Submarine Lava Morphology

Introduction

- Lava morphology
- Wax modeling
- Factors that affect lava morphology
- Morphology in different submarine settings
- Methods for studying lava morphology
- Implications

Types of Lava Morphology

Lava pillows

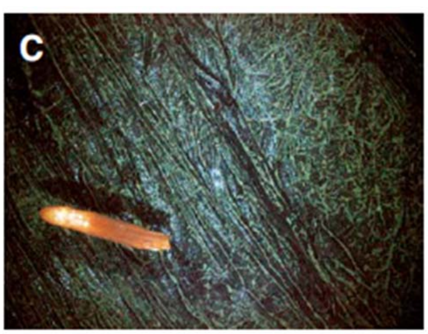
NOAA

Lobate Flow

NOAA

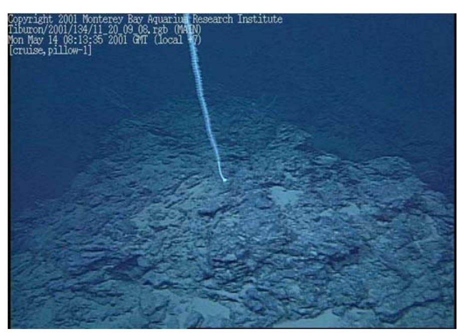
Lava Morphology: Sheet Flows

Lineated Sheet Flow



Soule et al. 2007

Hackly Flow



Monterrey Bay Aquarium Research Institute

Wax Models

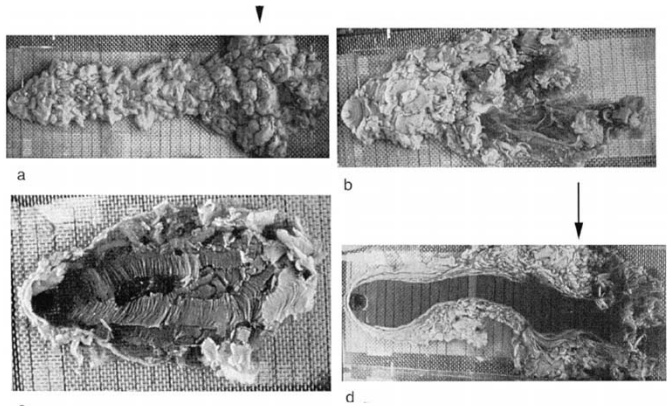


Fig. 1. Top views of typical morphologies obtained in the laboratory: (a) pillowed flows; (b) rifted flows; (c) folded flows; and (d) leveed flows. In each image, the vent is to the left and the lines on the tank floor are ~ 2 cm apart. Solid wax is light gray and liquid was is dark gray. Position of false floor is indicated (arrow) in (a) and (c); downstream of arrow, PEG traverses a horizontal surface.

Gregg and Fink 2000

Wax Models

Correlating Ψ to morph types:

$$\Psi = \frac{\text{time required for solidification of flow surface}}{\text{time required heat advection within the flow}}$$

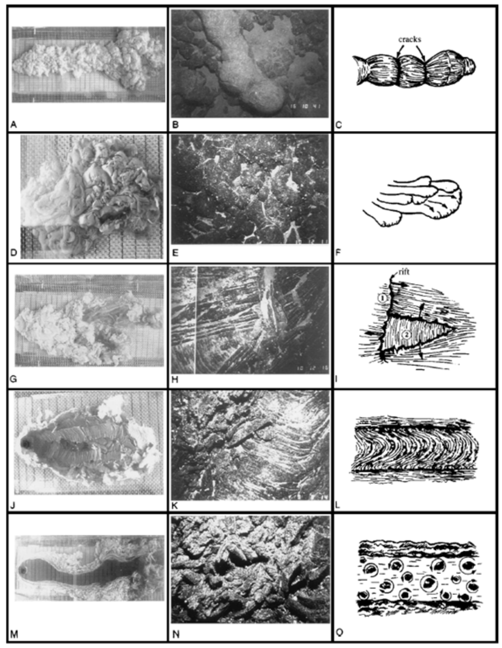
Laboratory morphology	Submarine morphology	Ψ 0° min	Cooling rate ↑	Slope ↓	Flow rate ↓
pillows	pillows				
	lobate sheets				
rifts	lineated sheets	3			
folds	ropy sheets	10			
levees	jumbled sheets	30			

Wax Simulations and Lava Flows

Morphologies
- 1st row: pillows
- 2nd row: lobate flows
- 3rd row: lineated sheet flows
- 4th row: folded flows
- 5th row: Jumbled sheet flows

Primarily controlled by:
- Effusion rate
- Slope

(Gregg and Fink 1995)



Wax Models and Folds

- Effusion Rate: Folds, viscosity and temperature
- Lava composition: Ratio of the 2nd generation fold wavelength to the first-generation fold wavelength

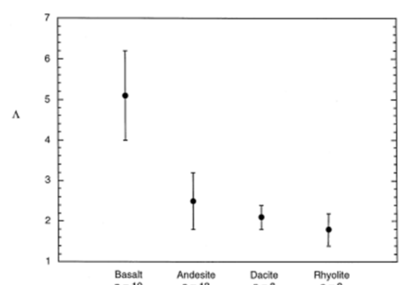


Fig. 2. The relation between the ratio (Λ) of second-generation fold wavelengths (L_2) and first-generation fold wavelengths (L_1) to terrestrial lava flows; n indicates the number of flows measured for each composition. Although Λ values for more evolved lavas overlap, basalts are distinct.

