

Geocological aspects of the underground erosion development in loessial massifs of Uzbekistan

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Abstract. The problem of the development of the underground erosion is considered in the article. The most brightly the underground erosion is shown in the massifs of the loessial breeds, which are widely developed in Uzbekistan. This phenomenon of consequences of the underground erosion development is described in science as the term "loessial pseudo-karst". The loessial pseudo-karst have received the greatest spread and development in places of an active technogenesis since the second half of the XX century. Besides the territories connected with civil, industrial and hydrotechnical engineering the loessial pseudo-karst develops actively in the connection with active irrigation of the massifs formed with the loessial breeds. In case of not dosed water supply for the irrigation of agricultural grounds and the subsequent uncivilized dumping of surplus of water there is an extremely fast development of a loessial pseudo-karst (a day and even several hours). The negative consequences of the development of the underground erosion in loessial massifs lead to the violation of fragile balance of the natural and technical geosystems (NTG) and their conclusion from the condition of metastable balance. When forming pseudo-karst sinkholes near settlements, their unreasoned elimination by filling happens generally at the expense of solid and liquid household waste that considerably accelerates process of destruction of the massif, due to the impact on the loessial breeds of aggressive infiltrate. In case of active development of the underground erosion there is a final fracture of the loessial massif and formation of so-called pseudo-karst "bedlend", that is sites where any economic activity is impossible. There are considerable economic, ecological and quite often social damages. It is easier to prevent a loessial pseudo-karst, than to fight against after its development has begun. The lack of due consideration to this promptly developing process annually causes the necessity of recultivation of the soil massifs broken by an underground erosion (pseudo-karst) or to the conclusion from the crop rotation of the most valuable irrigation lands in arid areas. The qualitative recommendations about the prevention of the development of a loessial pseudo-karst and minimization of damage are made.

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1 Introduction

The mankind promptly develops and grows. That means the increase in the population on the Earth, as well as the level of technical equipment of the modern person and opportunities of increasing transformation of the environment for the escalating requirements. Using equipment, creating multimillion cities, industrial complexes, cascades of reservoirs, dam systems, human began to pump water to the territory which have never accepted water earlier (earlier not irrigated). This process of change of natural complexes as the result of production activity of the person is known in the scientific literature as technogenesis. Since the beginning of the 20th century the activity of technically armed mankind became comparable to the geological forces changing the image of the Earth. As this process is connected with the ensuring activity of society, life and necessary activity of people (growth of population, development of technology and cultures, receiving necessary means for maintenance of processes of metabolism of the person), it is inevitable.

Such a widely developing process as the erosion is also connected with the active technogenesis. It is especially relevant for the pedosphere which is the first to assume the "erosive blow". The erosion of soils is one of the main global problems of mankind during the era of a technogenesis. It not only threatens the food security, but also threatens the steady functioning and even existence of biogeocenoses. However, the erosive process is not always visible and available to observation. It concerns, the so-called, underground erosion when destruction of an array happens below the Earth's surface. We can judge on its existence only by change of the relief of the surface. The phenomenon of the underground erosion in the initial stage include local sedimentations of the land surface, single funnels (ponor) or chains of funnels, sinkholes, or the formed debris cones in places of carrying out of the material destroyed by the underground erosion.

Nowadays many specialists consider that the underground erosion is a kind of suffosion. Suffosion is the process of destruction and carrying out by a flow of underwaters of separate components and large mass of the disperse and hardpan detrital breeds including composing structural elements of rocky arrays. F.V. Boilers (1978) [1] considers the erosive destruction of soil proceeding below the Earth's surface as the term "underground erosion". According to J. Hutchinson (J. Hutchinson, 1981) [2], the first published information on the underground erosion appeared in Great Britain in the end of the 18th century. Nowadays, there are two main directions in the research of this process.

