

Investigation of deformational processes in Tbilisi Underground Earth-Tidal Laboratory

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Abstract

The results of extensometer observations carried out to study the tidal phenomena in the Earth solid body can also be used for measuring slow and seismic deformations of the Earth's crust.

In order to observe the secular, tidal, meteorological, and seismic deformations of the Earth's surface, a three-component quartz extensometer has been set in the Tbilisi Underground Tidal Laboratory of the Institute of Geophysics of the Academy of Sciences of Georgia. In 1963-1976, horizontal extensometer used photo-optical transducers. Since 1976 all components (horizontal and vertical) use capacitive transducers KD-2. The component N66°5E with a 42 m base has the sensitivity of $0.22 \cdot 10^{-10} \text{ mm}^{-1}$. The component N30°W having the base of 14.5 m records with the sensitivity $0.70 \cdot 10^{-10} \text{ mm}^{-1}$ and third vertical component with a base 6.45 m have sensitivity $(0.57 - 1.75) \cdot 10^{-10} \text{ mm}^{-1}$ for different periods of observations.

The results of extensometer observations are given.

1. Introduction

Every point on the Earth's surface is subject to two forces: the force of gravity due to the attraction of the whole mass of the Earth and the centrifugal force due to the rotational movement of the Earth. The resultant of these two forces is a vector, directed towards the point considered, and whose direction defines, the direction of the vertical at the point. The last two elements cannot be strictly considered as constants because both the Sun and Moon attract the point under consideration; This attraction varies with time and with the paths of these two bodies. This phenomenon is the cause of oceanic tides, which result from the fact that the free surface of the sea constantly adapts itself to the level surface perpendicular to the pencil of disturbed verticals.

On an absolutely rigid crust, and provided with very sensitive instruments, we could observe directly the periodic deviations of the vertical (they reach a magnitude of 0''04) and the periodic variation of the intensity of gravity (which can be of the order of 0.2 mgal), due to the changing attractions of the Sun and the Moon.

The Transcaucasus, as is known, is situated in one of the most active area, of geodynamic processes. Strong earthquakes, landslides, and other phenomena, bringing danger to the people, can cause avalanches in mines and threaten the destruction of important places (dikes) of hydropower stations, bridges, tunnels, piers, roads, gas and oil pipelines, water reservoirs for big cities, etc.). The problem of prediction of earthquakes is the most demanding at present, but, unfortunately, in spite of all the progress realized, it is still far from being solved. Absent are the concepts of certain processes that take place in the Earth's crust before earthquakes; there is no kinetic theory concerning the seat of on earthquake; it is necessary to further extend observations and accumulate all the date about precursor phenomena.

The results of extensometric and tiltmeter observations carried out to study the tidal phenomena in the Earth's solid body can also be used for measuring slow deformations of the Earth's crust of tectonic or meteorological origin, deformations of the foundations of large engineering structures and for the possible detection of indications of impending earthquakes.

Anomalies which contributed to the advancement of the hypothesis on the block structure of the Earth have been discovered in the recordings of the instruments used in the observation of tidal phenomena. Attempts have been made to discover the timing of the anomalies in the course of the tilts with the time of occurrence of large earthquakes. In this connection a study of the recording of a tide-recording instrument freed from the tidal waves (and, as far as possible, from meteorological and instrumental disturbances) can provide information on the "secular" movements of the Earth's crust.

The Tbilisi Earth-Tidal Underground Laboratory has been founded in 1962. Since 1969 this Laboratory functions as an International Centre of Commission of the Academies of Sciences of Socialist Countries on the complex problem of "Planetary Geophysical Investigations" (KAPG) for the unification of tiltmeter observations. Subsequently the department of Earth tides and of Earth's crust dynamic (on Ingouri test Area) were established on the basis of the Earth-tidal Laboratory.

The Tbilisi Earth-tidal Laboratory have been occupied a well-appointed underground tunnel, which is characterized by constancy of temperature and absence of marked tectonic deformations.

The underground Laboratory constitutes a horizontal tunnel 102 m long flanked on either side by five large chambers.

