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Study of Structural-Geological Conditions of Landslide Processes Forming and Development of an Example of Odesa Portside Plant Territory (Ukraine)

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SUMMARY

Purpose of the work has been to reveal tectonic discreteness and assess its influence on development of deformation and displacement of rock in landslide slope on an example of Odesa Portside Plant territory. **Methodology.** Methodology of the data analysis and processing included determination of magnitude and direction of displacements, deformations and their derivatives, as well as cartographic modelling of the parameters obtained. **Results**. Based on the results of cartographic modelling performed using the data from geological drilling and geodetic monitoring, locations and typical strikes of zones of current engineering–geodynamic activeness have been established. Directions of displacement traces are controlled by diagonal directions characteristic of geological structure of the area. **Conclusions.** Spatial and temporal regularities of the deformations and landslide displacements forming and development are subordinated to structural and geological features of Odesa Portside Plant territory. The main reason of activation of deformation and landslide processes is hierarchic-block structure of the territory characterised by continuous and differentiated character of movement of geo-blocks of different order. Due to complicated spatial character of faults systems in rock mass and kinematic peculiarities of geo-deformation processes, they are to be considered in designing and building of constructions, organization and implementation of engineering-geodynamic monitoring.

Introduction. Generalisation and analysis of numerous factual data evidence that rock masses of marine and estuarine coasts in Ukrainian Black Sea area constitute complex systems desiccated by weakness surfaces and zones into separate structural-tectonic elements of different hierarchic level (Voskoboynikov V.M. et al, 1992, Cherkez E.A., et al 1996, 2006, 2012. 2014, Kozlova T. V. et al, 1998, 2001, 2013). Tectonic discreteness and block structure of rock masses, lithogeneous vertical inhomogeneity and presence of weak layers are the reasons of spatial frame and dynamically complicated structure of fields of deformation. Natural and technogenic impacts entail localization of sizes and directions of landslide displacements and their derivatives on the boundaries of tectonic and landslide blocks and in the layers of rock having relatively low strength. Meanwhile the matters pertaining to the influence of structural-tectonic features on landslide processes development are still the least studied. *Purpose of the work* was to reveal tectonic discreteness and assess its influence on development of deformation and displacement of rock in landslide slope on the example of Odesa Portside Plant territory.

Data & Methods. A set of instrumental observation methods comprising traditional geodetic measurements of vertical and horizontal displacement of surface ground reference marks and benchmarks, as well as registration of depth deformations in observation wells equipped with special mining surveillance devices (Freiberg E. et al, 2004, 2007, 2012) served as an effective instrument to identify and study block structure of rock mass and influence of lithological inhomogeneity on spatial distribution of magnitudes of deformation. Such set of observations was for the first time performed in the region at the territory of Odesa Portside Plant (operating since 1978) located on the landslide slope of Malyi Adzhalykskiy Estuary right bank (Figure 1A). Three organisations participated in equipping and performing of observations, as well as in data analyses: Chornomorndiproject, Odesa, Ukraine; Vedeneev VNIIG, Saint Petersburg, Russia; and Odesa National I.I. Mechnikov University, Ukraine.

For morphometric analysis of surface relief of the main stratigraphic units (Meotian clays, Pontian limestones, Pleiocene red-brown clays) in the territory of Odesa Portside Plant the data received from drilling (1973 -2010) of 117 deep observation wells were used. Cartographic modelling was used as methodological basis to study structural features of the territory and to reveal gradient zones in the relief of stratigraphic surfaces (Cherkez E.A. et al, 2014, Kozlova T.V. et al, 2017) (Figure 1B).

Geodetic observations of vertical and horizontal displacement of ground reference marks and benchmarks at the territory of Portside Plant were performed by Chornomorndiproject Institute from 1980 to 2017. Five cross-section profiles comprising 148 geodetic stations were orientated downhill towards the Estuary. Four longitudinal (along the coast) sections included 315 geodetic stations and were situated on berms of the slope with marks +26.6 m, +9.3 m and +1.7 m (Figure 1B). Methodology of data processing and analysis involved determination of magnitude of the displacements, deformations and their derivatives and cartographic modelling of the parameters received (Cherkez E.A. et al, 2006, 2014).

Observations of deep deformations of the slope rocks were performed using 4 observation wells 38 - 42 m deep located on berm of the slope with marks +9 m (Figure 1B). The wells were drilled in Meotian rocks represented by clays with sand and sandy loam strata. Deformations were registered using surveying projectometer PM-100 (Freiberg et al. 2004) on the results of fore-and-aft axes survey of the wells cased with polyethylene casing. Projectometer was used to determine horizontal projection of deviation of points on fore-and-aft axes in relation to spacing (downhole). During the period from October 2000 to October 2010, 20 cycles of instrumental measurements were performed (twice a year – in June and October). In each cycle of instrumental measurements, magnitudes of displacement of axes points' projection were determined for the 4 observation wells with depth interval of 2.0 m. The main tasks of the instrumental observations were to determine magnitude and dynamics of displacements, as well as to reveal the depth of the zone of potential landslide displacement surface forming (Freiberg et al. 2004, 2012, Cherkez at al. 2006, 2012).

