Results of the extensometric measurements at the Vyhne tidal station in the year 2021

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Abstract: The Vyhne tidal station has been continuously recording tides with a 22.5 m long quartz tube extensometer with a capacitive sensor since 1996. The quartz tube of the instrument was broken by burglars in January 2020. Afterwards, it was repaired and recalibrated. In this paper, we process the data registered in 2021 to verify the correct operation of the repaired instrument. During the evaluation of the data for the year 2021, obtaining a value close to 1 for the amplitude factor of the M2 wave shows that the extensometer is working properly. However, based on both the examination of the raw data and the evaluation of the tide, it can be concluded that due to the external disturbing effects, the determination of the other waves has relatively large errors. Further investigations are needed to find out the reason for this phenomenon.

Key words: Earth tides, strain, temperature effect

1. INTRODUCTION

In 1984, the Geophysical Institute of the Slovak Academy of Sciences in cooperation with the former Institute of Physics of the Earth of the USSR Academy of Sciences, Moscow installed an extensometer with photo-recorder in Vyhne, Slovakia (Brimich, 1988; Brimich & Latynina, 1989) for recording the Earth tide and recent tectonic movements. This instrument was equipped with the capacitive transducer made by Mentes in 1996 (Mentes, 1991, 2008, 2010). In January 2020, there was a break-in into the St. Anthony of Padua mining gallery. The quartz tube of the extensometer was cracked in multiple places and several suspension wires were torn off. In August 2020 it was repaired, recalibrated and put into service again. This study presents the results of the analysis of the extensometric data digitally recorded in the year 2021.

2. DESCRIPTION OF THE TIDAL STATION

The Vyhne tidal station is located in Central Slovakia in the centre of the Štiavnické vrchy Mts. range in the cadastre of Vyhne village (10 km NW from Banská Štiavnica). Its geographic coordinates are $\varphi = 48°29'52''$, $\lambda = 18°49'48''$ and its height is 420 m above the sea level. The extensometer was installed in the horizontal gallery of St. Anthony of Padua. The neighbourhood of the St. Anthony gallery is made up of Palaeozoic, Mesozoic, Palaeogene, and Neogene rocks (Fig. 1) (Brimich et al., 2016). At the time of the Late Palaeozoic, pronounced faults were generated here striking NW–SE. These faults were regenerated several times in the subsequent periods. In the Mesozoic, the fundamental fault zone was generated striking NE–SW. This fundamental line, regenerated tectonically several times, later separated the rising "Hodruško-Vyhniansky ostrov" island from the neighbouring SE depression (Brimich, 1988). Middle Miocene granodiorite and diorite intrusions and an older, Carboniferous, body of the Vyhne granite form a more rigid element in the structure of the complex, whereas the most tectonically mobile zone is situated at its edge. The gallery was driven mostly in the Palaeozoic-age granites associated with the Variscan orogeny. Those granites were tectonically disturbed on two occasions. The first event caused mylonitization of the granites, while the second was accompanied by the emplacement of young intrusions and mineralization within the tectonically modified medium (Dudášová, 1998). At a distance of 43 m from the gallery entrance, there is a distinct penetration of young dacite, striking N–S into the Carboniferous granite. The recording chamber is located beyond this penetration in a comparatively well-preserved granite. A vein zone with mylonite and quartz lenses runs along the gallery. Less stable places have been reinforced by a protective wall.

3. DATA PROCESSING

In the field of Earth tides, deformation is usually expressed by the quantity nanostrain [nstr], which is an engineering unit measuring strain. By definition, one strain is defined as the ratio of the change in length of an object to its original length. Strain is a dimensionless quantity and 1 nstr is equal to 10^{-9}.

Strain, inner and outer temperature data were recorded with a sampling rate of 10 minutes (Bednárik & Brimich, 2005). These data series were despiked, ungapped, low-pass filtered and decimated to one-hour sampling by the T-soft program (Van Camp & Vauterin, 2005). Figure 2 shows the corrected hourly measured data. There is a close negative correlation between strain and inner temperature data (correlation coefficient is – 0.95073), while the correlation between strain and outer temperature is lower (– 0.56525). Since the calibration factor of the extensometer is – 0.1503 [nstr/mV], the calibrated extensometric data have positive correlations with temperature data. Figure 2 shows that the inner temperature change during the measurement period was less than 1.6 °C, which could not have caused a 1400 nstr strain change due to the temperature dependence of the capacitive transducer. A clear phase lag can be seen between the outer and inner temperature change, which suggests that the long periodic

