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# Relations between Different Geodynamic Parameters and Seismicity in Areas of High and Low Seismic Hazards

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## Abstract

The objectives of this common research project are to evaluate deformation field variations observed with different means in different geodynamical areas of high and low seismic hazards. By the combined analysis of different inputs and a complex interpretation of the changes of stress and deformation fields we hope to provide an improvement in seismic hazard assessment. Experimental requirements and possibilities were tested by model computations regarding areas of special interest. Besides the evaluation of different archives to select long-term deformation data the improvement of on-going experiments was one task of the work. To compare seismicity with deformation changes the separation of environmental signals is necessary (correction mainly of meteorologically and hydrologically induced effects on tilt and strain). Finite-element-modelling (FEM) is used to simulate the situations in the areas under study with regard to stress release and deformation.

Under this co-operation the data in the archives of the partners from the NIS-countries (New Independent States) were made available, and a data base is being built up. Parts of these data are used here, and much more data still need to be treated. First results are presented.

## 1. Introduction

The main objective of this common research project is to compare data obtained with tidal instrumentation and seismometry, and to combine all the experiences and observations of the partners regarding seismicity and deformation. Especially the groups from the NIS countries (New Independent States) and Italy operated observatories for long time periods, and they obtained very long time series of deformation. These data shall be used to complete the understanding of the deformation field variations observed with different means in areas of different geodynamical setting, of high and low seismic hazards. Geodynamic areas involved are Italy / Southern Europe: Friuli area and Trieste: Grotta Gigante (Braitenberg, 1999a; Braitenberg and Zadro, 1999), Ukraine / Eastern Europe: Transcarpathian prognostic polygon (Verbitsky et al.,

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2000), and Kazakhstan / Central Asia: Tien Shan – Almaty – area (Tikhomirov and Latynina, 1999) as areas of high seismic hazard; areas of low seismic hazard involved are in Germany / Central Europe: Rhenish Earthquake Line (Kaiser, 2000) as well as East Thuringia and the Vogtland / West-Bohemian swarm quake area (Kracke et al., 2000), Observatories of Protvino and Obninsk (Russian platform: Boyarsky and Vasiliev, 2001; Vinogradova et al., 2001).

Based on the experiences and the long time series available by the co-authors the work aims to several objectives like (among others) (1) the evaluation of data archives of the partners from the NIS-countries and (2) the installation of new sensors at observatories already in operation, (3) correlation of tilt and strain with different environmental signals and (4) separation of meteorologically and hydrologically induced effects to separate tectonic signals, (5) Finite-Element-Modelling to study stress release and deformation with the geophysical observations as basic boundary conditions, and (6) derivation of criteria for the future use of borehole tiltmeters in addition to existing networks to use their flexibility to monitor crustal deformation in active areas. The last item (no. 6) will be treated in a separate paper.

Table 1 contains the observatories collecting deformation data over very long periods. Now, the present status is: In Friuli area five tilt and strain stations started in 1977, but since 1997 only one tilt-strain station is still in operation (Villanova: 46.26N, 13.28E). The long base pendulums in Trieste (Grotta Gigante: 45.71N, 13.76E) are still working, and a digital data acquisition system is being installed. In Kazakhstan the observatories around Almaty (Medeo: 43.13N, 77.05E, Turgen: 43.30N, 77.63E, Talgar: 43.40N, 77.38E) are in operation – except Talgar, where the activities are on a low level. In addition, the observatory Kurty was installed.

The Russian observatories Protvino (54.87N, 37.15E) and Obninsk (55.12N, 36.57E), both about 80 to 100 km south of Moscow, are in operation; here, improvements regarding data acquisition were made and new instruments are being tested.

Some of the topics have been developed in separate articles of this issue providing more details on the whole co-operation, like the Geodynamical Observatory Moxa / Germany and environmental effects observed there (Jahr et al., 2001; Kroner, 2001) as well as on the modelling of hydrological signals (Braitenberg and Zadro, 2001) and the FE-modelling of atmospheric pressure effects (Dal Moro et al., 2001).