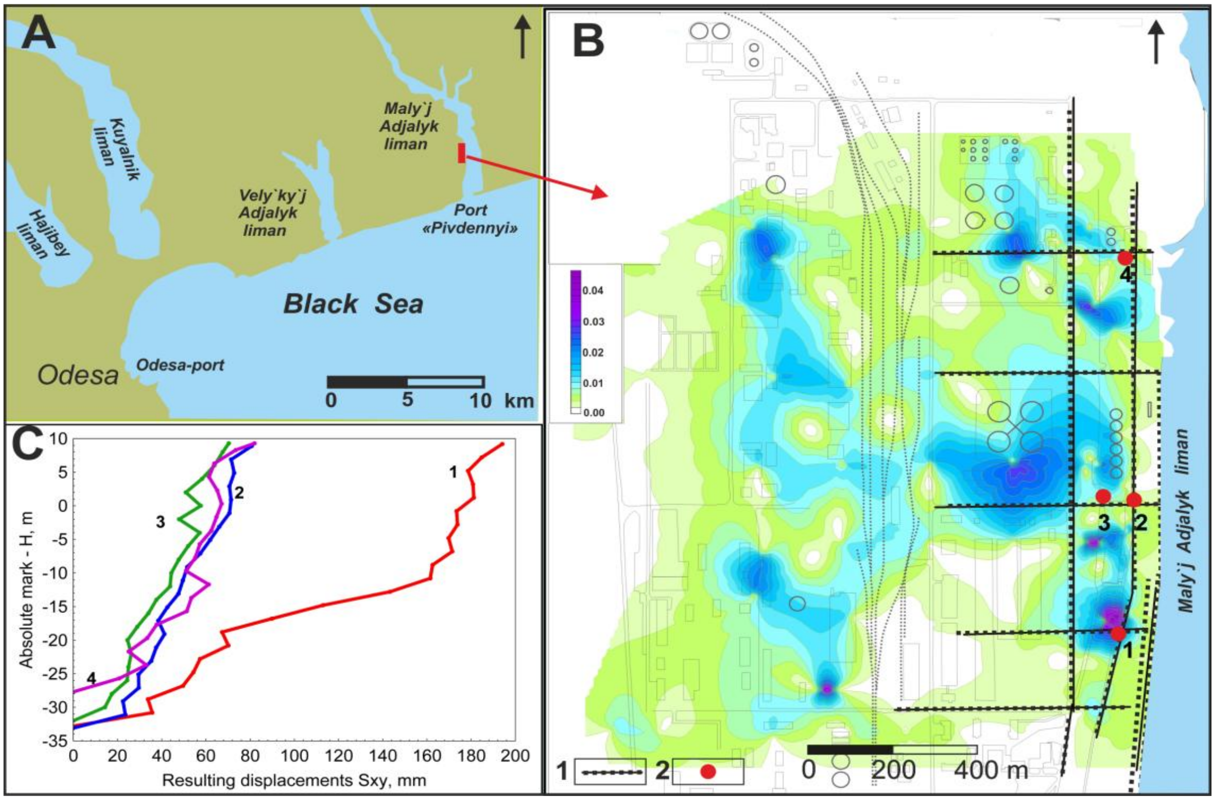

Figure 1. A – Location map of the studied area; B – map of absolute surface relief gradient of Meotian clays; 1 – geodetic profiles and cross-sections, 2 - observation wells and their numbers. C – accumulated resulting displacements (Sxy, mm) in the wells Nos. 1 – 4 for the period of observations (October 2000 – October 2010).

Results. Cartographic models based on drilling material analysis reflect geological structure of the territory and reveal showings of boundaries of different scale geo-blocks' differential movements. The main attention was focused on study of Meotian layer clay's relief as, being the main deformed horizon, these depositions play a key role in forming and development of deformation processes and landslide displacements. The most informative method to study structural features of the territory is cartographic modelling based on the identification of gradient zones, i.e. the zones where abnormally quick changes of elevation marks in any direction are observed (Cherkez at al, 2014). Cartographic modelling results are generalized in Figure 1B showing the map of absolute gradient of Meotian clays surface relief calculated as a sum of gradients in the directions 'south-west – north-east' and 'south-east – north-west'. It is known that in zones of maximal gradient where abnormally quick changes of relief marks in any direction are observed, the most intensive deformations could be concentrated – unlike the space inside geo-blocks where possible deformations and variations of stress pattern are less distinct (Cherkez E.A. at al, 2013, Kozlova T.V. at al, 2013).

