Research Article

SEISMIC MONITORING OF LANDSLIDE HAZARD ON ANGREN OPEN PIT (EASTERN UZBEKISTAN)

I.P. Sidorova[1], R.I. Sakhobidinov[*]
Institute of Geology and Geophysics named after Kh.M. Abdullaev
49 Olimlar st. 100041, Tashkent, Uzbekistan
**Author for Correspondence*

ABSTRACT
This article discusses the creation of an integrated tectonic-geophysical model of the Angren brown coal mine based on the results of seismic monitoring, tectonic-structural studies involving remote sensing materials to predict geological hazards, in particular, landslide movements within open pit. On the basis of three-dimensional integrated tectonic-geophysical model, the morphology of the high-speed body traced at a depth of 4.5 km and its influence on the surface of the basement and topography along the contour of Angren open pit. According to remote sensing digital database of geology and tectonics of the mine were also created on ArcGIS 10.1 software. Data related to Naugarzan, Central, Kokand, North and South landslides were added. Dynamic of the Kokand landslide movement were simulated on the RAMMS software. Using seismological seismic stations KARS, we recorded seismograms from far earthquakes and from explosions in the pit. Moreover, for the first time landslide movement seismograms were registered by station KARS.

Keywords: *Landslide, Seismic Monitoring, Open Pit, Seismic Station, Seismogram, Tectonic-Geophysical Model*

INTRODUCTION
To determine landslide hazards on Angren kaolin brown coal mine envisaged to provide detailed studies of both tectonic and man-made indicators of the development of landslide processes within an open pit by Resolution of the Cabinet of Ministers of the Republic of Uzbekistan dated 06.06.2013. №.161.
Seismic monitoring was provided for the period 2015-2017 years within applied project FA-A13-T123. The study of deep conditions of the subcoal layers and tectonic faults in combination with seismic monitoring and geological exploration allowed us to more closely link surface changes in landslides with the deep structure of region.

MATERIALS AND METHODS
Studies have been provided in “Structure of Lithosphere” laboratory of the Institute of Geology and Geophysics in several directions: (1) a complex of tectonic structural studies: the study of fault tectonics at various levels of dimension from micro and mesostructures (from the grade of cracks to fracture) and short-term (in geological understanding) events (earthquakes, landslides, short-term volume displacements of mountain masses) to megastructures (dimension of mountain ranges and their systems) and their long-term processes developments; (2) study of crustal horizons by seismic monitoring with seismic stations KARS and LAKKOLIT-24M; (3) cumulative analysis of surface structures based on remote sensing, morphology and deep structure of the region to create a three-dimensional tectonic-geophysical model of open pit. Tectonic-geophysical model was constructed on the basis of the researches. When constructing a three-dimensional model authors discovered a spatial correlation of the high-speed Angren body (Butovskaya *et al.,* 1977), lying at a depth of 4.5 km, and protrusions on the surface of basement and relief directly in the contour of the pit itself. By combining geophysical and tectonic data using the ArcGIS10.1 software, authors built the lateral three-dimensional basement and

relief surfaces, and as a result identified the initial cause of landslide phenomena on open pit, which is the existence of a rigid plinth at depth (figure 1), around which earlier (at the time of quaternary) landslides occurred long before the beginning of the mining exploration of coal horizons.

