GEODESY AT THE BOUNDARY GEOSCIENCES

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Abstract. *Study of recent crustal movements can be integrated in all scientific research fundamental nature that compete all studying geosciences crust dynamics, meaning the description of complex phenomena that occurs in both permanent and deep bark. The results obtained by correlating efforts alone or in the context of interdisciplinary research programs conducted by the geological sciences, geophysical oceanographic determinations to those resulting from surveying, compete in elucidating a host of problems on the time evolution of changes in the internal structure and of the upper crust, to the knowledge of the current processes and attempt to predict their future evolution. In this way, fundamental studies mentioned need the important clarifications for the applicative research, cun such as, for example, the massive constructions, the exploitation of its coalfields.*

1. Introduction

Participation geodesy of the programs studying crustal movements was determined and developed simultaneously with the acceptance of the concept of global tectonics. Those studies are designed to determine a very important precursor of earthquake prediction, namely that of determining crustal deformations (such as compressions, extensions, etc.). Surveying supplies, increasingly more accurate and more rapidly, other geosciences, information about displacements, deformations of the Earth's crust can be calculated within the limits determined by the assumptions of the statistical nature accepted, the amount of potential energy accumulated between series of measurements carried out.

By engaging in such studies geodesy were made profound changes in the training and work of surveying professionals. Thus, according to the theory of plate tectonics, that confirms that nothing in nature is not fixed in time and space, has established itself as absolutely necessary introduction to the Fourth dimension (time) repeated geodetic processing. To respond to the requests of other geosciences necessary competence, specialists surveyors must have a thorough knowledge of the areas that collaborate (geophysics, geology, construction, etc.), particularly in the mechanics of deformable solids, so the repeated geodetic measurements to determine those physical quantities (displacements, strains, stresses, potential energy) that can be used as precursors of a possible future seismic event.

Thus it can appreciate the timeliness of research undertaken and usefulness of the results obtained in studies of hazard, seismic risk and earthquake prediction.

2. Integration of geodetic measurements in studies of geodynamic parameters determining.

Over the years, quake prediction, prediction with historical events or outstanding natural phenomena such as war, disease, famine, flooding his were outstanding concerns of politicians, researchers, or even predictive of some of the so-called "prophets". Skepticism that accompanied such concerns is the current date, although efforts and means used are in continuous improvement.

If we confine ourselves only to the attack subject, we mention that works great international prestige **(Lyell,** 1968) is analyzed the time evolution of methods able to highlight earthquake precursor phenomena in legitimate desire to alert the population as operative possible the production of such a devastating phenomenon. Among such precursors traditional mentions: great changes of climate, terrain lifts and diving and abnormal behavior of animals, it was concluded that the universality of such popular myths have, not infrequently, a certain base objective, scientific . Many researchers have issued but the hypothesis of occurrence of such opinions or "theories" as psychological reactions of the population affected by disasters mentioned, and less scientifically substantiated determination or analysis. With the advent and development of appropriate tools and technologies that have been used in many seismic areas around the globe, including in our country, completing the list followed naturally on earth earthquake precursory phenomena with new components, whose determination acquire a strong scientific and that are held increasingly more necessary credibility.

A seismic event is characterized by the following geophysical effects:

- *Fracture mechanics lithosphere;*
- *Energy released inside the Earth;*
- *Radiation of elastic waves.*

and can be defined by the following parameters:

- *The position of the epicenter;*
- *The depth of the hypocenter;*
- *When the earthquake triggering and*
- *Energy released.*

If an earthquake occurs in the earth's crust, it may indicate the following stages of development:

- In any region of the crust, located, for example, around a fault is generated a field of endeavor we hydrostatic nature, which in turn leads to an accumulation of elastic energy;
- At some point there is a rupture along the fault and an important part of the stored energy is suddenly released by broadcasting two types of seismic waves: P waves (where the expansion), and S-waves (shear waves). Another big part of the energy is converted into heat energy and potential energy. The phenomenon described above summary is accompanied by environmental trends to find another state of equilibrium, with post-seismic shocks.

Given the study addressed in this paper, further expose briefly the phenomenon known as crustal displacement recent (land), to determine which surveying is quite remarkable contributions.

2.1. Earthquake parameters

2.2.2.1. The intensity of seismic motion is a simple way to quantify, in terms of engineering, the size of an earthquake, and highlights by different seismic intensity levels, biological consequences and materials of a particular location or for a particular area. The intensity of an earthquake, characterize and psychophysiological behavior of people, and free surface configuration of the land changes.

