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ON THE OBSERVATIONS OF THE TIDAL STRAINS AT OSAKAYAMA OBSERVATORY

By

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Abstracts

The studies on the observations of the earth's tidal strains and tiltings have been performed with extensometers, a recording water-tube tiltmeter and rotationmeter chiefly at Osakayama Observatory and partly at Kishu Mine and Suhara Observatory.

The tidal number h_2 and l_2, the quantities relating to their radial gradients are evaluated by analyses of the observing tidal extensions.

The tidal constants of the ground tilting are obtained from the observation with the water-tube tiltmeter and are compared to those of the pedulum type's tiltmeters obtained by E. Nishimura.

Recently, we have devised a rotationmeter to observe directly the tidal rotations and the horizontal shear strain, and has been carried out to observation at Osakayama Observatory. According to the observations, the result obtained with the rotationmeter seems to have approximate agreement with those obtained with extensometers.

1. Introduction

The observations of the linear strain have ever been made plans by Milne [1888] and others (Oddone [1900]) in early days, there after, are many special works like those of Benioff [1935], Takahashi [1934] and so on...... Perhaps, it is the first that the extensometer has been used for the observations of the tidal strains by Sassa [1951]. His great penetration decided that the tidal strains was observable by use of his extensometer. His sightness has been realized completely by his students' cooperations. Afterward, this observations have been developed at Kyoto University and at Tokyo University, especially by Ozawa [1957], and Hagiwara et al. [1951], respectively.

We cannot, however, overlook the studies of the earth's tidal theory by Takeuchi [1950], of the tidal tilting by Nishimura [1950], and passionate contributions by Melchior to promote the international studies in the history of the developments of the study of the earth tide.

The present author has found the actual posibility of the observations of the tidal strains at distant places from the ocean in the cooperation with Sassa et al.. And he (Ozawa [1957, 1959]) has established the fundamental formulas of the tidal strains, and has obtained some observing constants and numbers relating to the earth tide. And also he (Ozawa [1965]) has devised some types of highly sensitive extensometers.

2. Theory of the tidal strains

Let the earth's coordinates be r, θ, ϕ which are the radial, the colatitudinal and the prime vertical vectors respectively, then r, θ, ϕ components u_r, u_θ, u_ϕ of the tidal displacement, respectively, are written as

$$\left.\begin{aligned} u_r &= \frac{h_t}{g} W_t, \qquad H_t(a) = h_t, \\ u_\theta &= \frac{l_t}{g} \frac{\partial W_t}{\partial \theta}, \quad L_t(a) = l_t, \\ u_\phi &= \frac{l_t}{g \sin\theta} \frac{\partial W_t}{\partial \phi}, \end{aligned}\right\} \qquad \cdots\cdots(1)$$

where h_t and l_t are Love's [1909] and Shida's [1912] numbers, a is a distance from the earth's center, and g is an approximate numerical value of the gravity at an observing point. Some people (Melchior [1966]) treat of the g as a function

	Diurnal component	Semi-diurnal component	Ter-diurnal component
e_{rr}	$\times W_2/ag$ $\left\{a\frac{dH_2(a)}{dr}+2h_2\right\}$	$\times W_2/ag$ $\left\{a\frac{dH_2(a)}{dr}+2h_2\right\}$	$\times W_3/ag$ $\left\{a\frac{dH_3(a)}{dr}+3h_3\right\}$
$e_{\theta\theta}$	h_2-4l_2	$\frac{h_2\sin^2\theta+2l_2\cos 2\theta}{\sin^2\theta}$	$\frac{l_3(6\sin\theta\cos^2\theta-3\sin^3\theta)+h_3\sin^3\theta}{\sin^3\theta}$
$e_{\phi\phi}$	h_2-2l_2	$\frac{h_2\sin^2\theta-2l_2(1+\sin^2\theta)}{\sin^2\theta}$	$\frac{l_3(-9\sin\theta+3\sin\theta\cos^2\theta)+h_3\sin\theta}{\sin^3\theta}$
$e_{\theta\phi}$	$4l_2\sin\theta\{\tan(t+\phi)\}$	$-4l_2\cos\theta\{\tan 2(t+\phi)\}$	$\frac{-6l_3\sin 2\theta}{\sin^3\theta}\tan 3(t+\phi)$
Areal strain	$2(h_2-3l_2)$	$2(h_2-3l_2)$	$2(h_3-6l_3)$
Cubical dilatation	$\left\{a\frac{dH_2(a)}{dr}+4h_2-6l_2\right\}$	$\left\{a\frac{dH_2(a)}{dr}+4h_2-6l_2\right\}$	$\left\{a\frac{dH_3(a)}{dr}+5h_3-12l_3\right\}$
$e_{r\theta}$, $e_{r\phi}$	0	0	0
ω_r	0	0	0
ω_θ	$\frac{(l_2-h_2)}{\sin\theta}\tan(t+\phi)$	$\frac{2(l_2-h_2)}{\sin\theta}\tan 2(t+\phi)$	$\frac{3(l_3-h_3)}{\sin\theta}\tan 3(t+\phi)$
ω_ϕ	$2(l_2-h_2)\cot 2\theta$	$2(l_2-h_2)\cot\theta$	$3(l_3-h_3)\cot\theta$

