Stability investigation of the new three-dimensional extensometric observatory in Bakonya, Hungary

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Abstract

In year 2000 a new three-dimensional extensometric station was established in the western area of Mecsek Mts. in Hungary. The paper describes the new observatory and the instruments. Registered data and results from data analysis are given. The influence of the temperature and air pressure variations on the extensometric measurements were investigated and compared with those obtained in the case of the closed deep station in an abandoned uranium mine not far from the new 3D surface station. The results show that the new surface station is more sensitive to the temperature, air pressure variations and to the moisture variations of the soil above the station than the deep station in the mine. The measured large displacements are probably due to the cavity and local disturbing effects as a consequence of the geometry of the surface station.

1. Introduction

In May 1992 a deep extensometric station was established for local geodynamical observations in a uranium mine near Pécs. This station was closed in 1999 because the mining activity was given up and the mine was closed. In 2000 a new three dimensional (3D) extensometric station was established for the investigation of tectonic movements on a possible area to dispose high level radioactive wastes in the Western Mecsek Mts. in Hungary. Both observatories were built by the Mecsekérc Environmental Protection Public Limited Company in the frame of a scientific cooperation with the Geodetic and Geophysical Research Institute of the Hungarian Academy of Sciences (GGRI).

The paper presents the recorded data, investigates the influence of the environmental parameters. Since the geologic circumstances of the new 3D and the closed deep observatories are similar, they can be compared from the view-point of stability.

2. The 3D extensometric station in Bakonya

The 3D extensometric station was established near to the earlier deep station in the western part of the Mecsek Mts. as it is shown in Fig. 1. The coordinates of the observatory are: latitude 46.1145°N; longitude 18.1303°W. The new station was placed in an abandoned underground explosive repository of the uranium mine in Bakonya. It is a near surface observatory overlaid by the bedrock with a thickness of about 60 m. The ground-plan of the station is shown in Fig. 2. The extensometers are placed in the most inner gallery about 130 m from the entrance.

Figure 3 shows the extensometers in the gallery. The instruments are made of quartz tubes with a diameter of 45 mm, a wall thickness of 2 mm and have the same construction as the extensometer in the Sopron Observatory (Mentes, 1991). The three horizontal extensometers have a common pillar as one end of the instruments. In the longitudinal direction of the gallery there are two parallel extensometers a long (20 m) and a short (1.7 m) one.

Perpendicular to these extensometers there is a transversal short (1.7 m) instrument. At this end of the transversal extensometer the pillar for the displacement sensor is common with the one of the vertical extensometer, the other end of which is fastened to the top of the gallery. The length of the vertical extensometer is also 1.7 m.

All of the extensometers work with the capacitive sensor developed at the GGRI (Mentes, 1991). The sensor electronics were calibrated in the laboratory of the GGRI (Mentes, 1995). The short extensometers have no built-in calibration device, the long extensometer has a magnetostrictive calibration device developed at the GGRI. Beside the deformation data temperature, humidity and air pressure data are also recorded. The parameters of the extensometers are given in Table 1.

