The 2005 and 2010 dome collapse driven block and ash flows on Shiveluch volcano, Kamchatka: Morphological analysis using satellite- and field-based data

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Abstract

A new multi-scale investigation of recent block and ash flow (BAF) deposits on Shiveluch volcano, Kamchatka, using satellite- and field-based data has produced a detailed description of the surface deposits. In February, 2005 and October, 2010 Shiveluch produced large dome-collapse BAFs that travelled over 19 km down the southern flanks. These deposits have been interpreted using high-resolution (~0.5 m) WorldView-02 and QuickBird-02 panchromatic (PAN) satellite data to describe surficial morphologies, block distributions, forest devastation and the subsequent tree deposition. These data reveal complex deposits composed of overlapping flows and lobes with diverse morphologies including channel and levee structures, varying lobate terminations, compaction features, ridges, small hummock-like features, arcuate scarps, as well as post-depositional erosion and reworking, which were later investigated in the field. The deposits are composed of poorly sorted, porphyritic, dome material which is largely oxidized with rare evidence of hydrothermal alteration, as well as clasts eroded from older deposits, all within an ash-lapilli matrix. Large dome blocks up to 12 m in diameter are deposited to the distal edges of the deposit and are dominantly sub-rounded, and composed of banded, porphyritic, poorly vesicular, variably oxidized dome material with mafic xenolith inclusions. Many of these display fracturing and impact scours. This study links satellite-based interpretations of large BAF deposits to field observations, allowing the remote identification of morphological features. This multi-scale investigation of these morphologies can be applied elsewhere for rapid and safe identification of fresh deposits in dangerous or remote locations.

Location

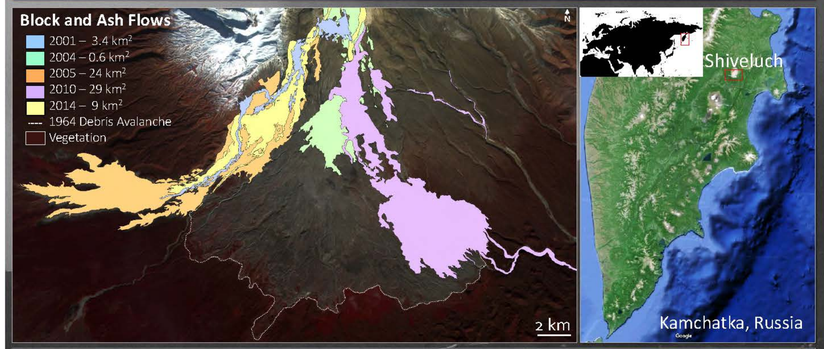

Fig. 1 Recent block and ash flow deposits on Shiveluch volcano mapped using ASTER VNIR data (Background image: ASTER VNIR acquired on 11 October 2010, RGB: 3,2,1).

Deposit Composition

Fig. 2 A) The deposits are composed of poorly sorted, porphyritic, variably oxidized dome material within an ash-lapilli matrix. There is no evidence of molten material, such as breadcrust bombs; **B)** surficial linear bands of wood fragments and vesicular andesite clasts eroded and entrained from the underlying 1964 pyroclastic flow deposit. This fluidized less dense material concentrated at the flow fronts, preserving lobe terminations. These bands are visible in the PAN data as high albedo (white) lineations that display overlapping relationships interpreted to represent the deposition of subsequent pulses of BAF over the duration of the eruption. **C)** Bedding and sorting is apparent in some locations.

Block Distributions

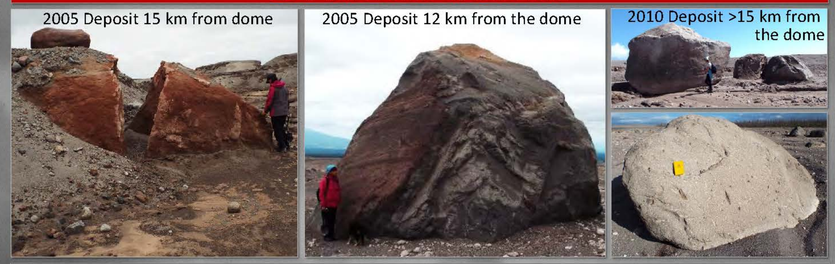

Fig. 3 Large blocks of unfragmented dome rock were transported large distances, attesting to the high energy of the BAFs. The distal reaches of the deposits retained high block concentrations. Many blocks (and trees) contain rounded to elongate surface impact marks from clast interactions.