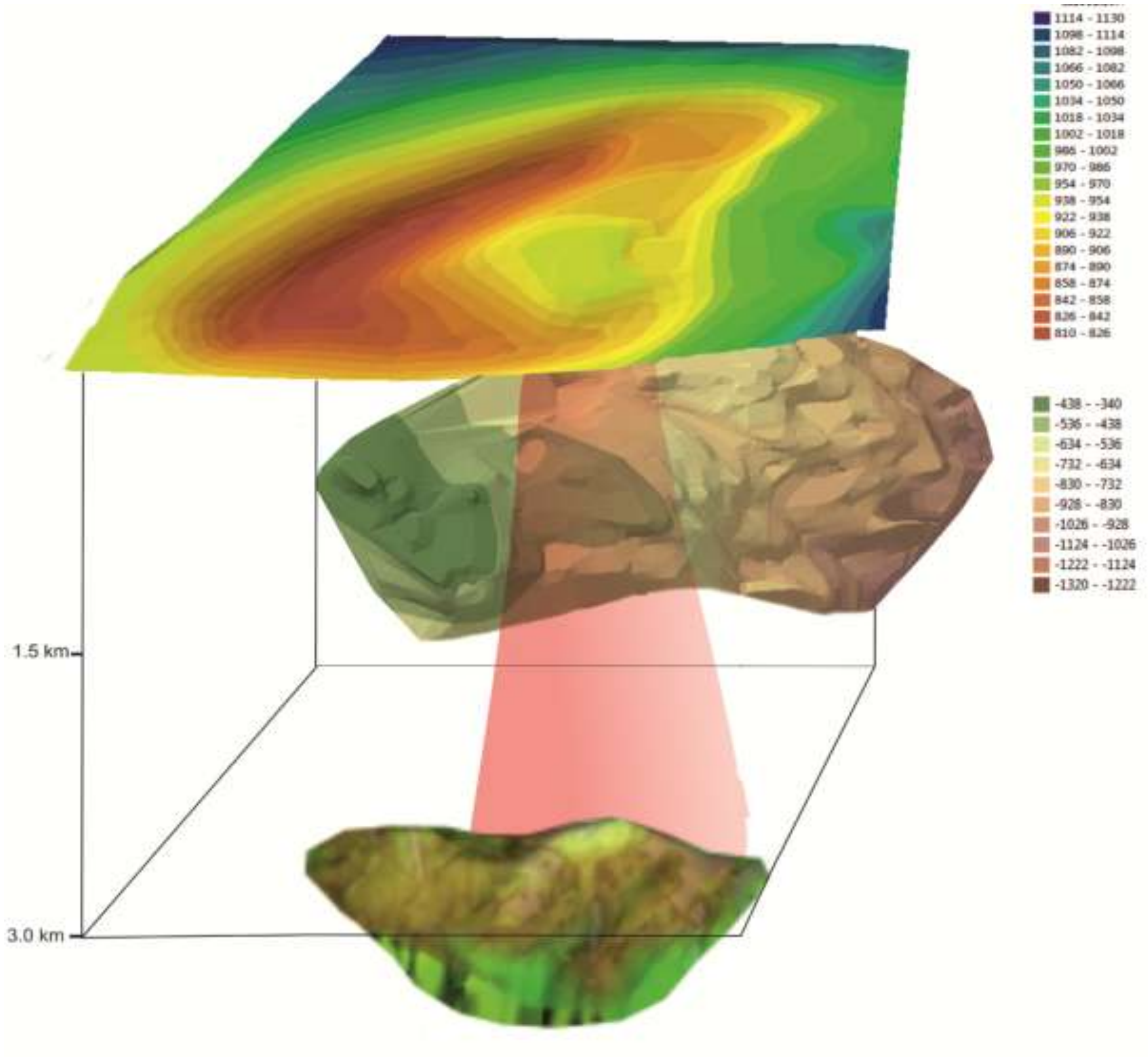

Figure 1. Regional deep tectonic-geophysical model of the Angren brown coal mine

Authors also clarified the technogenic causes of landslides on the pit walls: for example, it was confirmed which was earlier identified by B.S. Nurtaev and R.A. Niyazov (2009), the cumulative effect of distant earthquakes and explosions which carried out in the pit to activate landslides; typical seismic records of deep and crustal earthquakes were obtained - the information was identified according to the ASNN international catalog and the Institute of Seismology of the Academy of Sciences of the Republic of Uzbekistan. Seismograms of industrial explosions are valuable material, and for the first time in Uzbekistan, records of an unconventional source in seismology - a landslide (Sidorova *et al.,* 2016).

