Global and regional deformation fields

Final report of the OTKA project K109060

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1. Introduction

Recent tectonic movements, Earth tides and the related phenomena to Earth tides are recorded by extensometers in three observatories in the Pannonian Basin. In the Sopronbánfalva Geodynamic Observatory (SGO) 27-year long, in the Mátyáshegy Gravity and Geodynamic Observatory (MGGO) 18-year long and in the Vyhne Tidal Station (VTS) in Slovakia 16-year long extensometric data series were available to study local tectonic movements and deformations in the framework of the project.
In all observatories the quartz-tube extensometers have the same mechanical construction and the same electrical sensor. The sensors and the calibration instrument were developed in the former Geodetic and Geophysical Research Institute of the Hungarian Academy of Sciences, at present Geodetic and Geophysical Research Institute, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences (GGI RCAES). The uniform construction of the extensometers and the same calibration instrument ensures that in the course of comparison any differences in the measurement characteristics can be attributed to geologic, topographic properties and meteorological conditions of the measurement sites. Since tectonic movements are very small and very slow – they are in the order of possible instrumental drift – the regular calibration of the instruments is very important. The correct operation of the extensometers also depends on the state of the rock in the immediate vicinity of the observatory, therefore the connection of the instrument to the rock and the appearance of possible cracks in the rock were verified by the tidal parameters obtained in the tidal evaluation of the measured data.

2. Major aims of the research

Comparing local tectonic deformations measured by extensometers with the recent tectonic processes and earthquakes in the Pannonian Basin and to find an explanation for the changing strain rate measured in the SGO.
Investigation of the connection between global deformation fields and earthquake activity.
Investigation solid Earth tides and related phenomena e.g. the Free Core Nutation.
Developing new methods for correction of strain data for temperature and barometric pressure to obtain the best tidal parameters.
While changes in the radon gas concentration can precede geodynamic processes associated with tectonic, volcanic activities and earthquakes one of the main research object was to investigate the relationships between radon concentration and rock strain

3. Main results of the research

3.1. Results of local strain measurements

Extensometric data were recorded with a sampling rate of 1 min. The recorded data were pre-processed removing spikes and filling gaps and after that corrected for temperature and air pressure than the data were decimated to 1 hour sampling rate. These data series were tidal analysed. For the investigation of long-term tectonic movements, the annual series of data were concatenated into long continuous data series. The average strain rates were determined as the steepness of the line fitted to data series measured in the different observatories. Table 1. shows the measured average strain in the azimuth of the extensometers. These local strain rates were compared by strain rates determined from permanent and epoch-wise GPS measurements carried out in GPS networks (CEGRN, CEPER, HGRN, SGRN, TATRY, EMO). The extension rate measured in the VTS coincides very well with the rates obtained by GPS measurements, while strain rates measured in the SGO and MGGO (E2) are three orders of magnitude higher than measured in the GPS networks. We think that one of the reasons for the much higher strain rates measured by extensometers than strain rates determined from GPS measurements should be that the weak lithosphere (folding and compression) absorbs the strain in the Pannonian Basin while faults between GPS stations and earthquakes in the region release it. The other reason for the high strain rate measured by the extensometer in the SGO is probably the difference of the vertical velocities in the East Alpine region and in the Pannonian Basin. Results of this research are published by Eper-Pápai et al. (2014) and Brimich et al. (2016) in detail.

Table 1. Local strain rates measured extensometers in the observatories and regional strain rates determined from permanent and epoch-wise GPS measurements in GPS networks.

