57. *The Water Surface of a Lake as an Indicator of Crustal Deformation.*

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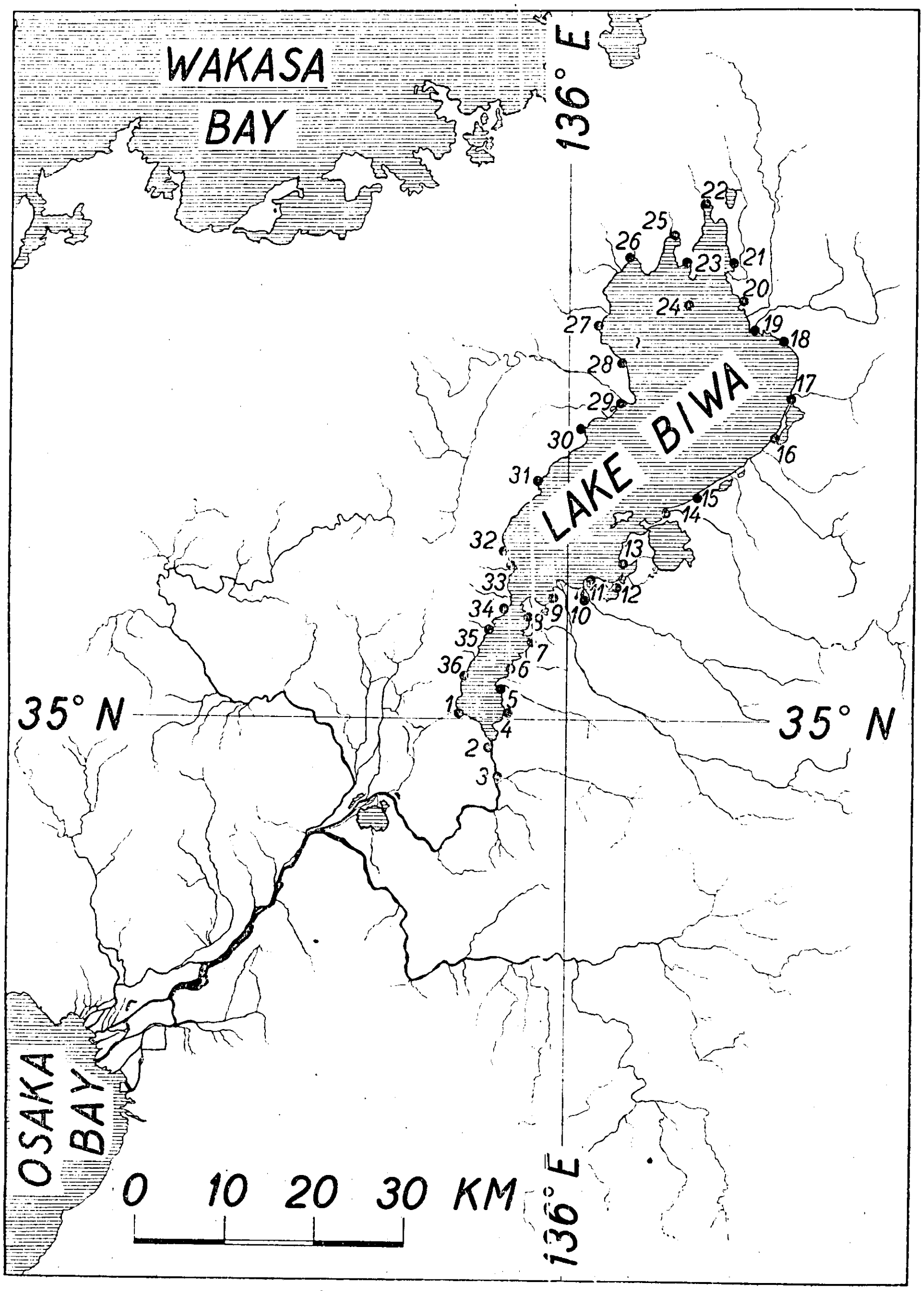
Lake Biwa, in Siga Prefecture, with a length of over 60 km in a NNE–SSW direction and an average width of 15 km, is the largest lake in Japan. Along its lute-shaped shore-line (biwa is the Japanese for lute), measuring more than 235 km, are distributed 36 recording or staff water-gauges as shown in Fig. 1, which are in use for civil engineering purposes. Since 1889, when the water-gauges, Nos. 1, 13, 18, 27, and 34 were erected, reading of the height of the lake water have been continued practically without interruption for over 50 years. Through the courtesy of the Siga Prefecture Civil Engineering Section, the writer had access to the monthly means of the height of the lake water as registered by all the gauges up to 1936. The object of the present study is to discuss this wealth of observational material from the geophysical point of view, particularly with reference to the crustal deformations around the lake. This study has been suggested by B. Gutenberg's[1] of crustal deformations in the Great Lakes District of North America.