Intensity scale of the most common are MM (**Modified Mercalli)** and MSK64 **(Medvedev-Sponheuer-Kärnik)** and include 12 levels of intensity. By convention, for example, assign intensity V earthquakes are perceived by the vast majority of existing in and that a large number of people located outside buildings, along with the appearance of superficial degradation construction. For situations occur when the total damage is assigned intensity level XII.

2.2.2.2. The magnitude of an earthquake is an objective measurement of energy released when the outbreak triggering seismic event, as determined on the basis of seismic recording instrument and, therefore, is independent of effects on the free surface of the land.

2.3. Main earthquake precursors

One directions of research in recent years, which keeps hope to reduce losses and damage caused by earthquakes, is represented by the determination of technologies able to predict them, the study measured physical precursors preceding earthquakes, in general, and especially the big ones. In the literature **(Rikitake,** 1976; **Vogel,** 1979.1980; **Scholtz,** 1994) there are several classifications of earthquake precursors.

Among those over 20 precursors **(Rikitake,** 1976, 1979, 1994) considered the implementation of the program Japanese earthquake prediction, recent crustal movements study is given an important place

2.3.1. Geodetical techniques and measurements of gravity

With the theory of plate tectonics occurs, geodetic measurements were attached to a new dimension, namely **time.** Geodesy was requested along with other geosciences: geophysics, geology, geomorphology, oceanography to bring their contribution in confirming (or completion) assumptions that underlie the theory.

2.3.1.1. Vertical geodetic networks.

The first attempts to determine the methods of geodetic recent crustal movements (land) had the foundation precision geometric leveling method which has continually evolved in recent years, reaching the mean square error per kilometer double leveling below the 0.3mm/km.

2.3.1.2. Horizontal geodetic networks.

Inserting instruments measure distances with high precision, produced significant changes in the structure of geodetic networks in the last 30 years, measurements of angle (triangulation) being supplemented or even replaced with distance measurements (trilateration).

2.3.1.3. Repeated measurements of gravity.

Changes in specific gravity over time in the size of an area may indicate either vertical movements or movements of masses inside the Earth. Both types of changes may occur not only in areas seismo-tectonic activity, but their specific by their precursor.

2.3.1.4. Space geodetic techniques.

The launch of the first satellite Sputnik on 04/10/1957 can be considered the beginning of the era of satellite geodesy. In this notion, it includes all processes for measuring and processing the satellites (artificial) can observe and measure the Earth itself or they are carriers of measurement systems. Geodetic satellites generated first opportunity to study this phenomenon in real space, three-dimensional zones becoming more extensive (groups of countries or continents) and then a considerable development of precision measurement results.

2.3.2. Continuous recording of the deformation of the crust (terrestrial)

Continuous measurements of the dynamic behavior of the Earth's crust are affected by various external and internal forces of the Earth, have become a substantial component of modern geodynamic studies. In this category we mention: the accumulation of tension, tilt and expansions crust which are highlighted by using strainmeters, tiltmeter, gravimetric and registering tide gauge.

2.4. Classification geodetic determinations of recent trips crust (terrestrial)

Geodesy fulfills an important role in earthquake prediction studies, studies that have a strong interdisciplinary character, the only geosciences can provide information geometric increasingly accurate, on-time deformation of the crust. The results obtained by correlating observations and studies of geology, geophysics, geomorphology, oceanography with those obtained from geodetic determinations, compete in elucidating the problems concerning the time evolution of surface and deep structure of the Earth, to the knowledge of the current processes that are part scale dynamics and attempt to provide their mode of expression in the future.

2.4.1. Classification in the report with the reference system considered

Depending on the reference system to which the geodetic determinations of crust displacement (land) use many types of classification.

2.4.1.1. *Absolute determinations* that can be defined in relation to some of the known global positioning systems. Absolute character of determinations from the fact that they are made and processed in a global Cartesian geocentric.

2.4.1.2. *Determination of relative vertical displacements, respectively horizontal* dimensional changes are the geodetic coordinates of the points in relation to a number of points whose position is considered stable.

2.4.2. Classification according to the magnitude determinations recent travels the Earth's crust

From this point of view there are the following determinations:

- *Global determinations* ;
- *Regional determinations* ;
- *Local determinations*.

