WET EXPLOSIVE ERUPTIONS

Hawaii
Photograph: Dorian Weisel

WET EXPLOSIVE ERUPTIONS

mechanisms

hot magma/ hot rock + water ⇒ pyroclasts + steam

- rapid expansion of gas

  → fragmentation of magma + wall rock
- **external water**: lake, river, sea, snow, ice; groundwater in pores, along joints & faults, aquifers
- end members **phreatomagmatic**

  hot magma/ lava interacts directly with water

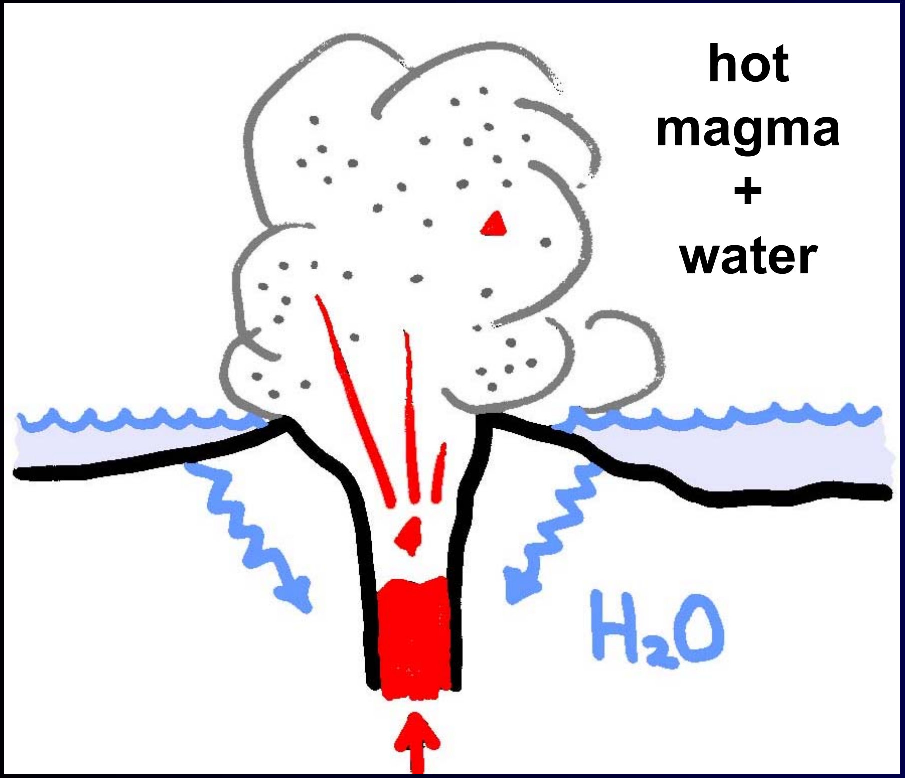
  → pyroclasts: juvenile + lithic

  phreatic

  magma heats wall rocks that contain water

  → pyroclasts: lithic

PHREATOMAGMATIC



fragmentation

- explosive expansion of steam ("steam explosivity")
- quench fragmentation
- volatile exsolution (same as for dry)
- potentially complex combination

steam explosivity

$$H_2O_{\text{liquid}} \xrightarrow[\text{decompression}]{\text{heating}} H_2O_{\text{vapour}}$$