The first direction is concentrated on studying of the underground erosion of natural origin proceeding in natural rock masses. The second direction studies the underground erosion developing within the natural and technical geosystems (NTG), mainly on objects of hydrotechnical construction for which this process constitutes serious danger. Besides, catastrophic influence of underground erosion is connected with the agricultural land reclamation.

The process of the underground erosion at agricultural land development, is shown most visually in the loessial arrays, despite its "stealthiness" from direct observation. It is the so-called, loessial pseudo-karst.

2 Materials and Methods

Loess is a geographically zoned formation, adapting to each concrete situation to the surrounding geographical environment [3]. About 10% of the surface of the continents of the Earth are covered with loessial breeds. The biggest arrays of loessial breeds are known in China where the power of loess deposits is maximum (up to 500 m) [4]. They have also gained broad development in Central Asia. Active use of natural resources of Central Asia and the requirement of environmental protection increasing in this regard makes the

complex studying of loessial deposits one of the most relevant directions of the research. The loess of sufficient power, covers more ancient, as a rule, neogene deposits, carrying out foothill and intermountain hollows. The exclusive fertility of farmlands, concentration of a great number of the population, and, as the result, construction of industrial and civil facilities is connected with this unique natural formation, dense network automobile and the railroads. Loessial breeds represent the substrate consisting generally of large and dusty particles, having some valuable properties and specific engineering-geological features which distinguish it in an enormous variety of deposits of the Quaternary Period. In fact, such ephemeral properties of loessial breeds as the insufficient compaction, low humidity, existence of unstable structural bonds, etc. are connected, first of all, with the climate, the nature of the relief and activity of live organisms. For example, the drawdown rate which is the characteristic property of loessial breeds remains only in areas with the radiation index of dryness R/Lr of more than 1 and less than 3 ($1 < R/Lr < 3$) where R is the radiation balance of kcal/cm^2 ; L is the latent heat of evaporation in kcal/g in a year; r is the sum of rainfall in g/cm^2 in a year; Lr is the sum is warm, annual precipitation, necessary for evaporation, expressed in kcal/cm^2 . If R/Lr values are less than 1, the climate becomes more humid and the processes of sag and the pseudo-carst formation do not remain as a rule [5]. During the development of new territories, against the background of large-scale development of the irrigation on earlier droughty loessial arrays, the developed natural balance is broken for centuries. Underestimation of danger of technogenic impact of human on loessial breeds during the irrigation of lands leads to the active development of a wide range of dangerous geological processes. These dangerous geological phenomena work in the paragenesis quite often. For example, in the coastal zone of reservoirs put by loessial breeds landslide process quite often initiates development of the loessial pseudo-karst; that finally accelerates abrasion several times.

The underground erosion is shown in the rather friable and not strongly condensed loessial breeds most actively. The particle density of soil is $2.67 - 2.7 \text{ t/m}^3$, with an average of 2.68 t/m^3 . The maintenance of carbonates (calcite, dolomite, siderite) - from 8 to 24% with the average value of 12%. In case of the maintenance of carbonates more than 20% the loessial pseudo-karst develops extremely slowly as the loess sated with a carbonate difficult gives in to fast washout. At a small amount there is a terrigenous plaster, the number of readily soluble connections no more than 1.5%. Deformation characteristics of loessial soil substantially are defined by humidity. At weight humidity up to 0.12 module of deformation, as a rule, does not exceed 200 MPas, coupling less than 1 kgf/cm^2 . The porosity more than 45% contributes to the development of a loessial pseudo-karst. Porosity coefficient not less than 0.7. At increase in humidity - the porosity and strength characteristics of the loess significantly decrease and the underground erosion develops extremely poorly, manifestations of a loessial pseudo-karst are insignificant and do not reach the big sizes [3, 5, 6, 7].

Loessial breeds are widely developed in Uzbekistan lying in the form of an integumentary cover in terraced surfaces and foothill plains. Places of transition from the leveled surfaces to mountains in Central Asia are named "adyr". Quite often plashcheobrazny bedding of loessial breeds is observed at tops of the isolated watersheds that certainly confirms their aeolian origin [8, 9].



