THE LANDSLIDES OF CHEBOKSARY POVOLGYE AND PROBLEMS OF CLASSIFICATION OF LANDSLIDE SYSTEMS

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ABSTRACT. The landslides of Cheboksary Povolgye and problems of classification of landslide system. The construction of a cascade of hydropower stations on the River Volga caused the radical transformation of the natural and technological conditions and activated geomorphic hazards. Besides, landslide triggering factors are: lithological, stratigraphical, geomorphological, and new factors is increased weight of the banks slopes as new factors of landslides. The results of landslide investigation in Cheboksary Povolgye are presented in the paper. The unified classification of landslides is submitted. At first it includes all their nature types with peculiarities of structure and displacement of landslides body. It based on own features of landslides, which was distinguish by system analyses.

Key words: geomorphic hazards, landslide, slope stability, reservoir banks, classification of the landslides, level of organization of landslides bodies, block, cycle, storey and multistory landslide, landslides taxonomy, structure and mechanism of landslides, cinematic computation model.

1. Introduction

Chuvash Republic (Russia) and its capital Cheboksary are situated in the Volga River basin, on Privolgsky upland (Plato). The depth of its erosion dividing more than 200 m, and some river banks are up to up 100 m high. Construction of the Cheboksary dam and the reservoir impoundment changed the style of its slopes evolution and bank erosion. So, instead the erosion–landsliding types of banks were formed abrasion–landsliding types especially on the right bank of the river Volga. It results in the activation of old landslides and in creation of new ones. The sliding slopes of the Cheboksary reservoir are lead to considerable damages in urban agglomeration. The right bank of Cheboksarsky reservoir in our town is defended by concrete constructions, but the new landslides appear in the upper part of the slope. Outside concrete construction landslide processes are gripping whole slope from foot to the top.

The high right bank of the River Volga from Nizhniy Novgorod to Volgograd is known as an area of intensive landslide, processes described in the scientific literature (I.S. Rogozin, G.S. Zolotarev, A.P. Dedkov, etc.) This area concentrates a considerable part of Russia's population and has an industrial and

agricultural potential. The right bank of the River Volga shows various exogenous processes, first due to the backwater effect of the Cheboksary hydropower plant, second to the geological, meteorological and geomorphic conditions, and third to the anthropogenic factor, the others being the result of a combination of factors. So, the problems of slope stability are very important here.

2. The matter of classification.

In Povolgye there are different groups of landslides: extruded, gliding, streaming and particular forms. In terms of sliding mechanism there are simple landslides (one-block and one-cycle) and complex landslides (multi-blocks and multi-cycles). In terms of morphology, there are frontal and cirque forms. By age and slope stability one finds active and stabilized forms, old stabilized rock-slides, open and covered landslides. A structural block sliding landslips represents such forms as mud-streams and mud-flows. Some these forms are present also in Cheboksary Povolgye.

More than 30 years later, when one of the authors - N.F. Petrov begun his investigation of the landslides during his work in Moldavian Republic, he understood, that the main problem in the landslides studies is the absence the unified classification of landslides (UCL) and conventional apparatus of notions. The history of studies show that the appearance of science classification of objects usually proceeded for transition from empirical to theoretical period of investigation. Now the landslides investigation has a lot of classification. We agree with G.I. Ter-Stepanyan (1984), who said, that simultaneous coexistence the large numbers of classifications is equate to its absence. Therefore, during more than 100 years, since A. Baltzer (1875) the landslides studies exist without classification, on empirical period. So it will be interest to introduce with our version of systematic of landslides, which was worked out in 1975-88 years, and was verified by time. This version was based on critic analyses of exist schemes and now will be present as the doctoral dissertation.

Investigation of the Cheboksary Povolgye landslide slope was prompted by building developments in the area. The authors used their own methodological projects, defined with greater precision such notions as *landslide, landslide process, landslide mechanism*, and put forward a set of taxonomic principles for simple and complex landslide systems. We consider the landsliding process as the separation of the part of rocks and soils, which set down the slope with preservation the material connection with its base. Landslide – is the system of rock's or soil's bodies with certain structure, dynamic and other features, which are formed under the landsliding process. Landslide – is the specific geological body which is formed under the landsliding process as the result of separating and displacement the part of rocks which set down the slope. The specific features of

landsliding process are: 1 -Appearance the stripping side; 2 -Preservation material connecting with surroundings.