In order to observe the tidal and secular deformation of the Earth's surface a three-component quartz extensometer composed of welded quartz tubes has been set in the Tbilisi Underground tidal Laboratory. The component $N66^{\circ}5E$ with a 42 m base has the sensitivity of $0.22 \cdot 10^{-10} \text{ mm}^{-1}$. Another component, $N 30^{\circ} W$ having the base of 14.5 m records with the sensitivity of $0.7 \cdot 10^{-10} \text{ mm}^{-1}$. The 6.45 m long quartz vertical extensometers sensitivity varies between $0.57 \cdot 10^{-10} \text{ mm}^{-1}$ and $1.75 \cdot 10^{-10} \text{ mm}^{-1}$ for different series of observations.

The drifts of extensometers, freed from the tidal waves, have been used for the present study.

Fig. 1 shows the drifts of the horizontal extensometers for the period from 1965 to 1972. Let us discuss these drift in detail. The long extensometer recorded compression from March 1965 till the end of 1968 with approximately constant velocity. During that period of time the total compression was $8,4 \cdot 10^{-6}$. From the beginning of 1969 till the middle of 1970 the drift was negligibly small, and from October 1970 till the end of 1972 the compression continued and amounted to $3,5 \cdot 10^{-6}$. Altogether, during the period from 1965 to 1972 the value of drift in the $N66^{\circ}5 E$ direction was $11,9 \cdot 10^{-6}$.

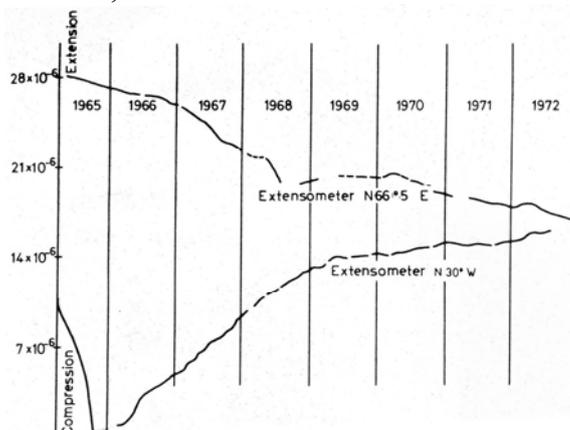


Fig. 1. The drifts of horizontal extensometer.

The short extensometer $N30^{\circ} W$ recorded compression with sufficiently high velocity from March to November 1965, the total deformation during this period of time being

$10.5 \cdot 10^{-6}$. The reason for this was the swelling of the main base which held the tube embedded in concrete; this forced us to transfer it to the opposite side, where the rocks were more monolithic and less moist. The recording on the new base was resumed in February 1966. Beginning with that time till May 1969 the given component recorded the extension with constant velocity, and the total extension during that period of time was $12.6 \cdot 10^{-6}$. From May 1969 till September 1972 the drift was very small and the extension during this period was $2.1 \cdot 10^{-6}$. From 1966 to 1972 the value of deformation (extension) in the N 30° W direction was $14.7 \cdot 10^{-6}$.

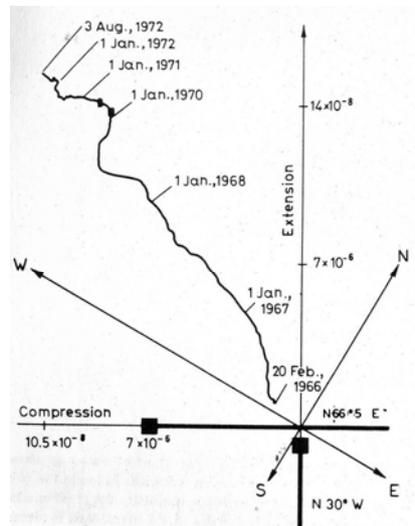


Fig. 2. The vector diagram of horizontal deformation.

This discussion enables us to assert that the drifts in question are largely not instrumental and they represent the picture of the real displacement of the control points.

In order to characterize the horizontal component of the vector deformation a vector diagram has been plotted in Fig. 2.

Fig 3 shows the drift of the vertical extensometer and variation atmospheric pressure for the period from 13.3.1984 – 21.3.1986.

The stress caused by the atmospheric pressure variations directly act on the vertical extensometer. It considerably amplifies the S, signal and disturbs of tidal S_2 component. At Findel Airport of Luxemburg which is practically 180° from the extensometers phase while the amplitude ratio, i.e. the admittance of the extensometers to the barometric pressure is

$$(4.43 \pm 0.250) 10^{-9} \text{ Mb.}$$

We found for Tbilisi vertical strainmeter an admittance of

$$(4.98 \pm 0.67) \cdot \frac{10^{-9}}{\text{Mb}}$$

A precise (if possible) calculation of the cavity effect on the vertical strain would be helpful to check the properties of the rocks and the response of the instruments to different kinds of perturbations.