$\cdots\cdots(2)$

of r, but this treatment is more complicated than that of A. E. H. Love. According to the Love's definition, the g is introduced instead of the gravitating constant and the mass of the earth which are both constant. And W_i in expressions (1) is the tide generating potential whose form is the solid spherical harmonic function of i-th order. If the distributions of the changes of the loadings due to the oceanic tide are given by the combinations of W_i, the respective combinations of the terms in the expressions (1) give the displacement components caused by the loading's too.

From the expressions (1) and formulas of relations the strain elements and the displacements, we have strains and rotations for diurnal, semidiurnal and ter-diurnal tides as shown in the table of the fromula (2).

These formulas express so-called primary effects due to the heavenly body and their respective combinations express also the general ones of so-called secondary effects due to the oceanic tides.

However, the loading strains in the near area are usually treated as a problem on a semi-infinite elastic body as followings.

The formulas of the loading strains were obtained by Boussinesq [1885], and Takahashi [1929] and Hagiwara et al. [1949] have calculated those considering the gradient of the sea bottom. However, we may neglect these additional terms of the strains at the distant from the sea, because the areas with the large gradients are narrow and are limitted within the neighbouring coast.

Putting an origin of a rectangular coordinate on a loading point, and x and y axes on the horizontal plane, and directing z-axis vertically, we have following strains near the ground,

$$\left.\begin{aligned}
e'_{xx} &= \frac{P}{4\pi(\lambda+\mu)}\frac{x^2-y^2}{r^4} = -e'_{yy},\\
e'_{xy} &= \frac{P}{\pi(\lambda+\mu)}\frac{xy}{r^4},\\
e'_{zz} &= e'_{zx} = e'_{yz} = 0,\\
\Delta' &= 0,\\
\omega'_x &= -\frac{P}{4\pi}\left[\frac{\lambda+2\mu}{\mu(\lambda+\mu)}\right]\frac{y}{r^3},\\
\omega'_y &= \frac{P}{4\pi}\left[\frac{\lambda+2\mu}{\mu(\lambda+\mu)}\right]\frac{x}{r^3},\\
\omega'_z &= 0,
\end{aligned}\right\} \qquad \cdots\cdots\cdots\cdots(3)$$

where λ and μ are Lamé's elastic constants, and P is the loading pressure on the point.

3. Observations

We have performed observations of the earth's tidal extensions at Osakayama observatory since 1947, and at some other observatories. The observations of the tiltings have been done with the horizontal pendulum type tiltmeters since 1947 and with a recording water-tube tiltmeter since 1965 at Osakayama observatory. Recently, we have begun the observation of the horizontal shear with a rotationmeter here.