Fig. 1. Deep trench which was beaten out by wheels and hoofs of animals in the soft loess which is scattered in dust and arried away by wind. (Drawing from the book *China* by F. Rikhtgofen, 1887) [8].

The problem of loessial pseudo-karst exists for more than 135 years. For the first time we find the description of unusual forms of destruction of loessial arrays in monumental work of Ferdinand Rikhtgofen *China* (1877) where the author describes very peculiar forms of destruction of loessial arrays not only as a result of a superficial, but also underground erosion [9] (fig. 1). Describing unusual forms of the erosion F. Rikhtgofen for the first time notes that growth of ravines in loessial arrays goes not according to the classical scheme from below up from basis of an erosion, and from top to down, from the place of penetration of water into a loessial array in a middle or upper part of a slope of a loessial array. L. Fuller in 1922 described pseudo-karst forms of the relief of China accompanying all with effective photos [10]. In the USSR the loessial pseudo-karst and forms of its manifestation were studied by M.M. Reshetkin, K.I. Lisitsin, I.G. Glukhov, etc. [3].

Dealing with the problem of the loess in various regions of the world, certainly throughout all his life, Nikolai Ivanovich Krieger could not bypass this problem and. In 1975 N.I. Krieger published his work "Loessial Pseudo-karst" where he considered the history and the analysis of formation of the term as in the USSR, and abroad [3] in works PNIISA. In the same place N.I. Krieger for the first time gives classification of diverse forms of a loessial pseudo-karst. There is the whole series of articles the devoted morphology, dynamics and methods of researches of a loessial pseudo-karst [5,6,7, 11] later. In standard literature of the USSR the term "loessial pseudo-karst" for the first time occurs in item 1.8 BCH 33-2.2.06-86 [12]. In Uzbekistan where loessial arrays have wide

circulation, the works by R.H. Khalimov, M.M. Mamatkulov, H.L. Rakhmatullayev [13, 14, 15] , etc. are devoted to the problem of loessial pseudo-karst.

Loessial pseudo-karst - result of the hydromechanical, gravitational, biological and physical and chemical zone processes proceeding in insufficiently compacted loessial breeds at their excess (usually technogenic) moistening of the forms of a relief leading to education which are very reminding typical karstic (funnels, wells, sinkholes, caves, tunnels, etc.) [16] (fig. 2).

The extensive complex of abiotic, biotic and technogenic factors is necessary for the formation and development of the loessial pseudo-karst (geomorphological, climatic, soil, lithologic, biological, etc.). The loessial pseudo-karst develops if there are loessial breeds with power not less than 3-5 m, with rather high porosity, low humidity, with the low maintenance of carbonates and also a possibility of incidental penetration of water into a loessial array. A source of water includes atmospheric precipitation (a climatic factor), leak of water from hydraulic structures, not dosed watering of fields, etc. (technogenic) [5]. The question of a role of organisms in the course of forming of a loessial pseudo-karst was already brought up in literature [5.15, etc.]. It was specified that in development of a loessial pseudo-karst activity of vertebral, higher plants, blue-green, green and other seaweed is of great importance.



Fig. 2. As the result of water leak the pseudo-karst ravine within 1 day was created from tray network. Javanese valley, Tajikistan. Photo by A.A. Lavrusevich, 1987.

Broken in the course of activity of vertebral, higher plants, tectonic influences and other factors. the loessial array is rather steady even at impact of the heavy rains characteristic of arid conditions as it is protected by a cespitose cover or is reforested.