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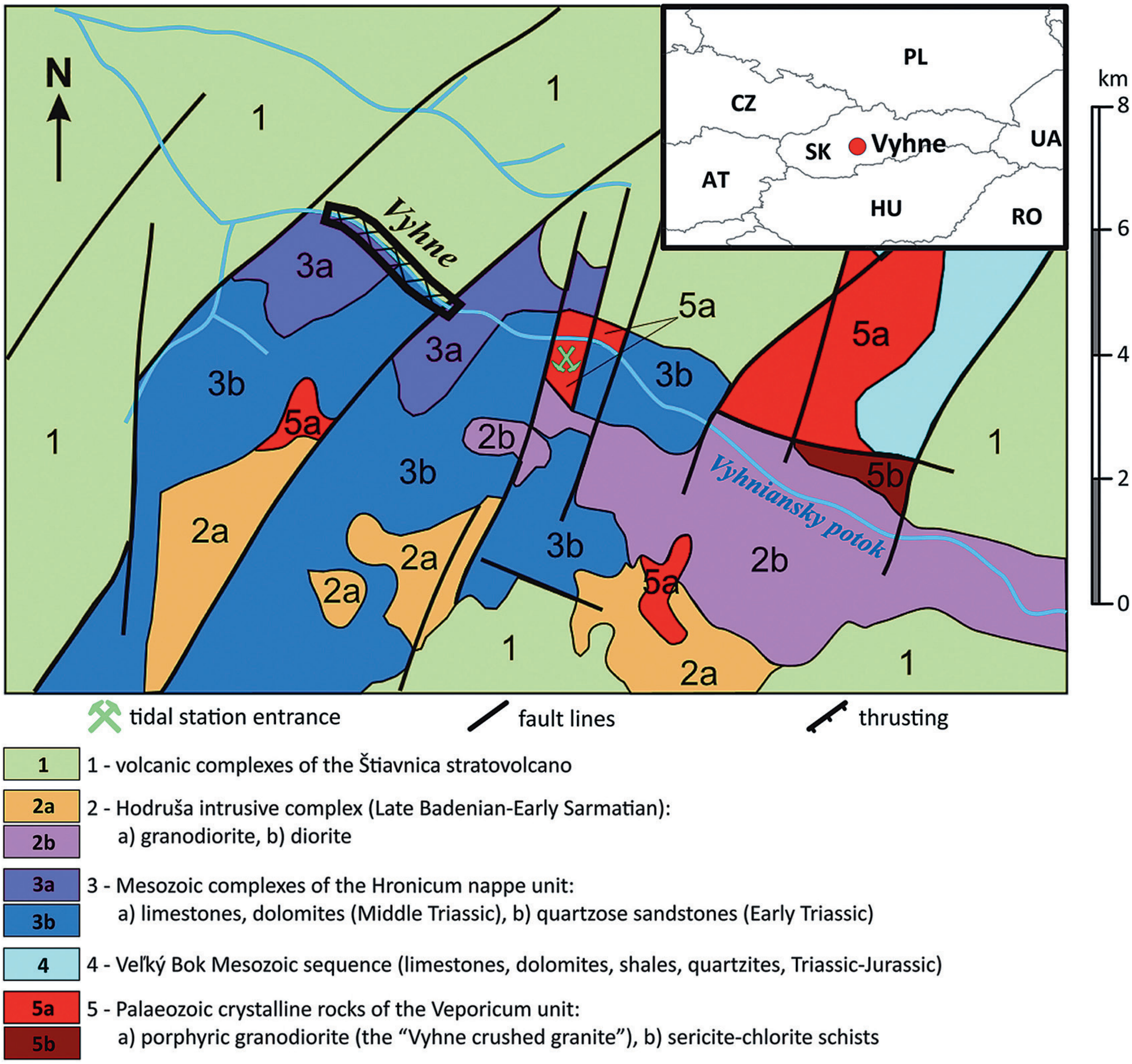

Fig. 1. A simplified geological scheme of the surroundings of the tidal station near Vyhne village, after Konečný et al. (1998) in Brimich et al. (2016). Reproduced and modified with permission.

internal temperature change is caused by the rock temperature change. This means that the instrument measures the dilatation of the rock due to temperature changes.