RESULTS AND DISCUSSION

Experimental seismic surveys were provided on the Naugarzan landslide with the 24-channel LAKKOLIT-24M seismic station and GS-20DX seismic receivers. Along the profile I, two full arrangements (lengths) of the streamer (each of 24 channels) were used the step between the seismic receivers 2 m. Profile length was 48 m. Weights 32 kg were used as a source of seismic waves for 5-6 shots at each point. Shots along the profile – on 1, 12, 24, channels (0, 23, 47 m, respectively). Shotpoint gaps were on -23 meters from the first channel and 23 meters from the last channel (Inatov *et al.*, 2016). According to recorded seismograms by the correlation method of refracted waves, systems of oncoming and catching hodographs were constructed, the inversion of which is represented as a seismic section along profile 1 (figure 2), which shows the geometry of the boundaries and speed parameters of the ground. Three layers are distinguished in the section: the first layer corresponds to made ground - the depth of the layer from the surface varies from 2 to 7.5 m, values of velocities of longitudinal waves V_p in the range from 239 to 393 m/s. Values of V_p waves velocities in the second layer varies from 398 m/s to 478m/s. The third layer's velocity of Vp varies from 598 m/s to 768 m/s, along the profile there are areas with highest velocity, which may indicate either a change in the density of rocks or their water saturation. The layer boundary is relatively even and is registered at 10-11m depth, varying slightly along the profile.

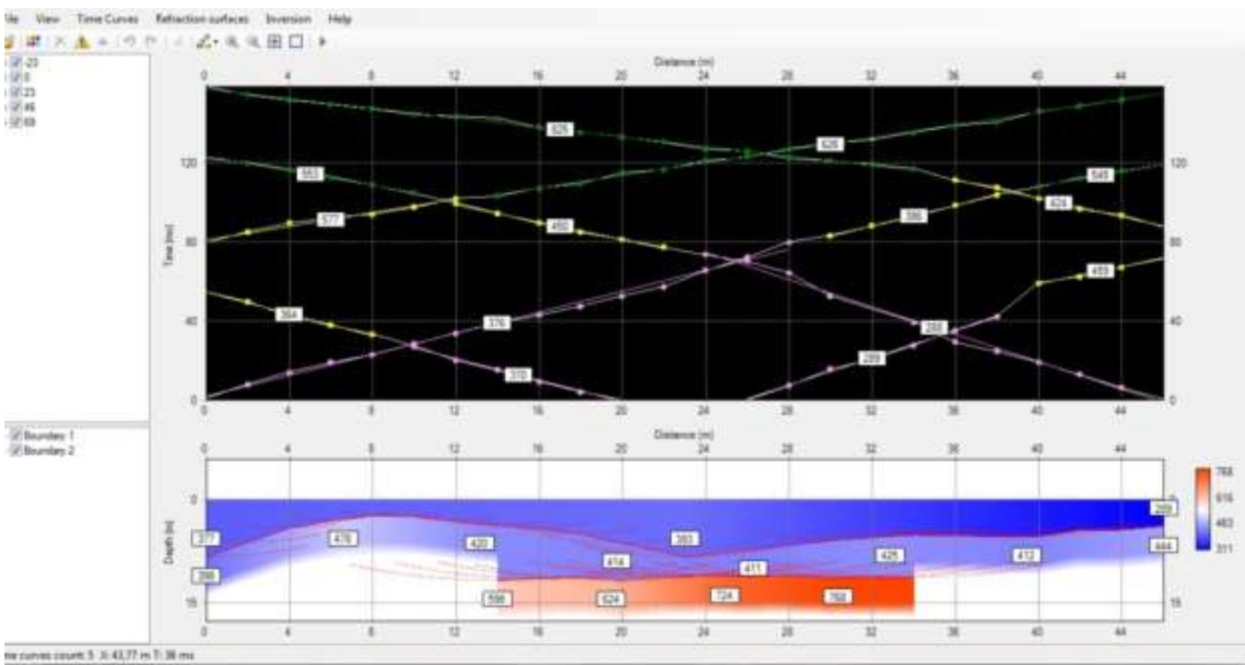

Figure 2. Seismic section along profile №1 on Naugarzan landslide

In 2017, seismic field works with a 24-channel seismic station LAKKOLIT-24M were provided on the newly formed Kokand landslide on Angren open pit (figures 3,4). Seismic sections with seismic horizons with different velocities respectively, were organized according to seismic data processing.
According to recorded seismograms by the correlation method of refracted waves, systems of oncoming and catching hodographs were constructed, the inversion of which is represented as a seismic section along profile 2 (figure 5).

