EVOLUTION OF METHODOLOGY MULTI-PARAMETRICAL OBSERVATION ON THE TERRITORY OF GEORGIA

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Abstract

Since 1979, researches for earthquake forecasting promoted development of a hydro-chemical network of special regime regional observation. On the territory of Georgia hydro-chemical observations are carried out on 23 boreholes. During observations a lot of anomalies were fixed, but because of the diversity of chemical water content it was impossible to conduct observations of the unified parameters for creating the complete picture of strains on the whole territory. This is the reason why we decided to conduct observations for those parameters which could fix tidal variations with deformation of 10^{-8} degree, what is compared with strains differences during earthquakes preparation period. Besides, it was possible to conduct unified observations. Water level in the deep boreholes was one of them. That way since 1885, the network of 10 boreholes of different depth (from 250 up to 3500 m) covers the whole territory of Georgia. Boreholes characterize all basic geo-plates and open waters of deep aquifer, actually they represent sensitive volumetric strainmeters, and react on the deformations about 10^{-7} -10^{-8}, caused both by endogenous, and exogenous factors. A borehole was considered informative if it was fixing tidal variations and was included in the network. Special monitoring equipment is installed at boreholes which record several parameters, i.e. water level and micro-temperature, atmosphere pressure and surface temperature, tilt, magnetic field and others. The data can be gathered in real time using the GSM net.

Keywords: Multi-parameters, network.

1. Introduction

Georgia is a part of a big geodynamical active region. As a result of plate migration, strong compressive strains are being built in the crust.

The energy released during sudden stress drop events may trigger earthquakes.

All over the world and in Georgia also, various anomalies (Hydro-dynamical, hydro-chemical, micro-temperature etc) are observed before earthquakes, besides in most cases, on enough distant places from epicentres. Therefore studying the geodynamical processes may help to forecast the natural catastrophes with reasonable probability.

2. Regional Geography and Geology

Georgia is a country in the Caucasus region of Eurasia. Situated at the juncture of Western and Eastern Asia. To the west it is bounded by the Black Sea, to the north - by Russia, to the south - by Turkey and Armenia, and to the east - by Azerbaijan. Georgia covers a territory of 69,700 km². The climate in Georgia varies significantly, and ranges from subtropical conditions on the Black Sea coast to continental with cold winters and hot summers in the east. The cold air from the north is prevented by the Greater Caucasus range. On the other hand, warm and moist air from the Black sea moves into the coastal lowlands, where the annual precipitation ranges between 1000 and 2000 mm, often exceeds 2000 mm on the coast, whereas the eastern part receives precipitation between 400 and 1600 mm during spring and autumn. The mean temperature in winter is 5 °C and in summer 22 °C

Geologically, the territory of Georgia is located in the Central and Western parts of the Transcaucasus and lies between the Eurasian and Afro-Arabian plates. The geologic evolution of Georgia is controlled, to a great extent, by the development of the whole Caucasus segment of the Mediterranean belt. Three major tectonic units can be distinguished according to the geologic evolution of Georgia: 1) Fold system of the Greater Caucasus which represents a marginal sea in the geological past, 2) Transcaucasian intermountain area which marks the northern part of the Transcaucasian island arc, 3) Fold system of the Lesser Caucasus, the southern part of the ancient Transcaucasian island arc.

2.1. HYDROCEMICAL MONITORING

Since 1979, the researches for the forecast of earthquakes promoted development of a hydro-chemical network of special regime regional observation. On the territory of Georgia hydro-chemical observations are carried out on the 23 boreholes (Fig. 1).