Table I. Annual Means of the Height of the Lake Water referred to 1897.

Year	Height	Year	Height	Year	Height	Year	Height
	cm		cm		cm		cm
1887	−19·6	1898	−29·9	1909	−57·9	1920	−64·2
88	−22·7	99	− 8·9	1910	−49·6	21	−43·0
89	16·6	1900	−24·6	11	−47·9	22	−81·0
1890	12·2	01	−51·2	12	−45·4	23	−43·1
91	− 7·3	02	−55·7	13	−42·1	24	−88·4
92	6·7	03	−38·8	14	−46·4	25	−63·5
93	− 8·5	04	−55·2	15	−38·7	26	−66·4
94	−42·6	05	−45·9	16	−40·1	27	−60·7
95	−14·3	06	−48·3	17	−38·4	28	−54·6
96	40·3	07	−35·2	18	−46·2	29	−49·9
97	0	08	−54·9	19	−61·7		

1) B. GUTENBERG, *Journ. Geol.*, **41** (1933), 449.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LAKE BIWA
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Fig. 1.

From the monthly means of the height of the lake water, the annual means were calculated for each of the 36 gauge stations. Since no determination has been made of the relative heights of the zeros of the gauges at different stations, and since we are here concerned only with the relative rise or fall of the lake water, the arbitrary constant peculiar to each station may be subtracted from the annual means for that station. For convenience, this constant was so taken as to reduce

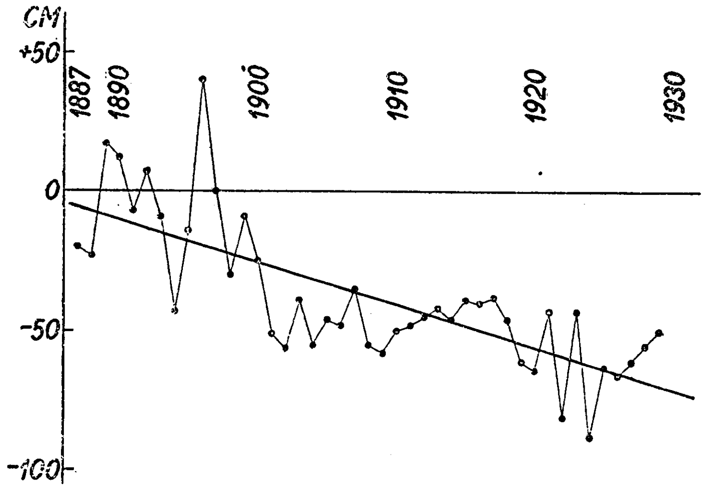

Fig. 2. General Fall of the Level of the Lake Water.

the annual means for 1897 for all the stations to zero.

The annual means for the various stations being thus referred to one common datum, the mean of the annual means was calculated for each year with the results given in Table I and plotted in Fig. 2. They clearly indicate the general fall of the water level of the lake.