Extensometer	Strain rate [μstr year^{-1}]	Type of deformation	Azimuth of the extensometer	Mesurement period	Strain rate and (direction) from GPS measurements [μstr year^{-1}]
SGO	–5.36	compression	116°	1991–2017	-0.008 (NW–SE)
MGGO E1	0.0076	extension	114°	2005–2013	~0
MGGO E2	–0.444	compression	38°	2005–2013	-0.0041(NEE–SWW)
VTS	0.038	extension	55°	2001–2016	0.020 (NEE–SWW)

In the SGO the 27-year long (1991-2017) strain record shows a continuous compression of the rock with changing rate. Figure 1a shows the average compressional yearly strain rate. We have found that the recorded compressive strain is in good accordance with the recent tectonic processes in the Pannonian Basin determined by GPS and geophysical measurements. The local strain rate variations were also compared with the temporal and spatial distribution as well as with the magnitudes of earthquakes occurred within 200 km from the observatory in two sectors around the azimuth of the extensometer (116°): 116°±15° (Fig. 1.b) and 296°±15° (Fig. 1c). The results show that earthquakes can decrease or increase the strain rate depending on the geological properties of their epicentres, but the uplift of the Alps, tectonic processes in the East Alpine region and in the Pannonian Basin play the most important role in the changing strain rate. The results of this research are described by Mentes and Kiszely (2018).

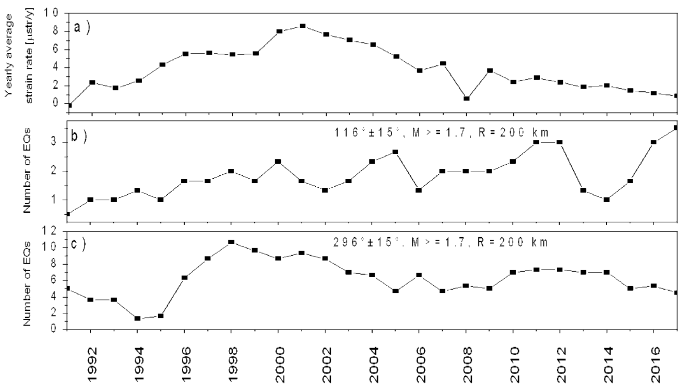

Fig. 1. Relationship between strain rate variations measured in the SGO and earthquakes (Mentes and Kiszely (2018) simplified figure).

3.2. Results of the investigation of relationships between global stresses and earthquake activity

In order to investigate the relationship between global stresses and earthquake activity, computer modelling was performed. We have shown that the stresses caused by the lunisolar (tidal) effect increase with the depth, and reach their maximum value, some kPa, at a depth of 900-1500 km, far below the deepest earthquake focal depth. The deepest known earthquake was 735 kilometres from the surface (Vanuatu, 2004, M4.2). The vast majority of earthquake energy (more than 90%) is released around 50 km depth, where the tidal induced stress is (0.0-1.0) · 103 Pa. We have shown that this much smaller stress than those released in case of large events, (1 to 30) MPa, in some cases may have an impact on the time of earthquake occurrence. From this point of view, the components of the tidal stress tensor parallel to the Earth surface play a role (Varga and Grafarend, 2018). The other result of our theoretical research is that we found a correlation between the Love-Shida numbers describing the deformities of the elastic Earth (Varga et al., 2018).

We have prepared a catalogue of earthquakes of magnitude M≥7.0 for the period from 1900 to 2016. We found that less than 1,850 such events occurred throughout the whole of the examined period. We have separately investigated the deep earthquakes (focal depth deeper than 300 km), which can be found only in six seismic zones of the Pacific. For our investigations gives a particular actuality that during the time of our project took place the strongest deep focus earthquake of all times under the Ohotsky Sea (May 24, 2013, M8.3). Based on the data obtained from the stations of the Hungarian, Russian, German and US national seismological network, not only the main shock , but also the fore- and the afteshocks were the subject of our investigations (Varga and Süle, 2014; Varga et al., 2017). It was found that the foreshocks originated from the part of the sinking Ohotsk plate east of Kamchatka, at the distance 800 to 900 km from the epicentre of the main shock. (we have catalogued 58 M≥5.0 foreshocks). The number of aftershocks following earthquakes is generally large (many thousands) and they are occurring in long time (several months after the main event). By contrast, after the earthquake of 24 May 2013, only 12 M ≥4.0 aftertshocks could be observed.