International Journal of Geology, Earth & Environmental Sciences ISSN: 2277-2081
An Open Access, Online International Journal Available at http://www.cibtech.org/jgee.htm
2019 Vol. 9 (3) September-December, pp. 1-7/Sidorova and Sakhobidinov
Research Article

Figures 3, 4. Kokand landslide on Angren open pit

Three layers are distinguished in the section: the first layer corresponds to ground - the depth of the layer from the surface varies from 1.5 to 2 m, values of velocities of longitudinal waves V_p in the range from 239 to 393 m/s. The second layer with velocities of V_p from 853 m/s to 1336 m/s is represented by newly formed Kokand landslide, with varying thickness from 5 to 15 m at the center of profile. Velocity of V_p in the third layer varies from 1818 m/s to 1842 m/s, which characterizes the denser rocks along which the landslide moves. According to seismic data, it was possible to confidently identify fractured and weathered rocks.

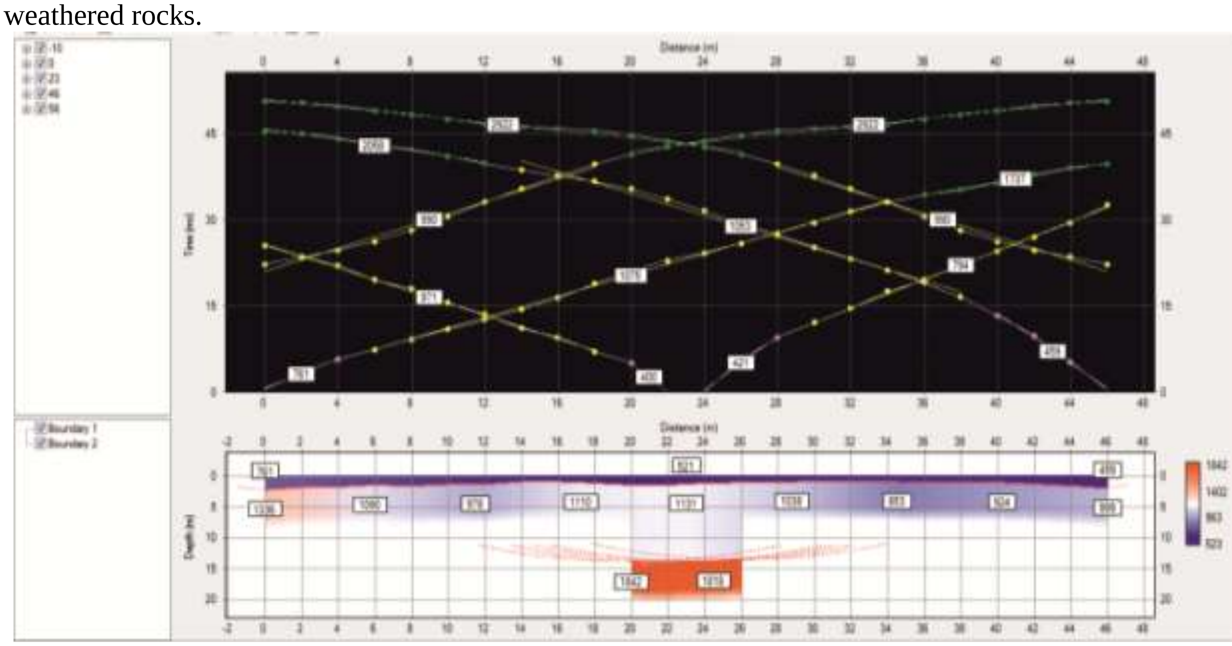

Figure 5. Seismic section along profile 2 on Kokand landslide

In addition, we modeled the movement of the Kokand landslide using the RAMMS software package. RAMMS (RApid Mass Movements Simulation) is a state-of-the-art numerical simulation model to calculate the motion of geophysical mass movements (snow avalanches, debris flows, rock-falls) from initiation to run out in three-dimensional terrain. It was designed to be used in practice by hazard engineers who need solutions to real, everyday problems. It is coupled with a user-friendly visualization tool that allows users to easily access, display and analyze simulation results. RAMMS was developed by the RAMMS program team at the WSL Institute for Snow and Avalanche Research SLF (Nurtaev *et al.*, 2017).

