

12.103
The Science and Policy of Natural Hazards

Module 3 Volcanoes



Image courtesy of USGS.

Spring 2010

Natural phenomenon



Natural hazard

The notion of hazard requires human presence (in the wrong place)



Image courtesy of USGS.

Natural hazard



Natural catastrophe

Armero (Nevado del Ruiz) - Nov 13, 1985

23,000 fatalities; 5000 injured; \$7,700M damage



Image courtesy of USGS.

Volcanoes

introduction

Volcanoes

definition 1: a vent in the crust of the earth or another planet through which lava, rock fragments, hot vapor, and gases erupt

definition 2: a mountain formed by volcanic material

Volcanoes

MAGMA: molten rock inside the earth

LAVA: magma that erupts at the Earth's surface

PYROCLAST: all solid fragments ejected from volcanoes

TEPHRA: all pyroclasts that fall to the ground from eruption columns

Volcanic environments

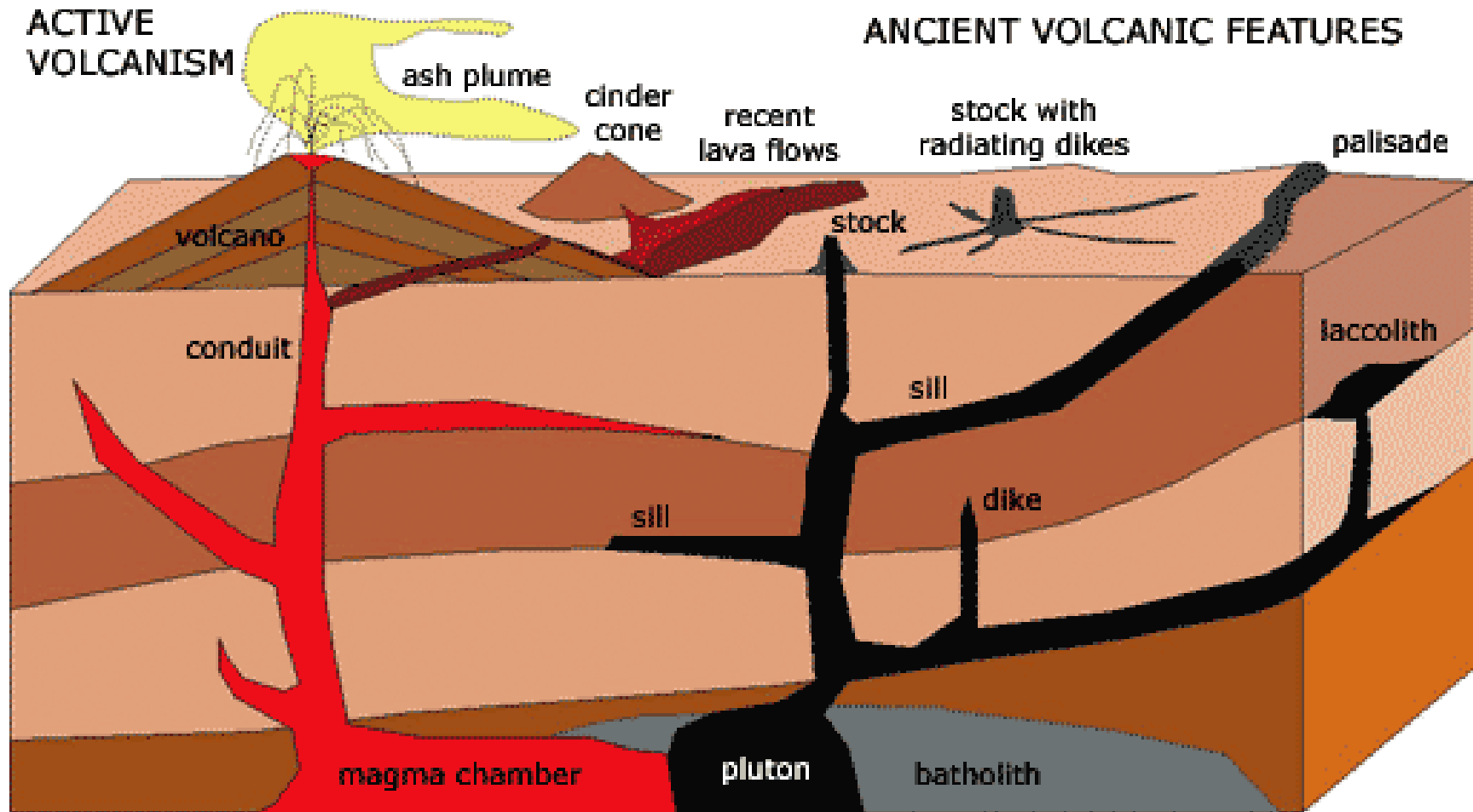


Image courtesy of USGS.