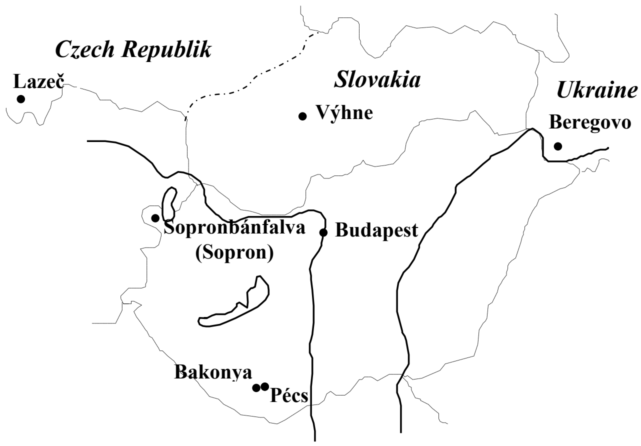

Fig. 1. Extensometric observatories in the Carpatho-Balkan Region

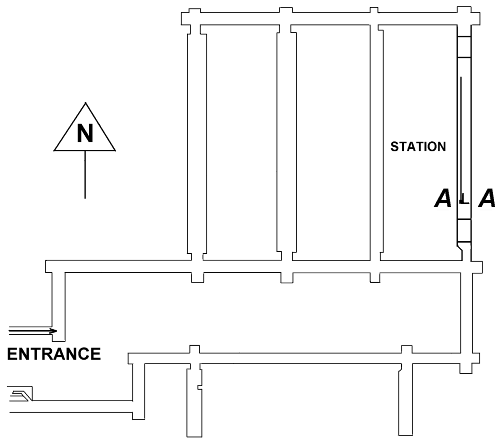

Fig. 2. The ground-plan of the 3D extensometric observatory

Table 1. Parameters of the extensometers

Extensometer	Length [m]	Direction	Scale factor [nm/mV]
Ext.1 (E1)	20	N-S	1,491
Ext.2 (E2)	1.7	N-S	1,385
Ext.3 (E3)	1.7	E-W	1,539
Ext.4 (E4)	1.7	Vertical	1,347

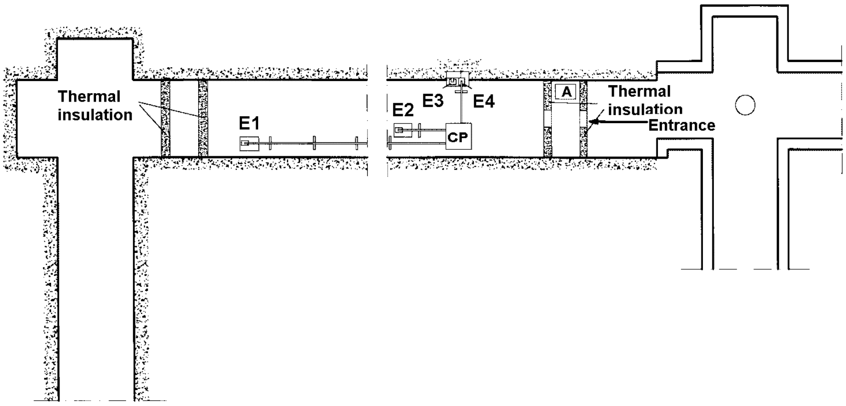

Fig. 3. Lay-out of the extensometers in the station

3. Results of data analysis

In spite of the fact that the station was established in 2000 due to some technical problems we have continuous data series only since the beginning of 2003. In this year the recorded displacements were very high and the signals went out from the measuring range very often. The situation was the same in year 2005, so the data series obtained in 2004 were chosen for the stability investigations of the observatory. In Fig. 4 the raw data measured in 2004 are given. Figure 4 shows clearly that after the first quarter of the year something happened and the measured displacements in all components became much higher than previously. The step corrected extensometric data are given in Fig. 5. The curves obtained from the parallel instruments Ext.1 and Ext.2 exhibit very similar characteristic, but their relative strain rates are different i.e. the ratio of the lengths of instruments differs from the ratio of the measured displacements. The absolute displacement measured by extensometer Ext.1 is about 75000 nm and the one obtained by Ext.2 is about 22500 nm. The difference is probably caused by the inhomogeneity of the rock. Displacements measured by the transversal (Ext.3) and the vertical (Ext.4) extensometers are much more disturbed than those measured by the longitudinal instruments. The reason is probably the fact that the gallery of the instruments is strongly deformed by the water content of the soil above the station. There are four galleries not far from each other (Fig. 2), therefore the transversal and vertical deformations of the observatory are much higher than the longitudinal one (cavity effect). Unfortunately, the precipitation was not measured during the investigated period, so it was not possible to investigate its influence on the registration.

To retrieve the tidal waves from the data a polynomial of 9th order was fitted to the raw data and this polynomial was subtracted from the original series to obtain short periodic variations. These residual data were Fourier-transformed to get the amplitude spectrum. Figure 6 shows the amplitude spectra of the data series. All the spectra show clearly the main diurnal and semidiurnal tidal waves except the vertical extensometer (Ext.4). One of the short horizontal extensometers (Ext.2) does not produce clearly emerging tidal lines in the diurnal band, these peaks are hidden by the spectral noise, while the other short extensometer (in the transversal direction) gives the proper spectral peaks in both tidal bands. Nevertheless at S_2 frequency the amplitude ratios calculated in the case of the parallel short and long extensometers are approximately the same as the ratio of their lengths.