2.4.3. Classification according to the accuracy of the geodetic

Another criterion for determining the classification of recent trips crust geodetic methods is the accuracy which they are made of. Thus, if the position of a point P on the surface can be determined by geodetic methods useto average *a posteriori error* $\pm\ m_P$, we can consider the change of position of this point with a size ΔD_P, between two sets of determinations statistically significant only when:

$$\left| \Delta D_P \right| > t_k \cdot \left| m_P \right| \qquad (1)$$

2.4.4. Classification report the results obtained by processing

2.4.4.1. *Vertical displacements* derived by surveying , the first geodetic methods for determining the movements of the crust (terrestrial) relied on recent trips leveling to determine the Earth's crust, both by volume measurements, and the accuracy of the results obtained.

2.4.4.2. *Horizontal displacement* derived from measurements of triangulation - trilateration.

2.4.5. Classification report prepared final product after repeated geodetic processing

The first step in the study of recent crustal movements geodesic is represented by using the most accurate methods of measurements and then repeat them in that include specific methods of processing. The second stage is represented by the processing and analysis of movements in the interdisciplinary studies, which detach and generate causes of displacement.

For this purpose prepare specialty products, which aresummarized below.

2.4.5.1. *Map vertical movements.*

2.4.5.2. *Horizontal gradients of vertical movements.*

2.4.6. Classification according to the processing methods repeated geodetic measurements

a - processing separate measurements on each phase measurements, from which the following conclusions main

b - block processing of all groups of measurements, which are taken into account the main conclusions obtained in separate processing described above.

2.5.Determination geodynamic parameters recent crustal movements

The classic definition of *geodynamics* dates from 1889, when scientist **G. Schiaparelli,** in a speech at the Russian Academy of Sciences, defined the object of study of the geosciences: *system dynamics Earth - Moon, each of these bodies are considered as deformabile.*

2.5.1. Determinations global or regional trips recent crust

As specified in **2.4.2. ,** *global or regional* determinations recent trips crust refers to large areas of the Earth's surface, including any number of countries or even continents, in their ensemble.

Currently stands two constellations using artificial satellites, launch navigation purposes to achieve the wish to consider:

- **GPS** (**G** lobal **P** ositioning **S** ystem) - with the administrator of the U.S. Ministry of Defense;
- **GLONASS** (**Glo** bal **Na** vigation **S**atellite **S**ystem), are under Russian administration.

As mentioned at the beginning of paragraph **2.1.** , the following categories of global tectonic movements are:

- *Divergent movements;*
- *Converging movements;*
- *Transcurente movements.*

From those basic concepts result geodynamic parameters main global crustal movements:

- *Coordinates of the rotation pole;*
- *Speed of rotation of plate tectonics;*
- *The boundaries between tectonic plates;*
- *Character rotation of plate tectonics that, especially from points of the edges of the plates considered;*
- *Cruising speeds in every geodesic, depending on their position from the pole of rotation of card.*

2.5.2. Determinations cvasiregionale

Over the years, geodesy was asked to determine *certain parameters geodynamics* of recent crustal movements, using standard measuring technology then existing, relatively large territories, such as for a specific region of a country, or sometimes even for more extensive territories.

2.5.3. Determinations local

As stated in 2.4.6.1. and 2.4.6.2. field campaigns necessary to achieve such measurements on small portions of land, but of particular interest (economic - such as Geodynamics of recent crustal movements:

-displacements resulting from the difference in those items geodesic coordinate measurements obtained at different times;

–deformation of a body defined as the change in position and shape of the body between the initial thought stage and another final thought;

– expansion or expansion average;

– average differential rotation;

– the shear strain tensor;

– tensions in the earth's crust;

– energy accumulated in the earth's crust;

– a possible earthquake magnitude M.

2.6. Predicting earthquakes

Earthquake prediction aims ultimately limit / avoid huge damage caused by them, and the loss of lives. About four decades ago, it is believed that earthquakes prediction could not be considered as a scientific research itself. In the years '60 appeared in Japan and U.S. research-oriented programs predicting earthquakes (**Rikitaki,** 1976 **Kislinger,** to 1975, to,) who denied previous hypothesis. Earthquakes accompanied the human and material losses that may be considered catastrophic and occurred in recent years in various parts of the globe (like the one that occurred in our country at 04.03.1977) fully demonstrates the need to address and resolve gradual extremely complex issue that is forecast earthquakes.