The physical model of RAMMS Debris Flow uses the Voellmy friction law. This model divides the frictional resistance into two parts: a dry-Coulomb type friction (coefficient μ) that scales with the normal stress and a velocity-squared drag or viscous-turbulent friction (coefficient ξ). The frictional resistance S (Pa) is then

$$S = \mu\rho H g cos(\varphi) + \frac{\rho g U^2}{\xi},$$

Where, ρ is the density, g the gravitational acceleration, φ the slope angle, H the flow height and U the flow velocity. The normal stress on the running surface, $\rho Hgcos(\varphi)$, can be summarized in a single parameter N. The Voellmy model accounts for the resistance of the solid phase (μ is sometimes expressed as the tangent of the internal shear angle) and a viscous or turbulent fluid phase (ξ was introduced by Voellmy using hydrodynamic arguments).

In our case, the best approximation to the actual mass distribution for a landslide is obtained with loessal rocks: friction coefficient μ = 0.12, shear strength τ = 3300 Pa and density ρ=1.80 g/cm^3 (figures 6, 7).

Simulation results:

Calculated Release Volume: 591650.51 m^3

Overall MAX flow height (m): 17.88

We used parameters μ and ξ corresponding to our region: the coefficient μ = 0.18 and the coefficient ξ = 5 m/s^2.

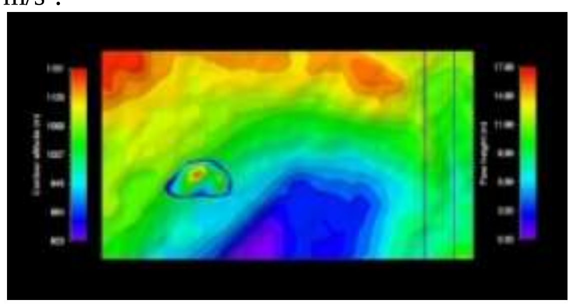

Figure 6. Initial stage of modeling in RAMMS

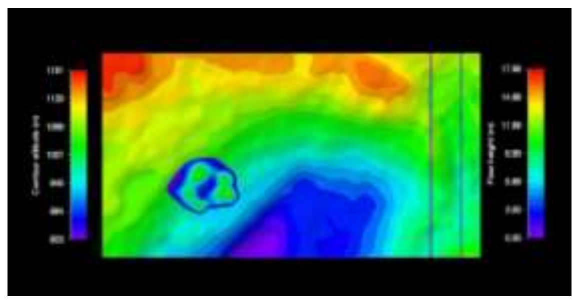

Figure 7. Disintegration of the Kokand landslide into several parts during the descent into Angren open pit contour

CONCLUSIONS

The performed studies show that geophysical methods have a number of undoubted advantages, of which we should highlight the possibility of obtaining a spatial-time assessment of the characteristics of the structure and state of rock massifs, have technological and renewable measurements, as well as the ability to control the volumes of landslide bodies of various scale levels. To the greatest extent, these requirements are satisfied by seismic monitoring, the methods of which are practically invariant relatively to the scale of the studied landslides.

The analysis of recorded seismic events in a logical sequence allowed us to identify and record the cumulative effect of distant earthquakes (identified by international catalog) and local explosions carried out in open pit on the activation of landslide movements, in particular, the newly formed Kokand landslide massif. The dynamics of Kokand landslide movement on RAMMS program are simulated. As a result of studies based on the identification of seismograms over time, the cumulative effect of earthquakes and industrial explosions carried out in open pit on the landslide movement activation has been established, and additional seismograms have been recorded with a characteristic type of seismic records, which unconventional type of source in seismology is – landslide.

