Bedded to non-bedded transition at Round Butte diatreme, Hopi Buttes volcanic field, Arizona

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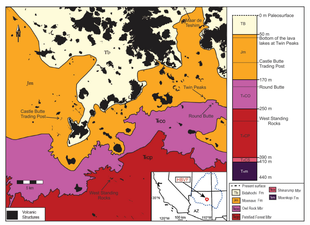
Abstract

The Hopi Buttes volcanic field (HBVF) in the Navajo Nation (Arizona, USA) provides excellent exposures of maar-diatreme volcanoes at different erosion depths, from the maar ejecta ring and crater infill (White 1991) to the deep diatreme (Lefebvre et al. 2013). This makes it an ideal locality to better understand eruptive processes for this type of volcano. We are currently investigating the Round Butte diatreme in the eastern portion of the HBVF. The current exposure lies at the top of the Owl Rock member of the Chinle formation (Upper Triassic) near the contact with the bottom of the Moenave formation (Lower Jurassic), 190 m below the eruptive paleosurface. At this depth, Round Butte is 130 m in diameter and the exposure consists of 30 m high cliffs. It displays the transition between the lower (non-bedded) and the upper (bedded) portions of the diatreme. This contact is irregular, varying in apparent angle from sub-horizontal to sub-vertical.

In order to constrain the morphologies of this contact and the processes that created Round Butte we carried out one month of field work. We mapped the cliffs of Round Butte, described and sampled all the units defined during the mapping and we did componentry measurements using the line count method proposed by Lefebvre (2013). Our preliminary observations highlighted that at Round Butte the upper part of the diatreme is composed of diffuse to well defined bedding with some accumulation levels of juvenile and lithic blocks, while the lower part is massive and non-bedded. A relatively large debris avalanche in the southwest of the outcrop seems to arrive early in the growth of Round Butte and shows a succession of Moenave and Bidahochi blocks intercalated by tuffs from the ejecta ring. In the south face, the transition seems to be linked to an intense activity of a "main vent".

Our preliminary model has four steps. (1) The first phase of crater excavation was deep and directly followed by (2) infilling with bedded units and a debris avalanche. The crater level must have been higher than the current top of the outcrop at this stage. (3) The "main vent" starts another phase of excavation that created the current upper-lower transition at Round Butte and that (4) deposited the last phase of crater infill.

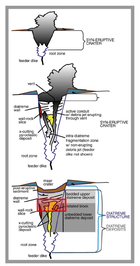
Geological setting



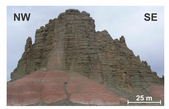
Geological map of the Hopi Buttes Volcanic Field showing some maar-diatremes and the major sedimentary formations of the area modified from Lefebvre (2013)

- The Hopi Buttes Volcanic Field (HBVF) is located in south part of the Colorado Plateau, Arizona
- The Colorado Plateau is tectonically stable and displays flat-lying stratas of Paleozoic and Mesozoic sediments
- From north to south you go deeper in the maar-diatremes structures from the maar and the ejecta ring (ex: Teshim Maar) to the lower diatreme (ex: West Standing Rocks)

Maar-diatreme features

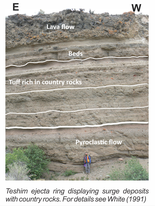


Cross-section of an erupting maar-diatreme after White and Ross (2011)

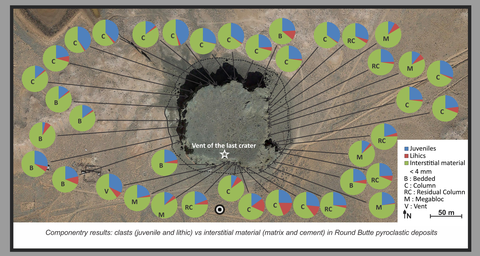


West Standing Rocks diatreme displaying non-bedded deposits. For details see Lefebvre et al. (2013)