(*a*) *Observations by means of the extensometers*

Sassa type extensometers were used for the observations of the tidal extensions in the early days, afterward the present author has devised some types of the highly sensitive extensometers, and then we have usually used these highly

Table 1. The Constants of Tidal Extensions
Observatory : Osakayama Observatory,
Location : 34°59.6′N., 135°51.5′E.
Distance from the nearest sea : 65 km,

Direction	Type	Length	Priod of analyses, Epoch	Mos.	Sensitivity $\times 10^{-8}$/mm	M_2-tide Amplitude $\times 10^{-8}$	M_2-tide Phase lag	O_1-tide Amplitude $\times -10^{-8}$	O_1-tide Phase lag	Weight
N38°E	Sa	20	47″, 10, 24.	18	0.63	0.330	43.0°	0.123	358.4°	23
N29°W	Sa	4.2	53″, 2, 19.	1	9.8	1.98	23			0.3
N61°E	H.W.G.	9.6	53″, 2, 12.	1	3.1	0.50	9			0.5
Vertical	V.W.B.	4.0	52″, 12, 25.	1	2.24	0.44	215			0.7
Vertical	V.W.B.	4.0	53″, 2, 12.	1	2.22	0.63	201			0.7
Vertical	V.W.B.	4.0	53″, 3, 12.	1	2.22	0.64	193			0.7
N29°W	Sa	4.2	54″, 5, 2.	1	3.0	1.38	8	1.19	34	0.6
N61°E	H.W.G.	9.6	54″, 8, 31.	1	1.82	0.56	14	0.36	29	0.7
Vertical	V.W.B.	4.0	54″, 10, 7.	1	1.85	0.74	174	0.61	232	0.7
Vertical	V.W.B.	4.0	54″, 11, 5.	1	1.85	0.84	192			0.7
S52°E 45°Dip	D.R.R.	5.1	55″, 1, 7.	0.5	1.34	0.12	56			0.4
S52°E 45°Dip	D.R.R.	5.1	55″, 11, 5.	1	1.34	0.06	271			0.9
N38°E 45°Dip	D.W.R.	6.4	56″, 7, 13.	1	2.46	0.26	331			0.6
E	H-59-B	5.3	59″, 1, 27.	1	1.81	0.636	4.6	0.672	22.0	0.7
E	H-59-B	5.3	59″, 3, 28.	1	0.53	0.735	359.7	0.735	16.3	1.4
E	H-59-B	5.3	59″, 5, 24.	3	0.37	0.880	357.8	0.760	3.5	4.9
N	H-59-B	5.3	59″, 4, 23.	3	0.57	1.362	10.9	0.640	20.8	4.0
S52°E	H-59-B	10	60″, 2, 19.	1	0.064	1.630	0.9	1.001	34.3	4.0
S38°W	H-59-B	22	60″, 8, 25.	3	0.202	0.395	6.3	0.213	355.6	6.7
S52°E	H-59-B	10	61″, 11, 5.	4.5	0.181	1.433	359.1	1.104	13.5	10.5
Vertical	V-59-D	6.0	64″, 8, 12.	1	0.562	0.510	198.3	0.757	202.6	1.3
Vertical	V-59-D	6.0	64″, 9, 16.	1	0.525	0.525	198.4	0.582	219.2	1.3
S38°W	H-59-B	12.0	65″, 8, 3.	1.5	0.207	0.385	11.0	0.244	334.4	3.3
S38°W	H-59-B	12.0	65″, 9, 24.	2	0.201	0.420	10.5	0.235	325.4	4.4

sensitive type extensometers.

The observing tidal strains generally contain some loading strains due to the oceanic tide. And so, we had performed the tripertite observations of the tidal extensions with every three components at Osakayama observatory, at Suhara observatory and at Kishu mine in order to prove the loading strains to obtain the primary effect. According to our observations, the loading tides have been able to estimated qualitatively by the formulas of J. Boussinesq. Although it was much difficult to evaluate in ditail, the loading extensions seem to be much smaller than those of the primary effects except at Suhara, because the sine-terms of the observed extensions are within their probable errors (Ozawa [1957a]).

Table 1 shows the tidal constants obtained from the observing extensions at Osakayama.