In predicting earthquakes can highlight the following aspects of the base (Figure 1) (**Dambara,** 1980).

- Location of the area where earthquakes may occur with high probability;
- Observation within these areas to measure changes in the precursors of earthquakes in the ccount of the point at which the earthquake may occur;
- Development of models represents the earthquake source to be able to make a correct interpretation of the evolution phenomenon and research results.

The basic principle of earthquake prediction is relatively simple, but not always easy to achieve, and can be stated as follows: any parameter that can be considered as a precursor to an earthquake that large changes occurs in relation to normal, can be used for earthquake prediction if there is the possibility to track / her in the evolution of temporal measurement.

Regarding the geodetic determinations, the general principle mentioned above can thus be applied: large and sudden changes in position geodetic points can often be associated with a future earthquake. Those changes can be no doubt strongly influenced by the system of marking those paragraphs. It must be realized that the movement of the crust layer on position does not influence the conclusions landmark. Studies should be undertaken to emphasize those geodetic displacements in these items and are a consequence of sudden releases accumulated tensions, to limit breakage, tectonic forces in action. Also a real efficiency can be achieved only with a high rate of repeatability Geodetic and certainly adequate coverage of the area surveyed geodetic points.

Therefore, in countries with an advanced economy and high seismicity, the financial effort for earthquake prediction studies is immense. Geodetic results contribute, usually a long-term prediction because such determinations have, however, a discreet. A short-term prediction can be made only keeping observations that require specialized equipment and personnel, so a considerable financial effort that can be supported only economically strong countries (Japan, U.S., Russia).

An earthquake prediction must provide the following main elements: the rupture, the magnitude and time of occurrence of the incident.

2.6.1. Predicting rupture zone

Predicting rupture zone or epicentral area is one of the mandatory elements of a complete terrestrial predictions. After the occurrence of an earthquake rupture zone can be identified by the area that includes the pre-shock epicenter main shock and post-shock, or the size of the area with crustal deformations pre-and co-seismic. For detection of anomalous crustal deformations corresponding to a seismic regions identified have made repeated geodetic measurements, research that can be considered as fundamental in nature.

Because the interval between successive fundamental research can be very short, because it's expensive and human effort is extremely high, their frequency may be somewhat higher only in special areas where the likelihood of an earthquake in the near future is high, considering the precursors of earthquakes and seismic activity earlier. For this purpose, in such regions are created geodynamic polygon test, which are performed not only in geodetic measurements, but otherwise (as mentioned in **2.3)** which are repeated at appropriate times.