To eliminate the large aperiodic changes, first, the linear trend was subtracted from the strain data. Subsequently, the long-term constituents of the strain and inner temperature data were approximated by fitting a polynomial of 6^{th} order to the data series and were subtracted from strain and temperature data, respectively. Thus obtained inner temperature data were used for the linear correction of the strain data (Fig. 3). Figure 3 shows that the corrected extensometer data still contain relatively large long- and short-periodic changes. One of the reasons is likely to be air pressure changes, and another reason may be tectonic movements. Unfortunately, in the absence of barometric pressure data, the proportion of the latter cannot be determined.

The corrected strain and outer temperature data were processed by the ETERNA 3.40 Earth tide data processing program package (Wenzel, 1996) using the Wahr-Dehant Earth model (Wahr, 1981; Dehant, 1987) and the HW95 tidal potential catalogue (Hartmann & Wenzel, 1995).

4. RESULTS AND DISCUSSION

The results of the tidal evaluation can be found in Table 1. The determination of the O1 diurnal tidal component was only possible with a large error, while an amplitude factor of nearly 1 was obtained for the M2 semidiurnal wave, whose determination error is nearly half of the value obtained in the case of the O1 wave. Only for the S2 wave, we obtained an amplitude factor close to 1, but the determination error of this was also large. Tidal

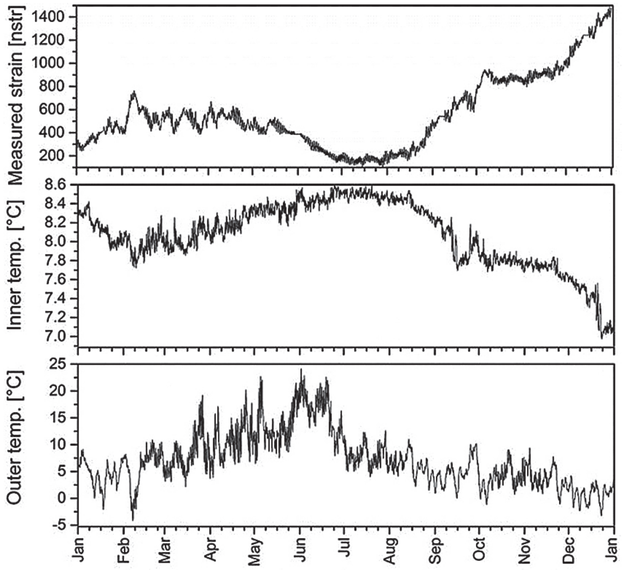

Fig. 2. Tidal deformations, inner and outer temperature measured in 2021 (from top to bottom).

evaluation of data measured between 2015 and 2019 resulted in amplitude factors close to 1 for both O1 and M2 waves with small

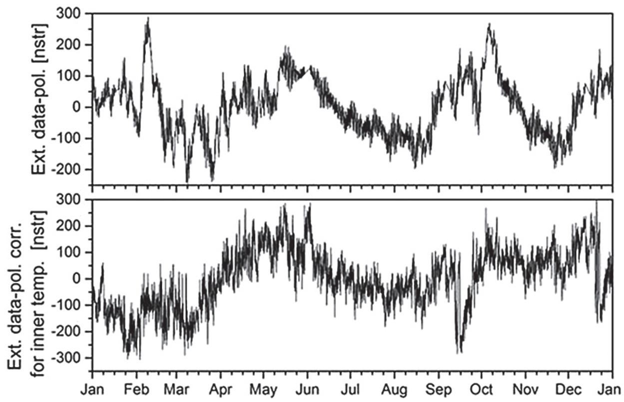

Fig. 3. Large changes eliminated in the strain data (upper section) and these data linear corrected by inner temperature data (lower section).

errors (Mentes et al., 2021). Since barometric pressure was not measured in these years either, we do not assume that the change in barometric pressure caused the 2021 results. By comparing the Fourier transforms of the data used for the evaluation of the tidal data and the residual data obtained during the evaluation, we can see that the investigated waves are still present with relatively large amplitude in the residual data (Fig. 4). Further