The tidal observations have been performed with three instruments in the vertical direction, with seven instruments in five horizontal directions and with two instruments in two dips directions. On the second fil in the table 1, the sign "Sa" shows the Sassa type extensometers [1951]. The Sassa type extensometer is the horizontal component's one, and it consists of a slacken wire as the standard wire and a tri-filamentary suspension like Schweyder type's gravimeter as the amplifier of the vertical change of a weight due to the slacking. The "H.W.G." is the horizontal component's and it consists of a slacken wire and a torsional galvanometer. The sign "V.W.B." is the vertical component's and it consists of a slacken wire and a bifilamentary suspension. The sign "D.R.R." is the inclined direction component, and it consists of a super-invar rod, is used as a pendulum to transform the relative displacement into the deflection of the pendulum, and the deflection is amplified with a roller. The sign "D.W.R." is also inclined one, and it consists of a super-invar wire and a roller. H-59 types are the horizontal components, and they have been devised in 1959 by this author (Ozawa [1965]). These types extensometers consist of super-invar rod or pipe whose diameter are one or three centimeters respectively. Their mechanism of the amplifier is that the relative displacement between the free end of the standard measure and its neighbouring base point on the ground are transformed with a lever into the tilting of an axis of the Zöllner suspension type tiltmeter, and then the tilting is enlarged with the horizontal pendulum and an optical lever. Their sensitivity are able to adjust at will within the region from 10^{-10} to 10^{-8} per one millimeter on the record. V-59 type is vertical one, and its mechanism of the amplifier and the sensitivity are like as H-59 type's.

The greater part of the tidal constants have been calculated by Darwin's method and the smaller ones have been done by Doodson's one.

Photo. 1a and b show the horizontal and the vertical extensional curves of

Photo. 4. Amplifier part of the H-59-D type extensometer.

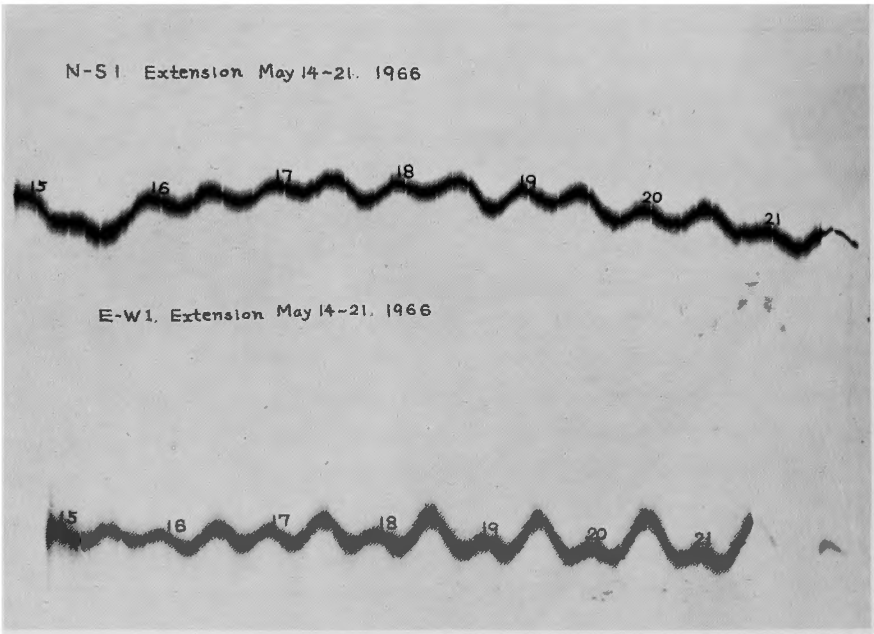

Photo. 1a. Recordings of the tidal extensions in the meridional and the prime vertical directions observed with the H-59-B type extensometers at Osakayama.

