Linking maar eruptions with diatremes: experimental insights from single and multiple buried explosions

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Maar-diatreme eruptions are hazardous to people and infrastructure; kimberlitic diatremes can also contain diamonds so they are economically important. Yet processes occurring in the subsurface diatreme and their relation to surface eruptions are not yet well understood. Previous laboratory studies have addressed different types of potential 'diatreme-forming' processes, whereas previous field-scale experimental studies have addressed cratering but without significant focus on sub-crater deposits, and only for single explosions. We conducted field-scale experiments at the Geohazards Field Station (University at Buffalo, NY) using single and multiple buried chemical explosions in a prepared, layered granular substrate. The explosions produced craters, extra-crater deposits and sub-crater deposits analogous to volcanic maar craters, tephra rings and incipient diatremes.

We excavated a series of vertical cross-sections through the deposits after the explosions. This revealed a significant zone of sub-crater deposits, extending several decimeters below the post-shot craters. Videos of the experiments show vertical ejection and fallback of material, especially for the explosions that occurred below optimal depth of burial. In other words, the majority of the material which formed these eruptive plumes fell back directly into the transient explosion craters. The sub-crater deposits have an upper zone containing domains sourced from different substrate depths, and an underlying zone distinguished primarily by being more loosely packed than the original substrate. We infer that much of the loosely packed material was disassembled, vertically transported to different heights during the explosions, then fell back without significant relative lateral movement of grains. One explosion ejected material from the deepest substrate horizon, but it was redeposited only within the crater and is unrepresented in the ejecta ring.

Implications of the experiments for maar-diatreme volcanoes are as follows: (1) vertical focusing of deep explosions in the diatreme explains the deficit of deep wallrock lithics observed at maar volcanoes; (2) direct vertical fallback is possibly a major process forming diatreme deposits; (3) direct fallback from numerous explosions at various depths and lateral positions would eventually produce a diatreme fill that looks "well mixed" overall; (4) even in our limited simulation the number and scaled depth of explosions clearly affect diatreme size and structure. While representing a pilot study, these initial results already advance our understanding of explosive cratering and have implications for understanding how some features of maar-diatreme volcanoes and some kimberlite pipes form.