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Exogenous dome growth at Molodoy Shiveluch Volcano, Kamchatka

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Summary
This study presents the extrusive activity features of Molodoy Shiveluch Volcano (Kamchatka) over the newest period since 2001. The author made interpretation of stereoscopic aerial imagery over the investigating period. Morphometric parameters were obtained by photogrammetric method. The investigation detected that current dome growth of the volcano occurs mostly on exogenous type and that the transition from endogenous to exogenous growth occurred in 2001. The aerial imagery interpretation revealed crease structures of various forms on the dome surface. On the basis of analysis of previous studies the author made a search for the most likely causes of the change in type of extrusive activity. The results show that except for the dome reaching the critical size, in which case the endogenous dome growth becomes obstructed, the cause also may be in the change of extrusive material physical properties due to increasing of SiO_2 in the groundmass.
Keywords: exogenous dome growth, crease structures

1. Introduction

Molodoy Shiveluch Volcano is the most active andesitic volcano on the Kamchatka Peninsula. It is located in the south-west part of Shiveluch massif at the junction of the Aleutian and Kamchatka volcanic arcs. The coordinates of the Molodoy Shiveluch highest point are N 56°38'10", E 161°18'54". Formation of the volcano during the Holocene was mostly due to extrusive processes, although thick andesitic lava flows which are remnants of a prehistoric effusive activity cover the eastern flank of the volcano.

Molodoy Shiveluch Volcano erupted catastrophically in 1964. This eruption resulted in collapse of old dome and formation of caldera (1.5×3 km), debris avalanche and pyroclastic flow deposits covered an area of 100 km^2 MELEKESTSEV *et al*. (2003). The new lava dome intensively growing inside the caldera since 1980 has being accompanied by large explosions with ash column over 10 km high and collapses of parts of the dome up to 0,28 km^3 in volume DVIGALO *et al*. (2011). The on-going eruptive activity of Molodoy Shiveluch Volcano is very hazardous for people and infrastructure of the region.

2. Description of the current extrusive activity

Since August 1980 to the end of 1981 comparatively small dome with height of 180 m had been forming at the center of northern part of the Molodoy Shiveluch caldera. After an 11-year pause in extrusive activity the dome growth resumed in April 1993 and continued until January 1995. During the second extrusive phase the dome height reached 300 m. Over the periods 1980-1981 and 1993-1995 the dome morphology was classical endogenous: its summit part was formed by large blocks of highly viscous andesitic lavas, talus mantle covered the flanks and the foot of the dome DVIGALO (1984), KHUBUNAYA *et al*. (1995).

Extrusive activity resuming at Molodoy Shiveluch in April 2001 and continuing until present differs with unusual for previous periods morphology and location of extruded lava forms SHEVCHENKO & SVIRID (2013).

During the 2001 eruption (Fig. 1 a) there was not single extrusive center. In the different parts of the old dome (on the west, the north-eastern flanks and in the western sector of its summit) three prominent crease structures were formed. Thus, in 2001 endogenous type of extrusive activity transformed into exogenous type.

The largest crease structure which formed on the west flank of the dome consists of separate lobes extending radially from the one center. Its material extruded through the talus mantle of the old dome. Its height over the flank surface is 140 m. Crease structure formed in the north-eastern sector of the old dome, composed of four pairs of divergent subhorizontal lobes. Such a shape was obtained when the ductile extrusive material was squeezing through a narrow crack in the steep slope at the foot of the dome. The height of this structure over the atrio bottom is 106 m. The formation of the third crease structure was noted in explosive funnel at the central part of the

old dome. Lobes of this structure have an irregular orientation of divergence: in the north-eastern sector they extended from south to north, in the south-west – diverge radially. Only the lobes of this structure have concentric bands of darker color, according to some of these bands cracking is observed. Its average height above the surface of the dome is 40 m.

In 2003 there was an inverse change in type of extrusive activity from exogenous to endogenous: three large blocks extruded in the western part of the dome. Among the crease structures observed on the previous images only one (north-eastern) had remained, it is almost had not changed in shape. The dome resumed to form exogenously in 2004, since then endogenous dome growth has never occurred. Crease structure on the Molodoy Shiveluch dome was also observed in 2005 by RAMSEY *et al*. (2012).

In the aerial image of 2012 lava dome (Fig. 1 b) a fracture can be seen, which bisected the surface of scoriaceous carapace of previously formed exogenous extrusive unit. Apparently this fracture formed much deeper – in the core of old endogenous dome. In the upper portion of the fracture a crease structure forms by extruding the ductile material. Shape of this structure is close to the mirror symmetric, its relative height is about 30 m.