For the construction of the landslides classification were investigate more than 150 features of the simple and complicate systems. Several of them are represented on figures 1-4. The fig.1 shows the structure elements of landslides, some of them leading and dependence, another inside and outer by their role in functioning of landslides systems. The real landslides consist of these elements and their combinations and they may be the simple and the complicate landslides. The main indication of the simple landslides is the features of the displacement. The main indication of the complicate landslides is the features of structure.

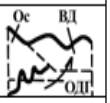
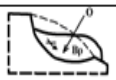
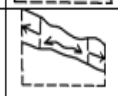
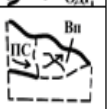
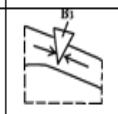
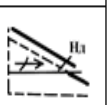
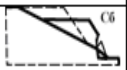
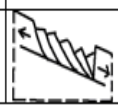
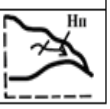
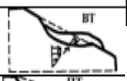
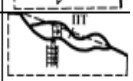
Leading, main elements				Inside dependence elements				Outer dependence elements (tongue)			
№	Name of the block	Index	Model	№	Name of the block	Index	Model	№	Name of the block	Index	Model
1	Subsi-dence	Ос		7	plastic compres sion	Сж		11	extruding	Вд	
2	Rotaion	Вр		8	plastic extension	Рс		12	protrusion	Вп	
3	flat sliding	ПС		9	fragile compresion (thrust block, horst)	Вз		13	trust	Нд	
4	fault	Сб		10	fragile extension (graben)	Рс		14	excrescence	Нп	
5	viscous flow	ВТ									
6	plastic flow	ПТ									

Fig. 1. *The least structure elements of the landslides systems – landslides block*

The fig.2 shows all the nature kinds of simple landslides. They represented by 12 types, which unites into 4 groups and then into 2 subclass and then into class of landslides. These types of simple landslides are form in nature a lot of number of combinations or complicate landslides of the different hierarchic level of organization.

They divide into one-cycle landslides (fig.3) and multycycle. The multycycle landslides divide into one-storey and multistory landslides (fig.4).

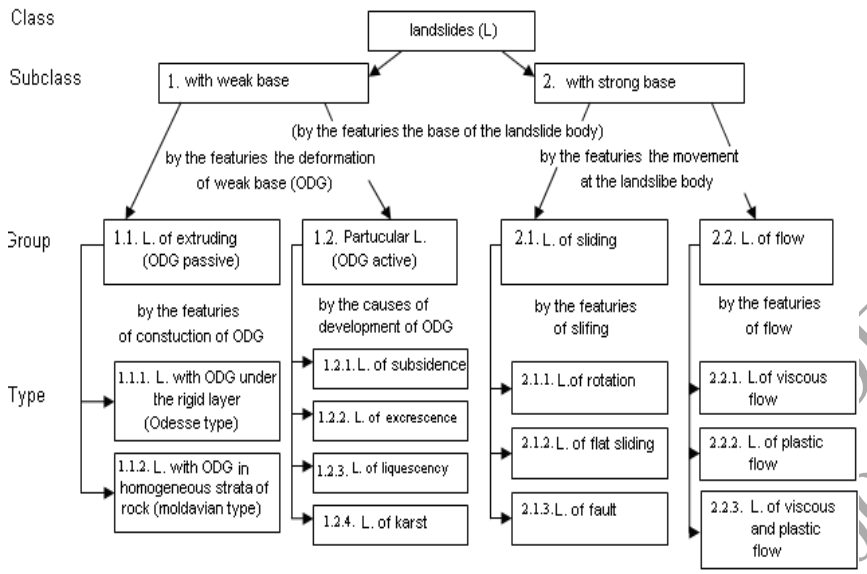


Fig. 2. *Classification of simple landslides.*

Landslides are the slope occurrences which formatted by displacement the part of the massive with making the shear band and without the isolation from own bed.