BIG INCREASE IN VOLUME

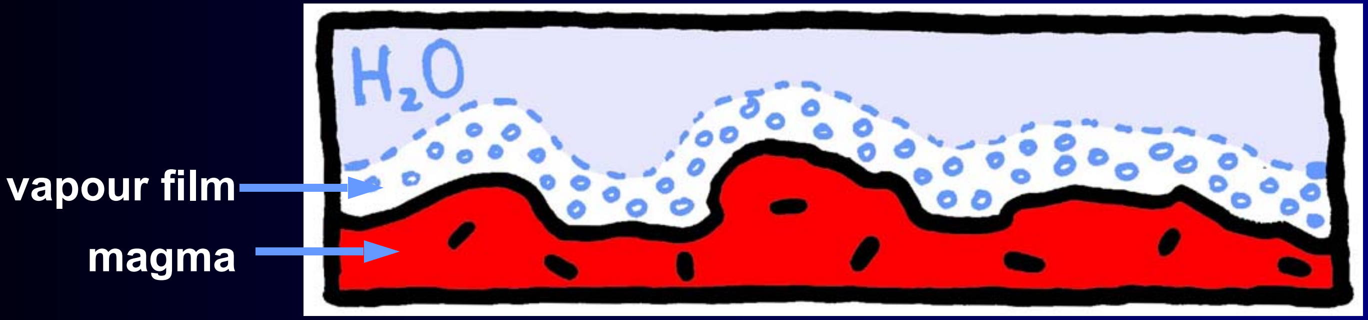
two situations: 1. contact-surface

2. bulk interaction

contact-surface steam explosivity

- magma comes in direct contact with water

  → vapour film forms along contact surfaces



- vapour film is unstable
- transfer of heat from magma to water

  → **explosion**

  → **magma fragmented**

  → **voluminous steam**

contact-surface steam explosivity

- cyclic behaviour:

magma fragmentation → heat transfer

EXPLOSION

- sustained phreatomagmatic eruptions involve hundreds of separate explosions

controls

1. mass ratio of water:magma
   - too high → magma quenched
     → no explosions
   - too low → water evaporates
     → may have "dry" explosions or lava effusion

controls

2. confining P, especially hydrostatic P

  - if too high, vapour film cannot expand

    → no explosions

  - water depths are poorly constrained

    → range 130 m - 5000 m

bulk interaction steam explosivity

- water ± sediment engulfed by lava
- water trapped near magma

} **water → steam**

- explosive expansion of steam

  → **magma fragmented**

- heat transfer by convection (relatively slow)
- **main controls:** confining P and volume of H_2O

circumstances

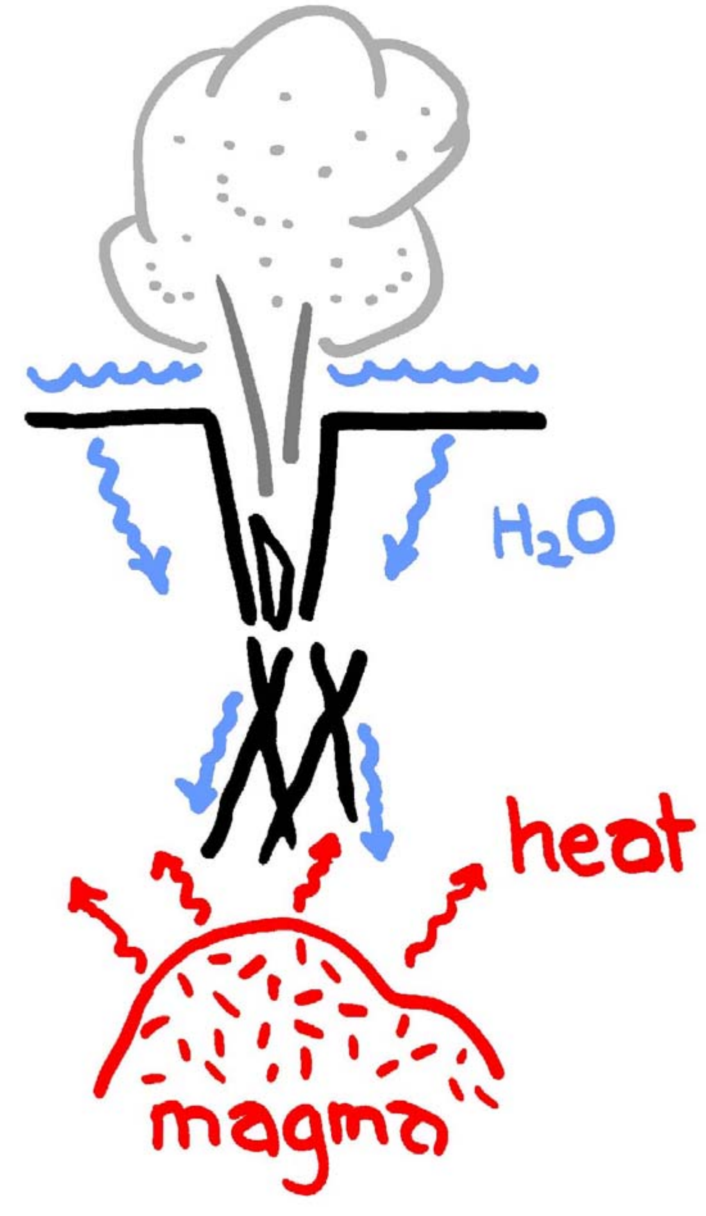
- vents under water
- vents in area with abundant groundwater (eg. marshy, coastal)
- temporarily sealed vents
- lava flowing into water or over wet ground
- pyroclastic flows into water, over water or over wet ground