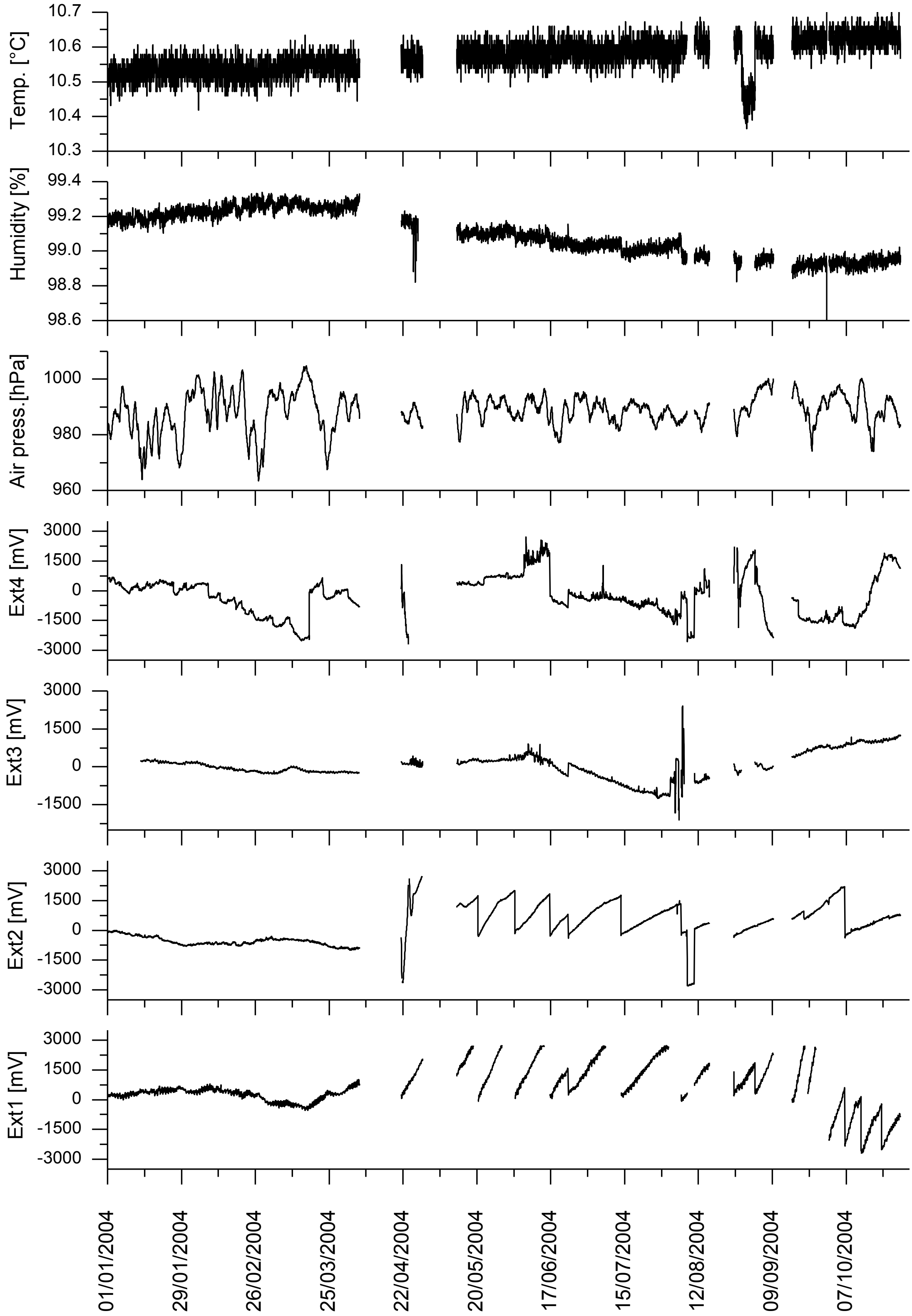

Fig. 4. Raw data measured at the Bakonya station in 2004

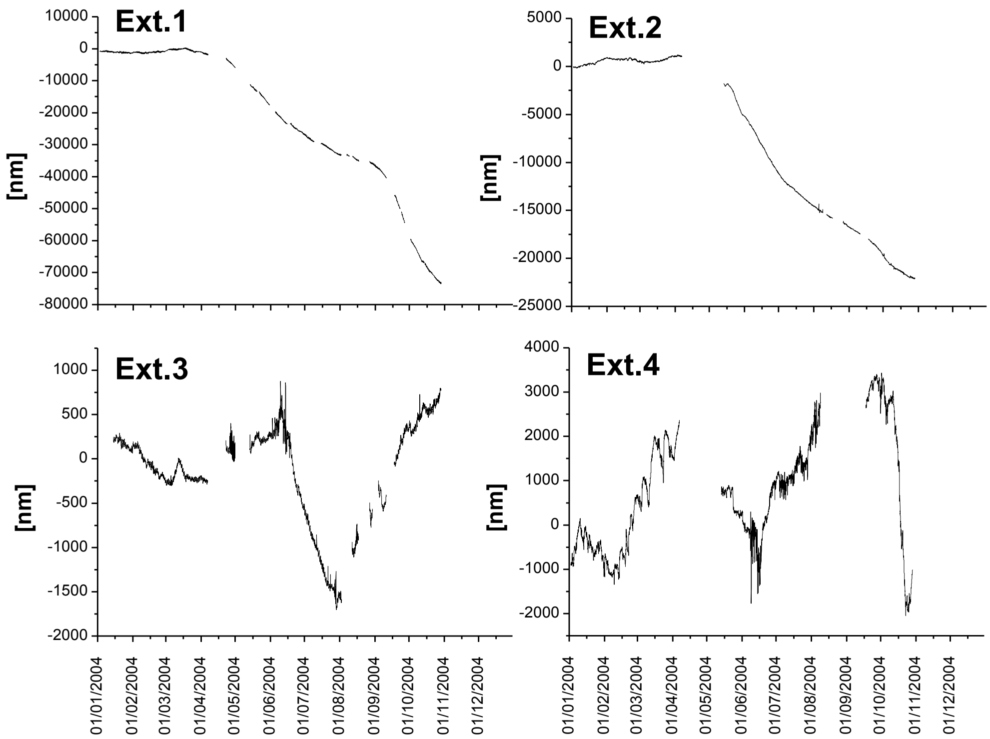

Fig. 5. The displacements recorded by extensometers at the Bakonya station in 2004