Deposit Morphology

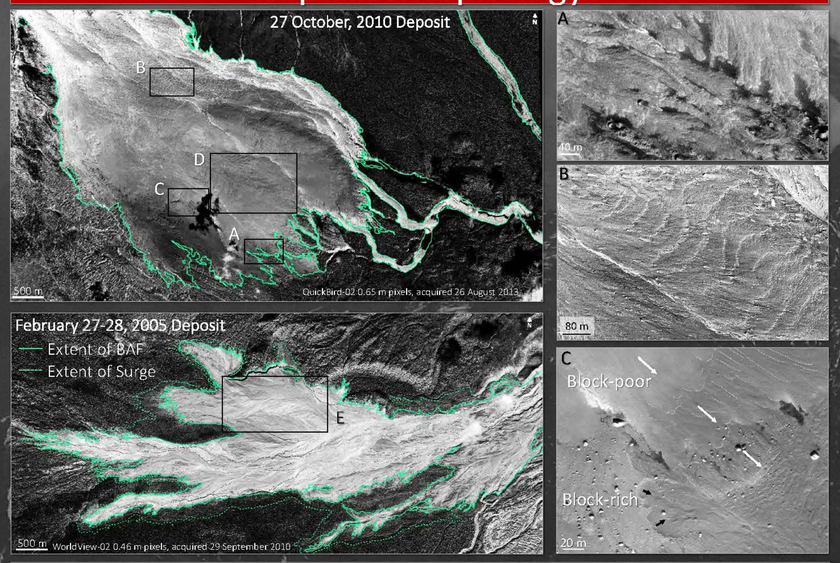

Fig. 4 A-C The main bodies of the 2005 and 2010 BAF deposits: A) feathery lobate flow terminations in the distal 2010 deposit; B) stepped ridges transverse to flow direction; C) multiple lobes variable block contents. Compression ridges resulted from the overlying deposit bulldozing into the fresh deposit.

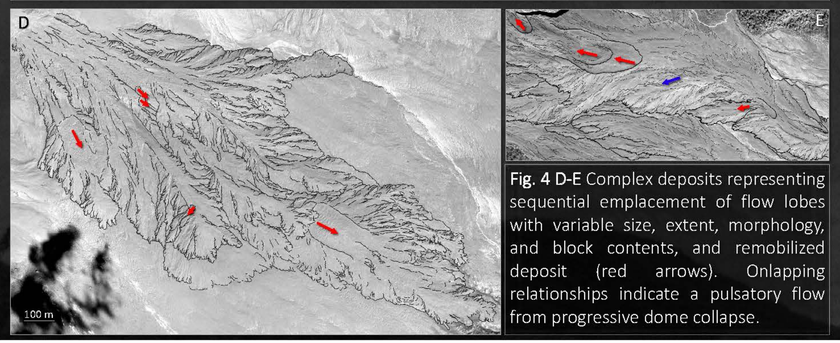

Fig. 4 D-E Complex deposits representing sequential emplacement of flow lobes with variable size, extent, morphology, and block contents, and remobilized deposit (red arrows). Onlapping relationships indicate a pulsatory flow from progressive dome collapse.

Vegetation Damage

Fig. 5 Four zones of vegetation damage: 1) complete tree removal and/or complete burial by deposit; 2) tree stumps remaining/felled trees in situ; 3) singe zone where dead trees remain standing reaching over 280 m from the BAF deposit; 4) No tree damage.

Field Observations

Fig. 6 A) Onlapping 2005 BAF deposit lobe with terminal vesicular andesite band preserving the flow edge; B) lobe located toward the distal end of the 2005 deposit; C) the southeastern 2005 deposit contained flow lobe deposits with steeper margins. White arrows indicate flow direction.

Conclusions

- The 2005 and 2010 large block and ash flow deposits comprise overlapping lobes with variable sizes, extents, morphologies and block contents that indicate a progressive dome collapse;
- Bands of less dense eroded and entrained clasts mark the terminus of fluidized flows, highlighting the sequential emplacement of flow lobes;
- The 2005 and 2010 BAFs transported and deposited large outsized dome blocks over 15 km from the dome;
- A detached dilute pyroclastic surge killed trees radially over 280 m from the 2005 BAF deposit.

Further Work

This research is also being carried out on smaller block and ash flows on Shiveluch volcano shown in Fig. 1. A database of surface morphological features is being constructed to aid identification using various spatial-resolution satellite datasets, and during field investigations. A comparison study will be undertaken to include column collapse pyroclastic flow deposits on the Mount St. Helens pumice plain to investigate depositional processes across the different granular flow types.

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