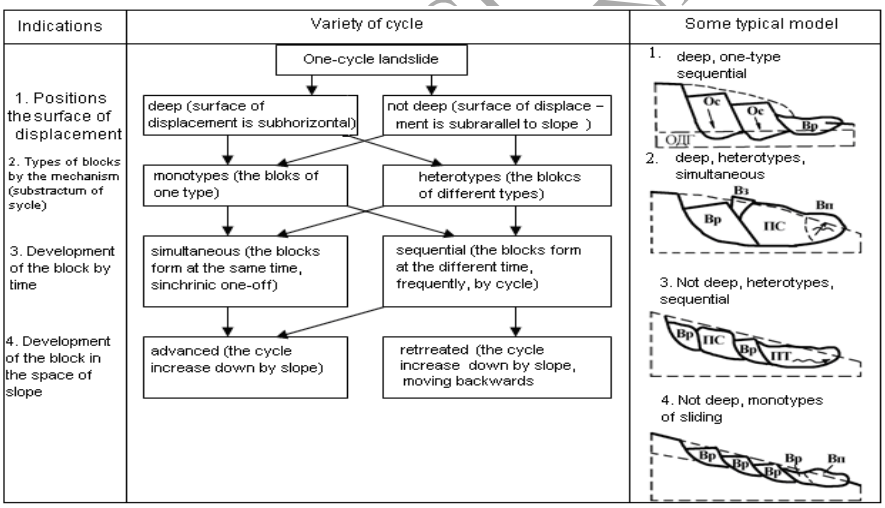


Fig. 3*. Classification of one-cycle landslides (the legend on fig. 1).*

For the first time landslides were classified by the features of the movement and the causes of deformation of the slope. This classification was made

for the simple landslides. The main taxonomic role in classification plays the features of structure. So they divide into 4 hierarchic levels from one-block to multistory landslides. All these classifications are complicated into unified classification of landslides - UCL. Our classification is not the classification of slope movements or slope processes. We attempted to summarize all experience of landslides investigation. The main contribution to science made A. Heim (1882), D. Molitor (1894), A.P. Pavlov(1903), P.Almagia (1910), K.I. Bogdanovich (1913), D. Newland (1916), K. Terzagi (1929), F.P. Savarensky (1935), C. F. Sharp (1938), I.V. Popov (1946), G.S. Zolotaryov (1950), E.P. Emelyanova (1951), M.N. Goldstein (1952), N.N. Maslov (1955), G.I. Ter-Stepanyan (1958), D. Varnes (1958), K. Zaruba (1961), G.L. Fisenko (1965), M. Saito (1965), M.K. Rzayeva (1968), A.W. Skempton, J.N. Hutchinson (1969), K.A. Gulakyan and V.V. Cyuntsel (1970), A. Nemcok (1971), V.I. Presnuchin (1976), I.O. Tichvinsky (1978), etc. Some of them (Zolotaryov, Goldstein, Maslov in former USSR) made science school with own principles). The proposed classification is based on the internal characteristics of landslide structure and motion.

The structure term "cycle landslides" is known in Russian scientist literature for a long time. But the term "multistory landslides" is appeared in 1982, when G.S. Zolotaryov translated the book D. Varnes into Russian. All these terms now are used in classification of the complicate landslides. For the description of the relationship in the structure we used such terms, as: "homogenous", "combined", "equal", "subordinated", "simultaneous", "and sequential" and others. These terms comes from foreign literature, bat in our classification they has clarity and definition.