It is possible to claim that in case of the absence of technogenic load of a loessial array when loessial breeds are in a condition of metastable balance, process of an underground erosion is not characteristic and manifestations of a loessial pseudo-karst are minimum [5]. However, at artificial irrigation water, usually, is brought to fields by construction of the main and distribution channels, and on fields the network of irrigation furrows is laid. Furrow irrigation, that is a self-flowing way, is optimum for active development of a surface erosion, especially in places of dumping of water to a carrying out zone. At water infiltration deep into of an array, the initial process of a mechanical suffosion forming an

initial channel of migration of water to a carrying out zone is replaced by the underground erosion which is actively broadening the canal. The underground erosion, considerably increases diameter of the erosive channel and amount of the loessial breed destroyed and taken out by a water flow. At receipt of enough water, literally within several hours erosive channels extend and form underground tunnels and caves. If the arches of caves and tunnels do not maintain a vertical load from overlying breeds, there is a failure or funneled sedimentation of a surface. Leak in the Western branch of the Nadterechny channel (East Ciscaucasia) can be a classical example where for several days failure forms in the form of funnels and failures with a diameter up to 1.5 m have left on a normal to an axis of the channel at distance up to 900 m from its edge [16, 17]. In Tajikistan one of authors fixed forming of a pseudo-karst ravine of 5 in depth, 8 wide and more than 30 meters long, as a result of leak of water from the bringing irrigating reinforced-concrete flumes within 1 day [17] (fig. 2).

At development of a loessial pseudo-karst a peculiar pseudo-karst landscape (funnels, or chains of funnels, water-absorbing ponor) wells, tunnels, caves, circuses, ravines, etc.) is formed very reminding typical karst (fig. 3). Quite often, in places of active development of pseudo-karst and defeat of a loessial array there are residual forms of a relief: walls, columns, etc. Classification of pseudo-karst forms is offered by N.I. Krieger [3], later it is expanded and added [5 11, etc.].



Fig. 3. Type of a pseudo-karst cavity in the thickness of the proluvial loess (the valley of the Surkhandarya River) [14].

When forming negative pseudo-karst forms of the relief (failures, funnels, wells), especially in close proximity to settlements and industrial zones, "population" has an unnatural desire to dump various industrial and household waste which after filling, is leveled, rammed and poured by a layer of loams (figure 4) in these negative forms of the relief.

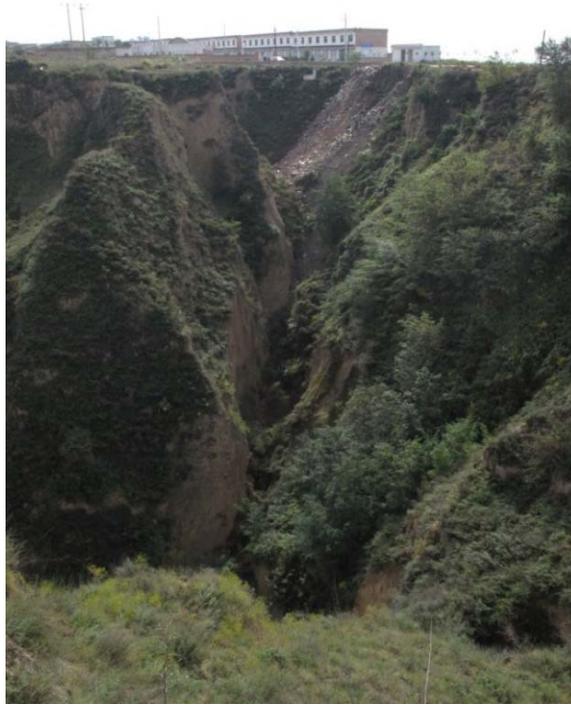


Fig. 4. Pseudo-karst ravine adjoining buildings and filling it with solid utility and household waste (Province of Gansu, China). Photo by A.A. Lavrushevich, 2010.

Unfortunately, those who make actions of this sort do not understand that pseudo-karst forms of a relief at a charge their waste not only do not stop the development, but also involve the aggressive infiltrate which is formed at filtration of an atmospheric precipitation and underwaters through thickness of waste in pseudo-karst process.

Quite often it happens to be the high-concentrated filtrate of hydro-carbonate, ammonium and sodium structure to the high content of fatty acids, heavy metals and other organic compounds. All this leads to a bigger and considerable activization of a loessial pseudo-karst.