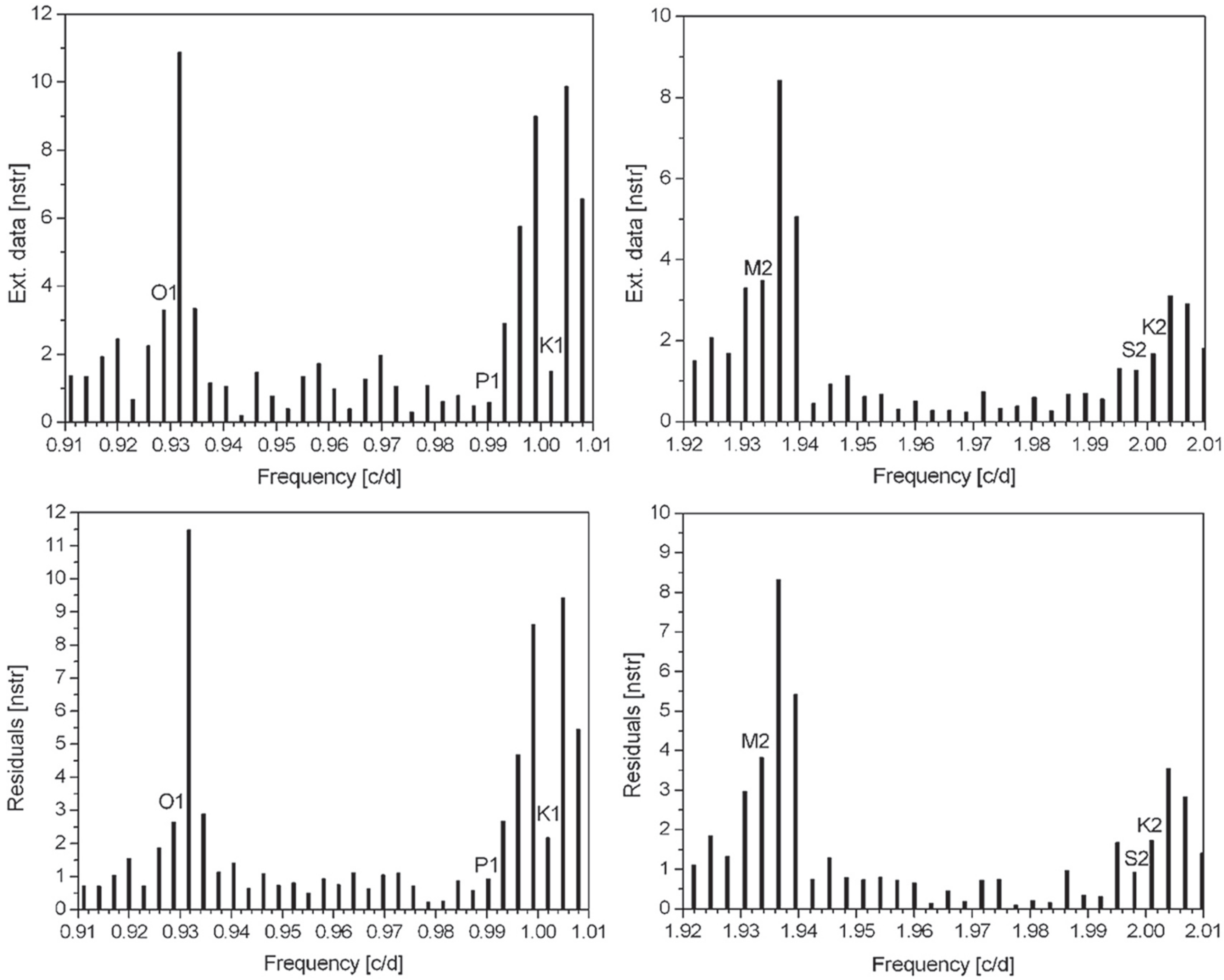

Fig. 4. Amplitude spectra of the strain data (top) and the residual data (bottom) after processing by ETERNA34.

investigations are needed to find out the reasons for the large error in the determination of the waves.

Table 1. Results of the tidal evaluation.

