Morphological features of debris avalanches deposits from Molodoy Shiveluch Volcano

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Keywords: andesitic volcano, debris avalanche, photogrammetry.

Molodoy Shiveluch is the most active andesitic volcano of the Kamchatka Peninsula. It is located at the junction of the Aleutian and Kamchatkan volcanic arcs. Its edifice was formed due to the lava domes growth, with their subsequent destruction by large explosions and gravitational processes. The southern foot of the volcano, where the bulk of the erupted material is carried out, is covered with pyroclastic flows and debris avalanches deposits of different ages.

The November 12, 1964, Molodoy Shiveluch catastrophic eruption destroyed several coalescing lava domes nested within a horseshoe-shaped caldera. As a result, a new double-shaped avalanche caldera was formed. The diameter of its northern part was 1750 m, and of the southern part was 2050 m. The volume of the collapsed material was 1.03 m^3. The debris avalanche covered 104 km^2 of the southern foot of the volcano. Pyroclastic flows that followed the collapse covered fanwise the area of 45.5 km^2. The thickness of the front of the debris avalanche deposits varies mostly from 1 to 8 m. In some places it is up to 20 m thick. The thickness of the pyroclastic flows has reached 10 m.

Deposits, possibly related to the previous large eruption of 1854, underlay the deposits from the 1964 catastrophic eruption. Though these deposits only fragmentarily protrude from the 1964 deposits (total area is 2.6 km^2), we can say with confidence that there are starkly different morphologies in their surfaces (Fig. 1, fig. 2).

The surface of the 1964 collapse deposits is similar to the surfaces of large mountain landslides and has a number of ridges elongated in the direction of movement. Previously, Melekestsev et al. (2003) assumed that these ridges had been formed due to the explosive-collapse nature of the avalanche movement. However, Dufresne and Davis (2009) presented landslide deposits that had the same ridges on the surface. Therefore, gravitational collapse is a sufficient precondition for the formation of such ridges, and their presence can't indicate the explosive origin of the avalanche.

The surface of the visible fragments of the underlying deposits is creased into wavelike folds stretched along the front of these deposits. Such folds could have been formed as a result of viscous-plastic flow. On the flanks of the fragments, especially in less flat areas, folds stretch along the slope in the form of levees. The wavelength of the folds varies from 13 to 40 m, and their heights reach 14 m. Most of the folds are straight. Their axial surfaces are vertical, and their limbs are symmetrical. Inter-limb angles range from 20° to 50°.

Fig. 1 – Aerial photo of southeastern sector of the Molodoy Shiveluch deposits field. Photo by L.B. Dmitriev and G.S. Shteinberg, November 17, 1964.

Previously, there were two suggestions for the appearance of such a relief. According to Melekestsev et al. (2003), these folds were formed as a result of the impact of the 1964 explosive material on the watered underlying deposits. Belousov et al. (1999) termed these deposits "bulldozer facies" since, in the opinion of the authors, they were folded by the 1964 debris avalanche that bulldozed the underlying surface.

However, interpretation and photogrammetric processing of recently found aerial photographs of November 17, 1964, showed that these deposits had been folded long before the 1964 eruption. In the photographs obtained five days after the events of 1964, we can see trees (10 m in average height) growing on the ridges of the folds and in the depressions between them. The trees' trunks stand vertically and have no signs of damage. The trees are felled only in the areas prone to the lahars of 1964. Consequently, the 1964 eruption may have no relation to the origin of the folds.

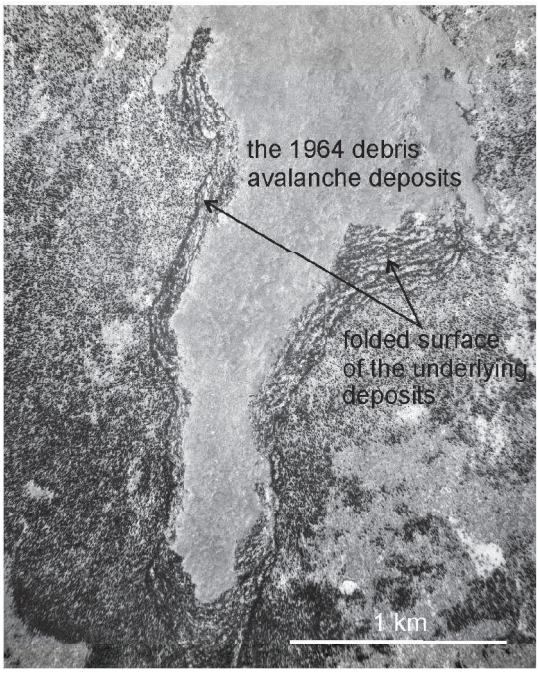

Fig. 2 – Aerial photo of the central part of the Molodoy Shiveluch deposits field. Photo by L.B. Dmitriev and G.S. Shteinberg, November 17, 1964.

There is also no correlation between the hinge lines of the folds and the front line of the 1964 deposits. In some places, the folds go under the surface of the 1964 deposits almost at right angles.

The formation of the folds due to the impact of the 1964 debris avalanche was impossible because of the very small thickness (first meters) of the avalanche front in these areas. It is hard to imagine that an avalanche with a thickness of up to 3 m formed up to 14-metre-thick folds on the underlying surface. Meanwhile, in the areas adjacent to the 1964 deposits front of high thickness (up to 15 m), no folds are observed. Besides, in some places we can observe large folds protruding through the thin surface of the 1964 deposits at a distance from the front.

Therefore, we can suggest that it was not the 1964 debris avalanche that formed this folded surface, but, on the contrary, the form of the bedding of the collapse material was caused by the already existing relief, which predetermined the movement of the 1964 debris avalanche so that its material accumulated in the local depressions, colliding with the folds.

Unfortunately, the materials of aerial photography of Molodoy Shiveluch that was performed in the 1940's are not available. So we can only guess what the morphology and location of the studied deposits had been like before the 1964 eruption.

In any case, it is necessary to find out how the described folded terrain was formed. We think that photogrammetric method has done everything it could, and the answer to this question is to be given by further direct geological studies.

References

Belousov A., Belousova M., Voight B., 1999. Multiple edifice failures, debris avalanches and associated eruptions in the Holocene history of Shiveluch volcano, Kamchatka, Russia. Bull. Volcanol. 61, 324-342.

Dufresne A., Davies T.R., 2009. Longitudinal ridges in mass movement deposits. Geomorphology. 105, 171-181.

Melekestsev I.V., Dvigalo V.N., Kirsanova T.P., Ponomareva V.V., Pevzner M.M., 2003. The 300 years of Kamchatka volcanoes: the Young Shiveluch. An analysis of the dynamics and impact of eruptive activity during the 17-20th centuries. Part I. 1650-1964. Vulkanol. Seismol. 5, 3-19 (in Russian).