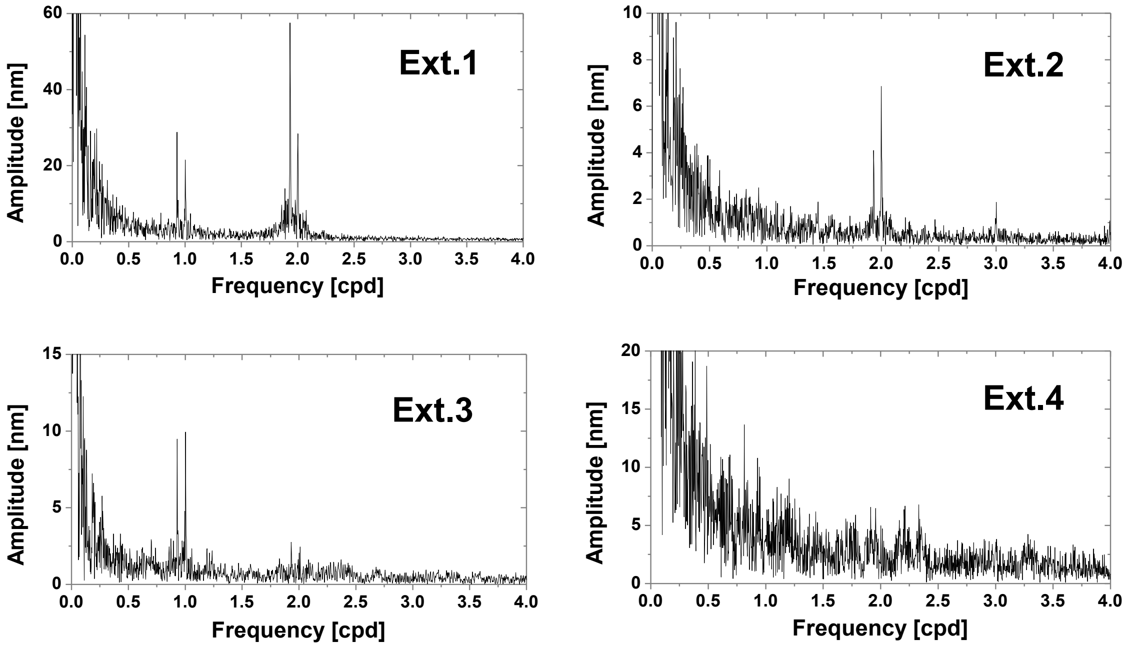

Fig. 6. Amplitude spectra of the extensometric data

Tidal parameters were calculated by means of the Earth tide data processing program ETERNA 3.30. (Wenzel, 1996). In the case of the vertical extensometer the tidal parameters could not be determined because of the