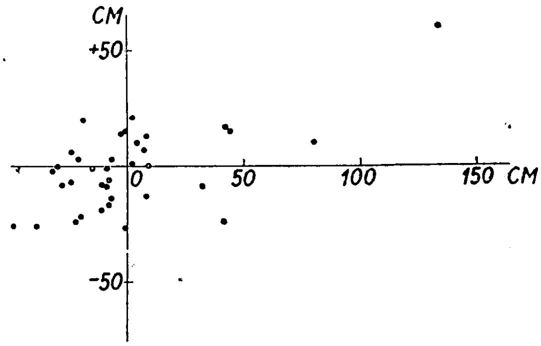

Fig. 3. Correlation Diagram between δh and δr.

If we assume the fall of the water level to be linear with respect to time, the height of the water h in any year was found to be given by

$$h = -1{\cdot}53t - 5{\cdot}5 \text{ (cm)}$$

by the method of least squares, where t is the number of years counted from 1887. The average rate of fall of the water level is thus 1·53 m per century. In this connection, it is interesting to note that around the lake at little more than 200 m above the present lake surface, lake terraces of diluvial age are well developed.

The fluctuations superposed on the general fall of the water level are probably caused by those in the precipitation in and around the lake. Fig. 3 is a diagram correlating the fluctuations in the height of the water level with those in the precipitation observed at Hikone, situated on the eastern coast of the lake. Although not very clearly, the diagram shows the suspected relation.

Table II. Fluctuations in the Height of the Lake Water (δh) and in the Precipitation at Hikone (δr).[2]

Year	δh	δr	Year	δh	δr	Year	δh	δr
	cm	cm		cm	cm		cm	cm
1894	−26·4	− 49	1906	−13·8	− 7	1918	+ 6·7	+ 7
95	+ 3·4	− 7	7	− 0·9	+ 2	19	− 7·3	−24
96	+59·6	+134	8	−17·3	− 8	20	− 8·2	−28
97	+20·8	+ 2	9	−18·8	−11	21	+14·5	+44
98	− 7·6	− 11	1910	− 8·9	− 9	22	−22·0	−20
99	+14·9	− 1	11	− 5·7	− 8	23	+17·4	+42
1900	+ 0·8	− 15	12	− 1·7	−32	24	−26·3	−39
1	−24·3	− 22	13	+ 3·1	−21	25	0	+ 9
2	−27·3	− 1	14	+ 0·3	−30	26	− 1·3	− 9
3	− 8·8	+ 32	15	+ 9·6	+ 4	27	+ 6·0	−24
4	−23·7	+ 41	16	+ 9·7	+80	28	+13·6	− 3
5	−12·9	+ 8	17	+13·0	+ 8	29	+19·8	−19

Deviations in the height of the lake water at a particular station from the corresponding mean are the anomalies for that station. The anomalies for several stations are plotted in Fig. 4. At Station No. 1, for instance, the curve indicates a fall of water level at a nearly uniform rate, while at Station No. 19 which is situated almost on the opposite side of the lake, the curve indicates a rise of the level with similar amount. Just as by tipping a water-bowl a relative rise of water is caused toward the direction of tipping and a fall in the opposite direction, the rise and fall of the water level just found are to be attributed to tilts of the earth's crust around the lake.

2) Taken from Monthly Weather Review of the Central Meteorological Observatory.

