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# DEBRIS FLOW EVENT OF 2014 AND ITS IMPACT ON THE ACCUMULATION OF THE SOLID FRACTION IN THE KYNGARGA RIVER CHANNEL, TUNKA VALLEY, SOUTHWESTERN CISBAIKALIA, RUSSIA

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**Abstract:** On 28 June 2014, debris flows brought large volumes of loose material into the Kyngarga river valley. The material was sourced from rock collapse and rock sliding on the valley slopes and delivered mainly to the river by debris flows from the side valleys of the river basin. Our field studies and analysis of the satellite images revealed that the potential debris volume received by the river amounted to about $1\times10^6$ $m^3$. The morphometric parameters of the Kyngarga river basin are favorable for the river-channel processes associated with floods, debris flows and water-rock flows.

**Key words:** debris flow; water-rock flow; Kyngarga river; morphometric analysis; debris flow basin

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# СЕЛЕВОЕ СОБЫТИЕ 2014 ГОДА И ЕГО ВЛИЯНИЕ НА АККУМУЛЯЦИЮ ТВЕРДОЙ ФРАКЦИИ ВОДОКАМЕННОГО СЕЛЯ В РУСЛЕ РЕКИ КЫНГАРГА, ТУНКИНСКАЯ ДОЛИНА, ЮГО-ЗАПАДНОЕ ПРИБАЙКАЛЬЕ

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**Аннотация:** В результате селевых потоков в долину реки Кынгарга 28 июня 2014 года поступило большое количество рыхлого материала. Источниками материала явились обвалы, осыпи со склонов бортов долины, большую часть материала поставили в русло реки селевые потоки, сошедшие с боковых долин бассейна. В результате полевых работ и дешифрирования космоснимков установлено, что в русло реки поступил потенциальный селевой материал в объеме около $1\times10^6$ м$^3$. Морфометрические параметры бассейна реки Кынгарга способствуют формированию русловых процессов, связанных с паводками и водокаменными селями.

**Ключевые слова:** сель; водокаменный сель; река Кынгарга; морфометрический анализ; селевой бассейн

## 1. Introduction

Prolonged heavy rains in mountain river basins cause floods and debris flows [*Fleischman, 1978; Perov, 2012*]. These phenomena are related to specific morphometric characteristics of the mountain river basins and the accumulation of loose sediments in large amounts in the river valleys due to gravity and erosion processes. Debris flows can occur when three basic conditions are combined: morphometric features to provide for the gravitational component, geological setting to facilitate the accumulation of loose material, and weather conditions to generate a sufficient water component.

Kyngarga is a small mountain river starting at an altitude of 2578 m in the Tunka ridge, Russia. Its average flow velocity amounts to 1.8 m/sec and can exceed 3 m/sec during spring flood seasons. The river depth is typically less than 1.0–1.5 m in the lower and middle stream and 0.5 m in the upstream. Many of its small tributaries dry up in dry seasons. The river is mainly fed by melt, rain and ground water [*Zonov, 1962*]. A small resort village of Arshan, visited by many thousands of local and foreign travellers year round, is located near the river outlet to the plain, with the village houses and buildings constructed on both sides of the river, many in close proximity to the beaches prone to flooding. The Kyngarga water-rock flows took place in 1897, 1971, and 2014 [*Lvov, Kropochev, 1909; Boudz, 1968; Levi et al., 2003; Makarov, 2012*]. The dendrochronological analyses show that water-rock flows occurred in 1928, 1935, 1939, 1952, 1960, 1961, 1962, 1971, 1973, and 1974 [*Agafonov, Makarov, 1996*].

According to the oral information from the Arshan residents and representatives of the village administration, an intense downpour lasted through the night of 27–28 June 2014. Its front was over the left tributary of the Kyngarga river and hanging cirques located east of the river [*Kadetova et al., 2016*]. Early in the morning on 28 June 2014, seven debris flows from the slopes of the Tunka ridge flooded the vicinity of the Arshan village, and a water-rock flow occurred in the Kyngarga river, and a significant damage was caused to the village houses and the infrastructure of the resort [*Laperdin et al., 2014; Makarov et al., 2014; Kadetova et al., 2016*]. The debris flows brought about $3\times10^6$ m$^3$ of debris materials to the vicinity of the Arshan village. The debris flows along the creek valleys in the Kyngarga river basin did not damage the village, but delivered large volumes of loose materials into the Kyngarda river valley, thus providing a solid fraction for potential water-rock-flows and debris flows.

The objectives of our study were to estimate the amount of loose materials delivered to the Kyngarda river during the debris flow event in June 2014, identify the main sources of such supplies into the river channel, and analyze the morphometric parameters of the river basin.