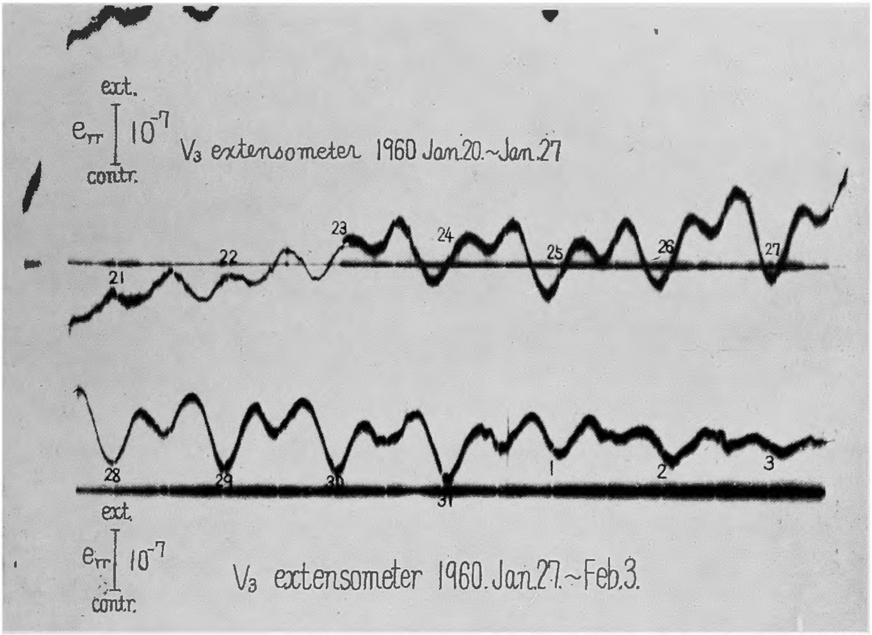

Photo. 1b. Recording of the tidal extension in vertical observed with the V-59-B type extensometer at Osakayama.

Table 2. The observed elements of the tidal strains in Osakayama

	for M_2-tide	for O_1-tidal
e_{rr}	$0.588\times10^{-8}\cos(2t-196.4°)$,	$0.647\times10^{-8}\cos(t-214.3°)$,
$e_{\theta\theta}$	$0.612\times10^{-8}\cos(2t-25.7°)$,	$0.553\times10^{-8}\cos(t-23.6°)$,
$e_{\phi\phi}$	$1.109\times10^{-8}\cos(2t-359.0°)$,	$0.698\times10^{-8}\cos(t-5.0°)$,
$e_{\theta\phi}$	$1.080\times10^{-8}\cos(2t-172.7°)$,	$0.972\times10^{-8}\cos(t-202.0°)$,
Areal strain	$1.678\times10^{-8}\cos(2t-6.1°)$,	$1.235\times10^{-8}\cos(t-13.2°)$,
Cubical dilatation	$1.109\times10^{-8}\cos(2t-1.6°)$,	$0.675\times10^{-8}\cos(t-353.3°)$,
h_2-3l_2	0.328,	0.416,
$a\frac{dH_2(a)}{dr}+4h_2-6l_2$	0.435,	0.461,
Horizontal maximum strain	in S57°E,	in S49°E.

the crust observed with H-59-B and V-59-B type's extensometers, respectively.

The strain elements have been calculated from the observed tidal constants in Table 1, and are shown in Table 2. The weights of the every constants in the calculations are defined as $T\sqrt{S}$, where T is the number of the months of the analyzed period, and S is the respective sensitivity.

And the tidal factors h_2-3l_2 and $a\frac{dH(a)}{dr}+4h_2-6l_2$ calculated from the areal and cubical dilatations which are free from the loading strain, are also shown in Table 2.

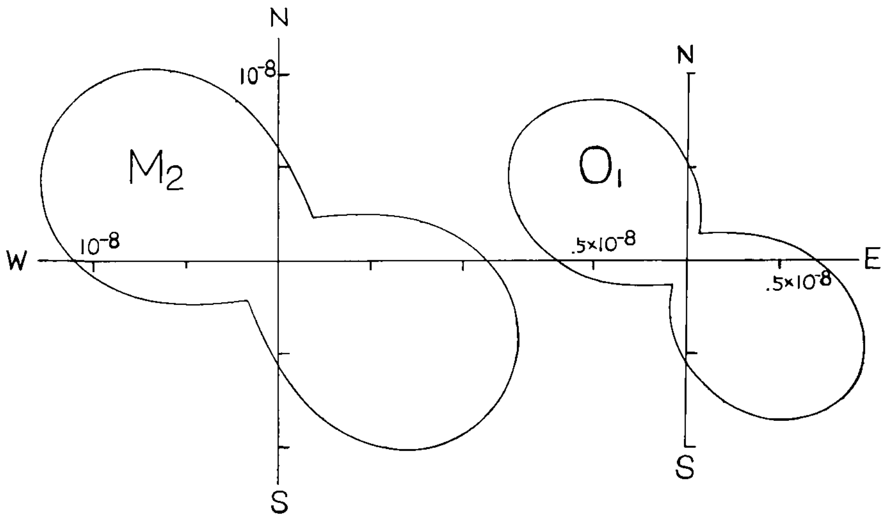

Fig. 1. Azimuthal pattern of the tidal extensions for M_2- and O_1-tides at Osakayama.