strongly disturbed signal. The obtained tidal amplitudes measured by the horizontal extensometers are compared with the theoretical values in Fig. 7.

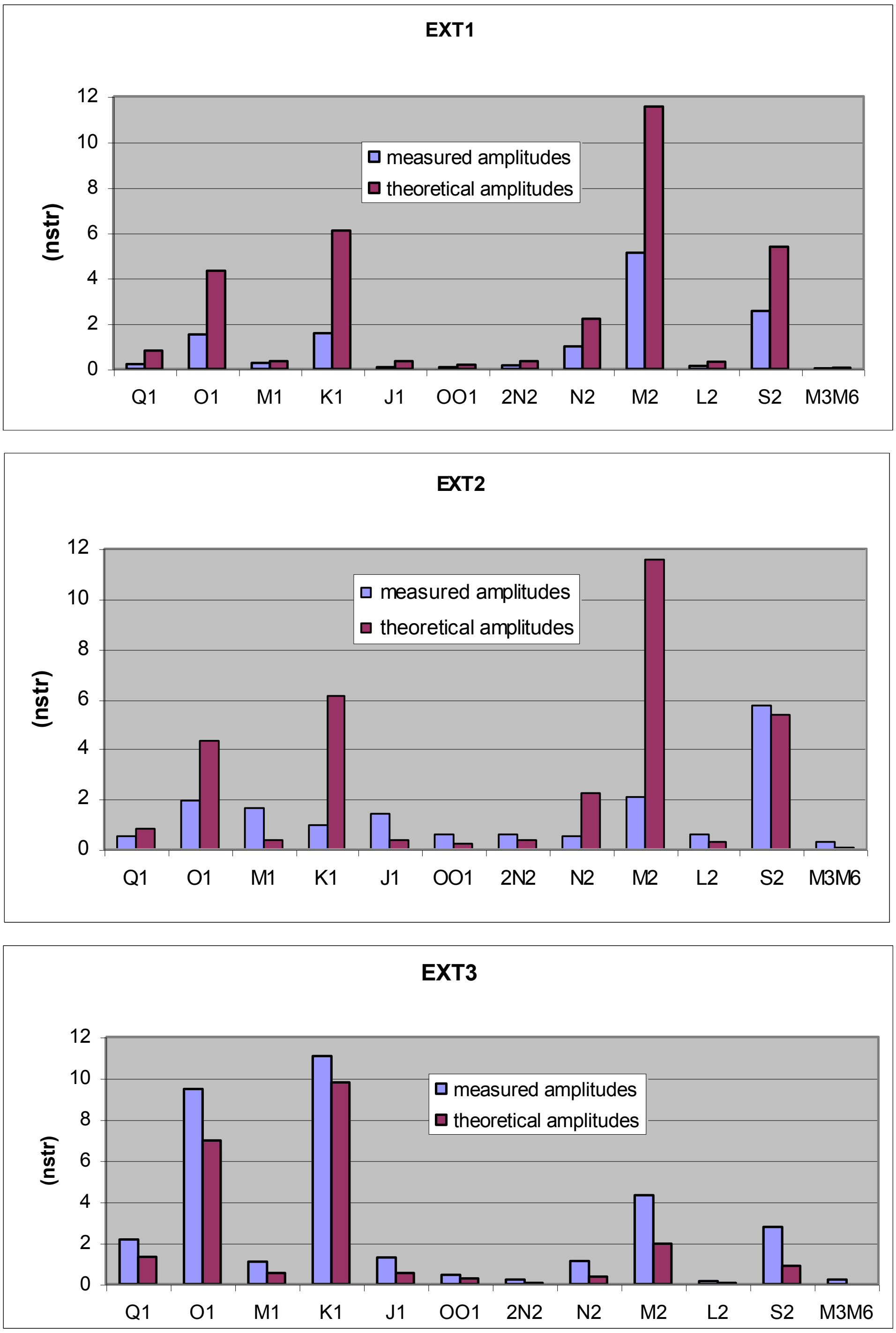

Fig. 7. The tidal amplitudes measured by the horizontal extensometers and the calculated theoretical amplitudes

