

## ANNOTATION

To PhD dissertation in the field of 6D071100 - Geodesy

*Kuralay Turzhanovna Kartbaeva*

**Dissertation title: "Monitoring of Earth Surface Displacements on the Almaty Geodynamic Polygon"**

### **Purpose**

Obtain operational information on the displacements of the earth's crust at the Almaty geodynamic test site through comprehensive monitoring to predict natural and manmade emergencies.

**The research location** is seismic zones of the earth's surface on the Almaty geodynamic test site.

**The research subject** is the displacement and deformation of the earth's surface.

### **An overview of the research work, its objectives and location:**

- analysis of local and external best practices in researches conducted at geodynamic polygons;
- enhanced methodology of geodetic observations using the current trends in geodetic instrumentation and technologies for integrated monitoring;
- identify the regularity of displacement changes in the process of deformation of the earth's crust depending on tectonic disturbances and seismic conditions on the Almaty geodynamic test site;
- a comparative analysis and create a spatial database of integrated monitoring using Gamit Globk and Giodis software packages.
- development of a monograph on the study and forecasting of the consequences of natural and man-made geodynamic disasters;
- implementation of the results obtained in the course of the study in the production and educational process;

**Research methods.** To solve these problems, a complex research method was applied, including the analysis of literature sources, geodetic methods of observations, modern devices and technologies for monitoring the movements of the earth's surface, computer modeling of the SSS of the earth's crust of seismically dangerous areas of south-eastern Kazakhstan.

**Relevance of the topic.** The problems of forecasting modern movements of the Earth's crust, in particular, the collection and processing of Sentinel radar images obtained during surveying in the C-band, the interpretation of observation results, are relevant to this day, since the short-term prediction of earthquakes is a still

unsolved scientific problem. This problem is doubly relevant for the city of Almaty, which needs constant study of modern movements of the Earth's crust of the Tien Shan – a seismically active geodynamic region. The demand for geodynamic research is also associated with the increase in large-scale high-rise construction in the city, including the densification of buildings and the sinking of the subway in the conditions of tectonic faults under the city.

According to statistics, 7 million Kazakhstanis and 450,000 square kilometers of the republic's territory will suffer from earthquakes. In general, 28 cities and 450 settlements are located in the earthquake-prone area. Including: Almaty, East Kazakhstan, Zhambyl, South Kazakhstan regions of the Republic of Kazakhstan and the city of Almaty are among the regions with devastating earthquakes:

1. Over the past 100-120 years, 9 destructive earthquakes have occurred in our country, three of which were included in the list of world catastrophes (Verny 1887; Ladle 1889; Kemin 1911).

An active increase in man-made human activity leads to a change in the ecological and geodynamic safety of the natural environment, so monitoring of its indicators is mandatory. One of the advanced methods and technologies for observing geodynamic phenomena is geodetic. The use of geodetic methods in combination with other scientific methods is of great importance due to the high accuracy of determining the absolute value of displacements of the earth's surface in the study of seismic zones.

A comprehensive study of geodynamic processes involves the use of classical geodetic methods along with the use of remote sensing technologies, GPS and GIS (Geographic Information Systems). A similar solution of an integrated approach is used all over the world, as well as in Central Asia, including Almaty.

The region of Central Asia (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan) is a complex terrain and its geodynamic study is not easy. Earthquakes, floods, landslides, glacial lake outbursts, mudflows, and other natural anomalies are the result of high geodynamic activity in Central Asia. Natural and man-made disasters lead to loss of life, material and economic losses, create environmental problems and, undoubtedly, negatively affect the sustainable development and well-being of society in Central Asia.

2. The recent earthquake in Turkey serves as a sad example and warning for Almaty. Turkey is located in one of the most active earthquake-prone zones in the world. The area where the earthquake occurred is located at the intersection of three tectonic plates: the Anatolian, the Arabian and the African. The Arabian Plate is moving northward, pushing the Anatolian Plate (on which most of Turkey rests) to the west. The movement of the plates creates pressure on the fault zones between them. The sudden release of the stored energy of this pressure causes earthquakes.

The mountainous territory of Almaty is formed by the confluence of the Indian Plate with the Eurasian Plate. The Almaty region is also located within the mountain formations and has five large faults on its territory (Ili, Almaty, Predgornyy, Boralday, Zhanaturmysky).