## 2. Geological, geomorphological and climate conditions

The Kyngarga river valley is located in the Tunka ridge, glacial erosion mountains with vertical dissection from 600 to 1200 m. The total length of the mountainous part of the river valley is 7.35 km. The river basin has two main channels starting from the hanging cirques located about 2578 m a.s.l. Traces of glacial activity are observed in the upper reaches of its tributaries. From the altitude of 1480–1520 m, all the tributaries of the Kyngarga river have V-shaped valleys without any traces of glacial impact.

At the altitude of 1250 m, the tributaries flow into a wide valley graben. Its section is trapezoidal, with a flat bottom (to 200 m wide). In the valley graben, there are no traces of any ancient glacier [*Shchetnikov, Ufimtsev, 2004*]. The valley is wide in the middle stream area. It sharply narrows and turns into a straight canyon-shaped gorge about 2 km to the exit from the mountains to the plain. The riverbed is a continuous series of rapids alternating with cascades and waterfalls [*Agafonov, 1996*]. The maximum width of the Kyngarga river basin is 8.9 km; the length of the basin until the outlet to the plain amounts to 7.35 km; the basin area is 40.2 km$^2$ (Table).

The structural-tectonic features and the recent regional seismic activity are favorable for further rock destruction and disintegration. Besides, gravitational displacements, such as landslides and rock collapse, may be stimulated by earthquakes. The rocks in the valley sides are tectonically fragmented as the valley belongs to the submeridional fault zone [*Parfeevets, Sankov, 2006*].

**Main parameters of the mountainous part of the Kyngarga river basin**

**Основные параметры горной части бассейна реки Кынгарга**

| Catchment area, km$^2$ | Maximum elevation, m | Minimum elevation, m | Elevation difference, m | Average width of the basin, km | Length of the basin, km | River length in the basin, km | Melton ratio [*Melton, 1965*] | Drainage density [*Horton, 1945*] |
|---|---|---|---|---|---|---|---|---|
| 40.21 | 2578.90 | 940.00 | 1638.90 | 5.47 | 7.35 | 65.65 | 0.26 | 1.63 |