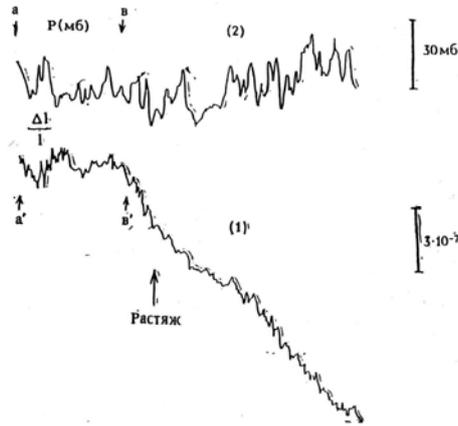


Fig.3. The drifts of vertical extensometer (1); variation of atmospheric pressure (2) Period of observation **13.3 · 1984 – 21.3 · 1986 (506 days)**

2. Experimental investigations of the linear strains

Observations of tidal deformations have been carried out since April 1963. First numerical results obtained with the aid of two bar extensometers with base 42 m long for N66.5°E component and 14.5 m long for N30° W component. In 1963-1976 this instruments used photooptical transducers. Since 1976 this extensometers use capacitive transducers KD-1 and KD-2. The amplitudes of the five main tidal waves have been determined. Then if we take the amplitude ratio of waves O_1 and M_2 , which by the way eliminates the difficult problem of calibration we obtained the following equation for different components and periods of observations:

$$A_i \left(\frac{h}{l}\right)^2 + B_i \left(\frac{h}{l}\right) + C_i = 0$$

where A_i, B_i, C_i - coefficients, h -Love's number, l is Shida's number, solution of which yields the numerical value h/l ratio. The value of the h/l ratio proved to equal:

Extensometer N **30°W**

1. Photooptical transducer

$$\frac{A_{M_2}}{A_{O_1}} = 2.063 = \frac{2.148 \cdot 10^{-8}}{1.579 \cdot 10^{-8}} \sqrt{\frac{h^2 - 3.4314hl + 7.139l^2}{h^2 - 7hl + 13.956l^2}}, \quad \frac{h}{l} = 7.004 \pm 0.272$$

2. Capacitive transducer

$$\frac{A_{M_2}}{A_{O_1}} = 2.127 = \frac{2.148 \cdot 10^{-8}}{1.579 \cdot 10^{-8}} \sqrt{\frac{h^2 - 3.4314hl + 7.139l^2}{h^2 - 7hl + 13.956l^2}}, \quad \frac{h}{l} = 6.671 \pm 0.169$$

Extensometer N **60°E**

Photooptical transducer

$$\frac{A_{M_2}}{A_{O_1}} = 0.777 = \frac{2.148 \cdot 10^{-8}}{1.579 \cdot 10^{-8}} \sqrt{\frac{h^2 - 9.5016hl + 25.5605l^2}{h^2 - 4.636hl + 6.59l^2}}, \quad \frac{h}{l} = 6.562 \pm 0.245$$

3. Capacitive transducer

$$\frac{A_{M_2}}{A_{O_1}} = 0.812 = \frac{2.148 \cdot 10^{-8}}{1.579 \cdot 10^{-8}} \sqrt{\frac{h^2 - 9.5016hl + 25.5605l^2}{h^2 - 4.636hl + 6.59l^2}}, \quad \frac{h}{l} = 7.154 \pm 0.282$$

from which we derive weighted mean values:

$$\frac{h}{l} = 6.80 \pm 0.20; \quad \frac{l}{h} = 0.147 \pm 0.004.$$

3. The vertical component of the extensometer

The third component of extensometer – vertical, has been installed in 1965. A hollow quartz tube of circular section has external diameter of 4 cm and thickness of 2 mm. Second part of the extensometers steel bar has external diameter of 3 cm and length about 2.5 m. A cylindrical hole having a diameter of 40 mm and a depth of 25 cm has been drilled into the rock and the steel bar was fixed with special mechanism. The lower

part of the steel bar was connected to the quartz tube, yielding the total length of 6.45 m.

