FACTORS OF DEBRISFLOW ORIGINATION IN THE SOUTH-WEST AREA OF LAKE BAIKAL

Valerii Kirillovich Laperdin
Doctor of Geologo-Mineralogical Sciences, Institute of Earth Crust,
Siberian Branch of Russian Academy of Sciences

Abstract

The structure of mud-rock streams (debris flow) in the south of Baikal region, as well as the recurrence of events, depend on the seismic and tectonic activity, morphology and relief (difference in elevation in the small area between the Lake Baikal's brink and the watershed, diverse geological structure of solid rocks, their physical-mechanical and physical-chemical characteristics in relation to weathering agents, as well as the degree of rock crush; peculiarities of heat- and humidity conditions in the area (the rates and distribution of atmospheric precipitation, according to season, elevation zones and within the long-term cycle.

Keywords: Debris flow, water flooding, fluid soil creep, debris flow control dikes, earthquakes, log jam, clogging of river

Introduction

In the south-west of the Lake Baikal area, the settlements Sludyanka and Baikalsk, as well as numerous health resorts and outdoor recreation and sports facilities are located in the region of debris flow hazard, that presents the highest risk in summer periods. These conditions resemble those of Alma-Ata, the former capital of Kazakhstan. In the narrow area of Lake Baikal shore, numerous engineering structures such as railway, motor-roads, connection lines and the electric power transmission lines are situated, which are of vital importance for development of the economic ties of Russia and the Pacific countries. In addition, the lying of the Russia-China gas pipeline is projected here. The developing infrastructure of Baikal region will require the special measures for protection against hazardous geological processes such as rockfall, shore abrasion, fluid soil creep, snow and stone avalanche. The most hazardous phenomena are presented by mud-stone streams of the 1600-2500 kg/m3 rate, derived silt (1600 kg/m3) and water flows. The disastrous debris flow incidents occur generally in the areas of river channels: in the 20th century, for example, the debris flow were recorded in 1863, 1889, 1903, 1915, 1924, 1927, 1932, 1934, 1935, 1938, 1940, 1951, 1955, 1959, 1960, 1962 and 1971; however, no debris flow occurred in the region during the period of 1971-2013. Within the recent 43 years, the cases of clogging of river channels by rocks and fallen trees were recorded; breaking of these obstacles could provoke the disastrous debris flow. Because of the certain calm during the recent years, the planned construction of special dams for debris flow protection was suspended.

Seismic causes

Owing to high seismicity of the territory located in the Baikal rift zone, as well as the combined effect of tectonic deformation (extension and contraction) in the sedimentary cover and crystalline base, which caused the rise of Khamar-Daban ridge and settling of the Baikal basin, the block faulted mountains were formed in the southern area of the Baikal region; this

is one of factors determining the intensity of seismic incidents (Seismotectonics …1968) which in some places exceed the 9 points magnitude (by Richter scale).

The strongest earthquakes were recorded in 1950, 1953, 1957, 1961, 1999 and 2008. Besides, the number of paleo- and seismic dislocations (known as Torskaya, Snezhnaya, Babkha, Khara-Murin etc.) as well as four nameless structures in the Khamar-Daban ridge's watershed area, are marked by high density of earthquakes (up to 11 points) magnitude in the past (Ruzhich 1972; Seismic zoning… 1977). Strong earth tremor in winter and spring periods provoke the massive stone, snow and fallen tree avalanche, which in some cases entrain up to 40% of stone and wood fragments. Clogging of the river channels can be the cause of arising debris streams. The occurrence of substantial caving forms of gravitation and seismic-gravitation origin in basins of rivers Pereyemnaya, Selenginka, Gromotukha, Babkha and others should speak to the truth of our opinion (Khromovskih1965). In this context, the specific role of seismic factor is bound up with the accumulation of the solid component of debris flow phenomenon and formation of dammed lakes in river channels as the consequence of earthquakes, rockfall, fluid soil slip, faults and avalanche. A number of rupture dislocations in the areas of Glavny Sayansky and Khamar-Daban faults which indicate the zones of crust stress, can be regarded as potential earthquake foci.

The seismic-tectonical conditions determine the high relief energy in the territory; the differential movements in the area of Khamar-Daban ridge and trough of Lake Baikal disturb the base level of erosion and lead to intense denudation. The river system is located in the zones of weakness, due to which the territory is marked by well-defined alternate arrangement of high-dipping and gently pitching thalweg areas and canyon-like valleys. These conditions induce the intensive stream. The extent of debris flow hazard is determined by the ruggedness of relief; the maximum height of Khamar-Daban ridge is 2100 m, with the elevation >1000 m a.s.l.; the mountain watershed is located at the 10-23 km distance from the Lake Baikal's shore. Considerable difference in elevation, short waterways and steep slopes determine the rates of flow and accumulation of precipitated water; these factors contribute to formation of rapid water streams of high erosion and carrying capacity. The structure of mountainous area is composed of Precambrian igneous (granitoides) and metamorphic (marble, gneiss) rocks, Cenozoic basalts confined to the ridge watershed area, and Quaternary deposits. The eluvial-deluvial sediments cover the ridge slopes, where the bedrocks intensely weather and displace downslope. The piedmont and high terraces of the Baikal area are composed of Neogene deposits overlain by 20-30 m-thick alluvial and glacial accumulations. The proluvial masses (gravel) accumulate in flattened areas of river channels. The dependence of debris flow initiation on the geological structure is determined by the dominating occurrence of metamorphic rocks (gneiss, shale, limestone, marble etc.). The products of weathering consist of small fractions which gradually increase up to 0.4 m and can be easily involved into the debris streams. At the heads of mountain rivers and streams, the glacial deposits presented by frontal and rarely marginal moraines of 25-30 m apparent thickness can be met. The products of rock weathering and moraine material can be easily washed-out and involved into the debris flow, contributing thus to its solid component.