In Figure 7 we can see that the measured amplitudes are smaller in the case of the longitudinal extensometers than the theoretical amplitudes. At the transversal extensometer (Ext.3) it is inverse, the amplitude factors are higher than 1.0. Although different characteristics of the tidal responses in the case of the perpendicular extensometers can be observed, this discrepancy presumably may be attributed to the same factors (local geological inhomogeneities, geometry, surface topography) which develop their effects differently into the perpendicular directions.

4. Comparison of the stability of the deep and the surface station

The deep extensometric station was established in the uranium mine in 1040 m depth. A detailed description of the station is given by Mentes and Berta (1997). The raw data recorded in the period between 1993 and 1999 is shown in Fig. 8. The calculated tidal parameters are given in Table II. For the sake of a numerical comparison the amplitudes and phase lags of the tidal waves obtained by the long extensometer (Ext.1) in Bakonya are given in Table III.

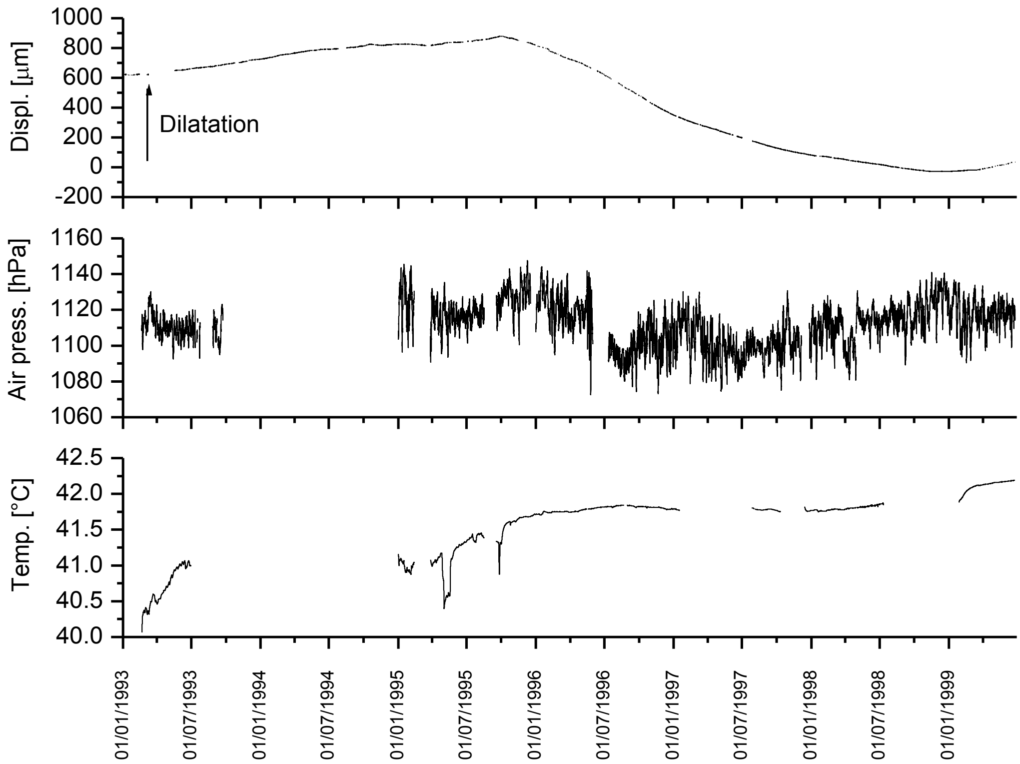

Fig. 8. Raw data recorded at the deep station in the uranium mine

The consistent tidal amplitude factors prove that stable deformation measurement conditions were provided in the deep observatory. In the case of the new 3D station we also get similar, almost uniform amplitude factors (in the range of 0.3-0.4). There is a difference in the tidal responses of the two measurement systems, namely from the surface station the amplitude factors have not exactly the same magnitude in the tidal frequency bands (in the diurnal band they are about 20 % lower). In case of the gravitational tide the solar effect is about the half of the lunar effect in contrast with the barometric waves, which are mainly guided by daily thermal variations (Chapman and Lindzen, 1970). The microbarograph measurements carried out by Mentes (2004) prove also that the S_2 solar semidiurnal wave is dominant in the atmospheric tide. The amplitude spectrum of the air pressure variations recorded at the 3D surface station shows clearly this fact (Fig. 9). The semidiurnal air pressure variations seem to induce higher strain loading in the surface station than in the deep observatory, so the atmospheric tidal loading is supposed to be responsible for the smaller diurnal tidal factors in the surface station. It means that the surface station should be more sensitive to air pressure variations than the deep observatory.