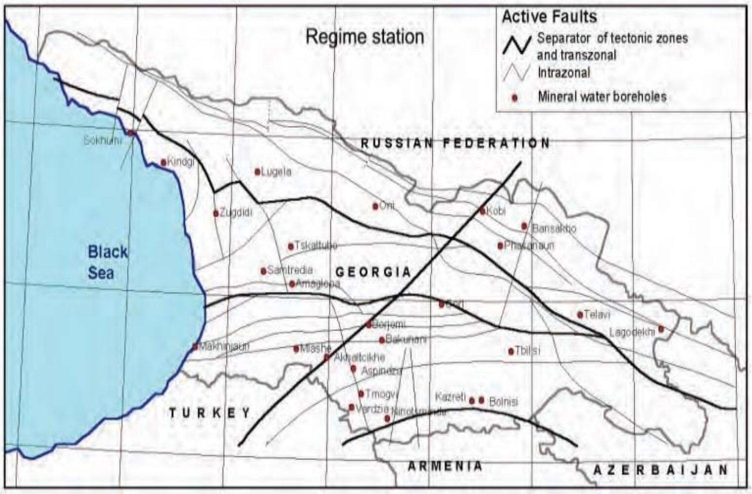

Fig.1. Scheme of hydro-chemical monitoring stations on the territory of Georgia

Measurements of water debit- by volumetric method, temperature of water and air - by mercury thermometer were daily carried out on the water points. Helium concentration was directly defined on the water points with the same frequency. Chemical composition of water was assessed on 20 components (HCO3, Cl, SO4, Na, K, Ca, Mg, J, Br-, Zn, Cu, Fe, Mn, He etc). Water chemical analysis was done by standard methodology.

The only way in the absence of criteria of estimation of information values was to make retrospective analysis on energy of occurred earthquakes (Fig. 2).

During observations a lot of anomalies were fixed, but because of the diversity of chemical water content it was impossible to conduct observations of the unified parameters for creating the complete picture of strains on the whole territory (Melikadze G., Adamchuk Y., et al., 1989).

This is the reason why was taken a decision to conduct observations for those parameters which could fix tidal variations with deformation of 10^{-8} degree, what is compared with strains differences during earthquakes preparation period. Besides it was possible to conduct unified observations. The water level in the deep boreholes was such a parameter (Hsieh et al., 1987, Hsieh et al., 1988).