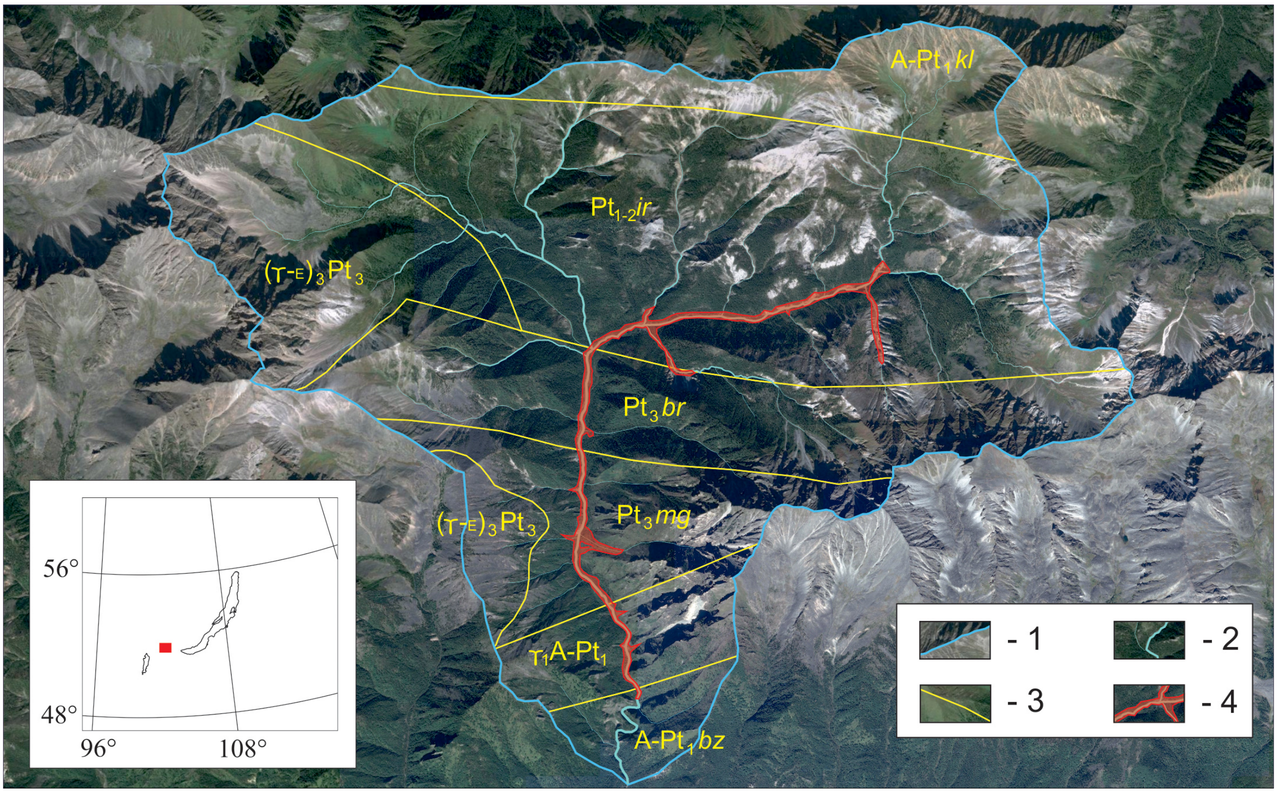


**Fig. 1.** Scheme of the Kyngarga river basin.

*1* – boundary of the Kungarga river basin; *2* – permanent and temporary streams of the Kyngarga river; *3* – geological boundaries; *4* – area of accumulative material resulting from heavy rains of 27–28 July 2014. Geological setting: $Pt_3$mg – Mongoshinskaya suite. Limestone, dolomite, metamorphic schist interlayers, conglomerates at the base; $Pt_3$br – Burungol suite. Metamorphic schist, limestone, volcanic rocks; $Pt_{1-2}$ir – Irkut suite. Marbleized limestone, gneisses interlayers, crustalline schist and quartzite, conglomerates at the base; A-$Pt_1$bz – Bezymyanskaya suite. Biotite, garnet-biotite, silimonite-biotite, amphibole-biotite gneiss, plagiogneiss and crystalline schist, rare marble interlayers; A-$Pt_1$kl – Kultuk suite (undifferentiated). Biotite, garnet-biotite, amphibole-biotite, amphibole-pyroxene gneiss, plagiogneiss and crystalline schist, marble interlayers; (γ-E)$_3$$Pt_3$ – Late Proterozoic intrusions, phase III. Microcline granite, granosyenite and syenite, granite-aplite dikes; $\gamma_1$A-$Pt_1$ – Archaean–Early Proterozoic intrusions, phase I. Foliated plagiogranite, ocellar gneiss-granite.

**Рис. 1.** Схема бассейна реки Кынгарга.

*1* – граница водосборного бассейна р. Кынгарга; *2* – постоянные и временные водотоки р. Кынгарга; *3* – геологические границы; *4* – площадь аккумулятивных форм в русле р. Кынгарга, образовавшихся после интенсивных осадков 27–28 июля 2014 года. Геологическое строение: $Pt_3$mg – Монгошинская свита. Известняки, доломиты, прослои метаморфических сланцев, в основании конгломераты; $Pt_3$br – Бурунгольская свита. Метаморфические сланцы, известняки, эффузивы; $Pt_{1-2}$ir – Иркутная свита. Мраморизованные известняки, прослои гнейсов, кристаллических сланцев и кварцитов, в основании конгломераты; A-$Pt_1$bz – Безымянская свита. Биотитовые, гранатово-биотитовые, силимонитово-биотитовые, амфиболово-биотитовые гнейсы, плагиогнейсы и кристаллические сланцы, редкие прослои мраморов; A-$Pt_1$kl – Култукская свита нерасчлененная. Биотитовые, гранатово-биотитовые, амфиболово-биотитовые, амфиболово-пироксеновые гнейсы, плагиогнейсы и кристалические сланцы, прослои мраморов; (γ-E)$_3$$Pt_3$ – позднепротерозойские интрузии, III фаза. Микроклиновые граниты, граносиениты и сиениты, дайки гранит-аплитов; $\gamma_1$A-$Pt_1$ – архейские-раннепротерозойские интрузии, I фаза. Разгнейсованные плагиограниты, очковые гнейсограниты.

Geologically, the mountain part of the Kyngarga river valley cuts through the Late Proterozoic and Archean intrusions represented by biotite, granite-biotite gneisses, schists and marbles [*Sumburgh, 1971*] (Fig. 1).