## 2. Environmental Effects on Tilt and Strain

The effects of meteorological and hydrological origin on long-term recordings of gravity, tilt and strain are well known, but the problem of modellisation and correction of these effects is still unsolved (see c.f. Jentzsch and Kroner, 1999*). Therefore, we emphasised our efforts to this problem in order to prepare the long time series available for tectonic interpretation. Parts of this work are published separately in this issue (Braitenberg and Zadro, 2001; Kroner, 2001). We also refer to our related papers already published: Braitenberg (1999b), Dal Moro and Zadro (1998), Dal Moro et al. (2000), Dubrov et al. (1998), Kroner and Jentzsch (1999), Latynina and

* Compare the discussion within the working group 7: 'Analysis of Environmental Data for the Interpretation of Gravity Measurements'

Table 1. Instrumentation and recording times for the observatories with very long time series available.

| Station | Rec. Period | Strain | Tilt | Micro-seismics | Precipi-tation | Ground water |
|---|---|---|---|---|---|---|
| Grotta Gigante / Italy | since 1967 | - | X | X | X | X |
| Friuli network / Italy | since 1977 | X | X | X | X | X |
| Protvino / Russia | since 1966 | X | X | - | - | X |
| Obninsk / Russia | 1987 - 1992 | X | X | - | - | X |
| Medeo / Kazakhstan | since 1980 | X | X | X | X | X |
| Talgar / Kazakhstan | 1960 - 1988 | X | X | X | X | X |
| Turgen / Kazakhstan | since 1974 | X | X | X | X | X |
| Beregovo / Ukraine | since 1985 | X | X | X | X | X |

Boyarskii (2000), Latynina and Vasiliev (2000), Verbitsky (2000).

Regarding air pressure a comparison between the findings of the Italian and the Russian groups provide regression factors of 1 to 2 nstrain/mb and 1 msec/mb at Villanova station (depth: 50 m; Garavaglia et al., 2000). Dubrov et al. (1998) found 2 to 4 nstrain/mb at 16 m depth (Protvino observatory), and 5 to 7 msec/mb at 30 m depth (Obninsk observatory), whereas at the test site Fryazino (Moscow region, ~ 140 km from Obninsk) a laser strain-meter installed in 2 m depth provided a strain / pressure ratio one order higher than at the deeper installation in Obninsk. Further, they realised that the energy transfer from air pressure to strain is concentrated to periods between about 3 minutes and one week. Generally, the observed hydrologically induced signals are one order of magnitude higher than the pressure effects (Dal Moro and Zadro, 1998). FE-modelling of the pressure effect on the cave of Villanova was used to correct for this signal treated as direct loading (Dal Moro et al., 2001).

Further, we also looked at the temperature: A significant annual temperature effect is usually observed at all stations; for example, at Villanova / Italy 80 nstrain /°C were observed as regression to external temperature (Garavaglia et al., 2000). An exemption is found at Medeo / Kazakhstan, where this effect is masked by probably strong hydrological effects (Figure 1) and strong long-term drifts (e.g. at Turgen: about 2000 nstrain/yr).

Seasonal variations of tidal parameters were observed, probably caused by meteorological effects (Latynina and Boyarskii, 2000) which mask strain changes due to tectonic effects causing changes in the elastic parameters (Karmaleeva, 2000).

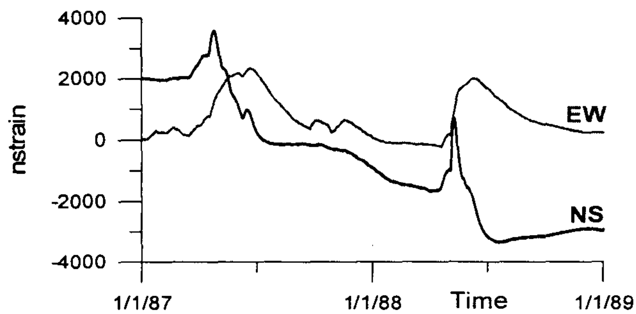


Fig. 1. Horizontal deformation at Medeo observatory near Almaty / Kazakhstan; note strong seasonal effects probably caused by hydrology and drift.

## 3. Long-term and Aperiodic Variations of Tilt and Sstrain

In Figures 2 and 3 we give the 20 years strain record of Talgar / Kazakhstan and the 30 years tilt records of Grotta Gigante / Italy, respectively, as an example for our data base. The spectrum of the Talgar strain record contains energy in the annual band, but also around 2 to 4 years. Remarkable is the long-term drift.