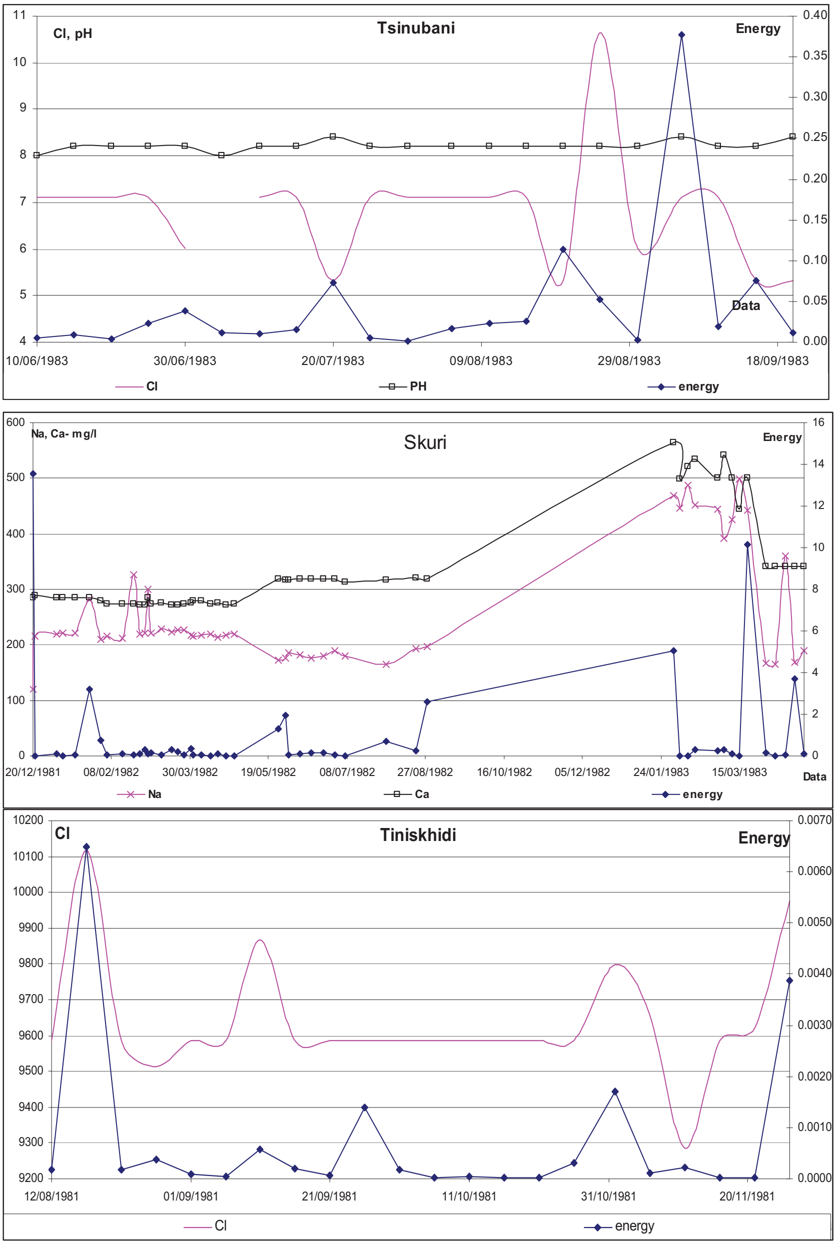

Fig. 2 Variation of hydro-chemical parameters and earthquakes energy at the Skuri, Tsinubani and Tiniskhidi stations

2.2. WATER LEVEL VARIATION MONITORING IN THE BOREHOLES

The modern methods of earthquakes forecast allow watching temporal and spatial changes of strain in the terrestrial crust. One of them is the monitoring method of hydrogeodeformation ground field (HGF). A regime network, according to the development of VSEGINGEO, in Caucasus has been established since 1985. Till now the network of 10 boreholes of different depth (from 250 up to 3500 m) covers the whole territory of Georgia. Boreholes characterize all basic geo-plates and open waters of deep aquifer, actually they represent sensitive volumetric strainmeters, and react on the deformations about 10^{-7} -10^{-8}, caused both by endogenous, and exogenous factors. A borehole was considered informative if it was fixing tidal variations and was included in the network (Melikadze G. et al., 1989).

They are situated in different tectonic areas. The deep boreholes with undisturbed regime were chosen for the observations which were not influenced by other boreholes.

Boreholes are equally spread all over the territory, basically on main geo-plates. These wells record all kinds of deformation caused by exogenous (atmospheric pressure, tidal variations and precipitation), as well as endogenous\ tectonic processes (Rojstaczer S. et al., 1998, Melikadze et al., 2002). On some boreholes, reaction of tidal-variation or atmosphere pressure dominated. For example, the atmospheric pressure is dominant at Adjameti and Oni boreholes and then tidal variations. But the tides are dominant on the Marneuli and Lagodekhi boreholes (Melikadze et al, 2004).

Distinctions in dominating factors are caused by depth of a borehole, its design, originality of a geological and hydro-geological structure water aquifer, value of the gas factor, etc.

For the conductance of qualitative observations appropriate equipment is necessary which could ensure frequent parameters inquiry, data transmission of determined frequency. After searching we have chosen data logger by American production to which 8 analogue ports and one pulse port are attached as well as corresponding sensors of water level or water pressure, atmospheric pressure and temperature.

This equipment ensures attachment of other informative sensors, which were chosen for such observation as magnetic and tiltmeter, Radon and Helium gases. The registration of this data occurs with a frequency of one time in a minute.

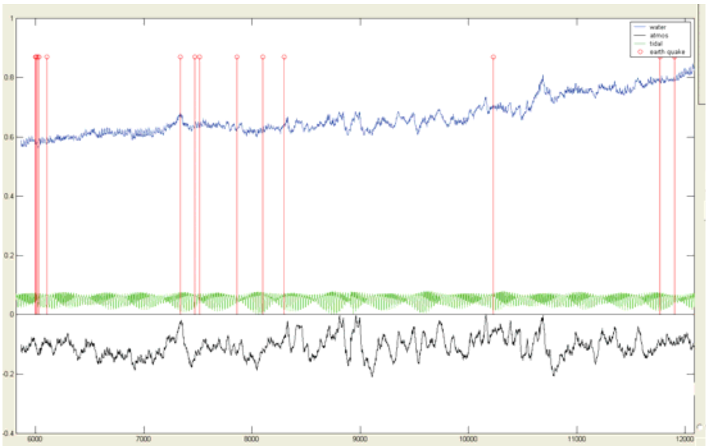

Fig. 5 Variations in time of water level (the bottom line), atmospheric pressure (the top line) and the tides (an average line) in the Adjameti borehole. Vertical lines correspond to the occurrence of earthquakes.