→ “rootless” or secondary steam explosions

deposit characteristics

- abundant fine pyroclasts (ash; <2 mm)
- poorly sorted - fine pyroclasts stick to coarse pyroclasts → ash-coated lapilli
- accretionary lapilli - ash clumps together
- blocky, usually poorly vesicular pyroclasts - volatile exsolution minor or stopped early
- commonly well bedded - cyclic, repeated explosions
- any composition
- small (surtseyan) → big (phreatoplinian)
- surge deposits common (“base surge deposits”)

PHREATIC



- magmatic heat → wallrock → water → steam
  - heat dissipated
  - relatively weak steam explosions
- hydrothermal explosions:
  - superheated hydrothermal fluid → steam
  - triggered by decompression
  - common in geothermal areas

deposit characteristics

- dominated by wallrock lithic pyroclasts
- very fine to very coarse
- ballistics common
- hydrothermally altered clasts common
- very small volumes (<<1 km^3)
- very limited extent (< few tens m from vent)
- ash-coated lapilli common (sticky pyroclasts)

ERUPTIONS UNDER WAT

- fresh or salty
- explosive or effusive

explosive

- hydrostatic P reduces volatile exsolution and expansion
- significant effects on explosive activity for vents deeper than ~1000m (depends on magma composition and volatile content)
- in relatively shallow water, “wet” explosive activity is common
- shallow-water deposits are easily resedimented into deeper water
- some pyroclasts are widely dispersed by water currents

  eg. very fine pyroclasts; pumice that floats
- wide variety of subaqueous pyroclastic deposit types

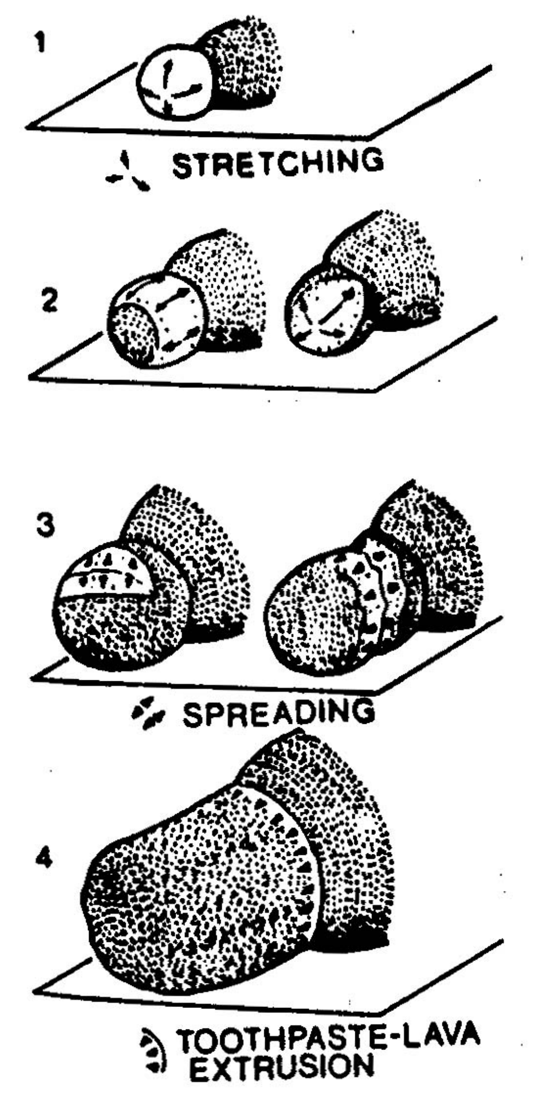
ERUPTIONS UNDER WAT

effusive

Lavas – pillow lava
– autoclastic facies: autobreccia
hyaloclastite
– other subaqueous lavas

