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Beauty of the Valley of the Geysers: Before and After Landslide on June 3, 2007

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ABSTRACT

Kamchatka is a huge natural museum of volcanology; its "exhibits" are active and extinct volcanoes as well as different associated formations, including geysers, fumaroles, and thermal springs, as shown in Figure 1. Dangerous slope processes such as landfalls and landslides are rather frequent phenomena for the present-day hydrothermal fields of Kamchatka. Formations of various scale and age are recognized there as being resultant of landfalls and landslides. Thus, the large landslide on June 3, 2007 (pictured in Figure 2) is not a unique phenomenon for the Valley of the Geysers. This natural catastrophe has strongly changed the Valley of the Geysers landscape: Geyizernaya River is now dammed up by landslide depositions, and as a result a new lake has been formed and some of the geysers have been destroyed. Nevertheless, the Valley of the Geysers still remains one of the main objects of ecological tourism in Kamchatka. The Valley of the Geysers is also part of the UNESCO World Natural Heritage Site "Volcanoes of Kamchatka."

The photos taken in the Valley of the Geysers in different years before and after the landside on June 3, 2007 are presented in this report as examples of the environmental impact of the landslide. The main information on the landslide is briefly summarized here as well.

The unique and complex landscape of the Valley of the Geysers did not become less interesting for visitors. A picturesque lake has appeared here, as well as nearly vertical parts of dislocation plane on the caldera slope (wall length - 800 m, height - about 150 m). Thes and other results of catastrophic landslide are displayed in Figures 3-13.

Figure 1. Visitors of Kronotskiy Biosphere Reserve on wooden tourist path in the Valley of the Geysers.

1. INTRODUCTION

The Valley of the Geysers is located in the territory of the Kronotskiy State Natural Biosphere Reserve. It is one of the most famous objects of ecological tourism in the world. Since 1996, the Valley of the Geysers has been included as a UNESCO World Natural Heritage Site: "Volcanoes of Kamchatka".

The UNESCO World Natural Heritage Site consolidates six separate areas (special nature-conservative territories on the peninsula) with total square 3.8 million hectares. Taken together, they reflect practically all of the main volcanic landscapes of Kamchatka, while at the same time, each of them offers outstanding individuality. "Volcanoes of Kamchatka" includes 30 active and 300 extinct volcanoes in total. The territory is also characterized by unique biological diversity. In May and June, the Valley of the Geysers becomes a place of concentration of the local brown bear population. During this period, it is closed to visitors.

The status as a UNESCO World Natural Heritage Site is very attractive, as it allows the territory to get a number of advantages, including the development of alternative kinds of nature management. Ecological tourism is the main factor that attracts resources from international funding sources. At the present time, development of ecological tourism is realized by the Global Environment Facility (GEF) in collaboration with the United Nations Environment Programme (UNEP).

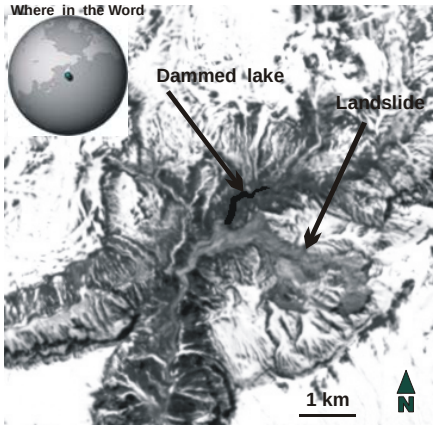

Figure 2. The landslide on June 3, 2007 buried the Valley of the Geysers. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on NASA's Terra satellite captured this infrared-enhanced image on June 11, 2007, a week after the slide. The image shows the valley, the landslide, and the new thermal lake. (Allen, 2007).

Figure 3: Large-block avalanche body near buildings of Kronotskiy Biosphere Reserve in the Valley of the Geysers. This is an example of the negative effects of natural disasters on constructions built without taking certain dangerous phenomena into consideration. Photo by S. Gorshkov (National Geographic). June 22, 2007.