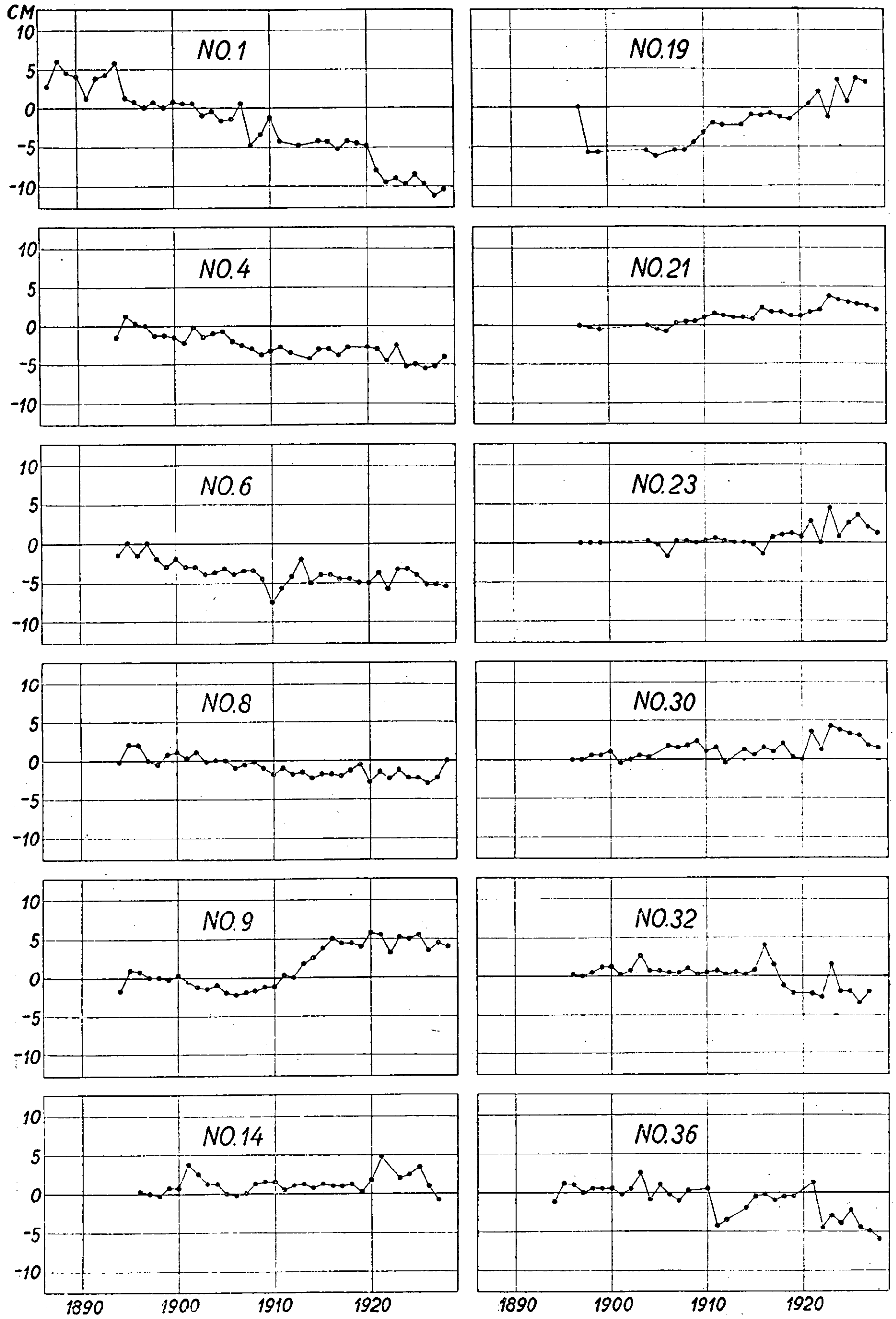

Fig. 4. Anomalies of the Level of the Lake Water.

In Fig. 5, the anomalies in the height of the water in 1928 are plotted against the station numbers. The distribution of the points suggests that since 1887, the earth's crust around the lake has tilted down in the direction from Station No. 1 to No. 20 by 0·7 second of arc. Miyabe's method[3] was also applied in order to determine more accurately the direction and amount of tilt, but it was found that the materials here used are unfortunately not accurate enough for this method of analysis.

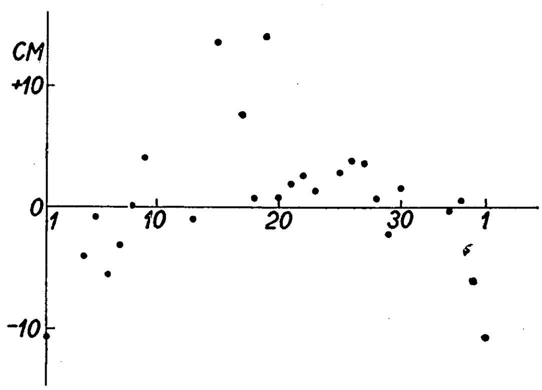

Fig. 5. Anomalies of the Level of the Lake Water plotted against Station Number.