(Gregg et. al 1998)

Factors that Affect Lava Morphology

- Characteristics of the Magma
  - Viscosity
  - Composition
  - Crystal content
- Characteristics of the Volcano/Eruption
  - Conduit
  - Effusion rate
- Characteristics of the surrounding area
  - Slope
  - Surface roughness

Properties of the Magma

- As viscosity increases, morphology changes
- Viscosity factors:
  - More crystals → higher viscosity
  - More felsic → higher viscosity

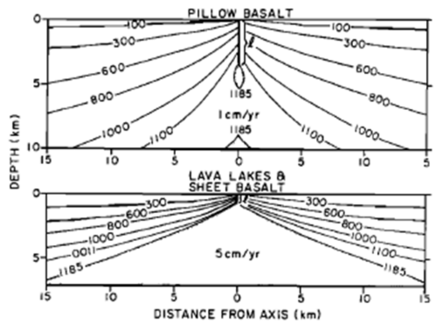
Characteristics of the Volcano

Effects of the conduit

- Long and narrow: Pillow lavas
- Short, wide conduits: Sheet lavas

Effusion Rate

- Low effusion rate: pillows
- High effusion rate: lava lakes and sheet flows



Bonatti and Harrison (1988)

Surrounding Area

Slope

Generally

- With increasing slope:
  - Velocity, pillow mound thickness, flow length, and distance from vent to first folds increase
  - Flow width decreases
- Slopes $\geq$ 40° have a greater effect on flow morphology than effusion rate or cooling

However:

- Slope has little effect if effusion is low and/or cooling is rapid
- Implications:
  - Gentle slopes to flat lands: lava morphology can be used to directly determine effusion rates
  - Steep slope (example where lavas flow over fault scarps): slope must be taken into account when estimating effusion rate

Surface Topography/Roughness

- Rough surfaces made transitions occur at higher effusion rates

Factors that affect Morphology

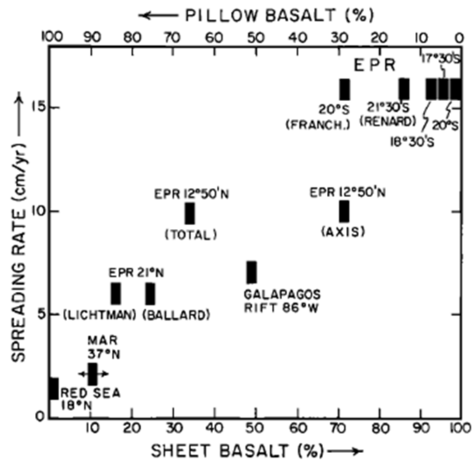
	Pillow Basalts	Lobate Flows	Sheet Flows	
High	←———	Viscosity	←———	Low
High	←———	Crystal Content	←———	Low
High	←———	Composition (SiO_2 content)	←———	Low
Low	———→	Temperature at Eruption	———→	High
Narrow	———→	Conduit Width	———→	Wide
Long	———→	Conduit Length	———→	Short
Low	———→	**Effusion Rate**	———→	High
Low	———→	**Slope**	———→	High
Rough	———→	Surface Roughness	———→	Smooth
Low	———→	**Spreading Rate**	———→	High

Adapted from Bonatti and Harrison (1988)

Other Features

- Collapse features: found with multiple lava flow morphologies
- Kipukas: can be used to estimate thickness of the flow

General Characteristics of Morphology at Different Settings



Bonatti and Harrison 1988

Fast Spreading Ridges

- In neovolcanic zone:
  - Lavas dominantly sheet flows
  - Few seamounts
- Outside of the neovolcanic zone:
  - Predominately lobate lava flows
  - Seafloor tubes and channels

Intermediate Spreading Ridges

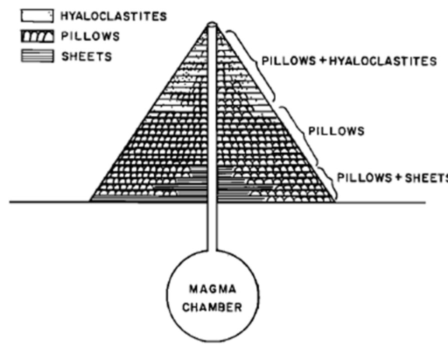
- Sheet and pillow lavas common
- Eruptive deposits ~ 1 km wide (wider than fast ridges, narrower than slow ridges)

Slow Spreading Ridges

- Mostly pillow lava
- Tectonism dominates over volcanism

Seamounts

- Pillowed flows on relatively flat slopes changing to sheet flows as slopes increase
- Mainly pillows at the margins with sheet flows in the central caldera or plateau.
- More voluminous eruptions initially forming pillows and sheets with decreasing volcanism later



Bonatti and Harrison (1988)

Research Methods

- Visual observations (dives and/or towed imaging surveys)
- Sidescan sonar
- Repeat bathymetry

Implications

- Many factors affect lava morphology
- Generally spreading rate, effusion rate and slope have the greatest effects on lava morphology
- Therefore, morphology is often used to determine effusion rate