Fig. 1 shows the azimuthal patterns of the tidal extensions for M_2- and O_1-tides. We find that the maximum extensions are in the directions of S-57°E and S-49°E, respectively. The maximum strains are ordinary in the meridional direction for M_2-tide and in the prime vertical direction for O_1-tide. According to this result, it seems that the crust in this district is considerably anisotropic. Perhaps, it is one of the important causes that the boundary of the upper mantle has steep gradient toward north-west direction here. And the directions of the maximum strains is nearly orthogonal to the direction of the Japan Island.

Rotating the directions of the horizontal axes of the coordinates 57° anticlockwize for M_2-tide and 41° clockwize for O_1-tide, respectively, we have the transformed strain elements as follows

	for M_2-tide	for O_1-tide
$e_{\theta'\theta'}$	$1.425\times10^{-8}\cos(2t-358.6)$,	$0.174\times10^{-8}\cos(t-343.3°)$,
$e_{\phi'\phi'}$	$0.319\times10^{-8}\cos(2t-42.8°)$,	$1.106\times10^{-8}\cos(t-20.8°)$,
$e_{\theta'\phi'}$	$0.344\times10^{-8}\cos(2t-310.7)$,	$0.214\times10^{-8}\cos(t-286.3°)$.

Putting the weight ratio between M_2- and O_1-tides' components three, and from these transformed strain elements, we have tidal numbers h_2 and l_2, and the quantities relating to the radial gradients of h_2 and l_2 as follows,

$$h_2=0.590\pm0.047, \quad a\frac{dH_2(a)}{dr}=-1.475\pm0.095,$$

$$l_2=0.088\pm0.012, \quad a\frac{dL_2(a)}{dr}=-0.680\pm0.049.$$

Although these values of the tidal numbers have somewhat big probable errors, these values have good agreements with those evaluated ones with the moduli of the earth's internal constitution like the Gutenberg's model by Takeuchi [1950] and others (Longman [1963]).

Next, using the tidal constants obtained with H-59 and V-59 types' extensometers which were performed with higher sensitivities and higher speed's recordings on four horizontal directions and one vertical direction for twenty-four total months only, we have following tidal strain elements and tidal numbers,

	for M_2-tide	for O_1-tide
e_{rr}	$0.517\times10^{-8}\cos(2t-198.4°)$,	$0.623\times10^{-8}\cos(t-209.8°)$,
$e_{\theta'\theta'}$	$1.425\times10^{-8}\cos(2t-0.7°)$,	$0.225\times10^{-8}\cos(t-342.6°)$,
$e_{\phi'\phi'}$	$0.289\times10^{-8}\cos(2t-15.3°)$,	$1.054\times10^{-8}\cos(t-16.7°)$,
$e_{\theta'\phi'}$	$0.125\times10^{-8}\cos(2t-321.8°)$,	$0.210\times10^{-8}\cos(t-105.1°)$,
h_2-3l_2	0.334,	0.435,
$\left\{a\dfrac{dH_2(a)}{dr}+4h_2-6l_2\right\}$	0.475,	0.470,

$$h_2=0.556\pm0.045, \qquad a\frac{dH_2(a)}{dr}=-1.405\pm0.091,$$

$$l_2=0.073\pm0.011, \qquad a\frac{dL_2(a)}{dr}=-0.630\pm0.046.$$

(*b*) *Observations with a recording water-tube tiltmeter*

There have been some experimental studies concernd to a recording water-tube tiltmeters (Tsumura [1960], Eto [1965]). We have performed the tidal observations of the ground tiltings at Osakayama observatory since 1965 by use of a recording water-tube tiltmeter devised by T. Eto. This water-tube tiltmeter consists of a water-tank whose diameter is about 70 cm and an amplifier pot whose diameter is about 10 cm. The tank and the amplifier pot is connected with a hard eslon pipe whose inner diameter is about 4 cm, and the pipe is set with an inclination of about 1/40. It is effective for sweeping of the bubbles that the connection pipe has a uniform inclination. The tank and the pot have each micrometers to observe the seculer tiltings. Bundles of many fine tubes are fixed at both ends of the connecting tube to damp the free oscillation of the contained water. There is a float containing mercury to damp the vibration of itself in the amplifier pot. The vertical displacement of the float is amplified with a pulley and with an optical lever. The interval length between the tank and the pot is sixty meters and sensitivity of the tiltmeter is about 1/300 second per one millimeter on the record. Its sensitivity is comparable to the highly sensitive tiltmeter of the pendulum type and its actions is more steady by far than that of the pendulum type's ones. Perhaps, the recording type water-tube tiltmeter will take place of those of pendulum types in near future.