2. THE VALLEY OF THE GEYSERS - A UNIQUE GEYSER FIELD

The Valley of the Geysers was found accidentally by geologist Tatyana Ustinova in 1941. The discovery of the Valley of the Geysers is considered as one of the most significant discoveries of the 20th century.

Geysers are a rare, nearly unique type of thermal spring with a regular flowing rhythm. Their activity resembles miniature volcanic eruptions in appearance: a column of boiling water and steam shoots up several tens of meters into the air. Its suddenness, beauty and power create an amazing impression. Geysers are found only in areas of active of recently extinct volcanoes. Their existence is always connected with special geothermal conditions and the presence of magma source.

Geyser activity can be broken down into four phases: rest, pouring out, eruption, and steaming. Almost every geyser has its own characteristic activity. Geyser regime is realized in a narrow diapason of physical conditions. It depends on temperature and pressure as well as on structure of underground channels and correlation of the different temperature water flows that feed the geyser. Even insignificant changes in physical conditions can lead to a geyser's "death:" it turns into a thermal water spring of jetting steam. Cases of geyser "deaths" were observed in Iceland in connection with the development of hydrothermal fields.

Geysers' vulnerability is determined by their closeness to areas of volcanic activity and present-day geological activity. For instance, the beautiful Tetarata Geyser on Northern Island of New Zealand disappeared as a result of the Taravera Volcano eruption in 1886. The strongest among known geyser deaths is that of the Vajmangu Geyser, which originated on the Northern Island in New Zealand in 1899. During each eruption, 800 tons of water flowed forth at heights greater than 450 m. Vajmangu Geyser ceased its activity in 1904 due to modification of hydrological conditions. Some geysers in the Valley of the Geysers in Kamchatka also suffered from the increase of geological activity that caused the landslide on June 3, 2007 and the subsequent lake formation.

Geyser fields, or concentrations of a large number of geysers within limited territories, are some of the most unique natural