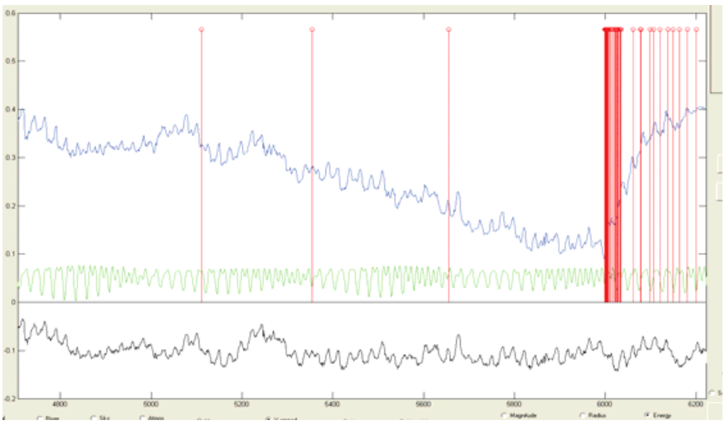

Fig. 6. Variations in time of water level (the bottom line), an atmospheric pressure (the top line) and the tides (an average line) in the Oni borehole. Vertical lines correspond to the occurrence of earthquakes.

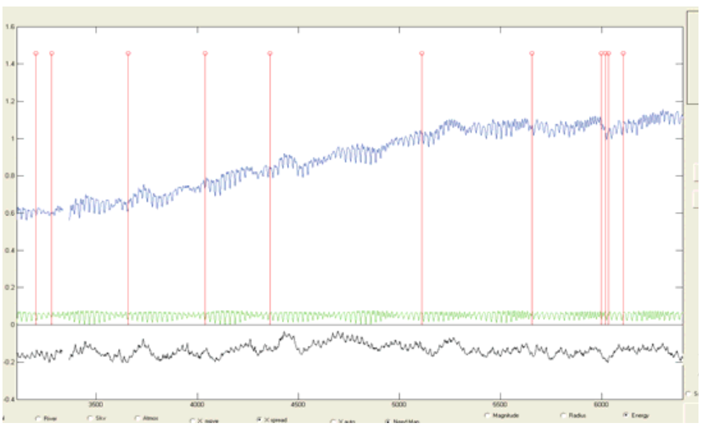

Fig. 7 Variations in time of water level (the bottom line), atmospheric pressure (the top line) and the tides (an average line) in the Marneuli borehole. Vertical lines correspond to the occurrence of earthquakes.

The data collection takes place with a frequency of one time in a day or more rarely. The data reception is ensured with the help of software of American data-logger.

All the data is collected in Matlab for the following processing, water level, atmospheric pressure, temperature, tilt-meter, which we get from the boreholes, tidal variations, which we calculate from the special program (GRAV To) and earthquakes data, which we receive from seismic station. In Matlab we calculate the stress condition from the earthquakes data, for each borehole by Dobrovolsky's $e=10^{1,3M-8,19}/R^3$ equation.

2.3. MICROTEMPERATURE MONITORING

Since 1999, authors with German colleagues have been carrying out researches at Tbilisi hydrothermal field in Eastern Georgia to study hydrodynamical and microtemperarture precursors of earthquakes.

Has been analyzed the long-time period materials; which was kept for today and give them possibility to find out relations between microteperature and hydrodynamic variation and tectonic motion and to define the short-term precursors of earthquakes.

2.3.1. *Equipment*

In order to achieve the objectives of the present research the innovative equipment (Buntebarth, 1999) was tested and installed in boreholes in THF. The devices are able to record very weak water migrations in the subsurface either by high-precision temperature measurements or by combined temperature and water level records. As far as the equipment operates in autonomous mode with energy saving electronics it can record data for several weeks or months depending on the reading frequency when using three alkaline batteries of size D. The regime observations of on the level, pressure and microtemperatures were organized at boreholes, located on Saburtalo (Lisi) and Tbilisi Central hydrothermal areas as well as at Sartichala-Teleti oil field (Fig. 4).

Temperature and water level data were recorded in boreholes with accuracy 0.5 microKelvin and 0.1cm correspondingly at a frequency of 10 or 20 min at the depths of the order of 200 m.

After selecting 9 boreholes the equipment was installed in some of them.

2.3.2. *Data analysis*

The temperature regime of underground waters shows the hydrothermal processes in the earth crust that is influenced by movement of thermal waters.

Stress/strain variations in the crust produce the changes in the local strain field as well as pressure of water, saturating pore and cracks system. Movement of stationary heat flow occurs through pore system as well. That’s why microtemperature changes are observed– anomalies coupled with stress/strain variations.