The tidal constants obtained by the observations with the water-tube tiltmeter are shown as follows.

The observed constants of the tidal tiltings

Observatory: Osakayama observatory,

Direction of the observation: N38°E,

Used instrument: Recording water-tube tiltmeter,

Analysed period: One month from August 4th, 1965,

During sensitivity: 0.00173''/mm,

Tidal-constants: M_2-tide 0.00125''cos(2t−281.7°),

O_1-tide 0.00282''cos(t−353.8),

$O_1/M_2=2.27$,

Analysed Period: One month from January 13th, 1966,

During sensitivity: 0.00346''/mm,

Tidal constants: M_2-tide 0.00194''cos(2t−286.4°),

O_1-tide 0.00435''cos(t−347.8°),

$O_1/M_2=2.24$.

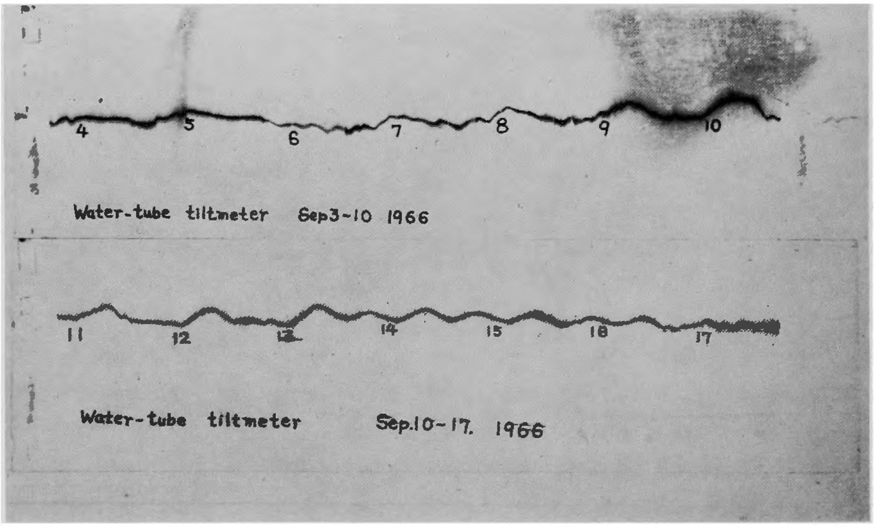

Photo. 2. Recordings of the tidal tiltings in the N38°E direction observed with the water-tube tiltmeter at Osakayama.

Photo. 2 shows the observing curves with the recording water-tube tiltmeter during two weeks.

Let these observed constants compare to those obtained with pendulum types' ones at Kamikamo by Nishimura [1945] and at Osakayama by I. Ozawa.

Nishimura's result

Observatory: Kamikamo Observatory (135°42'E., 35°02'N.),

Used instruments: Ishimoto type tiltmeters made of silica,
Analysed period: Six months from May, 1939,
During mean sensitivity: 0.004″/mm,
Resultant tidal constants in the direction of N38°E,

M_2-tide $0.00233''\cos(2t-299.7°)$,
O_1-tide $0.00409''\cos(t-354.8°)$,
$O_1/M_2=1.75$.

Ozawa's results

Observatory: Osakayama observatory (135°51.5′E., 34°59.6′N.),
Used instruments: Ishimoto-Nishimura type tiltmeter made of invar,
Analysed periods: Twelve months from February 1948,
During sensitivity: 0.0127∼0.0184″/mm,
Resultant tidal constants in the direction of N38°E,

M_2-tide $0.00072''\cos(2t-247.4°)$,
O_1-tide $0.00196''\cos(t-322.3°)$,
$O_1/M_2=2.71$.