*It should be noted that in addition to constant monitoring of the movements of the earth's surface, it is necessary to strictly control the quality of development. According to Yeraly Shokparov, a representative of KazNIISA: "It is possible to build anything other than individual housing construction on faults only on the basis of technical specifications. This is a special document that is developed for each specific building. The fact is that the loads on the structure on tectonic faults increase by 1.5-2 times in comparison with buildings that stand in the seismic zone. That is, a house with special technical conditions and a house located 200 meters from it without them are two different buildings, since they must withstand completely different loads. Such projects are developed taking into account special coefficients based on geological surveys at the site. The requirements for structural stability can increase from 1 to 1.5 times. In addition, tectonic faults have a nine-story height limit." Overall, Turkey's experience has shown that when builders and contractors deviate from the requirements of existing regulations, it leads to devastating consequences. If a building is built strictly according to a project developed taking into account special technical conditions, then it must withstand an earthquake of 7 or more points. However, in the absence of specific checks, there is no guarantee that builders will comply with strict safety requirements in practice.*

Taking into account all the above-mentioned natural and man-made factors of Almaty, one of the main components of building a seismic hazard forecasting map is the parameters of the stress-strain cover of the Earth's crust (SSS). To form a database of SSS parameters, high-precision geodetic monitoring data are used. In order to create a database and test the proposed method, comprehensive observations were carried out at the Almaty geodynamic test site (GDP). and archived data from previous observations.

The most effective form of integrated geodetic monitoring, which ensures the speed and high accuracy of collecting spatial-temporal information, is the following technologies: GNSS, GIS and remote sensing. The implementation of the results of the research work in GIS will increase the efficiency of timely decision-making on seismic hazard in the territories.

Another proof of the relevance of the dissertation is the fact that the research was carried out within the framework of the COPE program "Seismological Monitoring at Geodynamic Polygons of Kazakhstan".

Research on the study of geodynamic processes corresponds to the priority areas of development of science and technology of the Republic of Kazakhstan and has scientific and practical value.

### **Scientific propositions to be defended:**

1. The use of integrated monitoring, including high-precision re-leveling, GNSS observations, the results of processing satellite images by radar interferometry and geophysical research, significantly increases labor productivity, and also makes it possible to form an electronic database of spatial data for their subsequent analysis of the state of the earth's crust in seismic zones.

2. The Almaty prognostic geodynamic polygon has a tendency of slow deformation of the earth's crust, which is directly related to some seismic indicators and tectonic disturbances of the Trans-Ili Alatau.

### **Main results of the study.**

1. A methodology for conducting integrated monitoring has been developed, taking into account modern geodetic instrumentation and satellite technologies, which makes it possible to increase: the accuracy of measurements and labor productivity during repeated observations at geodynamic polygons. On the basis of the developed complex methodology, vertical and horizontal displacements were detected at the Port Arthur point.

2. In the Almaty SDP, there were major changes in the vertical and horizontal shift at the Port Arthur point of the Class 1 geodetic network. It was also determined that the vertical displacement was -216 mm/yr, in contrast to the value of the relative velocity of vertical movement between 2015-2016.

3. According to the results of GNSS observations for 2017-2021, the horizontal displacement vector at the Port Arthur point of the NE was 74.7 mm.

4. Regularities of changes in the process of deformation of the earth's crust depending on the indicators of tectonic disturbances and seismic conditions on the territory of the Almaty geodynamic test site have been obtained.

5. A spatial database of integrated monitoring and a comparative analysis of two programs using Gamit Globk and Giodis software packages (32 global GNSS stations and 10 local GNSS stations of the study area for the period 2017-2021) were created.

6. Based on satellite imagery observations for the period from 2017 to 2021, displacements in the southeastern parts of the Earth's surface of the object under study were identified and recorded on the territory of the Almaty geodynamic test site.

7. The results of the dissertation work were implemented in the production of the Seismological Institute of Almaty and included in the lecture materials, practical classes for undergraduates of the International Educational Corporation, which is confirmed by the relevant Acts of implementation (Appendix A, A).

### **Scientific novelty and importance of the results obtained:**

- A methodology for comprehensive monitoring has been developed, taking into account modern geodetic instrumentation and satellite technologies. The

technique makes it possible to increase: the accuracy of measurements and labor productivity during repeated observations at geodynamic polygons, as well as the reliability of determining the tension-deformed state of the earth's crust;

- regularities of changes in the process of deformation of the earth's crust depending on the indicators of tectonic disturbances and seismic conditions on the territory of the Almaty geodynamic test site were obtained;

- A comparative analysis was carried out and a spatial database of integrated monitoring was created using Gamit Globk and Giodis software packages (32 global GNSS stations and 10 local GNSS stations of the study area for the period 2017-2021).