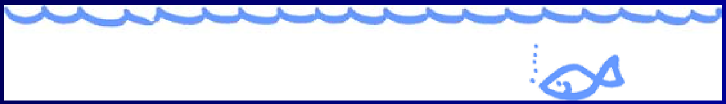
pillow lava

- interconnected tubes or lobes of lava
- pillows propagate by stretching and cracking of the crust → new bud



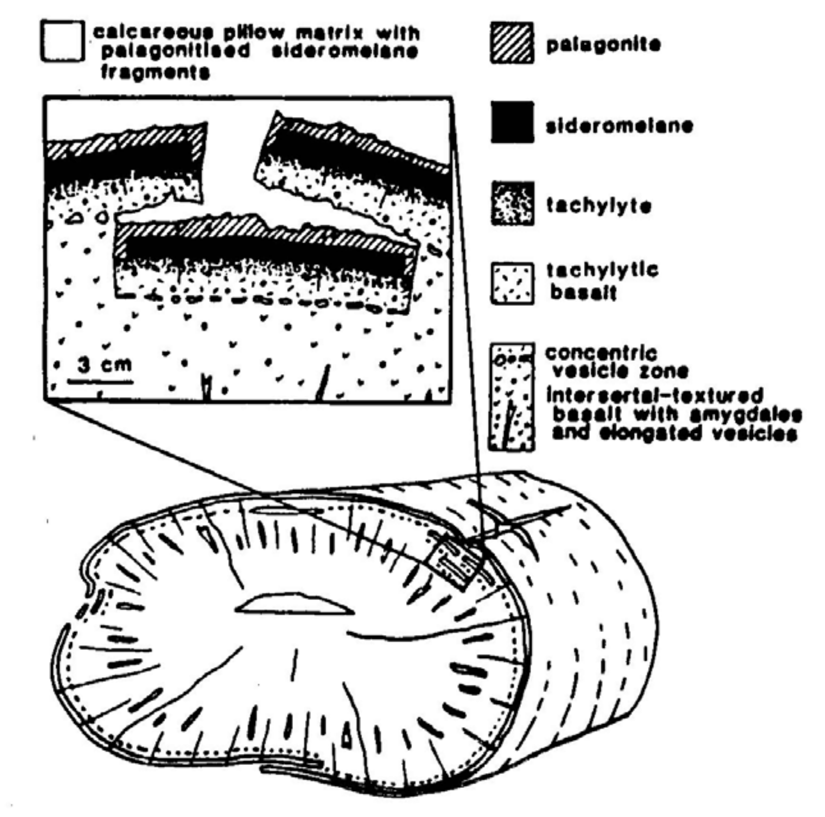
Four different kinds of pillow-growth mechanisms (Walker 1992).

pillow lava



- close packed or matrix present
  - sediment
  - hyaloclastite from broken pillows
  - mixture

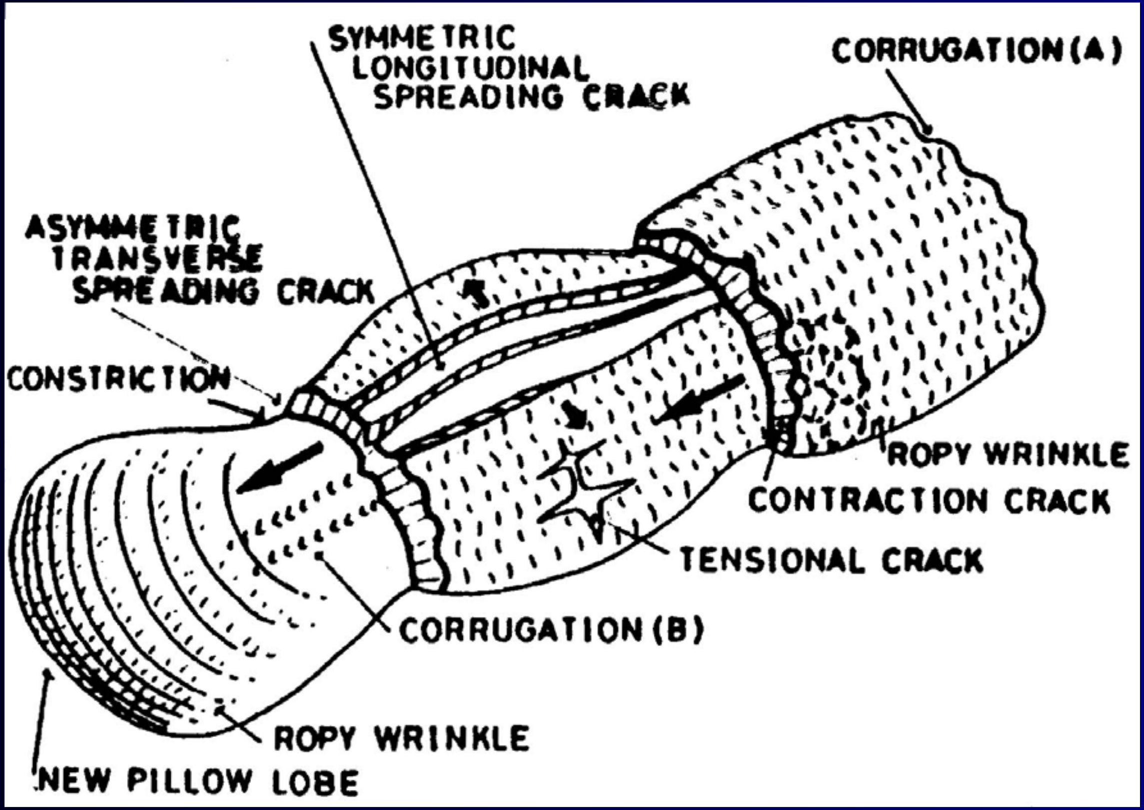
- glassy crust; radial or concentric patterns of vesicles and joints



