STRUCTURAL-GEOLOGICAL AND LITHOSPHERIC FACTORS AFFECTING DEFORMATIONS OF THE UPPER CRUST

André Gebauer*, Corinna Kroner*, Thomas Jahr**
* Helmholz Centre, Potsdam, GFZ German Research Centre for Geosciences, Germany
** Institute of Geosciences, Friedrich-Schiller-University Jena, Germany

Extended Abstract

Deformations are observable by various kinds of geodetic and geophysical instruments, e.g. strainmeters, tiltmeters, seismometers, permanent GPS-stations. The present study focuses on horizontal deformation components. The observed deformation contains signals of different amplitudes and greatly diverse origin:

- periodic signals (tides, …)
- aperiodic signals (tectonics, …)
- local influences (cavity effect, topographic effect, …)

The periodic and aperiodic signals have been investigated in several studies, for e.g. the tides (Zürn, 1997). From these investigations emerges, that many influences caused by local surroundings of the instrument can be some orders larger than the signals of interest. The locally induced deformations are related to the gallery geometry (cavity effect), to topographic features, structural-geological and lithologic factors for hydrologic, and atmospheric as well as tidal and ocean loading (e.g. Harrison, 1976; Harrison & Herbst 1977). Likewise temperature-related influences are found.

A number of studies have been carried out in order to determine the magnitude of the effects originating from the surroundings of an instrument location and influencing seismometer, tilt- or strainmeter observations (e.g. Kroner et al., 2005; Steffen, 2006; Steffen et al., 2006).

Recently, the studies related to atmospheric load have been continued and extended. The influence of several factors has been investigated systematically. The objective of this principle study is to determine the order of magnitude and the transfer mechanisms. The results are used to improve reduction methods related to deformations caused by effects of the local observatory surroundings and to provide a physical basis for the development of new algorithms. Furthermore, criteria are inferred for selecting locations of new observatory sites.

Elastic models are developed using the Finite Element software ABAQUS. The dimension of the models is 5 km x 5 km x 1.6 km. For loading two different barometric pressure scenarios are considered: a uniform load and a high pressure area moving across the model in different directions, both with an amplitude of 1 hPa. Since elastic rheology is used, the modelled deformations are scaleable according to different load amplitudes.

In the galleries, which are included in the models perpendicular to the topography, an instrumentation of strain- and tiltmeters is assumed. The strainmeters are 'installed' at the bottom of the gallery cut inside the slope and on the model surface (Fig. 1), oriented either parallel or perpendicular to the gallery. Tiltmeters are 'installed' in boreholes. The instruments have a nominal resolution of 0.2 nstrain and 1 nrad.

The influence of cavities is investigated for different gallery lengths and thicknesses of the coverage above the gallery. The topographic influence is studied with respect to rock coverage of an observation site, changes in the sloping of a hill flank or width of a valley (Gebauer et al., 2009). For this part of the investigations all mod-

els are parameterized after PREM (Dziewonski & Anderson, 1981). The result with respect to changes in the slope angle is given in Fig. 1. The slope angle is changed between 15° and 90° in 5° steps. At the foot of the slope in the centre of the model a 50 m long gallery with a quadratic cross section of 2 m x 2 m (Fig.1 d) is incorporated. The barometric pressure load acts always normal to the surface. For small slope angles the barometric pressure has basically a vertical component and for larger angles the horizontal component dominates. The deformations for the strain- and tiltmeter located in front of the gallery are used for comparison (Fig.1 d). For increased slope angles a non-linear increase of the deformation amplitudes perpendicular to topography occurs (Fig.1 a). For the strainmeter dilatations in the range of 0.4 and 0.7 nstrain are obtained. For larger slope angles than about 50° the influence of the slope is nearly constant. The amplitudes for the tiltmeter range between 0.07 and 0.35 nrad, in which the bottom of the tiltmeter moves away from the slope with respect to its top.