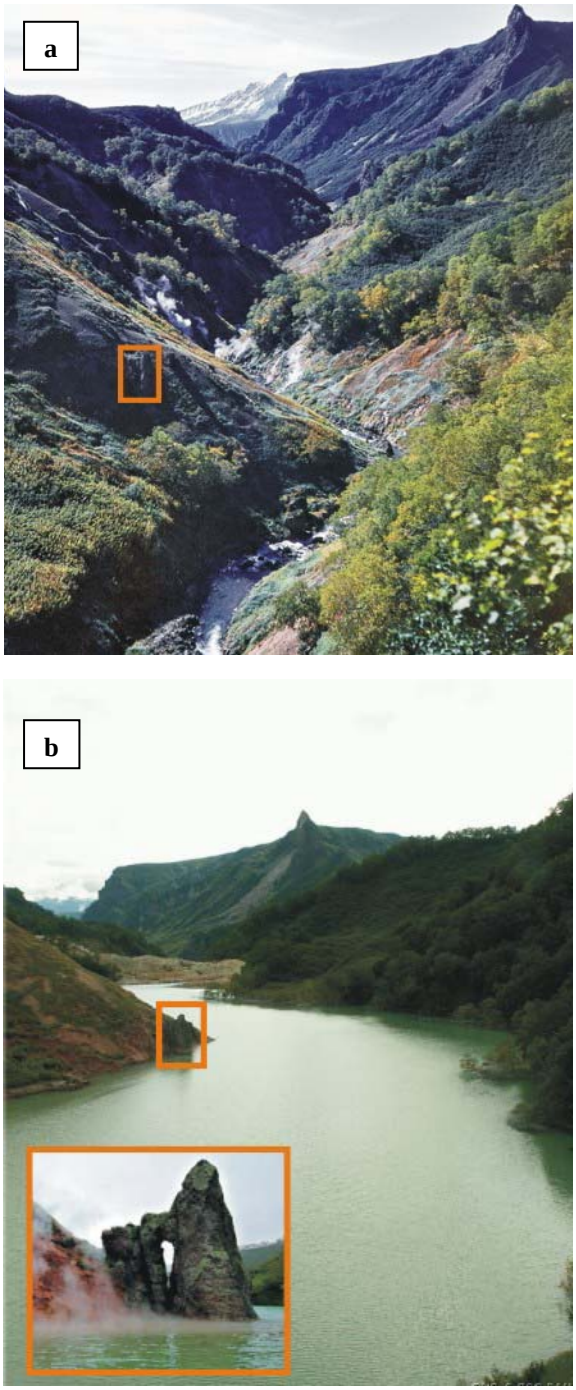

Figure 4. Pre (a) and post (b) landslide view of the middle part of the Valley of the Geysers. Photo: N.Smelov, V.Saltykov

phenomena. At present, four large geyser fields are known on the Earth: Rotorua in New Zealand, Yellowstone geysers in North America, the Haudakalur geyser field in the south of Iceland, and the Valley of the Geysers in Kamchatka. Isolated geysers also exist also in Japan, Tibet and a small square of geysers called El Tatio is located in a mountainous area in northern Chile.

Figure 5. A series of hot springs known as "Vitrazh" ("Stained glass window") in the Valley of the Geysers.

a, b – 2005, before landslide. Photo by I. Shpilenok,

c - on June 7, 2007. Water level in the dammed lake is maximal (30 m). Lower part of the Vitrazh Wall is submerged. Photo by I. Delemen;

d - After dam was burst by the river, the lake level lowered by 10 m. In the photo: new entry of Geyizernaya River in October 2008. In the place where river flows into the lake (on the left), thin fragmented material deposits and river valley fills with alluvial sediments. The Vitrazh Wall did not suffer and is completely open. Photo by Yu.Kugaenko

Figure 6. Geyser Malyi (Lesser) – the most productive geyser of the Valley erupted about 8 tons of water every 40 min. At present, Malyi Geyser is flooded by the lake and is located at depth about 14 m.

a – Eruption of Malyi Geyser, 2005. Photo by I. Shpilenok.

b – last eruption of Malyi Geyser on June 4, 2007. Photo by M.Filatkina, WWF.

c – the same place in October, 2008. Malyi Geyser is 14 m underwater. Photo by A.Konovalova.

A peculiar feature of the geyser field in the Valley of the Geysers is its landscape appearance, which includes plenty of plants, picturesque valley flanks, and a variety of colors.

The geological, hydrological and morphological features of the Valley of the Geysers along with the high geodynamic activity of the North-Western Pacific determine the increased landslide risk in this territory (Gordeev et al. 2007, Kugaenko 2008).

Figure 7. The dam, new channel of Geysernaia River, and new thermal lakes on the surface of the avalanche. Photo by S. Gorshkov (National Geographic). June 22, 2007.

Figure 8. The landslide-dammed lake. Left – geysers of "Vitrazh". In the background – landslide of June 3, 2007 and the cleavage wall. Photo by S. Gorshkov. (National Geographic) June 22, 2007.

3. LANDSLIDE, SLOPE FAILURE AND MUD-STONE AVALANCHE IN THE VALLEY OF THE GEYSERS ON JUNE 3, 2007

A giant mud-stone avalanche, formed by the landslide, descended along the Vodopadnyi stream bed into Geiyzernaya River on June 3, 2007 in the Valley of the Geysers (Fig.2, 3, 7, 8), (Leonov V. and Leonov A., 2007).

Basic characteristics of the disaster:

Location: The Valley of the Geysers, Kamchatka, Russia (54.44 º N, 160.14 º E)

Date of Slide: June 3, 2007

Size of Slide: Length: 2 km; Width: 200-400 m; Depth: 5–60 m; Area: 2 km^2. Volume: 20 $\times 10^6$ m^3. (Droznin et al., 2008).