Table II. Tidal parameters obtained in the uranium mine in Pécs

Wave group	Theoretical amplitude [nstr]	Calculated amplitude [nstr]	Phase lead [degree]
Q1	0.909	0.232±0.165	-41.754±37.092
O1	4.749	2.235±0.036	-21.029±4.331
M1	0.373	0.059±0.344	-108.542±123.984
P1	2.209	1.077±0.065	-41.343±7.6573
K1	6.676	2.662±0.024	-19.322±3.485
J1	0.373	0.410±0.428	-10.949±22.330
OO1	0.204	0.204±0.998	-37.368±54.235
2N2	0.333	0.181±0.237	-54.951±25.128
N2	2.087	1.024±0.052	-39.696±6.021
M2	10.902	5.041±0.010	-46.265±1.271
L2	0.308	0.296±0.405	-74.083±24.168
S2	5.072	2.382±0.022	-45.408±2.734
K2	1.378	0.711±0.106	-48.696±11.810

Table III. Tidal parameters obtained by the long extensometer (Ext.1) in Bakonya

Wave group	Theoretical amplitude [nstr]	Measured amplitude [nstr]	Phase lead [deg]
Q1	0.830	0.218±0.136	-41.605±22.624
O1	4.335	1.518±0.024	-33.102±2.961
M1	0.341	0.274±0.426	-26.080±22.823
K1	6.094	1.572±0.019	-42.264±0.210
J1	0.341	0.071±0.370	-48.278±75.712
OO1	0.187	0.071±0.404	-27.432±45.628
2N2	0.354	0.163±0.118	0.625±10.775
N2	2.214	0.989±0.017	-6.629±1.581
M2	11.563	5.109±0.003	-10.681±0.260
L2	0.327	0.133±0.079	-10.585±7.955
S2	5.379	2.558±0.005	-16.797±0.437

On the basis of investigations for meteorological effects (Mentes and Eper-Pápai, 2006), the data of the deep extensometer have rather small pressure induced noise in the tidal frequency bands. According to data analysis of the 3D station, clear correlation exists between the atmospheric pressure and deformation data (in the long-term scale) which is more expressed than in the case of the 1 km deep station. It should be also noted that the yearly long-term strain rates from the deep extensometric and the new reliable Ext.1 data are in good agreement. The results of investigation of the barometric effect by regression analysis are summarized in Table IV.

The rates of the displacements measured by deep and surface instruments are given in Table V. The magnitudes of the extensions are the same from the deep and the Ext.1. extensometers. It is realistic since the two stations are not far from each other and the main tectonic structure should be the same at both stations. The deformation rate measured by Ext.2 is much higher than it should be on the basis of the length-ratio of the parallel instruments. The reason of the difference is unknown, probably it is in connection with the local rock inhomogeneities as it was mentioned above. The rates measured by the transversal and the vertical extensometers do not seem to be reliable as the measurements are highly disturbed.