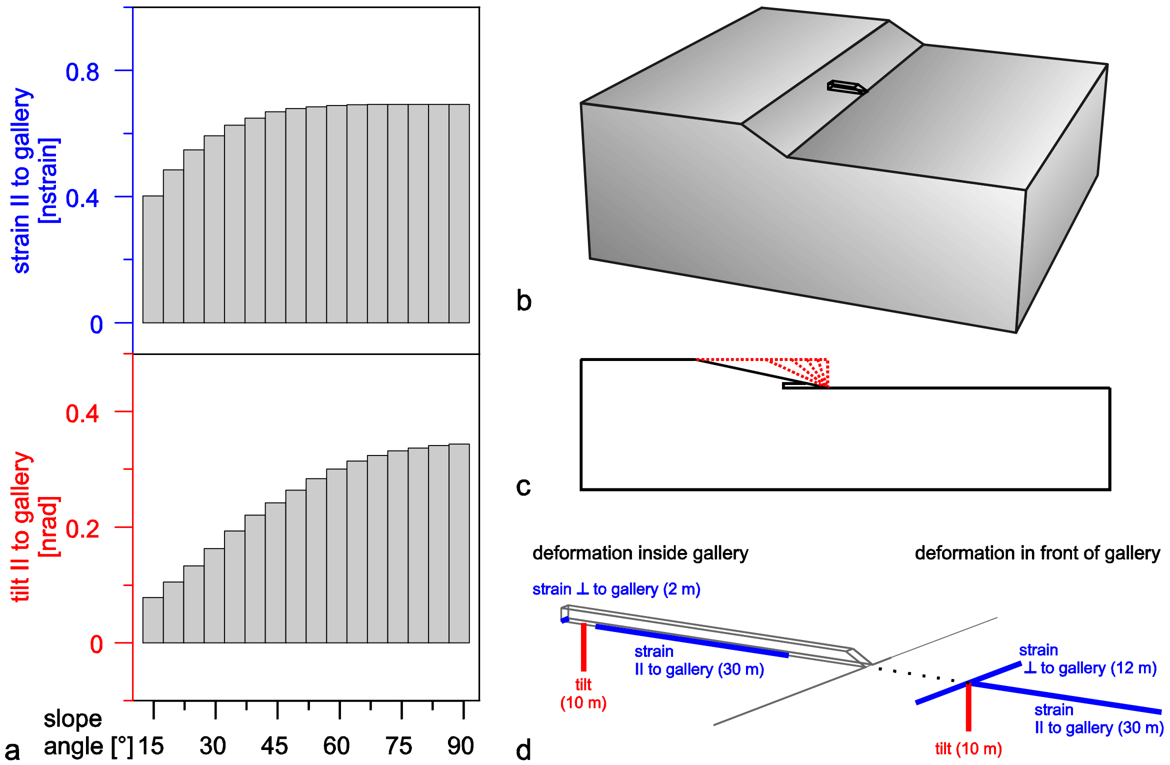

Fig. 1: Determined deformation (a) for a slope model (b) related to a changing slope angle (c). The deformation additionally is determined in front of the gallery (d) as reference.

The systematic study has been extended to the effect of local geological heterogeneities such as different lithological units and faults. The findings of the study regarding different influencing factors are summarized in Tab. 1.

Tab. 1: Maximum amplitudes of the different effects calculated in the principle study for 1 hPa barometric pressure load.

effect	strain [nstrain]	tilt [nrad]
cavity	0.5	1
topography	2	2
lithology	3	7
fault	7	2

For the analysis and interpretation of deformation observations all of the effects are significant. Generally, the deformation components oriented perpendicularly to topographic (hill flanks) or geologic features show the biggest influences. The various effects overlap in the observations in a complex way. Thus, a separation of the different effects in the data is difficult and therefore a better understanding can only be realized by modeling.

In a further step the investigations have been applied to the observatories of Wettzell, Sopron, Moxa, and Schiltach. All these observatories show characteristic topographies and comprehensive information on station conditions is available. The model topographies are realized based on digital terrain models (DTM). The models include the real galleries and instrumentation. From the studies it is found that even small topographic features like scarps in the local vicinity can produce strong deformations.

The investigations related to local influences will be continued and also extended to influences on regional scale. For this a model of central Europe will be developed.

References

Dziewonski, A. M. & Anderson, D. L., 1981. Preliminary reference Earth model, *Phys. Earth Planet. Inter.*, **25**, 297-356.

Harrison, J.C., 1976. Cavity and topographic effects in tilt and strain measurements, *J. Geophys. Res.*, **81**, 319-328.

Harrison, J.C., Herbst, K., 1977. Thermoelastic strains and tilt revisited, *Geophys. Res. Lett.*, **4** (11), 535-537.

Gebauer, A., Kroner, C., Jahr, T., 2009. The influence of topographic and lithologic features on horizontal deformations, *Geophys. J. Int.*, in press.

Kroner, C., Jahr, T., Kuhlmann, S., Fischer, K. D., 2005. Pressure-induced noise on horizontal seismometer and strainmeter records evaluated by finite element modeling, *Geophys. J. Int.*, **161**, 167-178.

Steffen, H., 2006. The importance of instrument location on barometric pressure induced noise, *Bull. d'Information Marées Terr.*, **141**, 11293-11302.

Steffen, H., Kuhlmann, S., Jahr, T., Kroner, C., 2006. Numerical Modeling of the Barometric Pressure-Induced Noise in Horizontal Components for the Observatories Moxa and Schiltach, *J. Geodyn*, **41**(1-3), 242-252.

Zürn, W., 1997. Earth Tide Observation and Interpretation. In: Wilhelm, H., Zürn, W., Wenzel, H.- G. (Hrsg.), 1997. Lecture Notes in Earth Science: Tidal Phenomena, Springer Verlag, 77-94.