaltigen Fortschritte von Relativitäts- und Quantentheorie haben bewirkt, daß Sterne, die Millionen von Lichtjahren entfernt sind, uns besser bekannt sind als das Erdinnere, ja sogar besser als die unmittelbar benachbarte feste Erdkruste von 50 bis 100 km Dicke. Zur Entschuldigung kann aber dienen: das wichtigste Hilfsmittel der astronomischen Analyse, die Strahlung jeder Art, auf welche sich die meisten Sätze der Relativitäts- und Quanten-

*) B. Numerov: Results of gravity observations in the region of Grosny. Bull. Astr. Inst. 1929, No. 23 (Russian).

**) Derselbe: Reduction of observations with gravity variometer for topography. Ebenda 1927, No. 17 (Russian).