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Bombs, welded spatter, rockfall and cross-cutting breccia enclosed in avalanche deposits 300 m deep in a debris-filled vent (diatreme), Hopi Buttes, Arizona

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Diatremes are debris-filled vents that are surprisingly large relative to the small maar volcanoes that are their surface expression. Field characteristics of well-exposed diatreme deposits in the Hopi Buttes volcanic field, in Arizona, USA, challenge existing diatreme models, but may provide insight into the broader behavior of magma plumbing systems feeding small basaltic volcanoes.

Standing Rocks East is a volcanic "neck" rising 35 m above the adjacent land surface. It was previously identified as the deposit of a "root zone", i.e. the fragmental zone at the base of a diatreme structure, based on the depth of exposure, textural diversity of its deposits, irregular dikes that terminate within it, and its small footprint relative to a nearby diatreme remnant. Painstaking mapping in a new study reveals: (1) most of the diatreme structure at the level of the "neck" is filled by a coarse country-rock breccia, which contains blocks sourced both from as far as 200 m below exposure, and as much as 300 m above it at the paleosurface; (2) a zone of juvenile-rich heterolithic lapilli tuff, with domainal map-view variations in deposit granulometry and componentry were emplaced after the country-rock breccia but before the rocks of the neck; (3) the neck comprises an architecturally complex range of deposits in which metres-wide subvertical sheets dominated by coherent basaltic rock cut, locally with surface wrinkes and clast imprints, and locally grade outward into, subhorizontally layered domains, up to several metres in extent, of breccia and welded spatter including large isolated boulders of mixed pyroclastic and host mud/mudrock that deformed adjacent spattery deposits. From these relationships we draw these conclusions. (A) The neck is not a root zone, because it is entirely enclosed within earlier deposits in the diatreme structure – it is not at the bottom of this diatreme structure, and hence represents an intra-diatreme fragmentation zone. (B) This fragmentation zone formed after coarse country-rock breccias in which blocks spanning hundreds of metres of stratigraphy below and above current exposure level, filled a deep vent structure, and after these breccias were cut through by explosively emplaced heterolithic lapilli tuff. (C) Weak fragmentation of fluid magma at the irregular and unstable floor of a deep crater pocked by subcraters allowed emplacement of the bewildering sequence of steeply to shallowly dipping, coherent to welded to fully fragmental, mixed, and locally hot-deposit-deforming rocks of the neck.

During development even of this small volcano, there was great diversity of activity. The country rock breccia requires excavation of a deep, largely open, crater at the same time that large country-rock blocks were brought upward from their source. Heterolithic tuff is from effective and repeated explosive fragmentation events, while the neck comprises small-volume deposits of material emplaced at the base of a deep open crater. The small volume of solidified magma here indicates formation of a large diatreme structure despite limited magma supply; at times transfer of magma elsewhere along the feeding system probably facilitated deepening of explosion sites by drawing magma downward in the structure.