The regional climate is sharply continental. The climatic conditions of the Eastern Sayan region are defined by the three major factors: large temperature fluctuations (resulting in strong physical weathering), the presence of permafrost and seasonal frost, and significant rainfalls and frequent intense downpours. All of the above factors contributes to the formation of debris flows. The precipitation is irregular in the study area and depends mainly on the terrain. The annual precipitation patterns is as follows: the smallest amount in winter (~30–35 mm), and the largest amount in summer (~350–400 mm). The annual records show that an average daily precipitation exceeds 30 mm in the Arshan village. According to the data from the Arshan weather station, the daily rainfall amount


**Fig. 2.** Accumulative material in the Kyngarga river valley: *a* – alluvial fan of debris flow; *b* – debris flow deposits (terraces) along the riverbed; *c* – loose material from the rock collapse; *d* – material from the rockslide.

**Рис. 2.** Аккумулятивные формы в долине реки Кынгарга: *a* – конус выноса селевого потока; *b* – селевые отложения (террасы) вдоль русла реки; *c* – рыхлый материал, поступивший в русло в результате обвала; *d* – материал, поступивший в русло реки в результате осыпи.

in summer may reach 170 mm [*Meteorological Monthly Magazine, 1972*].

## 3. Sources of the solid component of the debris flows in the Kyngarga river valley

The Kyngarga river valley is filled with loose material that is constantly delivered with the valley sides due to rock collapse and rock sliding processes, as well as due to erosion and debris flow processes after intense rainfalls. According to [*Agafonov, 1996*], large masses of loose material have been accumulated at the bottom of the river valley. The loose material volume is changeable – the river flow partially removes the accumulated material, but new amounts are delivered.

The field observations and the analysis of satellite images of the study area show that the Kyngarga river received a huge volume of loose debris after the heavy rains in June 2014, which caused the debris flows, rock collapse and landslides (Fig. 2). River valley is cut by the creek valleys, i.e. elementary catchment areas. Most of such areas show active landsliding and develop as debris flow basins that supply loose material from the slopes directly to the river. There are nine debris flows of different sizes in the Kyngarga river basin, and the total accumulation area amounts to 0.57 km$^2$ (see Fig. 1). The toes of the alluvial fans reached the riverbed and were partially washed out. The largest debris flow came down from the debris flow basin on the left side of the Kyngarga river basin. The area of its alluvial fan is 0.056 km$^2$. The volume of material delivered by this debris flow amounted to 0.168 km$^3$. The maximum size of the boulders transported by the debris flow amounts to 3 m. It should be noted that the river was not dammed because the debris flow alluvial fans were washed out by the water-rock flow that came down the Kyngarga river.

In the canyon-shaped segment of the Kyngarga river valley, loose material is supplied due to rock collapse, landslides and rockslides on the steep rocky slopes. Such material includes large unrounded boulders, some of which are more than 5 m (Fig. 2). The talus cones contain gravel and rock blocks up to 2 m.

The river channel also contains some loose material delivered into the valley from the upper reaches of the river as a result of the water-rock flow. The material delivered from the valley sides, from the upper to lower reaches of the river, is redistributed and deposited in accumulation structures, such as lateral levees and terraces (up to 2 m thick). This material contains rounded rock pieces and thus differs from the rock-collapse and landslide materials.

## 4. Morphometric parameters of the Kyngarga river basin

By analyzing the morphometric parameters of the Kyngarga river basin, we estimated the Melton ratio at 0.26 for the basin's length of 7.35 km (Table 1). The established regularities [*Wilford et al., 2004; Welsh, 2007*] suggest that such combination of parameters is favorable for the occurrence of floods and water-rock flows.

The Kyngarga river basin is large and branched. The drainage density is 1.63, i.e. the network of water-courses is quite dense. Such conditions provide for a more even distribution of rainfall in the basin, while due to the large catchment area, larger water volumes are accumulated in the basin during rainfalls.

The geological structure of the river basin is specific – the river channel narrows at the exit from the mountains to the plain and has some sharp bends. Therefore, solid materials cannot be moved freely down the river and have to accumulate in the canyon-shaped segment. Moreover, such structure of river valley can result in cumulative effect of debris flow during the high flood [*Agafonov, 1996*].

## 5. Conclusion

The debris flows, rock collapse and landslides in June 2014 supplied about $1{\times}10^6$ $m^3$ of loose material to the Kyngarga river valley. Such material is the solid component of potential mudflows. Based on our analysis of the morphometric parameters of the Kyngarga river basin, there are grounds to conclude that the local conditions are favourable for the development of river-channel processes associated with floods and water-rock flows. The geological structure of the basin and recent tectonic activity in the study area are favourable for the accumulation of loose material in the branching creek valleys, which is then either carried into the main river valley or stored directly in the valley. A potential for the occurrence of catastrophic events in the Kyngarga river valley is high, should the above-described conditions be further complicated by prolonged intense rainfalls.

## 6. Acknowledgements

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