The changes of long-term drifts in all records, especially at Grotta Gigante, cannot be simply explained by instrumental effects because of the stability of the recording conditions. Statistical analyses of the long-term records of Grotta Gigante and Friuli stations revealed correlated multi-year deformation signals (Rossi and Zadro, 1997).

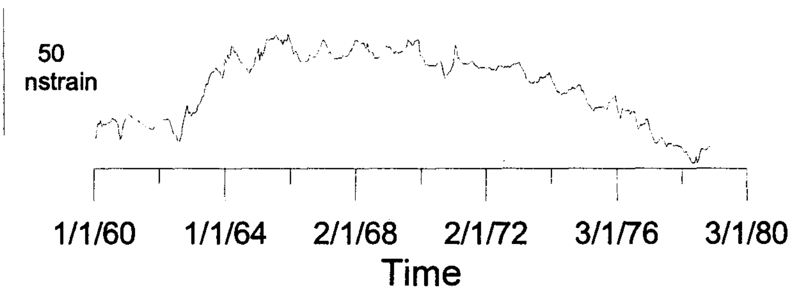


Fig. 2. Strain record North-South from Talgar / Kazakhstan covering 20 years (bi-monthly sampling).

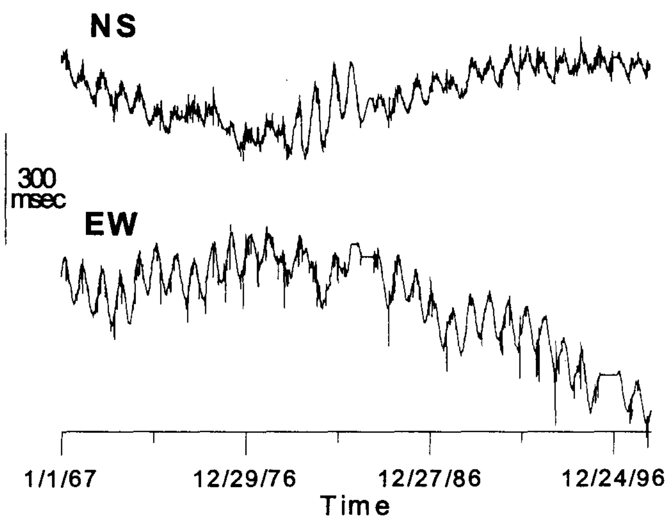


Fig. 3. Tilt records from Grotta Gigante / Italy covering 30 years (daily sampling).

## 4. Local Seismicity: Pre- and Co-seismic Deformations

Screening seismic events close to the Friuli network showed that pre-seismic events could be observed for the events M = 4.1, 1988/02/01, at station Cesclans (CE) and M = 3.9, 1991/10/05, at station Villanova (VI), where the epicentral distance was smaller than three times the fault length. Remarkable is also the annual tilt changing its ordinary shape in connection with changes in the local seismicity (Dal Moro and Zadro, 1999). For the earthquake near Bovec / Slovenia (M = 5.6, 12.04. 1998) significant co-seismic deformations could be seen at Villanova, 30 km away (Braitenberg, 1999a). These results are in support of the magnitude/ distance relations developed by Wyatt (1988) and Dobrovolsky et al. (1979). FE-modelling based on geological information on the character of the drift between Adria and Eurasia as well as the observed tilts, strains, precise levelling and crustal models (Rossi et al., 1999), provided a stress field patter n which is in a good agreement with the local areal distribution of seismicity.

## 5. Conclusions

A revision of the archives of the involved groups was carried out and the data-bases were made available and exchanged between the partners. A comparison revealed that secular strain rates are greatest at the Kazakhstan stations, but this has to be proved by more studies, especially with regard to meteorological and hydrological effects. Modelling and correction of environmental signals is crucial for the separation of tectonic signals. But up to now we only can derive local transfer functions. Our first results suggest to extend the evaluation of the relations between meteorological and hydrological parameters and tilt and strain to more time series available in the NIS countries and to compare them with our results from other sites (e.g. Kroner, 2001), especially regarding tilt (Weise et al., 1999; Ishii et al., 2001).

In the long run we hope to obtain an improved understanding of the deformation field variations in the different geodynamical areas under study as well as a generalisation of the findings concerning the relation of seismicity and deformation.

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