Heavy rainfall events

The origination of debris flow is caused to a large extent by heavy rains (over 1.0 mm/min, the total amount of precipitation reaching 50-100 mm/day, and about 400 mm/day in the context of incessant rainfall). According to the data obtained by the Khamar-Daban Meteorological Service, the annual precipitation rate amounts to 1400 mm in the area of Khamar-Daban river heads, and about 550-600 mm in the coast zone. The major amount of atmospheric precipitation (70-75%) is recorded in July due to the cyclonic phenomena. Definite meteorological parameters inducing the origination of debris flow should be noted.

For example, in the southern part of the Baikal region the precipitation maximum of 195 mm/day was recorded in 1934 and 152 mm/day in 1960; in 1971 the Khamar-Daban Meteorological Service recorded the precipitation amount of 250 mm/day, 203 mm/day in the area of Utulik, and 197 mm/day in Baikalsk. The recorded maximum precipitation intensity was 0.62-0.72 mm/min (Arsentyev et al. 1972). The normal trend in the rainfall pattern in this region is that the intensity increases with the duration; this is one of the main factors taken into account in the short-term forecast of debris flow events. In 1971, a number of dams, bridges and pipelines were damaged by intensive floods and debris streams; the light-weight structures were washed-off and carried into the Lake Baikal, whereas the heavy ones clogged the river watercourses. These events have revealed the shortage of the existing protection measures in Baikalsk, and can be regarded as a sort of disaster typical of the Baikal region.

Debris flow mitigation measures

Before the Sludyanka-Baikalsk motor-road was constructed, the section of the railway which runs in parallel along the Lake Baikal shore was subject to repeating mud-rock streams from the mountain slopes; the debris masses could easily damage the railway and reach the Baikal shore. In the course of the lying of motor-road, the special dikes were constructed in the areas of debris flow active rivers. The efficiency of these protection measures is not yet proved to the necessary extent. In the case of damage or clogging of the dams, the recondition works would be as expensive as the dam construction itself. Besides, the accumulation of loose material on the slopes and in river channels can disturb the natural transport of weathered products to the lake shore and prevent the beach formation. In 1971, for example, the cases of flush flooding induced the transport of 30-100 thousands m3 of weak material by river water. The pecuniary loss of US $ 200 millions. proved the urgent need for construction of the debris flow dams for protection of the settlements Sludyanka, Baikalsk, Sukhoi Ruchei and others. The present situation requires the up-dating of existing as well as development of more advanced measures; in the designing of debris flow control dikes, the clearance for free transport of debris mass to the Lake Baikal should be provided (as with the case of Sludyanka-river channel). In the area of Baikalsk, the 22 m-high scree-gravel dam at the Kharlakhta-river and the debris mass storage capacity (482000 m3), for the subsequent discharge by special dikes were designed. During 1990-1996, only 14% of the whole sum assigned for the Project (US $ 20 millions) have been expended. The debris-flood control measures should be complex, since the settlement Baikalsk is confined to rivers Solzan and Babkha; besides, the Kharlakhta-river and the streams Krasny Kluch and Bolotny run across the settlement. Even the geographical location of Baikalsk makes the construction of debris control dams urgent. Peculiar consideration should be given to the study of fluid soil creep phenomenon (mud-rock streams containing the wood fragments), that are the cause of debris flow initiation and blocking of bridge apertures. The existing measures of debris flow control decrease to a certain extent the hazard to buildings and persons, as well as to linear structures, being however, not entirely reliable.

Conclusion

The problem of debris flow control is of vital importance not only for the areas of Sludyanka, Irkutsk and Baikalsk, but also for many other territories of Russia. At present, the foci of debris flow are recorded in numerous river channels. Therefore, the forecast of debris flow events should base on the consideration of the meteorological conditions. The permanent and comprehensive investigation of the debris flow phenomenon is required for the updating of the debris flow control measures, as well as assessment of the degree of vulnerability, hazard and risks

The disposition of civil and industrial structures close to the Lake Baikal is accounted for the relief character of the territory and the abundance of the freshwater resources. However, the natural conditions of the area restricting the economical development of the region, benefit to the certain protection against the unwarranted human impact upon the Lake Baikal's environment.

References :

Arsentyev, G.I., Demina, G.I. Kara, E. 1972. The summer floods of 1971 in the Baikal region, and their consequences. *Flooding events in the Far East region and measures of their mitigation*. Vladivostok. 26-29 (in Russian).

Khromovskih, V.S. 1965. *Seismogeology of the southern Baikal region*. Moscow: Nauka. 121 p. (in Russian).

Ruzhich, V.V. 1972. On the dynamics of tectonical development of the Baikal region in Cenozoic. *Russian Geology and Geophysics* 4:122-126 (in Russian).

Seismotectonics and seismicity of the rift system of Baikal region. 1968. Ed. by V.P.Solonenko. Moscow: Nauka. 220 p. (in Russian).

The seismic zoning in East Siberia and its geologic-geophysical Fundamentals. 1977. Ed. by V.P.Solonenko. Novosibirsk: Nauka. 303 p. (in Russian).