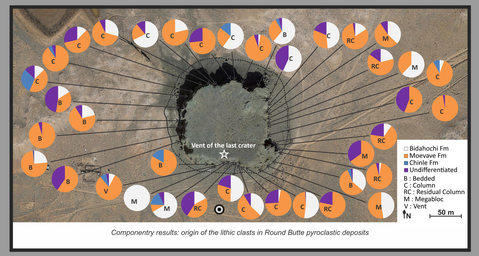
- Maars are cut into the pre-eruptive surface
- The formation of the maar is linked to the excavation of country rocks toward the ejecta ring
- The lower diatreme is non-bedded sometimes with internal vertical contacts (columns) while the upper diatreme is bedded with sub-horizontal contacts
- Debris jets occur in the lower diatreme creating columns and sometime vent at the surface
- Round Butte outcrop is located at the transition between lower and upper diatreme (red box on the figure)



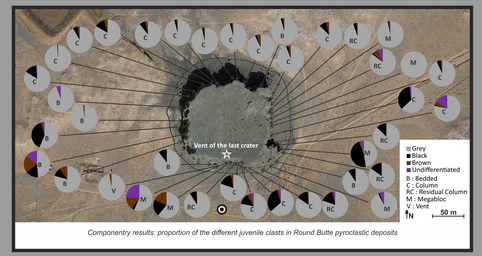
Teshim ejecta ring displaying surge deposits with country rocks. For details see White (1991)



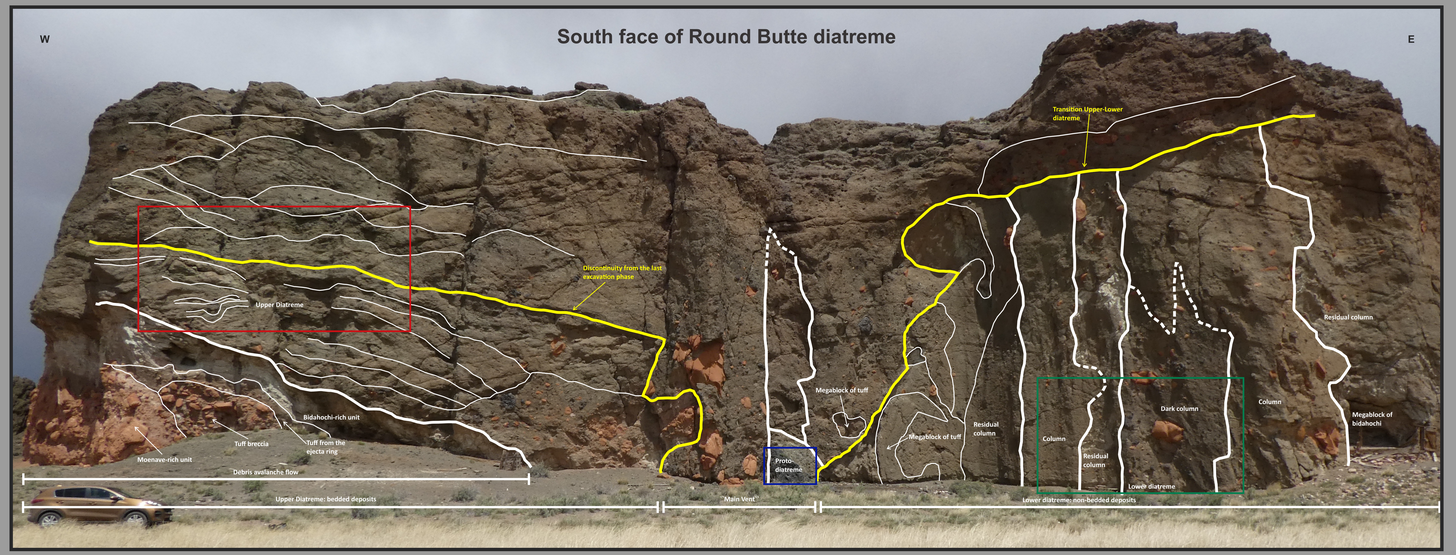
Componentry results: clasts (juvenile and lithic) vs interstitial material (matrix and cement) in Round Butte pyroclastic deposits