Cross-section of pillow (Kawachi & Pringle 1988).

pillow lava

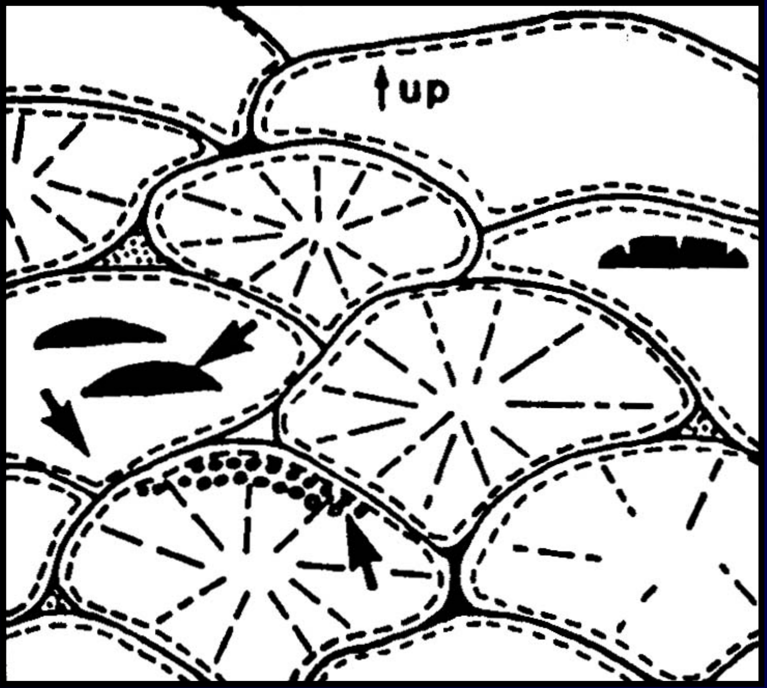
- surface: ropy wrinkles, corrugations, spreading cracks, tortoise shell joints



Characteristic surface structures of pillow lobe (Yamagishi 1985).

pillow lava

- basalt, andesite, trachyte (rarely higher SiO_2)
- important in ancient volcanic successions
  - → indicate depositional environment
  - → indicate younging direction



Pillowed lavas in cross-section. Arrows give way-up indicators (Easton & Johns 1986).