Damages: The landslide luckily did not have any human victims. Nevertheless, helipads, bridges, and household buildings were crushed or partially destroyed. Debris from the avalanche came to a stop only one meter from Visitor Center Building of the Kronotskiy Reserve. Several beautiful geysers were lost forever (Leonov, 2007, Gordeev et al., 2007).

Topographic and Geologic Conditions: The Valley of the Geysers is confined to the eastern edge of the vast and complicatedly arranged Uzon-Geyzernaya volcano-tectonic depression elongated in the WNW direction (Leonov et al., 1991). The Uzon-Geyzernaya volcano-tectonic depression represents a caldera failure bordered by ring fault-downdip block of a generally north-western direction. The fault is manifested by scarp in present-day relief. The visible amplitude of displacement along the fault is 300-400 m. The depth of the upper edge of the supposed magma source beneath the caldera and its diameter are estimated at 7-8 km and 10 km, respectively. The Uzon-Geyzernaya volcano-tectonic depression area belongs to the Eastern volcanic belt of Kamchatka. It is connected to a crossing knot of major faults with north-eastern and latitudinal strikes. A network of faults oriented concentrically around the Uzon-Geyzernaya depression was also distinguished. The area is characterized by steep relief. The thickness of lacustrine sediments destroyed by the Geysernaia River is about 300 m.

On June 3, 2007, the process of gravitational failure and downward propagation of the original flows lasted about 2.5 min. The landslide in the Valley of the Geysers exhibited complicated multiphase character. According to the rock displacement rate, it was a rapid landslide and thus, a very dangerous one, with velocities reaching 30-40 km/hour. Three big blocks broke away from the caldera slope and came down successively. The massif integrity was compromised during the movement.

Present-day hydrothermal activity is observed in the Geyizrnaya River valley and in its upper reaches near south-western foot of the Kikhpinych Volcano. Geysers and other forms of hydrothermal activity represent surface manifestations of the large hydrothermal field of Geyizernaya. The supposed feeding area of this hydrothermal system is the Kikhpinych volcanic massif.

The results of the landslide investigation show that heated rocks in the mountain massif were involved in the failure. One of the main reasons for the landslide was the weakening of semi-rock pumice soils due to their steaming

during a hidden unloading of the hydrothermal system.(Droznin et al., 2008).

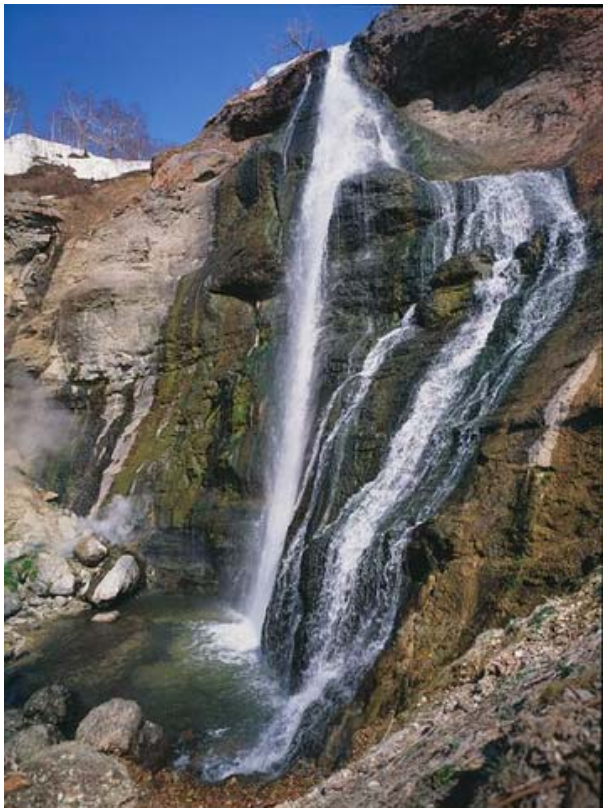

Figure 9. Warm waterfall (h ≈ 30 m) on the Vodopadny stream. The waterfall is now forever buried under the avalanche. Photo by V. Gippenreter.