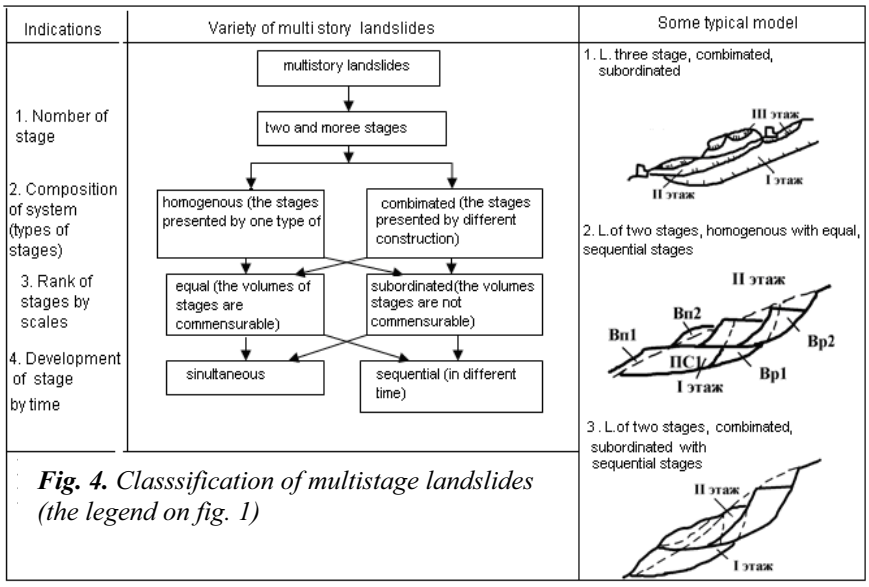


Fig. 4. *Classsification of multistage landslides (the legend on fig. 1)*

Proposed classification worked out by consecutive decision of the next three groups of methodological problems. The first group: 1) determination the object and subject of landslides investigation; 2) work out the principles (rules, aspects and aims) of system analyses of the landslides and their classification; 3) make out the indications of landslides systems for the aim of selecting the own features. The second group: 1) dividing the own indications on the groups by their role in structure and in functioning of the landslides systems; 2) ranking indications inside propose groups for the taxonomic aims; 3) setting up the nomenclature and diagnosis of the taxons of the landslides systems. The third grope: 1) dividing the simple and the complicate landslides; 2) the monographic description the taxons of the simple landslides by their mechanism; 3) the monographic description the taxons of the complicate landslides by the level of level of organization of landslides bodies – block (first level), cycle (second level), one-storey (third level) and multistory (fourth level).

With the decision of theoretical problems were decided the applied problems of landslides investigation: 1) mapping the landslides systems and their parts (fig. 5); 2) identifying the taxons of landslides in nature by their indications;

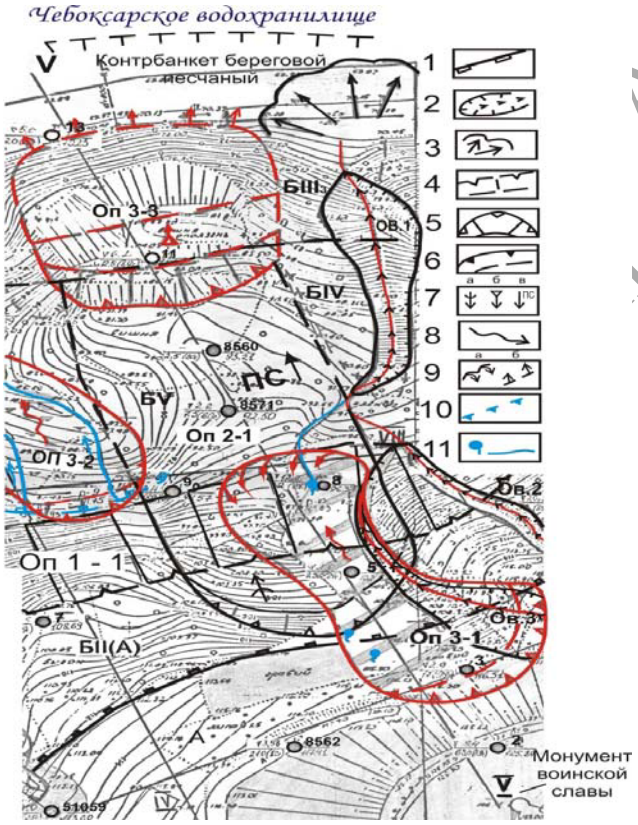


Fig.5. *Map of the Victory Park Landslide (Cheboksary). The legend of Geological map: 1 – the border of Privolgsky Plato (A) or lip of river Volga denudation slope (Б II); 2 – the growing ravine and its number (ов. 1); 3 – proluvial debris cone; 4 – 6 – shears the landslides of first, second and third order, which form 1,2,3 stages of landsliding system; 7 – the structure blocks: а) rotation, б) fault, в) flat sliding (ПС); 8 – the flow landslides; 9 – landsliding tongue: а) protrusion, б) thrust; 10 – frontal issue of underground water zone; 11 – well spring.*

3) working out the cinematic computation model, which allowed receiving optimal landslides stress and to offer the successive engineering protection measures (fig.6).