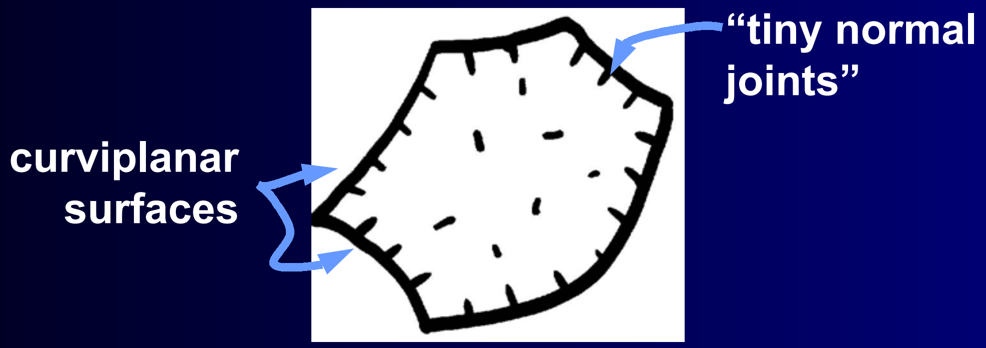
AUTOCLASTIC FACIES

- non-explosive fragmentation
- flow fragmentation → autobreccia
- quench fragmentation → hyaloclastite:

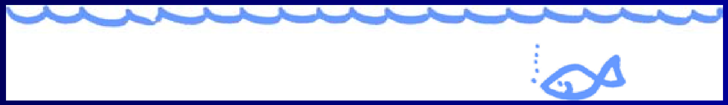
    contact with water → lava is quenched → fractured due to cooling contraction

hyaloclastite

- clast shapes: reflect origin by quenching



HYALOCLASTITE



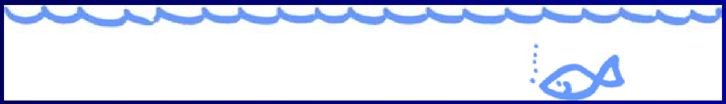
- ***in situ* hyaloclastite** (undisturbed)
  - jigsaw-fit texture
  - glassy or partly glassy clasts
  - monomictic
  - unstratified
  - gradation to coherent facies

- **clast-rotated hyaloclastite** (minor disturbance)
  - domains of jigsaw-fit *vs*. disturbed
  - glassy, monomictic, unstratified, grades to *in situ*

- **resedimented hyaloclastite** (disturbed during or after lava emplacement)
  - clast shapes the same but not strictly monomictic, no jigsaw-fit, may be bedded

- any composition

subaqueous lavas



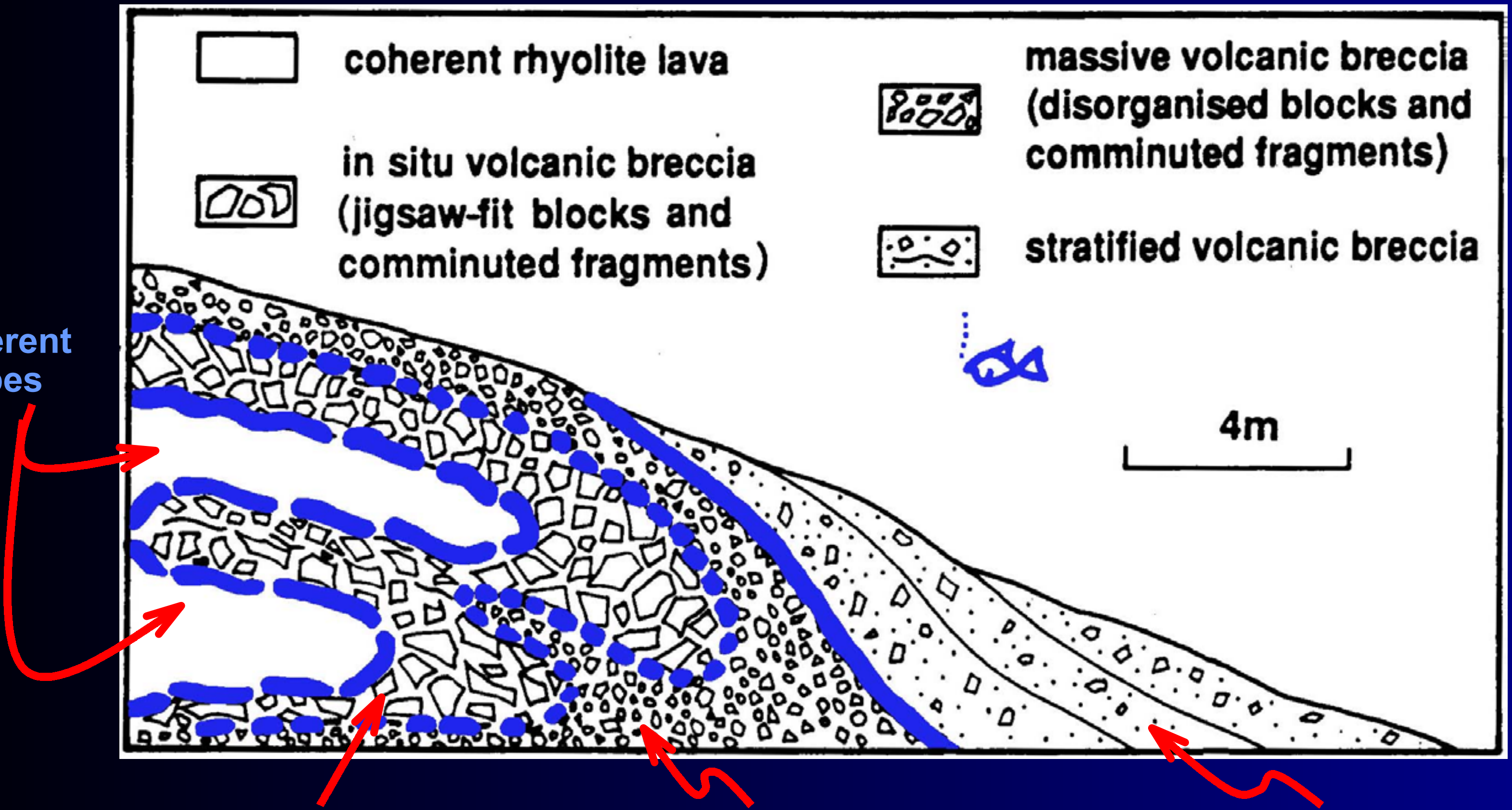
- **rhyolite, dacites, andesites**
- **some effects of eruption in water:**