4. MAIN LANDSLIDE CONSEQUENCES FOR ENVIRONMENT IN THE VALLEY OF THE GEYSERS.

The catastrophe has changed everything in the Valley, including drastic changes in some places. Some new things appeared, some things may be restored with time, and some things are lost forever.

1. A new characteristic that appeared in the Valley is the actual mass associated with the mud-stone avalanche; it even became an integral part of landscape. The body of slide consists of a soft, water-saturated mass of mud shale debris with size ranging from 5-meter rocks to small crushed stones, in which it is easy to fall through up to the waist. This mass can be seen in Figures 3, 7, and 8.

2. A natural rock-filled dam was formed with a length of about 300 m, a height of 50-60 m, and a width from 40-60 m in the most narrow places of the river valley and up to 200-250 m in the widest places, as shown in Figures 7 and 8.

3. A dammed lake with a length of about 2 km appeared. During first days after the catastrophe, the water level in the lake rose 30 m, but later, when the Geiyzernaya River washed out the upper part of the dam, the water level in the lake lowered to 20 m mark and practically became stable. The lake is shown in Figures 4, 8, and 11.

4. Significant parts of the geysers were buried by the avalanche and flooded by lake that formed, as shown in Figures 6 and 10-13. However, the rest geysers remain active. Part of the geysers and thermal springs appeared on the surface after water level fell in the lake and indicated their activity (Droznin et al., 2007).

5. On the rocky surface of the avalanche, some new lakes appeared, as shown in Figure 7. Some of them are warm and suitable for bathing.