According to got data influence of season variations effects differently on the water level in the nearby located different boreholes. Water temperature changes by increasing depth and it means that there is close connection between water level and its temperature variations. And this connection is closer in the deep wells, where the influence of atmospheric pressure is excluded.

25 April 2002 the significant earthquake (M = 4.5) occured in the centre of Tbilisi that causes damage, assessed as 200 mln USD. The EQ was preceded by two foreshocks at 11 and 20 of April. Duration of shaking was 3 s. Observed macroseismic intensity was 6-7 in the epicentral area and the maximal horizontal acceleration was 0.11 g at the distance 8 km from epicenter. The EQ was followed by aftershocks, some of them with intensity 3.

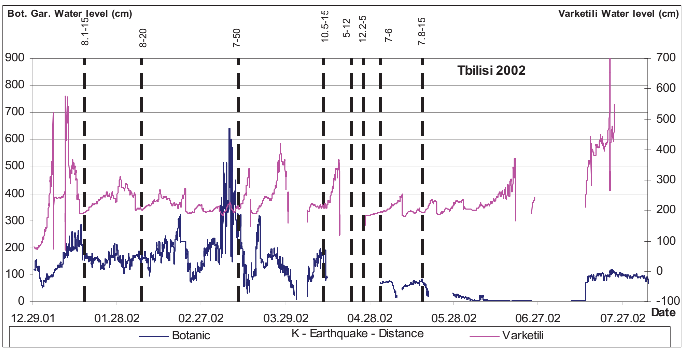

Fig. 6 Water level changes in Varketili and Botanic garden boreholes in 2002

Unfortunately, the water level equipment was not operating during that event (see Fig. 6), but on the other hand we observe very impressive microtemperature (microT) anomaly at Varkertili well before that EQ (Fig. 4). The epicentral distance was around 3 km. The anomaly is expressed as a strong scatter of temperatures around the background values and is evident at all three levels of recording: 150, 200 and 250 m. Deviations began at the 150 m-level on 5 April 5.00 and on deeper levels on 6 April, 00.00 that is 50 days before mainshock and 36 days before the first foreshock. The scatter was in the range 0.970, 0.01 and 0.025 Mk on the levels 150, 200 and 250 m respectively with predominant tendency to lower temperature values. After the anomalous period, which lasts 12-13 days, the mT values return to their background level and stay close to the old baseline for 6-7 days that is till the EQ of 25 April occurs.

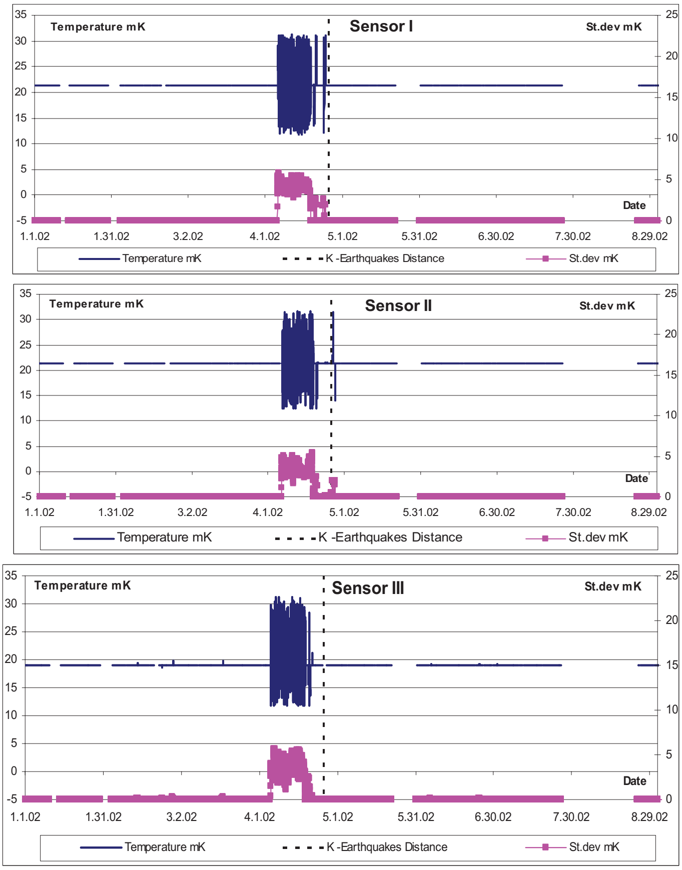

Fig 8. Time series of microtemperatures (upper curves) and standard deviations of T (lower curves) before, during and after the Tbilisi earthquake 25 April 2002 (M=4.5) at Varketili well, which is situated 3 km apart from the epicenter. Sensors I, II and III are deployed at depths 100, 150 and 200m accordingly.