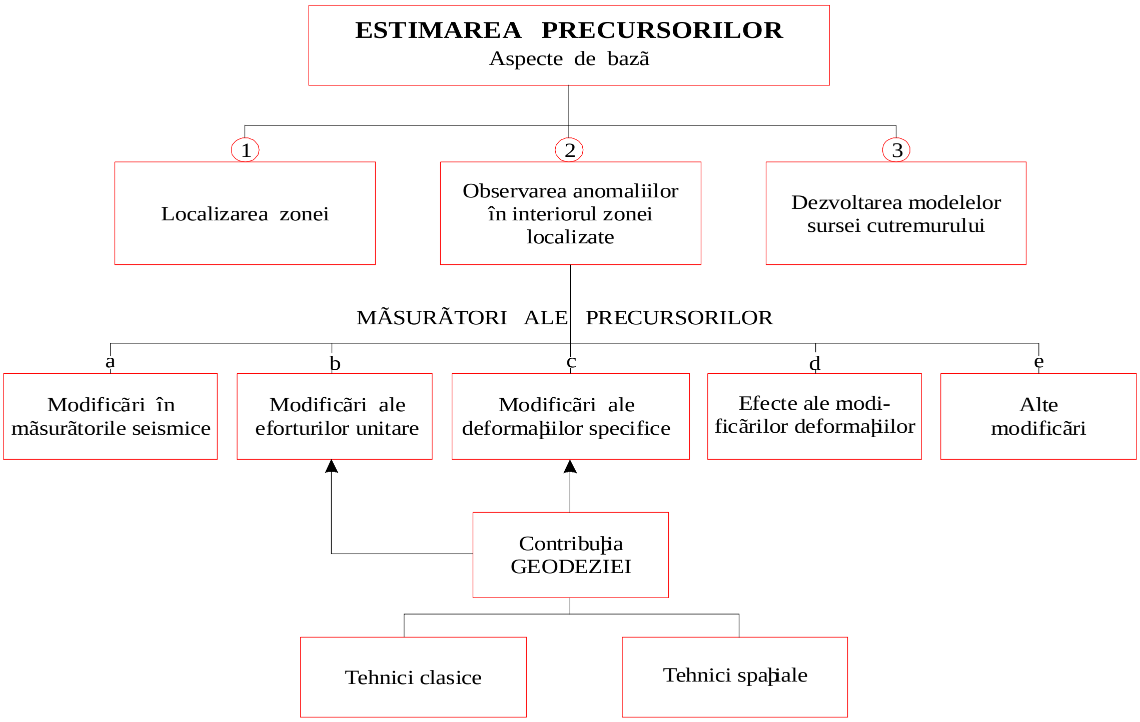

Figure 1. Aspect fundamental on the prediction of earthquakes (after **Dambara** , 1980)

2.6.2. Magnitude prediction

Voltages that can accumulated in a unit volume of the crust and are more or less uniform, depending, in general, the geology of the area, and the internal structure of the lithosphere. Thus, it is accepted that strong seismic phenomena involve large areas of the surface, crustal deformation associated with the earthquake. Such a relationship between magnitude earthquake and crustal deformation area was obtained **Dambara** in 1966, and subsequently corrected in 1981:

$$M = 1.91 \lg r + 4.43, \qquad (2)$$

where M is the earthquake magnitude, and r is the mean radius of the area in km crustal deformations.

2.6.3. The prediction of the time of earthquake

Establish dependency relationships between earthquake magnitude M and the time T in crustal movements occurring preoccupied several authors (**Tsubokawa,** 1969, 1973, **Scholz** ; 1973) resulting variants, of which the most common is:

$$\lg T = 0.65 M - 1.2 \qquad (3)$$

where T is the precursor time measured in years.

Rikitake (1979, 1994), which analyzed data available precursors, which are an order of magnitude higher than the previous study, obtained the following equation:

$$\lg T = 0.60 M - 1.01 \qquad (4)$$

Note that there are small differences between the results of the two equations for magnitudes **M <7,** differences that are large but when there magnitude **M>7.0** exemplifying were considered seismic data from the same area (**Dambara,** 1981).

Precursor time when geodetic can be seen on the diagram shown in Fig. 2. and described as follows:

(α) - extensive crustal movements over a long period of time occurring anomalous movements which tension spring;

(β_1) - extended anomalous movements over a period of time **,** a few years before an earthquake. In this period there were dilated processes;

(β_2) - anomalous movements occurring shortly before an earthquake;

(γ_1) - in this beam equalization occurs producing tensions preceding the main shock **(period γ_2)** and release tensions **(between γ_3).** This sudden and large deformations occur;

(δ) - this phase is a sequence of random movements occurring immediately after the shock.

After the restart cycle phases mentioned which tension **(α)** .

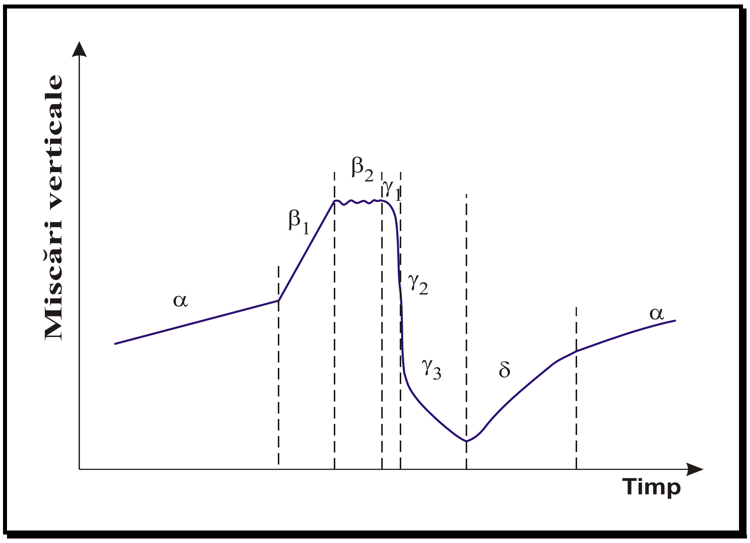

Fig.2. Qualitative representation typical crustal movements vertical seismic active areas (after **Dambara** , 1981)

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