During the time of researches provided experimental seismic field works with seismic station LAKKOLIT-24M, as a result, method of providing seismic surveys on landslides of Angren brown coal open pit and method of processing experimental seismic data have been created. As a result of the experimental work with LAKKOLIT-24M seismic station on Naugarzan and Kokand landslides, seismic sections were organized, in which revealed landslide horizons covered by loose bulk soil — buttress that can be activated in the autumn-spring period, i.e., come into motion.

Method which is developed at the laboratory "Structure of Lithosphere" for studying landslide activity, allowed to determine the main landslide-forming natural and man-made factors, identify the most landslide occurring geological formations, observe movement of development of landslide processes. Researches results show that methods of sensing the geological environment based on a combination of remote and ground geophysical surveys and geo-information systems valuable information has been obtained as a result of comprehensive coverage of influencing factors in the identification and characterization of individual landslides.

In the process of providing scientific researches using the seismic monitoring on Angren open pit, the software in the programming language “Wolfram Mathematica 7” has been developed, which makes it possible to divide seismic P and S waves by mathematical modeling. On the basis of synthetic seismograms we (Sidorova *et al.*, 2017) showed that by means of in the mind's eye rotations of the axes of the seismic receiver for the seismograms with superimposed P and S waves, we can obtain a seismogram with “clear” components of P and S waves. This allows to more accurately determine beginning of the first arrivals of P and S waves and their values on the seismograms. The values of these velocities inform about the intensity of the geological environment and, thus, can be indicators to predict approaching tectonic hazard. Certificates of the Agency for Intellectual Property of the Republic of Uzbekistan for software products "Division of P-S" from 15.06.2017 for №DGU04477 and "Division of 3D P-S" from 18.05.2018 for №DGU05454 have been obtained.

REFERENCES

Bakhtiar Nurtaev, Nurbek Inatov, Diyor Nurtaev, Dilshoda Kurbanova, Yves Buhler (2017). Numerical simulations of mudflow movements using RAMMS: HILLSLOPE Software: a case study from Uzbekistan. Abstract Volume 15th Swiss Geoscience Meeting. Davos. 249-250.

Butovskaya EM, Nechayev YuV, Florentsev VI, Shubina MYu, Goltseva TM, Surov VP (1977). Seismological works report provided with stations “Zemlya” within Lashkirek ore field and Kamchik trough in 1975-1977. *Library materials of IGG, Tashkent*.

DECO Geophysical SC (2016). Plus-Minus Method of Refraction Seismic Data Analysis in RadExPro Software. *Moscow State University Science Park 1-77 Leninskie Gory Moscow 119992, Russia*. *Available: http://radexpro.com/wp-content/pdf/tutorials/EN_Tutorial_Refraction_161128.pdf*

Inatov NK, Sahobidinov RI (2016). Seismic method using for study geological hazards on Angren brown coal mine. *Young scientists meeting “Geopokolenie XXI veka”*. *Tashkent*. 75-77.

Sahobidinov RI, Sidorova IP, Inatov NK (2017). Seismic monitoring of landslide hazard on Angren coal mine (East Uzbekistan). Proceedings of the VII International Symposium. *Problems of Geodynamics and Geoecology of Intracontinental Orogen*s. June 19-24, Bishkek, 191-193.

Sidorova IP, Inatov NK, Sahobidinov RI, Isroilov KhB, Khidoyatova NM, Nabieva SKh (2016). New results of seismic monitoring of landslide hazard on Angren brown coal mine. *Geology and mineral resources*. 6 56-60.

Sidorova IP, Rajapov L, Nabieva SKh (2017). Certificates of the Agency for Intellectual Property of the Republic of Uzbekistan for software product "Division of P-S" from 15.06.2017 for №DGU04477. Tashkent.

Sidorova IP, Rajapov L, Sahobidinov RI, Inatov NK, Nabieva SKh (2018). Certificates of the Agency for Intellectual Property of the Republic of Uzbekistan for software product "3D Division of P-S" from 18.05.2018 for №DGU05454. Tashkent.