Cartographic modelling based on data of geological drilling enabled us to establish locations and typical trending of the zones of possible modern engineering-geological activation. Based on geodetic monitoring data the map of distribution of vertical displacements' absolute maximal gradient was built. On the map this parameter formed two systems – diagonal and orthogonal (Cherkez at al, 2014), i.e. the systems similar to those found on the gradient maps of Meotian overlying bed relief. However, the map built using the data of geodetic observations shows distinctively smaller specific intervals between gradient zones. In this case 'blocks' and 'zones' have intervals 100 m and less. This is probably due to higher sensitivity of geodetic monitoring data compared with data on Meotian relief. It should be stressed that the planned

'picture' of benchmarks horizontal displacement is identical to the character of vertical velocities distribution. In general, the results of cartographic modelling based on geodetic monitoring data evidence the hierarchic-block structure and show gradient zones of displacement and deformation with diagonal directions typical of geology of the territory.
Analysis of data from instrumental observations of deep deformation of rocks in observation wells shows that in the period 2000 – 2010 the most significant displacements (up to 200 mm) are registered in well No. 1 where at the depth -11 ÷ -18 m a zone of shear deformation has been formed (Figure 1B). General character of displacement distribution curve for this well shows that below this zone the shear deformations die out and acquire a character of angular beveling. In wells Nos. 2 – 4 displacements (up to 70 – 80 mm) evenly die out with depth and are not localized along a single displacement surface. Data of the registered displacement of fore-and-aft axes points' projection for the wells Nos. 1 - 4 in the direction of X and Y axes were used as coordinates to build planned displacement traces, the quantity of which correspond to the number of measurements at different depths (Figure 2). Each trace consists of vectors whose quantity corresponds to the number of observation cycles in well. All the traces look broken and step-shaped as the result of changing of displacement direction 30° - 60° - 90°. At generally south-eastern direction of the displacements, component of displacement along X or Y axis could prevail in some periods.

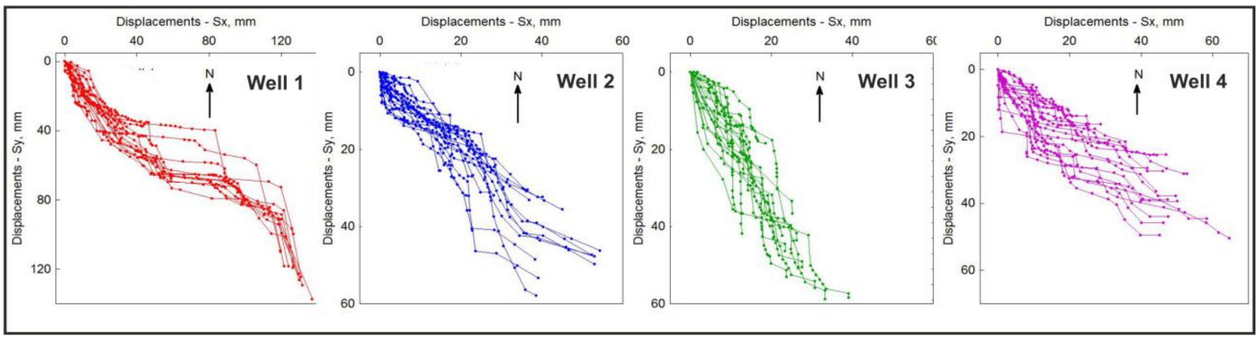

Figure 2. Displacement traces of axes points' projections for observation wells Nos. 1-4 from October 2000 to October 2010. Dot on a trace line corresponds to an observation cycle

Comparison of typical displacement traces directions of well axes points' projection with main directions of Meotian clays relief gradients – erosion cuttings of the Malyi Adzhalyk Estuary valley – shows that the identified selectivity in the directions of deformations and displacements of rocks in the territory of the Port Plant is controlled by diagonal directions characteristic of geology of the area, while current activeness of these zones is supported by continuous and differentiated character of movement of the different in scale geo-blocks.

Conclusion. It has been established that non-homogeneity of geological environment consisting in its micro-block structure plays a significant role in forming and development of deformation processes. Extreme gradients of deformation and displacement are typical of inter-block zones and are caused by differential character of blocks movement. Directions and magnitude of shearing deformations and landslide displacements are subordinated to structural and geological features of Odesa Porstside Plant territory. Complex spatial character of faults systems in rock mass and kinematic peculiarities of geo-deformation processes cause the necessity of their taking into consideration when designing and building constructions, organizing and implementing engineering-geodynamic monitoring.

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