These amplitudes and phase lags of these observations are nearly equal each other. Speaking in detail, however, the amplitude ratio O_1/M_2 obtained with the water tube and pendulum types' tiltmeters at Osakayama are somewhat bigger than those with the pendulum types' tiltmeters at Kamikamo. Perhaps, it seems that the observing curves of the water-tube tiltmeter contain some one whose periods are around one day like the air tide beside the earth tidal changes or have the effects of anisotropic crust.

Assuming M_2-tide of the secondary effect due to the oceanic tidal loadings by use of Shida and Matsuyama's calculations [1912] as follow,

$$M_2(\text{loading}) \quad 0.00455''\cos(2t-31.0°) \text{ in N38°E},$$

and then, we have the M_2-tide of the primary effect as

$$M_2(\text{primary}) \quad 0.00487''\cos(2t-224.8°).$$

Although this value is calculated boldly, we have the diminishing factor and the phase lag as

$$D=0.54, \qquad \Delta K=-18.6°,$$

from the observations by means of the water tube tiltmeter.

(*c*) *Observation with the rotationmeter*

The present author has devised a rotationmeter in order to observe directly the rotations and shear strains, and has carried out the observations with the instrument at Osakayama observatory since 1966.

This rotationmeter consists of two canti-levers, eight meters long, framed with super-invar boards, and they are put along the parallel lines near by each other to make one series. The outer ends of the each levers are fixed, and the inner (facing) ends are free. And then, the change of interval perpendicular to the series between the both levers are observed by amplifiing with a lever and Zöllner suspention type tiltmeter like that of the H-59 type extensometer. We have could rise its routin sensitivity as about 2×10^{-9} per one millimeter on the record.

In generally, we able to observe one rotational and one shear elements with two components of the instruments along the orthogonal directions each other (Watanabe [1960]). Advantageously, we able to observe directly the tidal hori-

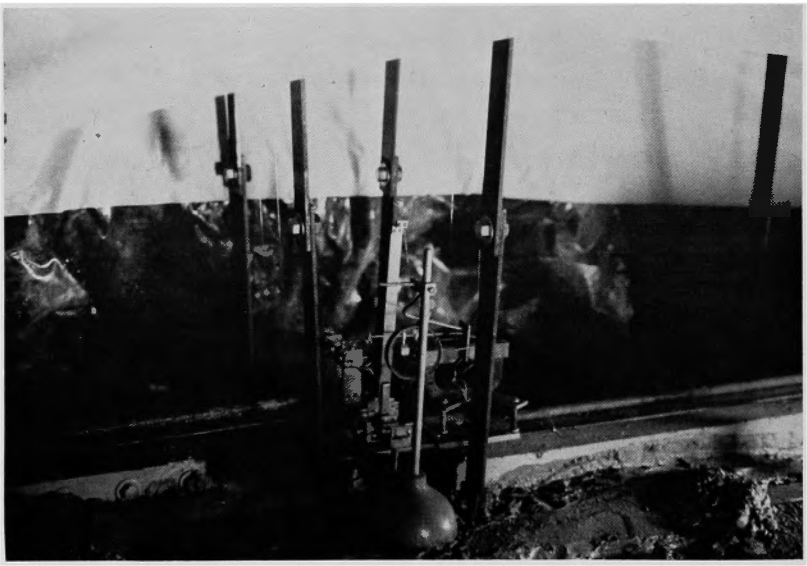

Photo. 5. Amplifier part of the rotationmeter at Osakayama.

Photo. 3. Recording of the torsional strain around the plumb line observed with the rotationmeter at Osakayama.

zontal shear $e_{\theta\phi}$ and two elements of rotations ω_θ and ω_ϕ with three rotaionmeters set perpendicularly to three orthogonal axes, because the tidal rotation ω_r around the plumb line and the tidal shear on the vertical planes $e_{r\theta}$ and $e_{r\phi}$, are nil.

Photo. 3 shows the observing curve obtained with this rotationmeter at Osakayama observatory from September 10th to 17th 1966. This curve maybe shows the horizontal shear, and the upward shows negative shear. According this curve, its phase lags is about nil, and the amplitude is as nearly as that calculated theoretically. So, it seems to be in approximative agreement with the results obtained by the observation with rotationmeter and those obtained with extensometers'.

Since the study on the observations by the rotationmeter is still incomplete, we hope to be able to have complete ones before long.

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