Why collapsed pits are so common in subaqueous sheet flows?

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Coalescence and inflation of flow lobes are common to fluidal basaltic lava emplaced on a gentle slope and a flat field. These mechanisms are fundamental to form vast sheet-like lava flows such as flood basalt on land, and subaqueous lobate sheet flows, the most common lava form in intermediate- to fast-spreading ridges. Unlike subaerial flows, subaqueous lava occasionally forms a hollow flow with collapsed roof crust. Previous studies suggested that such collapsed pits were formed by drainback of molten lava beneath a lava pond directly above a vent. I suggest that the formation of collapsed pits is an inevitable consequence of inflation of subaqueous sheet flows.

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Chadwick et al. (1999) described a lobate sheet flow field from the EPR 45?. The lava flowed 6 km along the axis toward a southern topographic low and formed collapsed pits there. The floors of the pits are covered with wrinkled sheets and jumbled flows. Apparently, these collapsed pits were not formed by drainback of lava to the vent.

The south rift zone of Loihi seamount extends 20 km SSE from 1,200 to 5,000 m in depth. The ridge broadens at deeper than 3,000 m to a deltaic shape, making the rift axis equivocal. The delta consists of numerous flat terraces 5-10 m high fringed with lobate steep slopes. Some terraces are surrounded by lobate slopes almost 3/4 of the periphery, suggestive of half buried flat-topped cones. "KAIKO" and "SHINKAI" dives on the largest cone showed that the flat top was covered by lobate sheet flows accompanied by a small amount of pillows, cut by open fissures running north-south in echelon. Beyond the southern rim of the flat top, the lobate sheet changes downslope into elongated pahoehoe lobes, which then grade into elongated pillows on steeper lower slopes. The upper slope on the north of the flat top is covered by elongate pillows with different lithology. Therefore, the lobate sheets on the top did not flow down from the upper rift, but were ponded in the summit crater on the top of the lava cone. Spilt lava over the crater rim draped down on the slope formed pillow flows. No collapsed pits were found on the lobate lava lake.

Further down on the rift zone from 4860-4820 m in depth are four terraces fringed with lobate slopes. The slopes consist of pillows, while the terraces have abundant collapsed pits on lobate flow fields. Lava channels exist on the floor of the pits, filled by fluidal lava with ropy wrinkles and jumbled crusts, and lineated sheet flows.

Lava forms indicative of faster flow rates appear on the bottom of collapsed pits are common to the Loihi south rift zone, the axial rift zones of the Galapagos Spreading Centre and the EPR. The collapsed lobate sheet flows are not ponded lava lakes, but were emplaced downslope away from the source areas. The collapses cannot be explained by drainback of lava to the vent during the waning stage of the eruption. It is concluded that the cause of the collapses are rapid drainage of molten lava within the inflating lobate sheets as is observed on much smaller, hollow pahoehoe lobes. Under water, effective cooling by water rapidly forms brittle crust on the surface of a flow, which prohibits lava to continue flowing. Then, the lava lobe stops flowing and begins to inflate much earlier than subaerial flows with an identical supply rate of lava. Thin viscoelastic layer beneath the brittle crust is stretched as the lobe inflates, and eventually breaks to drain out lava inside. Wrinkled and jumbled sheet flows, which are taken as an indicator of high eruption rates, are merely the result of rapid drainage of lava from collapsed inflated sheets, and do not necessary indicate high discharge rates of lava from the source vent.