The main event was marked by the post-seismic temperature step-like increase by 1 mK, 0.3 mK and 1 mK for sensors at 250, 200 and 150 m respectively. The microT-step lag relatively to the moment of the EQ was of order of 14 hours. Analysis of data of Fig. 15 shows that the strong microT anomaly originates a week before the first foreshock and finishes two days before the second foreshock; we cannot see any clear immediate responses to the foreshocks or to the main shock. This entire means that the connection between microT anomalies and tectonic/seismic events is quite complicated and different hydraulic effects can both precede seismic events and lag after them.

We could mention here the water level anomalies that can be related to 25 April events (Fig.14), though the anomalies in WL are not so clear due to technical reasons. At the Varketili well the strong increase of WL level (50 cm) began in August-October that is 7 months before the EQ;

Considering Figs 8 and 9 and taking we can conclude that the rise of seismic activity in Tbilisi area in the spring 2002 could be predicted if there were telemetric system for operative transmission of data and corresponding operative proceeding centre, because clear pre-seismic effects were observed in various geophysical and geochemical fields (Figs.6-9)

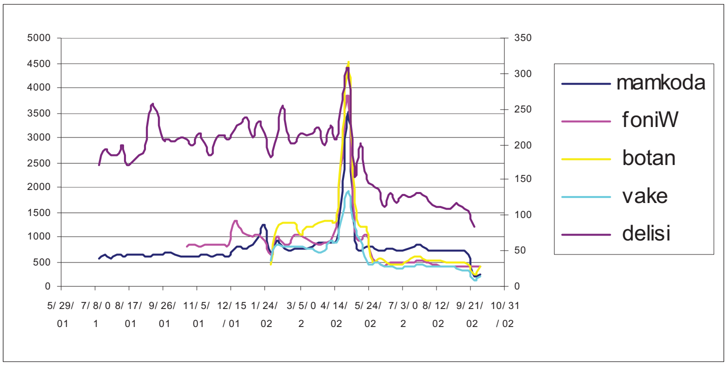

Fig.4. Radon concentration change before Tbilisi earthquake 25.04.02

3. Hydrodynamical observation station

Site selection is an important moment in deploying the hydrodynamic observation network. There are wells, which are more sensitive to the strain than others. The same is related to the depth of observations: the strain-sensitivity in the same well is different at different level.

In principle, the ideal hydrodynamic observation station should provide monitoring of following parameters:

1. Atmospheric pressure
2. Precipitation, snowfall and snowmelt
3. Air (surface) temperature
4. Tecnogenic impact
5. Aquifer characteristics (storetility, transmissivity, hydraulic conductivity, screened area, drained and undrained poroelastic parameters, gas phase content)
6. Seismic catalogue of strong and near events
7. Strains (Tides, tectonic movements, slow earthquakes)
8. Water level
9. Water temperature at various depths (temperature gradient)
10. Water conductivity in the borehole
11. Water chemistry
12. Rn concentration variation
13. Electromagnetic field anomalies

Such integrated observations could provide for quantitative interpretation of observed anomalies. It is obligatory to have most of this data in order to give at least reasonable qualitative conclusions.

4. Conclusion

According to the new methodology, we have selected informatively deep boreholes for the special network, which covers the whole territory of Georgia and characterizes all basic geo-plates. They represent sensitive strainmeters and fix the deformations processes about 10^{-7} -10^{-8}, caused both by endogenous and exogenous factors.

All over the world including Georgia, various anomalies (Hydro-dynamical, hydro-chemical, micro-temperature etc) are observed before earthquakes, besides in most cases, on enough distant places from epicentres. Therefore, studying the geodynamical processes may help to forecast the natural catastrophes with reasonable probability.

Analyzing data of different parameters show us the importance of improving the existing multiparametric observation network by adding new parameters as well as to expansion of contacts and collaboration with colleagues from our neighbouring countries in order to exchange data and to create the observation network on the territory of whole Caucasus and Black Sea region.

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