3. Probable causes of the change in the type of extrusive activity

The transition from endogenous to exogenous growth may be caused by the dome reaching the critical size, when extrusion of large blocks leads to their cracking accompanied by release of a fresh material to the surface. However, this assumption does not agree with the fact that endogenous dome growth resumed in 2003.

Another probable cause for transforming the type of extrusive activity can be change in the physical properties of extrusive material due to variations of its chemical composition. Increase in the content of silica from 60.41-61.30% in 1980 to 62.44-62.52% in 1993 was noted in KHUBUNAYA *et al*. (1995). GORBACH (2006) revealed the transition from andesite to andesite-dacite (63.47-64.17 % SiO_2) in 2004.

According to RITTMANN (1962, p. 112-113) "crystalline phases … must not be taken into account in equating the chemistry of the magma with the type of eruption. The character of the eruption is, therefore, not determined by the bulk chemistry of the magma, but only by the chemical composition of the residual fluid part". GORBACH (2006) pointed that with an andesitic-

dacitic composition of the bulk sample from the 2004 dome its residual glass is rhyolitic (79.42 % SiO_2). The previous known value of silica content in residual glass of 1993 dome rock according to TOLSTYKH *et al*. (1998) was 76.08 % (61.26 % in the bulk).

In conclusion, it should be noted that in case when an extrusive dome growing endogenously reaches the critical size, possible course of events is a catastrophic collapse of the dome, as it was in 1964. The on-going exogenous extrusive activity at Molodoy Shiveluch Volcano to some extent protects its active dome from such catastrophic events.

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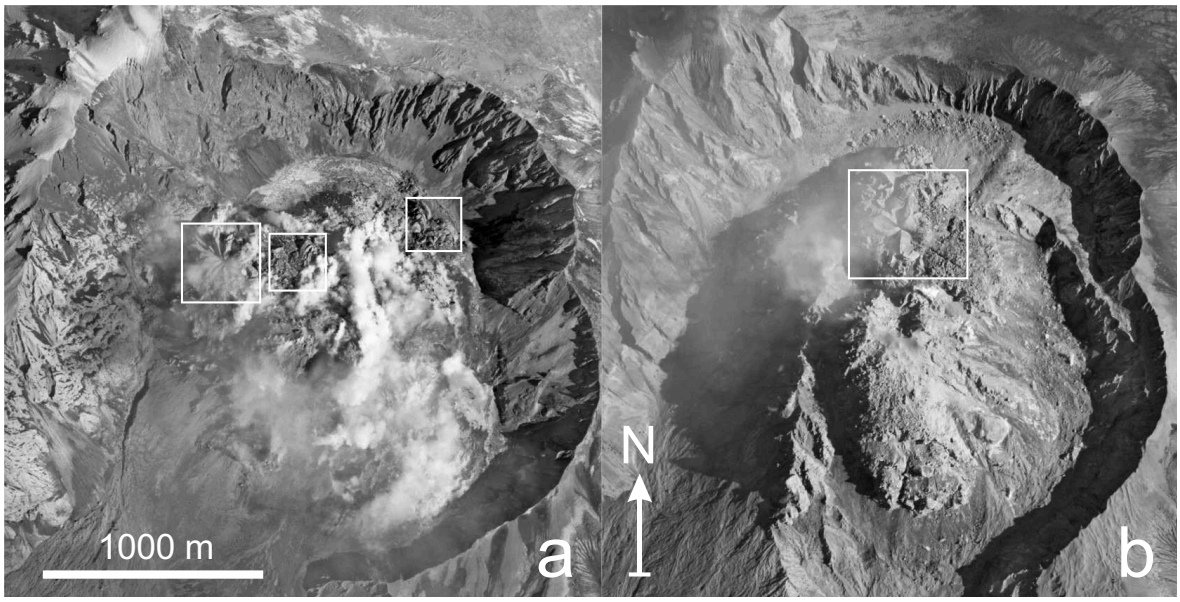

Fig. 1. Exogenous dome growth at Molodoy Shiveluch Volcano. (a) Aerial image of the dome taken on 16 May 2001 (courtesy of V. N. Dvigalo, Institute of Volcanology and Seismology). (b) Aerial image of the dome taken on 12 July 2012 (courtesy of I. Yu. Svirid, Institute of Volcanology and Seismology). White rectangles delineate crease structures. Scale bar corresponds to the average scale of the terrain.