  high confining P → non-explosive degassing
  → pumiceous facies common
  quenching → hyaloclastite (abundant glass)

- **lavas:** coherent (lobes) + hyaloclastite
- **feeder dykes:** coherent dykes+ lobes + hyaloclastite
- **domes:** coherent + hyaloclastite ± tuff cones (phreatomagmatic)
- **cryptodomes:** coherent + peperite

subaqueous lavas

coherent lobes + hyaloclastite



coherent lobes

in situ

clast-rotated

resedimented

subaqueous feeder dyke

A. active feeder dyke

→ quench fragmentation

→ hyaloclastite

B. continued supply of magma

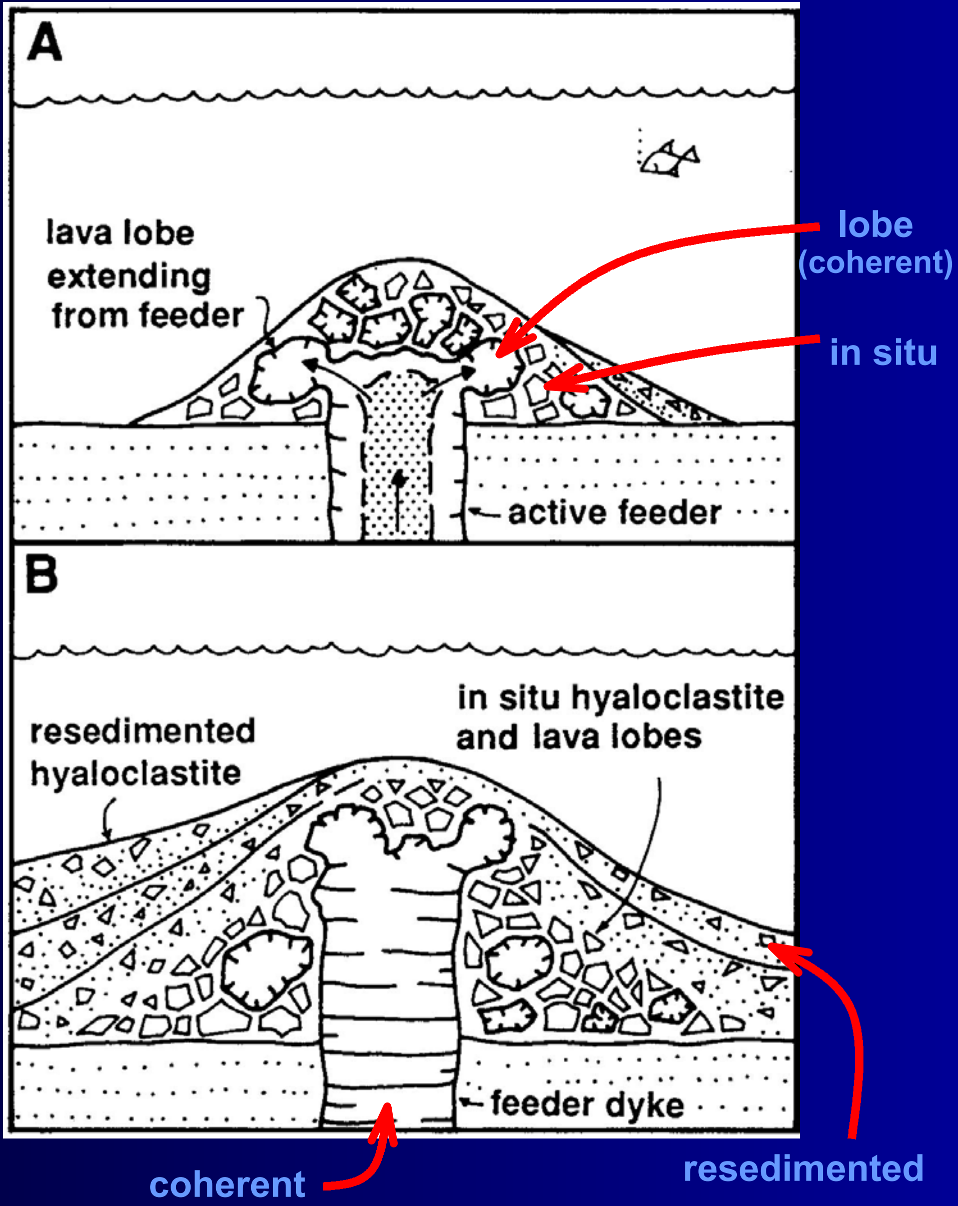
→ dyke intrudes co-genetic hyaloclastite

→ dyke divides into lobes

→ *in situ* hyaloclastite disturbed (continued intrusion ± topographic relief)

