Lava-Fed Delta

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Definition

A distinctive nearly flat-topped steep-sided volcanic landform sourced in a subaerial volcano that is formed principally by mafic lava where it enters standing water (sea or lake, including glacial lakes formed by eruptions of subglacial volcanoes). It is the volcanic equivalent of a sedimentary delta.

Category

A type of lava flow

Synonyms

Hyaloclastite delta; Hydroclastic delta; Hydrovolcanic delta; Lava delta; Volcanic delta

Description

Lava-fed deltas are morphologically distinctive. They are composed of a nearly flat-lying resistant caprock formed of subaerial lava flows that are analogous to topset beds in a sedimentary delta and steep evenly dipping large-scale beds of breccia analogous to foreset beds that give the steep flanks to the landform. A generally flat-lying internal planar surface separates the lava flows from hyaloclastite and is a subaerial–subaqueous transition known as a passage zone (Jones 1969; Skilling 2002; Smellie 2006).

Morphometry

The deltas are bench- or terrace-like fans, with lobate (cat’s paw) or digitate (bird’s foot) terminations; they become thinner (i.e., are wedge shaped) when traced to their source volcano. In protected shallow-water environments (e.g., most lakes), the deltas are able to advance far into water, whereas they are commonly deflected parallel to the coastline in a marine setting, possibly due to the action of surf spraying cold water on the lava flow front and causing the construction a barrier of chilled lava that deflects later lava effusion (Umino et al. 2006). Most described examples are a few tens to a few 100 m thick, but rare terrestrial glaciovolcanic examples might exceed 1 km (Smellie 2013). Mars

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may also contain even thicker, very ancient lava-fed deltas exceeding 100 km in extent (Chapman and Tanaka 2001).

Subtypes

Two types have been described thus far: those (1) fed by pahoehoe lava (Figs. 1, 2, and 3) and those (2) fed by aa lava (Figs. 4 and 5). Block lava also forms deltas but has not yet been described in detail. The constituent lithofacies and lithofacies associations of pahoehoe- and aa-fed deltas are distinctively different (Skilling 2002; Smellie et al. 2011a, b, 2013), but there are only slight differences in gross morphology, principally that the margins of aa lava-fed deltas dip less steeply (c. 10°–20°) than their pahoehoe-fed counterpart (c. 25°–40°).

Interpretation

In pahoehoe-fed deltas, lava lobes enter water, chill, and rapidly disintegrate into breccia formed of a mixture of glassy and very fine-grained lava accompanied by more coarsely crystalline lava fragments in cases where the caprock (a lava bench or terrace) has also collapsed and broken up en masse (Behncke 2004; Skilling 2002). In aa lava-fed deltas, the generally thicker and faster-moving channelized lava is able to penetrate further below the water surface before it freezes or disintegrates into breccias (Smellie et al. 2011a). Distinctive internal features of lava-fed deltas, particularly morphological details of the passage zone, are known to be diagnostic of eruptive setting.
Fig. 2  Pahoehoe lava-fed delta filling Kaimū Bay, Hawaii (Fig. 3a from Umino et al. 2006); the dotted line depicts the coastline prior to construction of the delta.

Fig. 3  Pahoehoe lava-fed delta at Kamoamoa in Hawaii entering the sea (USGS/C Heliker/1992)
Fig. 4  Aa lava-fed delta advancing in a glacial meltwater lake at Veniaminof volcano (USGS/E. Yount/1983)

![Diagram of a lava-fed delta](image)

Fig. 5  Schematic diagram showing the construction and internal structure of an aa lava-fed delta emplaced in an ice sheet (From Smellie et al. 2011a)
and can be used to distinguish glacial, lacustrine, and marine environments (Jones and Nelson 1970; Skilling 2002; Smellie 2006; Smellie et al. 2011a, b).

**Formation**

See Porebski and Gradzinski (1990), Skilling (2002), Behncke (2004), Smellie (2006), and Smellie et al. (2011a, 2013) for details.

**Age**

Lava-fed deltas will form wherever subaerial lava enters water. They are not age diagnostic.

**Degradation**

Posteruptive gravitational collapse of lava benches, steep delta fronts, and flanks occurs frequently (Skilling 2002; Behncke 2004; Komatsu et al. 2007). They are a volcanic hazard and have been observed during the current eruption in Hawaii (see http://hvo.wr.usgs.gov/hazards/oceanentry/deltacollapse).

**Surface/Structural Units**

The surfaces of deltas are a lava field formed from, and showing the characteristics of, pahoehoe or aa lava (see ≥ lava flow).

**Composition**

Overwhelmingly basaltic. There are much rarer examples with dacite, mugearite, tephriphonolite, and trachyte compositions, but no rhyolite lava-fed deltas are known.

**Studied Locations**


**Prominent Examples**

Brown Bluff, James Ross Island, and Hallett Coast, Antarctica (Skilling 1994, 2002; Smellie 2006; Smellie et al. 2011a, b, 2013); Disko Island, Greenland (Pedersen et al. 2002); Hawaii (Moore et al. 1973; Umino et al. 2006).
Significance

The positive identification of lava-fed deltas on non-Earth planets (especially Mars) will be diagnostic of the former presence of ponded surface water (Ghatan and Head 2002). Internal features of lava-fed deltas can be used to infer the former presence of glacier ice (Smellie 2006).

Astrobiological Significance


Planetary Analogs

Examples are also inferred on Mars, associated with postulated subglacial volcanoes (Chapman and Tanaka 2001; Ghatan and Head 2002).

History of Investigation

Mathews (1947) may be the earliest description of a lava-fed delta associated with a subglacial volcano. Skilling (2002) provides a brief history of research into the construction and emplacement of lava-fed deltas in all environments.

Database

Smellie (2013) has provided a database of thickness, area, and volume for lava-fed deltas associated with subglacial volcanoes.

Origin of Term

First use of lava-fed delta was probably by Porębski and Gradzinski (1990), but see also Skilling (2002).

See Also

- Delta
- Lava Flow
- Subglacial Volcano
References

Porębski SJ, Gradzinski R (1990) Lava-fed Gilbert-type delta in the Polonez Cove Formation (Lower Oligocene), King George Island, west Antarctica. IAS Spec Publ 10:335–351