6. The landslide had some registered impact upon insect biodiversity, but the negative effects were not significant.

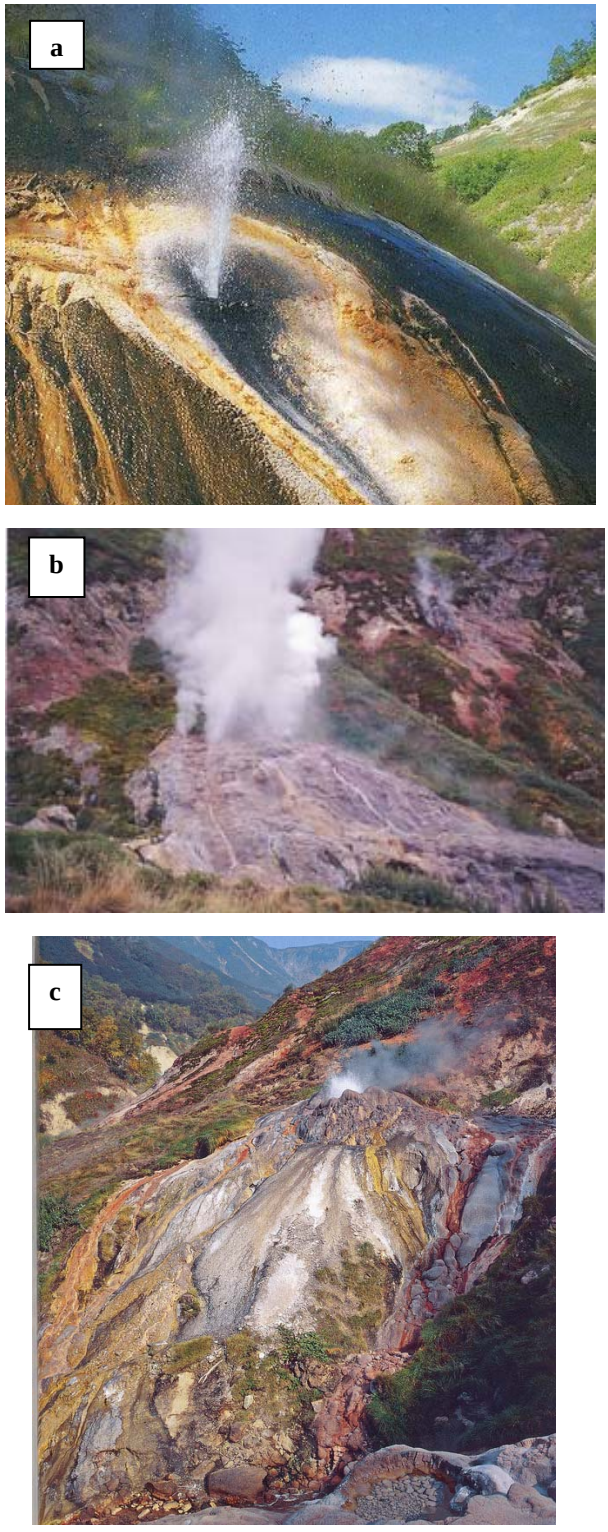

Figure 10. These Wonders of Nature are lost forever (buried by the avalanche). A – Jet Geyser , b – Geyser Triple, c -Sugar Geyser. Photo by A.Nechaev.

Figure 11. Bol'shoyi (Large) Geyser was also flooded by the lake and buried 10 m underwater. It got free from water in beginning of September 2007 and reactivated.

a – eruption of Bol'shoyi Geyser, 2005. Photo by I. Shpilenok.

b – Bol'shoyi Geyser is at a depth about 10 m on June 7, 2007. Photo by I. Delemen from the same place..

c – crater of Bol'shoyi Geyser on July 31, 2007. Photo by G.Shestakova.

d – Bol'shoyi Geyser is alive! First eruption after flood on September 12, 2007. Photo by V.A. Droznin.

e – New lake in the Valley of the Geysers and the crater of Bol'shoyi Geyser. The water level in the lake became stabilized. Photo by Ya. Muraviev. November 29, 2007

Figure 12. Image of the pulsating hot spring Malachite Grotto. The name has been gained from the green color of thermophile algae covering the geyserite walls. After the formation of the landslide and dammed lake, Grotto appeared to be about 10 m underwater. The spring reactivated after lake level sank.

a - Malachite Grotto before landslide. 1980. Photo by N. Smelov;

b – A brown bear crossing the Geysernaya River near Malachite Grotto on May 20, 2006. Photo by V.Zlotnikov, Kronotskiy State Natural Biosphere Reserve;

c - Malachite Grotto on October 3, 2008, after landslide and lake level lowering. It is difficult to recognize it: nearly the whole geyserite edifice is covered by thin fragmental material brought by the Geyizrnaya River.

Figure 13. Geyser Pervenets – the first geyser, discovered by T.Ustinova in 1941.

a – before landslide,

b – in October, 2008. We had observed a big hole (diameter 5-6 m, depth 4-5 v) on the Geyser Pervenets with two steamed springs on the bottom. Photo by V.Saltykov

c – The hole at Geyser Pervenets. Photo by V.Saltykov

Figure 14. View of the avalanche body from the opposite site of the Valley of the Geysers. Left – Vitrazh thermal springs and part of the dammed lake. Photo by V.Saltykov

5. CONCLUSIONS

The events which occurred in the Valley of the Geysers on June 3, 2007 should not be considered an ecological catastrophe. It was part of a natural process and an element of the geological evolution of the territory. This process introduced certain additions to the unique landscape of the UNESCO World Natural Heritage Site "Volcanoes of Kamchatka".

The unique and complex landscape of the Valley of the Geysers did not become less interesting to visitors. A picturesque lake has appeared here, and there are now nearly vertical parts of the dislocation plane on the caldera slope (wall length - 800 m, height - about 150 m). One can see some other results of catastrophic landslide, including lakes originating on the avalanche flow surface. The reorganization of the surface hydrothermal system regime proceeds at present time in the Valley of the Geysers;, as abrupt alterations of the level of the dammed lake activated further development of landslide processes on the Valley slopes.

The Valley of the Geysers became even more interesting from a scientific point of view. Nature gave investigators a unique possibility to observe and study a wide spectrum of present-day geological processes caused by the natural disaster on the geyser field.

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