On a global scale, we investigated the relationship between variations of Earth' rotation and other geodynamic phenomena during the Phanerozoic and Archean as well as in the Proterozoic (that is, the last 3.5 billion years of earth history). For this purpose, we investigated the relationship between the magnitude of the magnetic dipole and the changes in the length of the day. We have concluded that the strength of the geomagnetic dipolic field in the remote geological time was significantly lower than it is nowadays. However, the increase in field strength has stopped at the beginning of the Phanerozoic (Schreider et al., 2015; Schreider et al., 2016). Earth's rotation has slowed down during the billions of years under review,, but the rate of deceleration was 4.4 times less than in the course of the last 550-600 million years of Earth's history (Varga, 2014).

Based on paleogeographic maps, it was found that the area of continents increased significantly over the last six hundred million years (to seven percent of the total surface of the Earth). The processing of these maps also showed that Eötvös's "escape from the poles" („polflucht kraft") had an impact on the continent's position during the entire duration of the fancerosis, that is, continents have been largely in the equatorial environment during the last 600 million years of geological history (Varga et al., 2014).

3.3. New methods developed for correction of strain data for temperature and barometric pressure

To get more accurate tidal factors to study earth tide phenomena and the effect of the Free Core Nutation (FCN) on tidal parameters, the tidal transfer of the observatories were investigated by coherence analysis between the theoretical and the measured extensometric data (Eper-Pápai et al., 2014; Brimich et al., 2016) and a lot of efforts were made to enhance the effectiveness of the correction of strain data for temperature and barometric pressure. The developed methods are described by Bán et al. (2018) in detail. Since the highly sensitive strain meters detect also rock strain variations caused by remote weather patterns we have developed a method using artificial neural network for correction strain data for remote barometric pressure variations (Mentes, 2015).

3.4. Results of the investigation of the Free Core nutation

We continued the investigation of the effect of the Free Core Nutation (FCN) on the basis of Earth tidal measurements by quartz tube extensometers in four observatories (Budapest, Pécs, Sopronbánfalva in Hungary and Vyhne in Slovakia). The effect of the FCN on the P1, K1, Ψ1 and Φ1 tidal waves were studied by the comparison of the theoretical and measured amplitude factors and their ratios to the amplitude factors (theoretical and measured) of the O1 tidal wave. The theoretical K1/O1, P1/O1, Ψ1/O1 and Φ1/O1 ratios were calculated for the azimuth of the instruments. The amplitude factors were calculated using the Wahr-Dehant Earth model, the HW95 tidal potential catalogue and for the ocean tide prediction the SPOTL routine was applied using the Gutenberg-Bullen Earth model “gr.gbocen.wef.p02.ce.gz”, the ocean model “csr4tr” and the local ocean model “osu.mediterranean”. The obtained K1/O1 ratios are close to the theoretical values with exception of the Pécs station. We found a discrepancy between the observed and theoretical P1/O1 values for all stations with exception of the Budapest station. It was found that the difference between the measured and theoretical Ψ1/O1 and Φ1/O1 ratios was very large independently of correction of the strain data. These discrepancies need further investigations. The method and results are described by Bán et al. (2018) in detail.

3.5. Results of the investigation of the relationships between radon concentration and rock strain

Changes in the radon gas concentration can precede geodynamic processes associated with tectonic, volcanic activities and earthquakes. For this reason the relationship between rock strain and radon concentration is an important scientific issue to be answered. The relationship between rock deformation and radon concentration was investigated together with the temperature and barometric pressure effects. It was found that the strain induced radon concentration variations are in the order of 10 – 100 Bq $nstr^{-1}$, while the concentration variations bear more considerable similarity and relation to the temperature and barometric variations (Mentes and Eper-Pápai, 2015). The theoretical tide at the location of the measurement site and tidal components computed from strain, radon concentration, barometric pressure and temperature data were compared with each other. Spectral and tidal analysis of data demonstrated that only the thermally induced solar components S1 and S2 are present in the radon concentration but their amplitudes hardly exceed the spectral noise level. The principal lunar semidiurnal M2 and diurnal O1 tidal waves cause the largest rock strain variations. The lack of the O1 and M2 constituents in the radon concentration confirms the fact that the detected S1 and S2 tidal components appear due to the barometric tide and the daily variations of the temperature and barometric pressure (Mentes, 2018).

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