Development of the loessial pseudo-karst leads to the violation of geo-ecological equilibrium of loessial arrays. Active development of the pseudo-karst leads to degradation of the existing natural complexes and biogeocenosis. The pseudo-karst in the irrigated agricultural territories considerably damages crops, there is a washout of fertilizers and pesticides that leads to decrease in productivity of various crops [14]. The pseudo-karst in the irrigated territories partitions a loessial array dense network of ravines that results in impossibility of their further machining, violation of the mode of watering, fertilizing introduction, to destruction of drainage and collector network and, finally, to gradual degradation of these sites of land use.

Broad development of the loessial pseudo-karst quite often leads to development of the pseudo-karst bedlend (sites up to several tens hectares of not restored lands) which rehabilitation of each hectare will involve multimillion costs (figures 5, 6).



Fig. 5. Suffosion (pseudo-karst funnels and sinkholes) on the surface of the proluvial terrace (the left bank of the Surkhandarya River) [14].

3 Results and Discussion

We can provide some very brief recommendations. Two options of the solution of the arisen problem of loessial pseudo-karst are possible: passive and active.

The passive option supposes, that actions are carried out after phenomenon of the loessial pseudo-karst on the land surface in the form of sinkholes, funnels, wells, etc. The causes of emptiness are removed. Ditches, other meliorative actions for the elimination of forming of the concentrated water flows are projected on the mountain slopes. Filling of the pseudo-solution cavities, found as the result of geophysical surveys and the subsequent drilling, with the condensed soil or concrete mix is made.



Fig. 6. Site of loessial array of the pseudo-karst complicated by the development to the condition of a bedland (the Province of Gansu, China). Photo by A.A. Lavrusevich, 2010.

The active option, represents the warning actions interfering the development of the loessial pseudo-karst. The careful waterproofing of the water bearing communications and regime observations of their state as well as monitoring of water consumption, for timely detection of uncontrollable water flow rate belongs to them.

The prevention of a loessial pseudo-karst needs the following measures:

a) to make systematic observations of the sites predisposed to development of the loessial pseudo-karst;

b) not to allow watering of fields in the self-flowing way, to introduce the water-spray equipment in agricultural production more widely;

c) to observe a watering dosage at irrigation agriculture strictly;

d) to support hydraulic structures in the appropriate technical condition, without allowing the concentrated leak of water in the soil array;

e) when dumping water from loessial arrays to control the water flow transit to the thalweg of a ravine using reinforced-concrete step flumes to energy clearing, console dumpings.

The actions for the recultivation of the loessial pseudo-karst include: silicification, heat treatment, downloading in pseudo-karst cavities of sand-gravel cement mortar, charge of pseudo-karst cavities clay soil with layer-by-layer tamper, etc.

4 Conclusions

It is easier to prevent a loessial pseudo-karst, than to be engaged in restoration of the broken arrays. The authors carried out monitoring of the site of irrigation agriculture in the Tursunzoda district of Tajikistan when annual recultivation of the site of the cotton field (2.1 hectares) affected with the underground erosion did not give the expected effect. The next year, there were caves, tunnels, chains of funnels, sinkholes, ravines and bridges on the same place again. For several years of annual recultivation (alignment of the territory by the bulldozer, with the subsequent plowing of the field by the plow tractor) the general decrease in the surface of the relief was more than 0.25 m. Thus, about 5 thousand m³ of the most valuable irrigation soils have been taken out only from the irrigated area of the cotton field to basis of the erosion for the 4-year period of observations!

The phenomenon of loessial pseudo-karst is most actively shown in case of technogenic impact on the arrays, put by loessial breeds. Within the development of loessial pseudo-karst there is a degradation of loessial breeds expressed in forming of a pseudo-karst bedlend, destruction of natural complexes and biogeocenoses and aggravation of the general geocological situation of the area.

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