Two lines of precise levels were run along the lake coast, the one on its east side and the other on the west as shown in Fig. 6. Each of these lines were surveyed in 1888, 1918 and 1927, and in 1885 1899, 1917 and 1928 respectively. The changes in the heights of the bench marks are given in Table III and plotted in Figs. 7, 8. The tilting of the earth's crust around the lake as found by repeated levellings agree well both in direction and amount with what has been deduced from the data of height of the lake water.

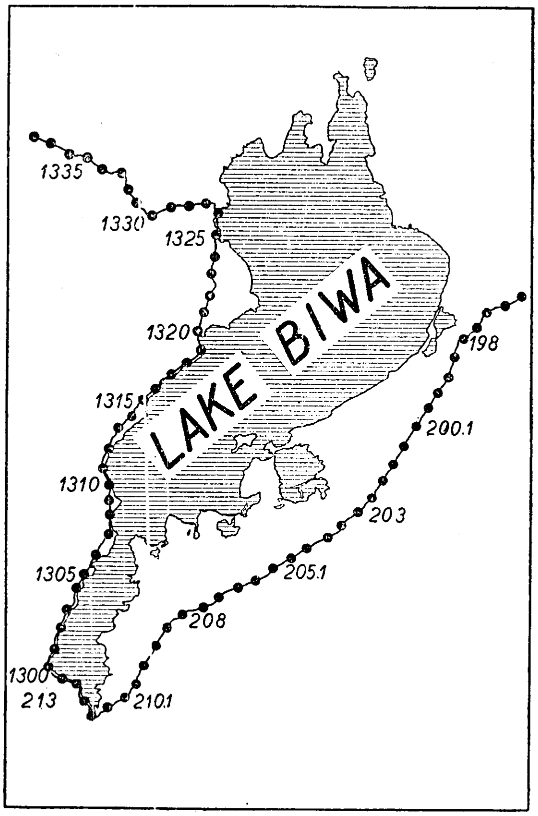

Fig. 6. Lines of Precise Levels around the Lake.

3) N. MIYABE, *Bull. Earthq. Res. Inst.*, 9 (1931), 256.

After all, a lake is a large level by means of which tilts of the earth's crust may be detected. The fact that no great accuracy is to be expected from it does not detract from its usefulness in this respect. If due allowance are made for the effects of meteorological dis-

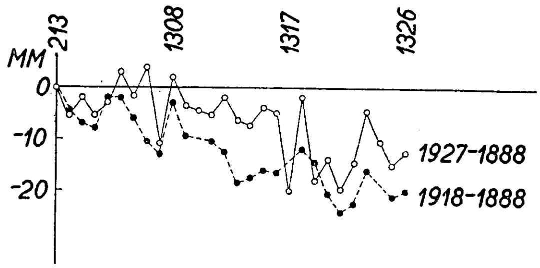

Fig. 7. Changes in the Heights of the Bench Marks.

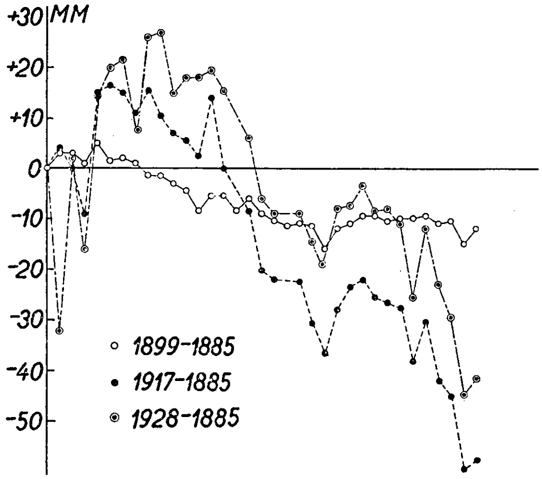

Fig. 8. Changes in the Heights of the Bench Marks.

turbances, such as by wind and rain, both of which bring about changes in the height of the water, the means above-mentiond can be availed of in a protracted and continuous watch for regional tilts of the earth's crust, provided of course that there is a lake in or near that region.