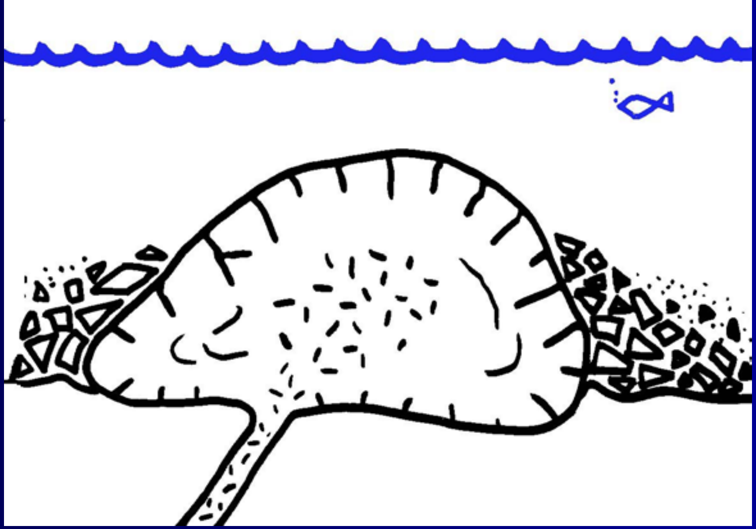
→ clast-rotated hyaloclastite

→ resedimented hyaloclastite



subaqueous domes

- small: 10’s m across and high
- big: a few 100’s m across and high



coherent core + **clastic margin**

- variably crystalline
- flow banded or massive
- columnar joints

- glassy
- hyaloclastite
- may be pumiceous

shallow setting - low confining P

- explosive eruptions, wet or dry
- pyroclastic cone on or adjacent to the dome or dome remnants

VOLCANICLASTIC

- general descriptive term
- made of clasts/ particles/ fragments
- clasts are volcanic
  - any size, shape, composition
  - no clast-forming process implied

so far……….

pyroclastic = explosive

autoclastic = non-explosive

………types of primary volcaniclastic deposits