The displacement of the lower end of the tube is measured by the capacitive transducer of the **KD-2** type. The sensibility of transducer is 100 mv/ μm .

The radial strain at the surface is given by the equation.

$$e_{rr} = \left[a \frac{dH(a)}{dr} + 2h \right] \frac{W_2}{ag} = n \frac{W_2}{ag}$$

Ozawa obtained

$$D(r) = F(r) \frac{W_2}{ag} = (n + 2h + 6l) \frac{W_2}{ag};$$

where a is mean radius of the Earth, g is gravity, W_2 is tidal generating potential, $n = ah' + 2h$. $D(r)$ – cubic dilatation, $r = a$, $H(a) = h$, $F(a) = f$ (fourth Love's number);

the materials of observations of 506 days (13.3.1984-21.3.1986) were chosen for processing by the method of harmonic analysis [1].

Taking into account of the main tidal waves ($M_{12}, S_{12}, N_{1l}, K_{1l}, O_{1l}$) and $n = 0.536 \pm 0.016, l = 0.079 \pm 0.0023$ (from horizontal extensometers) we get weighted mean values for Tbilisi:

$$n = -0.262 \pm 0.034, ah' = -1.342 \pm 0.073, f = 0.316 \pm 0.08, D(a) = 2.69 \cdot 10^{-8}.$$

Expressing Poisson's ratio σ in terms of Love number h and l and n we have at the surface of the Earth

$$\sigma = \frac{n}{n + 6l + rh}.$$

For Tbilisi we find $\sigma = 0.305 \pm 0.034$.

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Исследование деформационных процессов в Тбилисской подземной приливной лаборатории

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Резюме

Известно, что твёрдое тело Земли деформируется различными силами, действующими на её поверхности. Эти деформации могут быть периодическими (земные приливы, сейсмические колебания) и непериодическими (медленные тектонические деформации, деформации, вызванные вариациями атмосферного давления и т. д.).

Используемый в Тбилисской подземной приливной лаборатории трёх-компонентный экстензометр с ёмкостным преобразователем малых смещений КД-2 даёт возможность регистрировать изменения базы прибора для компонентов со следующими параметрами:

1. Компонента N66⁰5E - база 42 м , чувствительность $0.22 \cdot 10^{-10} \text{ mm}^{-1}$.
2. Компонента N 30⁰ W- база 14.5 м , чувствительность $0.70 \cdot 10^{-10} \text{ mm}^{-1}$.
3. Вертикальная компонента – база 6,45 м, чувствительность $(0.57 - 1.75) \cdot 10^{-10} \text{ mm}^{-1}$

В работе приводятся результаты многолетних наблюдений этим уникальным прибором как для приливных, так и метеорологических и тектонических деформаций.

დეფორმაციული პროცესების კვლევა თბილისის მიწისქვეშა მიმოქცევით ლაბორატორიაში

კარლო ზ. ქართველიშვილი

რეზიუმე

მყარ დედამიწაში მიმდინარე მიმოქცევით მოვლენების მონიტორინგის შედეგები შესაძლებელია გამოყენებულ იქნას აგრეთვე დედამიწის ქერქისნეღი და სეისმური დეფორმაციის კვლევისათვის.

დედამიწის ზედაპირის საუკუნოვანი, მიმოქცევითი და სეისმური დეფორმაციების საქარველოს მეცნიერებათა აკადემიის გეოფიზიკის ინსტიტუტის მიწისქვეშა მიმოქცევით ლაბორატორიაში გამოყენებულა კვარცის სამკომპონენტანი ექსტენზომეტრი შემდეგი პარამეტრებით:

1. კომპონენტა N66⁰5E - ბაზა 42 მ, მგრძნობიარობა $0.22 \cdot 10^{-10} \text{ mm}^{-1}$;
2. კომპონენტა N30⁰W - ბაზა 14.5 მ მგრძნობიარობა $0.70 \cdot 10^{-10} \text{ mm}^{-1}$
3. ვერტიკალური კომპონენტა – ბაზა 6.45 მ მგრძნობიარობა $(0.57 - 1.75) \cdot 10^{-10} \text{ mm}^{-1}$.

ნაშრომში მოყვანილია ამ უნიკალური ხელსაწყოთი მიღებული მრავალწლიანი დაკვირვებების შედეგები როგორც მიმოქცევით, ასევე მეტეოროლოგიური და ტექტონიკური დეფორმაციებისათვის.