



## **Large scale failures and debris avalanche deposits of volcanoes of Kurile Islands.**

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Investigations of air and space images of Kurile Islands supplemented by observations during two research cruises have allowed us to identify 40 well-preserved horseshoe-shaped scars formed by large-scale collapses. The collapses occurred at active (33 cases) as well as extinct (7 cases) volcanoes. Widths of breaches of the most of the scars (30 cases) range from 0.5 to 2 km indicating moderate volumes of the failures - around 1 km<sup>3</sup>. Three largest 3 to 4 km-across scars (which were formed by failures with volumes about 5 km<sup>3</sup>) belong to Milne, Sinarka and Stokap volcanoes. Most of the failures occurred on andesitic volcanoes which dominate in the region. At least 3 volcanoes (Harimkotan, Ekarma and Mendeleev) experienced multiple (3 or more) failures. Few failures occurred on dominantly basaltic stratovolcanoes (Alaid, Brouton and possibly Atsonupuri). Most of the collapsed volcanoes of Kurile arc have strong hydrothermal alteration of rocks inside their horseshoe-shaped scars, and their debris avalanche deposits contain large proportion of clayey material. This suggests that weakening of rocks composing volcanic edifices caused by hydrothermal alteration played leading role in gravitational destabilization of the volcanoes. In 50% of cases of volcanic failures in Kuriles were followed by magmatic activity - the horseshoe-shaped craters are partially filled by younger volcanic cones. This indicates that the failure surfaces intersected upper parts of feeding channels of active volcanoes - possibly the failures were triggered by magma intruding into the volcanic edifices. Apart from failures on volcanoes there are multiple rather large scale (>0,01 km<sup>3</sup>) failures along sea cliffs of the islands which involved volcanic rocks. These cases are transitional to non-volcanic failures. Debris avalanches of all of the studied failures traveled far beyond the shore line of Okhotskoye Sea or the Pacific Ocean and thus their exact

lengths and drop heights are unknown. Entering of the debris avalanches into the sea obviously generated tsunamis. The studied failures have Late Pleistocene - Holocene ages; and one historical case - failure of Harimkotan volcano on January 8, 1933 with the volume 0.4 km<sup>3</sup>. The failure generated tsunami up to 20 m high with 2 reported victims on nearby Onekotan Island. The failure followed by strong 5-days-long Plinian eruption with deposition of pyroclastic flows and subsequent dome growth during several months.