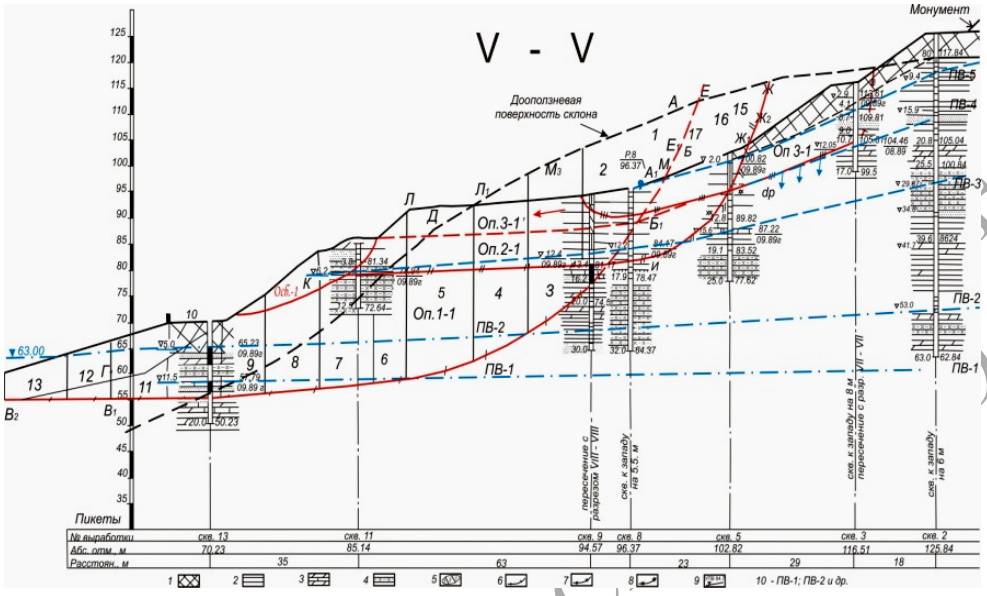


Fig. 6. *The Geological section of the 3-storey landslide system (Victory Park, Cheboksary). The legend of Geological section:*
1 – technogenous deposits (sand); 2 – 4 – the Tatarsky stage rocks (i.e. upper Perm rocks), including deformed by landslides – clay (2), limestone and marl (3), sand and sandstone interlayer (4); calculation models: 5 – calculation compartments in landslide block or cycle; 6 – 8 – the landsliding moving surfaces, which content 1,2,3 storey of landslide system; underground waters (ПВ): 9 – the level of уровень underground waters, 10 – underground waters horizons in slope.

3. Conclusions

Proposed classification worked out by consecutive decision of the next three groups of methodological problems. The first group: 1) determination the object and subject of landslides investigation; 2) work out the principles (rules, aspects and aims) of system analyses of the landslides and their classification; 3) make out the indications of landslides systems for the aim of selecting the own features. The second group: 1) dividing the own indications on the groups by their role in structure and in functioning of the landslides systems; 2) ranking indications inside propose groups for the taxonomic aims; 3) setting up the nomenclature and diagnosis of the taxons of the landslides systems.

Fig.7. *The head part of multistory landslide in Cheboksary*

Fig.8. *Landslidig slope of Cheboksarsky reservoir*

The third grope: 1) dividing the simple and the complicate landslides; 2) the monographic description the taxons of the simple landslides by their mechanism; 3) the monographic description the taxons of the complicate landslides by the level of level of organization of landslides bodies – block (first level), cycle (second level), one-storey (third level) and multistory (fourth level).

With the decision of theoretical problems were decided the applied problems of landslides investigation: 1) mapping the landslides systems and their parts; 2) identifying the taxons of landslides in nature by their indications; 3) working out the cinematic computation model, which allowed receiving optimal landslides stress and to offer the successive engineering protection measures.

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