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How do cirques form in ocean island volcanoes: the case of Piton des Neiges (Réunion Island, Indian Ocean)

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“Cirques” are funnel-shaped, seaward-narrowing valleys commonly observed on many volcanic islands worldwide, such as Tahiti (French Polynesia), La Palma or Gran Canaria (Canary), Anjouan (Comores), and Maui or Molokai (Hawai’i). Because they contradict the basics of regressive erosion by rivers, these geomorphic structures have been interpreted in many ways, including the erosion of volcano-tectonic depressions (crater, caldera, rift zone), the formation of leaf grabens caused by volcano spreading, or the subsidence of dense plutonic bodies within edifices. Piton des Neiges volcano (Réunion Island) is dissected by three cirques (Salazie, Mafate and Cilaos) and thus provides an excellent case to study the processes that lead to the formation of these funnel-shaped valleys. To do so, we performed a detailed field and photogrammetric mapping of the volcanic and volcanoclastic products outcropping in the cirques using an updated chronostratigraphy.

Our mapping reveals that the three cirques of Piton des Neiges are not delimited by faults, which excludes vertical movements as the primary cause of their formation. Rather, the cirques are built on former horseshoe-shaped depressions filled with volcanoclastic breccias (mostly related to debris avalanches and debris flows), and later covered by lava flow units. Importantly, the breccias are several hundred meters thick in the innermost parts of the cirques, but thin out until complete disappearance toward the outer flanks of the volcano.

In consequence, we interpret the basal volcanoclastic breccias as playing a major role in the formation of the cirques, by offering a weaker resistance than the lava flow units. This contrasted resistance leads to greater erosion rates on the inside of the volcano than on the outer flanks and, hence explaining the reverted funnel shape of the cirques. In our model, cirques are therefore erosional structures mostly guided by past dismantling episodes rather than by tectonic or volcano-tectonic structures.