**The author's personal contribution consists of:**

- setting the purpose of the research, tasks for solving the problem, determining the methods and directions of research;

- performing part of field measurements, processing instrumental observation data, processing satellite images;

- formation and substantiation of scientific principles of geodetic studies of geodynamic processes;

- analysis of geodetic methods of monitoring and accuracy of their implementation;

- improvement of classical geodetic methods of monitoring, taking into account modern instrumentation and satellite technologies;

- Implementation of the results obtained in the course of the study in the production and training process.

**The practical significance of the dissertation** lies in the creation of a spatial database of geodetic monitoring using the GAMIT GLOBK and Giodis software packages, as well as an updated catalog of GNSS measurements of the State Geodetic Survey of Almaty for 2017-2021. This database is successfully used in solving the problems of forecasting and minimizing the consequences of geodynamic disasters of natural and man-made nature by conducting comprehensive monitoring.

**The validity and reliability of scientific provisions and conclusions is confirmed** by the mathematically processed results of repeated high-precision geodetic leveling and GNSS observations carried out at the Almaty geodynamic test site. All the results of integrated geodynamic monitoring were applied in the work of the Almaty Institute of Seismology, the methodology was introduced into the educational process of the IOC (implementation acts are given in Annexes A and A).

**The scientific significance of the dissertation** lies in the theoretical and experimental justification of the use of modern technologies to collect information on the spatial-temporal state of the territory of the Almaty geodynamic polygon,

predict the SSS of the earth's crust and obtain new knowledge about earthquake-prone zones.

**Publication and approbation of the work.** The main results of the dissertation: Satpayev Readings (Almaty, KazNRTU, 2018, 2019); International Scientific and Practical Conference "Modern Problems and Prospects for the Development of Rational and Safe Subsoil Use" (Tashkent: Tashkent State Technical University, 2018); International Scientific and Practical Conference "Effective Use of Mineral and Man-Made Raw Materials in the Context of Industry 4.0" (Almaty: Satpayev University, 2019); International Forum of Surveyors (ISM) International Forum of Surveyors (ISM) "Digital Technologies in Geodesy, Mine Surveying and Geomechanics" (Karaganli: KSTU, 2019); "Problems of Creating Subsoil in the XXI Century through the Eyes of the Young" International Scientific School (Moscow, IPKON RAS, 2019); "XVII International Congress (ISM) of Surveyors" (Irkutsk: IrNRTU, 2019) and Satpayev University at the scientific seminar of the Department of Mine Surveying and Geodesy (2020).

**Structure and scope of the dissertation.** The dissertation is presented in a 123-page computer text consisting of an introduction, 4 chapters, a conclusion and an appendix. It includes 54 figures, 12 tables, a conclusion, a list of references and appendices.

**Compliance with the directions of science development or state programs.** The dissertation was carried out within the framework of the COPE program "Seismological Monitoring at Geodynamic Polygons of Kazakhstan".

**On the topic of the dissertation, 16 publications were published,** in which the doctoral student was directly involved as an author and co-author:

1. Nurpeissova M.1, Menayakov K.T.1, Kartbayeva K.T. 1, Ashirov B.M. 2, Dai Huayang<sup>3</sup>. Satellite observations of earth crust at almaty geodynamic polygon / Proceedings of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, Issue 6(450), 2021, pp. 93-101 percentile 37% ISSN 2224-5278, <https://doi.org/10.32014/2021.2518-170X.124>

2. Caiya Yue, Qiang Yang, Kartbayeva K.T. Present-day movement trends of the major tectonic faults in the Sichuan-Yunnan region based on the constraint of GPS velocity fields// Advances in Space Research (ASR), Май, 2021, С.1719-1731, ISSN: 0273-1177 DOI:10.1016/j.asr.2021.04.014, процентиль 83%

3. Nurpeissova M.B., Kenesbaeva A., Kartbaeva K.T. Complex evaluation of geodynamic safety in the development of hydrocarbon reserves deposits// Proceedings of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, No 1, Volume 1, Issue 439, 2020, pp. 90-98 ISSN 22245278 DOI10.32014/2020.2518-170X.11, percentile 37%