Wave	Theor. ampl.	Ampl. factor	Stdv*	Phase lead [deg.]	Stdv* [deg]
Q1	1,206	0,255	1,269	-85,369	285,530
O1	6,301	0,667	0,262	129,307	22,484
M1	0,495	3,363	3,172	-16,728	54,054
P1	2,931	2,907	0,639	-30,145	12,822
K1	8,858	0,426	0,202	-75,472	27,670
J1	0,495	1,658	3,450	-1,116	119,251
OO1	0,271	4,607	4,690	0,444	58,249
2N2	0,193	3,176	4,374	137,331	78,935
N2	1,210	1,907	0,913	52,206	27,448
M2	6,321	1,001	0,177	3,850	10,131
L2	0,179	4,151	4,737	137,628	65,406
S2	2,941	1,085	0,368	-131,428	19,402
K2	0,799	2,334	1,208	-60,479	29,546
M3M6	0,031	11,689	18,055	93,362	88,491

*Standard deviation

5. CONCLUSIONS

The results of the tidal evaluation show that while the amplitude factor of the tidal wave M2 was close to 1, the amplitude factor of the other waves significantly differed from 1. The reason for this still needs further investigation. Probably, the deviations are caused by external disturbing effects, since the amplitude factor obtained for the M2 wave indicates that the extensometer is working properly. To find out the disturbing effects, the barometric pressure should be measured, and the tectonic movements caused by nearby small earthquakes should be examined in detail. Furthermore, the tidal station in Vyhne is situated in the region of the highest heat flow in Central Slovakia. Therefore, we suppose that the extensometric signal could be influenced by the thermoelastic deformation due to the anomalous heat flow in this region.

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References

Bednárik M. & Brimich L., 2005: Implementation of extensometer calibration and decimation filtering on Campbell Scientic CR10X datalogger. *Contributions to Geophysics and Geodesy,* 35, 4, 373–390.

Brimich L., 1988: Extensometric measurements at the Vyhne tidal station. *Contributions to Geophysics and Geodesy,* 18, 58–62.

Brimich L. & Latynina L.A., 1989: The results of the extensometric observations in Vyhne. *Proceedings of the 6-th International Symposium, Geodesy and Physics of the Earth ZIPE*, Potsdam, 239–254.

Brimich L., Bednárik M., Bezák V., Kohút I., Bán D., Eper-Pápai I. & Mentes G., 2016: Extensometric observation of Earth tides and local tectonic processes at the Vyhne station, Slovakia. *Contributions to Geophysics and Geodesy*, 46, 2, 75–90.

Dehant V., 1987: Tidal parameters for an unelastic Earth. *Physics of the Earth and Planetary Interiors,* 49, 97–116.

Dudášová V., 1998: Description of the renovated extensometer at the Vyhne tidal station. *Contributions to Geophysics and Geodesy,* 18, 197–203.

Hartmann T. & Wenzel H.G., 1995: Catalogue HW95 of the tide generating potential. *Marees Terrestres Bulletin D'Informations,* 123, 9278–9301.

Konečný V., Lexa J., Halouzka R., Dublan L., Šimon L., Stolár M., Nagy A., Polák M., Vozár J., Havrila M. & Pristaš J., 1998: Geological map of the region Štiavnické vrchy Mts. and Pohronský Inovec Mts. Geological Survey of the Slovak Republic, Bratislava.

Mentes G., 1991: Installation of a quartz tube extensometer at the Sopron Observatory. *Marees Terrestres Bulletin D'Informations,* 110, 7936–7939.

Mentes G., 2008: Observation of recent tectonic movements by extensometers in the Pannonian Basin. *Journal of Geodynamics,* 45, 4, 169–177.

Mentes G., 2010: Quartz tube extensometer for observation of Earth tides and local tectonic deformations at the Sopronbánfalva Geodynamic Observatory, Hungary. *Review of Scientific Instruments,* 81, 7, 074501.

Mentes G., Brimich L., Bednárik M. & Bódi, J., 2021: Comparison of extensometric results measured in the Vyhne Tidal Station (Slovakia) and in the Sopronbánfalva Geodynamic Observatory (Hungary). *Contributions to Geophysics and Geodesy*, 51, 4, 391–402.

Van Camp M. & Vauterin P., 2005: Tsoft: graphical and interactive software for the analysis of time series and Earth tides. *Computers & Geosciences,* 31, 5, 631–640.

Wahr J.M., 1981: Body tides on an elliptical, rotating, elastic and oceanless Earth, *Geophysical Journal International,* Royal Astronomical Society, 64, 677–703.

Wenzel H.G., 1996: The nanogal Software: Earth tide data processing package Eterna 3.30. *Marees Terrestres Bulletin D'Informations,* 124, 9425–9439.