Physical process of cryptodome formation by precise DEM analysis- Mt. Usu (1977-82) and Mt. St. Helens (March-May, 1980)

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Active dacitic volcanoes are often suffered from not only huge amount of upheaval but also localized subsidence during magmatic intrusion activity. In the 1977-82 activity of Mt. Usu, a new cryptodome (Usu-Shinzan) (maximum apparent height change: 273 m by DEM) was born. The doming deformation was investigated by means of Digital Elevation Model (DEM). Precise DEM (1 m grid) were newly developed by large-scale topographic maps (1:2,500 and 1:5,000 with contour interval: 2 m and 5 m) in the periods of October 17, 1976, August 23, 1977, October 23, 1977, November 4, 1977, and October 1983. The analysis of differential DEM before and after the 1977-82 intrusive episodes revealed the thrusting up of Usu-Shinzan block which was delineated by U-shape fault (northward thrusting was about 205 m at the north ridge by DEM). Local subsidence was taken place at preexistent lava domes, Ko-Usu, Oo-Usu, and Ogariyama. Asymmetric graben was formed along the merge of Usu-Shinzan U-shape block. The lava domes subsided significantly in the graben (-10 m to -70 m). Total volume loss of Ko-Usu lava dome was estimated as $2.3*10^6$ m^3. Most of the subsidence occurred from August to early November, 1977 accompanying with the occurrence of intensive earthquake swarms (earthquake family) beneath Ko-Usu.

Similar volcanic subsidence has been reported at Mt. St. Helens in 1980 (Moore and Albee, 1981) and Bezymianny in 1956 (Gorshkov, 1959). For conducting comparative study between Mt. Usu in 1977-82 and Mt. St. Helens on March-May in 1980, DEM was also created for Mt. St. Helens. The remarkable bulging of northern flank (apparent elevation change: more than -150 m), significant subsidence of the preexistent lava dome (more than -100 m), and the occurrence of intensive shallow earthquake swarms were quite similar phenomena in both doming activities of Mt. Usu 1977-82 and Mt. St. Helens 1980. Rapid intrusion rate (1-$3*10^6$ m^3/day) and directional graben formation were a clear evidence of the progressive dike intrusion beneath the summit in the early doming stage. Remarkable lateral ground movement such as U-shape faulting (in Mt. Usu) or flank bulging (in Mt. St. Helens) strongly suggested the lateral growth of the magma.

The lateral growth of the magma induced flank instability at the north flank and a following devastated sector collapse on May 18 in 1980 at Mt. St. Helens. On the other hand, no sector collapse occurred at Mt. Usu in 1977-82 because the doming deformation occurred at the nearly flat ground not at the steep flank like Mt. St. Helens and Bezymianny. Mt. Usu was already truncated the summit area by the sector collapse several thousand years ago, thus fortunately no more collapsed. However, the magmatic intrusion process was quite similar each other. The dike intrusion allowed not only the summit graben formation by the extensional stress but also repeated slips at the root of lava domes which may produce the shallow earthquake swarms beneath the lava dome. The total increased volume was nearly equivalent in order between Mt. Usu in 1977-82 ($175*10^6$ m^3) and Mt. St. Helens March-May in 1980 ($115*10^6$ m^3)(Okada, 2007). The common physical process of dacitic magma intrusion exists between them, that is a rapid dike intrusion and the 10^8 m^3 orders of the lateral growth of cryptodome. The topographic analysis utilizing DEM is one of the most powerful tools for evaluating huge amount of deformation such as doming deformation.

References:
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