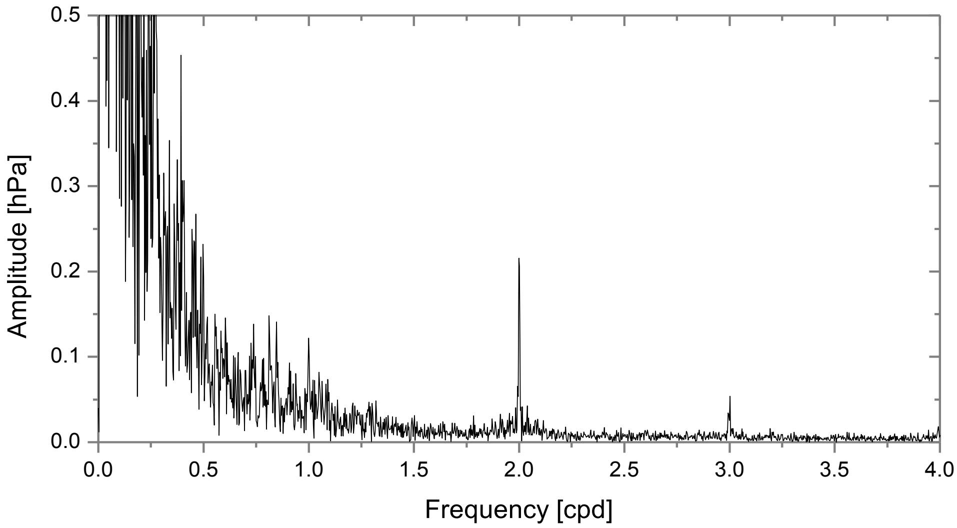

Fig. 9. Amplitude spectrum of the air pressure data recorded at the 3D surface station

Table IV. Comparision of the air pressure effect

Air pressure effect	Deep station	3D surface station
Short-term	0.3 nm/hPa	16 nm/hPa
Long-term	6.6 nm/hPa	124 nm/hPa

Table V. Comparison of the rates of the measured extensions

Extensometer	Rate of extension [μm/year]	Direction of the displacement
Deep extensometer	-85	contraction
Ext.1	-84	contraction
Ext.2	-32	contraction
Ext.3	-0.064	not reliable!
Ext.4	+2.5	not reliable!

Conclusions

Both the results of the tidal analysis and the investigations of the meteorological effects show unambiguously that the surface station is much more sensitive to the air pressure variations than the deep observatory. The pressure induced deformations are clearly superposed on the deformation signal of the instrument. From the analysis it seems that in the tidal frequency bands there is also pressure induced noise due to atmospheric tide, and this effect is of higher extent than in the deep station.

The displacement curves measured by the longitudinal extensometers in the 3D surface station are very similar but have difference in the magnitude, the reason of which can be the different local geological inhomogeneities between the ends of the instruments.

The vertical extensometer (Ext.4) does not provide useable data and the measured displacements of the transversal instrument (Ext.3) are very high. The construction of the station (cavity effect) is responsible for the disturbed data measured by the transversal extensometer which should be placed in the middle line of a long gallery. Probably the variations of the soil moisture above the station cause the high vertical deformations and presumably they are responsible for the high transversal displacements also. It could be proved by recording the precipitation and the ground water level above the station.

We can now state that the station is not suitable for recording reliable deformation measurements in the transversal and vertical directions because of the high disturbances caused by local and meteorological effects.

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References

Chapman S, Lindzen R S 1970: Atmospheric tides. D. Reidel Publishing Co.

Mentes Gy 1991: Installation of a quartz tube extensometer at the Sopron Observatory. Marees Terrestres Bulletin d'Informations. Bruxelles, No. 110, pp. 7936-7939.

Mentes Gy 1995: High Precision Calibration of Quartz Tube Extensometers. Proceedings of the Twelfth International Symposium on Earth Tides (Ed. H. T. Hsu), Science Press, Beijing, New York, pp. 209-214.

Mentes Gy 2004: Atmospheric tide obtained by the microbarograph developed at the Geodetic and Geophysical Research Institute of the Hungarian Academy of Sciences. Acta Geod. Geoph. Hung., Vol. 39, No. 1, pp. 39-48.

Mentes Gy, Berta Zs 1997: First results of the extensometric measurements in South Hungary. Marees Terrestres Bulletin d' Informations. Bruxelles, No. 127, pp. 9744-9749.

Mentes Gy., I. Eper-Pápai I. 2006: Investigation of meteorological effects on strain measurements at two stations in Hungary. Journal of Geodynamics, Vol. 41, No. 1-3, pp. 259-267.

Wenzel H-G 1996: The nanogal software: Earth tide data processing package ETERNA 3.30. Marees Terrestres Bulletin d' Informations, No. 124, pp. 9425-9439.