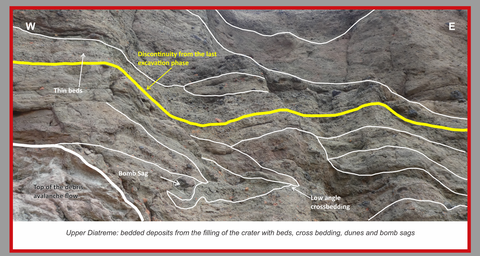


Componentry results: origin of the lithic clasts in Round Butte pyroclastic deposits

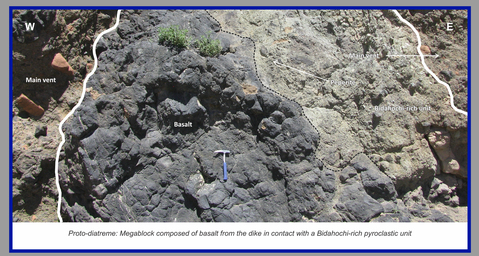


Componentry results: proportion of the different juvenile clasts in Round Butte pyroclastic deposits

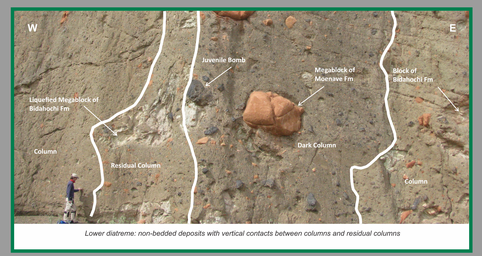




Upper Diatreme: bedded deposits from the filling of the crater with beds, cross bedding, dunes and bomb sags

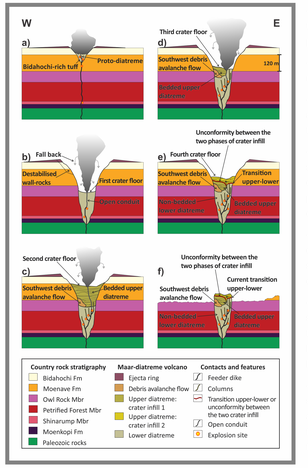


Proto-diatreme: Megablock composed of basalt from the dike in contact with a Bidahochi-rich pyroclastic unit



Lower diatreme: non-bedded deposits with vertical contacts between columns and residual columns

Preliminary model for the South face



Preliminary model showing the evolution of the south face of Round Butte during its activity

- a) Onset of the activity: creation of the proto-diatreme and Bidahochi-rich pyroclastic rocks
- b) First excavation phase: country rocks are deeply excavated
- c) First phase of crater infill: surges and debris avalanche flows are filling the crater with the ongoing activity
- d) Second excavation phase: a new strong activity period deepens the crater again and exposes non-bedded pyroclastic rocks at the bottom of the crater
- e) Second phase of crater infill: ongoing activity is filling the crater with surges and fall deposits; eruption ends
- f) Current erosion level: the current south face of Round Butte displaying the transition between the upper and lower diatreme and an unconformity between the two phases of crater infill
- Future work are to analyze the thin sections to quantify the componentry and to link the other faces to the south face to create the final model of the formation of Round Butte

Conclusion

Round Butte is a small diatreme lying 190 m below the eruptive paleosurface displaying the transition between the lower and the upper diatreme. Analysis of the different units on the south face allowed us to build a preliminary model of Round Butte formation. This model involves four distinct crater floor positions. The first was deeper than the current outcrop while the second one was higher than the current outcrop top. The third crater position is directly visible in the South face and corresponds to either the current transition between the lower (unbedded, with columns) and the upper (bedded) diatreme, or to a discontinuity between the two phases of bedded crater infill. The fourth crater position was again higher than the current top of Round Butte and corresponded to the bottom of the maar at the end of the activity.

Future work will improve our preliminary model by better integrating the other (already mapped) faces of Round Butte. Componentry measurements will be carried out on thin sections, using line counting and point counting methods. These data will be added to the field line counts to obtain the composition of the units. With this, and the field descriptions, a facies map will be generated and the relations between facies will be analyzed to have a more detailed and complete idea of Round Butte formation.

Acknowledgments

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