4. Kartbaeva K.T., Nurpeisova M.B. Analysis and interpretation of geodynamic monitoring data // Vestnik KazGASA, No. 4 (74), 2019, pp. 302-308. ISSN 1680-080X

5. Kartbaeva K.T., Nurpeisova M.B. The role of space geodesy in determining vertical movements of the earth's surface // Vestnik KazNRTU, no. 1(131), 2019, pp.12-15, ISSN 1680-9211

6. Kartbaeva K.T., Nurpeisova M.B. Geodetic observations at the Almaty geodynamic test site / Vestnik KazGASA, No1(71), 2019, S.182-188. ISSN 1680-080X

7. Kartbaeva K.T., Omirzhanova Zh.T., Kirgizbaeva D.M. Organizatsiya sistemy obrazheniya na Almatinskogo geodinamicheskogo polygon [Organization of the observation system at the Almaty geodynamic polygon]// Marksheideria i nedropol'zovaniye, No. 2, March-April 2019, pp. 22-31, ISSN 2079-3332.

8. Nurpeisova M., Dai Huayang, Omirzhanova Zh.T. Primenenie GPS monitoring v otsenki sovremennykh deformii zemlykh kory na Almatinskogo GDP [Application of GPS monitoring in the assessment of modern deformations of the earth's crust at the Almaty GDP]// "Problems of subsoil development in the XXI century through the eyes of the young", Sbornik 14-MNSh MU i S. - M: IPKON RAS, 2019, PP.132-135, ISBN 978-5-6041084-8-2.

9. Kartbaeva K.T., Nurpeisova M.B. Almaty geodynamicalyq polygonyndaǵy geodeziyalıq baqylaýlar nátiyesi// International Forum of Surveyors (ISM) "Digital Technologies in Geodesy, Surveying and Geomechanics", 19-20 April 2019, Karaganda, KSTU, pp. 941-945, ISBN 979-601-315-731-3

10. Kartbaeva K.T., Nurpeisova M.B. Geodeziyalıq polygondarda geodeziyalıq baqylaýlar júrgizýdiń ádistemesi// International Scientific and Practical Conference "Rational Use of Mineral and Technogenic Raw Materials in the Conditions of Industry 4.0", 14-15 March 2019, Satpayev University, pp. 79-83, ISBN 978-601-323-168-6

11. Kartbaeva K.T., Nurpeisova M.B. Almaty geodynamicalyq polygonyndaǵy geodeziyalıq baqylaýlar// Proceedings of Satpayev Readings "Innovative Technologies – Key to the Successful Solution of Fundamental and Applied Problems in the Ore and Oil and Gas Sectors of the Economy of the Republic of Kazakhstan", Vol. 1, 2019, pp. 888-892, ISBN 978-601-323-145-7

12. Kartbaeva K.T., Nurpeisova M.B. O geodinamicheskikh polygonakh i sputniknoy sistemy obucheniya za deformami geosredy [On geodynamic polygons and satellite observation system for deformations of the geoenvironment]// Proceedings of Satpayev Readings – 2018, "Innovative Solutions to Traditional Problems: Engineering and Technologies", KazUZZU, 2018, pp. 941-945, ISBN-601-341-174-3



13. Kartbaeva K.T., Nurpeisova M.B. Geodesic support of geodynamic polygons// Mining Journal of Kazakhstan, No4, 2018, pp.14-18 ISSN 2227-4766

14. Kartbaeva K.T., Nurpeisova M.B., Omirzhanova Zh.T. Geodetic observations at the Almaty geodynamic polygon// "Gornyi vestnik Uzbekistana", Tashkent, Tashkent State Technical University, 2018, pp.63-74, ISSN 2181-7383

15. Kartbaeva K.T., Omirzhanova Zh.T. Analysis of the deformation of the earth's surface at the Almaty GDP // Collection of materials of the XXXII international scientific conference "Trends in the development of science and education" dated November 30, 2017, No. 32, part 4, Izd. Research Center "L-Journal", Samara, 2017, pp. 56-59, SPLN 001-000001-0216-LJ

16. Kartbaeva K.T., Nurpeisova M.B., Omirzhanova Zh.T. Izuchenie geodinamicheskikh protsessov na territorii Srednei Azii i Kazakhstan [Study of geodynamic processes in the territory of Central Asia and Kazakhstan (Monograph)]// Germany, Lambert, 2020, 125 p., ISBN 978-616-9-84036-6.