

GEOL 104 Lecture 17
Yellowstone National Park: Hot-Spots, Calderas, and Geysers

I. Mantle Hot-Spots (Plumes) – a Review

A. Hot-Spot = surface expression of Mantle Plume

B. Mantle Plume

1. Anomalously Hot Mantle rising from great depth (possibly core-mantle boundary)
2. Rising plume melts to produce volcanoes on surface of lithosphere (a Hot-Spot).
 - a. As lithosphere moves (plate tectonics) over the plume, a track of volcanoes is produced
 - b. This is a Hot-Spot track

II Melting of the Plume

A. Melting by decompression

1. Anomalously hot mantle rises buoyantly (this is the plume)
 - a. As it rises it does not lose heat (adiabatic ascent)
 - b. Because it is rising fast through an already hot mantle
2. As the hot mantle rises, eventually it will cross its melting curve (Temperature of melting at a given depth or Pressure).
3. These melts then travel through the lithosphere feeding the magmatic-volcanic system in the crust.

B. Note: This is one of the two ways that the mantle melts. We will return to this Idea at Hawaii and discuss the second type of melting (hydration melting) later.

III. Magmatic-Volcanic Systems

A. Plutonic system (Magma Chamber)

1. Fed with melt from mantle (recall mantle melting?)
2. Stores magma for processing and eruption.
3. Rocks from magma chamber (deep in earth) = intrusive
 - a. Magma = mixture of liquid (melt) and mineral crystals
 - b. Intrusive rocks cool deep in the Earth (slow cooling = large crystals)

B. Hypabyssal Rocks = intrusive rocks injected from magma chamber to shallow depth

1. Dike = vertical tabular intrusion
2. Sill = horizontal tabular intrusion

C. Volcanic system = conduit for magma to the surface

1. Lava = magma extruded onto surface
2. Rocks from volcanic system (surface of earth) = extrusive
 - Extrusive rocks - erupted onto surface, cool quickly (small crystals)

IV. Volcanoes

A. Where are volcanoes located

1. Mid-Ocean Ridge!
 - a. 65,000 km long volcanic system
 - b. Most active volcanic system on earth: $>10 \text{ km}^3 / \text{year}$

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2. Subduction Zones

- a. Familiar volcano shape – stratovolcano
- b. Hazardous
- c. Historical eruptions: Tambora (1815), Krakatau (1883), Vesuvius (79 AD Pompeii), Mt St Helens (1980), Pinatubo (1991), Montserrat

3. Intraplate – hotspots

- Few in number: Hawaii, Iceland, Yellowstone, S. Atlantic, Galapagos

B. Types of Volcanoes

1. Shield volcanoes

- a. Size: 10s-100s km diameter, 1-10 km high
- b. Build of layers of lava flows pouring out onto surface
- c. Examples: intraplate hotspots and divergent boundaries
 - MOR – EPR, Hawaii: Mauna Loa 13680' (vs. Everest 29028')
- e. Tectonic Setting: Divergent boundaries and oceanic hotspots
- f. Eruption style: Fissure eruptions of fluid basaltic lava

2. Stratovolcanoes

- a. Size: 1-10 km diameter, < 5 km tall
- b. Built of inter-layered basalt and ash
- c. Examples: Shasta, Rainer, Fuji, Stromboli, Vesuvius
- d. Setting: Subduction zones
- e. Eruption style: fluid basaltic eruptions and occasional explosive (pyroclastic) – gas rich eruptions creating ash 'plinian' = large eruptions

3. Cinder cones

- a. Small < km wide, 100s m tall
- b. Built of cinders ejected from vent – usually located on top of larger volcano
- c. Examples: Sunset Crater Co, Paricutin Mex (really a stratovolcano)

4. Calderas

- a. Large 10s-100's Km in diameter, build large plateaus
- b. Made of ash and lava
- c. Very explosive eruptions are common
- d. Examples: Long Valley Caldera CA, and Yellowstone

V. Calderas erupt huge quantities of magma

A. Magma chamber inflates

- This lifts the crust above the magma chamber, cracking the surface in a ring pattern of fissures.

B. Magma erupts out of the Fissures

1. As the eruption begins, a volume of magma is removed from the chamber
2. This effectively reduces the pressure on the magma, allowing gasses to exsolve (like bubbles from a soda)
 - These bubbles expand and push more magma out the fissures
3. Sometimes, so much magma is expelled that the roof of crust overlying the magma chamber falls into the chamber and works to force more magma out (like a piston) in a catastrophically huge eruption.

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VI. Geologic History of Yellowstone

A. Sediments overly Precambrian Basement:

1. Basement is of old Precambrian metamorphic rocks
2. Paleozoic and Mesozoic sediments from repeated transgressions and regressions
 - a. Recall the History of Colorado Plateau?
 - b. This area accumulated hugely thick sediment packages: 3000' thick Paleozoic and ~6000 Mesozoic

B. Laramide Orogeny (~80-40 Ma) produced deformation in this area (Faults and folds)
- Uplifting some areas and leaving others low to fill with sediment derived from the uplifted regions.

C. Eocene (~50 Ma) eruptions of the Absaroka Volcanic Supergroup

1. Volcanic centers located to east of Yellowstone (caused by subducting slab)
2. Covered Yellowstone in ~10,000 feet of volcanic rocks (basalt flows and ash deposits) with intrusions of dikes too.

D. End of the Tertiary (~ 5 Ma), Basin and Range extension caused faulting in the area
- This raised Yellowstone and the Tetons and lowered Jackson Hole (continues today)

E. History of Eruptions at Yellowstone

1. Background

- a. Columbia River Flood Basalts = huge outpourings of lavas from fissure eruptions ~15Ma
- b. Snake River Plane = more flood basalts as hot-spot track approaches current location

2. Eruption of the Yellowstone Group (2 to ~1.2 Ma)

- a. 2 Ma Collapse of Island Park Caldera ~30 to 50 mi in diameter produced the Huckleberry Ridge Tuff.
- b. 1.3 Ma smaller collapse produced the Mesa Falls Tuff
- c. 1.2 Ma system shifts from Island Park to Yellowstone Caldera
 - i. 0.63 Ma catastrophic eruption of > 1000 km³ of magma
- Ash covered mid-continent of NA (Lava Creek Tuff)
 - ii. Collapsed Caldera was 45 x 25 mile and 0.5 mi deep
 - iii. 'Minor' eruptions of lava followed some up to 1000 feet thick
- d. Resurgent Doming – two domes are growing within the caldera (~1 in per year) indicating continued activity.

VII. Hydrothermal Activity: Geysers, Mud Pots and Paint Pots

A. Groundwater flows through the rocks of the plateau and is heated by the magma body at depth.

1. Paint and Mud Pots:

- a. Where this hot water rises as springs to the surface
- b. Paint pots = hot springs with archaeobacteria making colors

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Note: archaeobacteria are extremophile prokaryotes – not bacteria, these are a ‘newly discovered’ form of life.

c. Mud Pots = hot springs in volcanic ash (bentonite) making mud.

B. Geysers

1. Constricted conduit fills with water. The water gains heat from magma.
2. Deep in the conduit, the water is under hydrostatic pressure (so the boiling point is higher). Water in the upper part of conduit (under atmospheric pressure) heats to boiling and begins bubbling out of the spring. Removal of this ‘weight’ of overlying water decompresses the lower portion of the conduit and the water there flashes to steam causing the ‘eruption’.