Table III. Changes in Heights of Bench Marks (mm).

B.M.	1918—1888	1927—1988	B.M.	1899—1885	1917—1885	1928—1885
213	0·0	0·0	213	0·0	0·0	0·0
1300	− 4·3	− 5·3	212·1	+ 3·0	+ 3·8	−31·9
1	− 6·9	− 2·1	212	+ 3·0	+ 0·1	+ 2·0
2	− 7·9	− 5·6	211·1	+ 1·0	− 9·2	−16·2
3	− 1·9	− 2·9	211	+ 4·9	+15·0	+14·6
4	− 1·9	+ 2·9	210·1	+ 1·3	+16·3	+19·8
5	− 6·1	− 1·7	210	+ 1·9	+14·9	+21·5
6	−10·7	+ 4·0	209·1	+ 1·1	+12·1	+10·6
7	−13·1	−10·9	209	− 1·6	+15·5	+26·1
8	− 3·1	+ 2·2	208·1	− 1·4	+10·7	+21·8
9	− 9·8	− 3·3	208	− 3·0	+ 7·1	+14·9
1310	——	− 4·8	207·1	− 4·7	+ 5·6	+17·8
1	−10·3	− 5·4	207	− 8·3	+ 2·5	+17·8
2	−12·7	− 2·2	206·1	− 5·6	+13·8	+19·6
3	−18·5	− 6·5	206	− 5·6	+ 0·3	+15·6
4	−17·3	− 7·4	205·1	− 8·4	——	——
5	−16·0	− 4·2	205	− 6·0	− 8·5	+ 6·1
6	−16·7	− 5·0	204·1	− 9·2	−20·1	− 5·8
7	——	−19·8	204	−10·3	−22·2	− 8·9
8	−11·8	− 1·8	203·1	−11·4	——	——
9	−14·8	−17·9	203	−11·0	−22·4	− 9·0
1320	−20·3	−14·2	202·1	−11·7	−30·3	−14·4
1	−24·2	−19·6	202	−15·9	−36·3	−16·7
2	−22·6	−14·3	201·1	−12·0	−28·0	− 8·0
3	−16·2	− 4·7	201	−11·2	−23·7	− 7·5
4	——	−10·5	200·1	− 9·3	−21·9	− 3·5
5	−21·0	−14·9	200	− 9·5	−25·7	− 8·7
1326	−20·0	−12·5	199·1	−10·7	−26·3	− 7·8
			199	− 9·8	−27·6	−11·0
			198·1	−10·2	−38·2	−25·7
			198	− 9·7	−30·3	−11·9
			197·1	−11·0	−42·2	−22·9
			197	−10·6	−45·1	−29·6
			196·1	−14·8	−59·3	−44·6
			196	−11·8	−57·3	−41·6

57. 琵琶湖の水位に就いて

地震研究所 坪井忠二

滋賀縣當局の御好意によつて，明治 20 年以降の琵琶湖水位の月別平均の値を入手する事が出來たのでそれを整理した．觀測點の數は 36 の多きに上つてゐる．まづ各點に就き年平均を求めそれを更に各年に就き平均するこ琵琶湖水面の一般的昇降が求められる筈である．その結果によるこ水面は 100 年に 1·53 m の割で低下して來た事が分つた．琵琶湖の周圍には湖岸段丘が發達してゐるこの事であるが，これは以上の事實こ對照して面白い事である．此の一般的低下にはかなりの上り下りが伴つてゐるが，これは附近の降水量に支配されるものであらう．

此の一般的低下を差引いた値について見るこ，或る點では水位が次第に高まり，又これこ湖の反對岸にある點では逆に低まる傾向がある．これは丁度水を入れた茶碗を傾けたのこ同じ樣に，附近の地殼が傾斜したここを意味する．明治 20 年以來湖の長軸の方向に北側が凡そ 0·7 秒傾下したここになる．湖岸に沿つて行はれた水準測量の結果もこれこ一致する．