Distribution of volcanoes



- **active volcanoes:** have erupted in the last 10,000 yr and still have the potential to erupt (~1500 active volcanoes; ~60 eruptions per year; ~20 eruptions at any given time)
- **dormant volcanoes:** have not erupted in the last 10,000 yr but still have the potential to erupt
- **extinct volcanoes:** have “no chance” of ever erupting again

Distribution of volcanoes



spreading ridge volcanism: ~75%
subduction zone volcanism: ~15%
intraplate volcanism: ~10%

Image courtesy of USGS.

Distribution of volcanoes

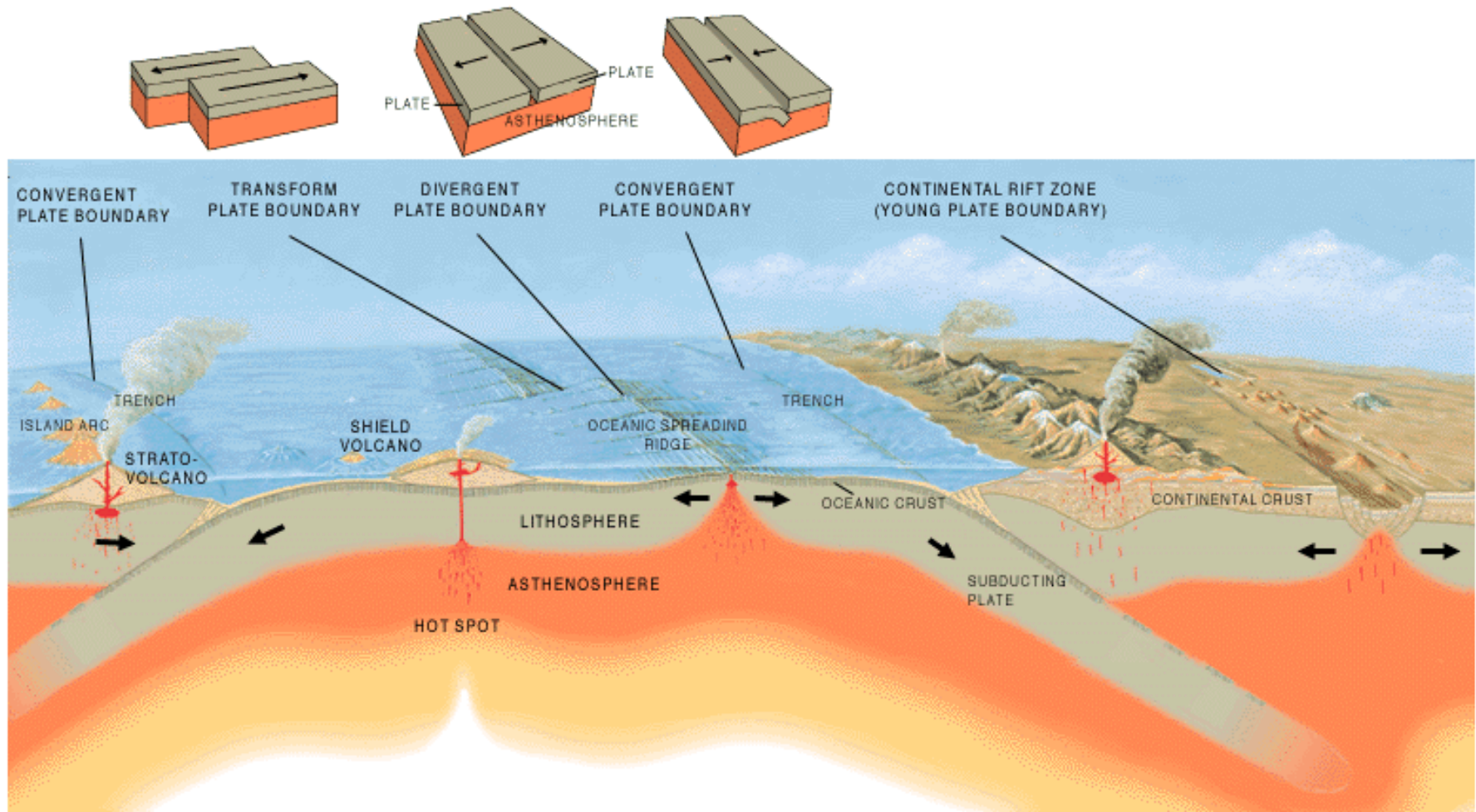


Image courtesy of NOAA.

Melting rocks in the earth

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Please see “Melting rocks in the earth” in:

Houghton, B., H. Rymer, J. Stix, S. McNutt, H. Sigurdsson.

Encyclopedia of Volcanoes. San Diego, Calif. : Academic, c2000.

ISBN: 9780126431407.

Melting rocks in the earth



Image courtesy of NASA.

peridotite

Melting rocks in the earth

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Melting at spreading ridge

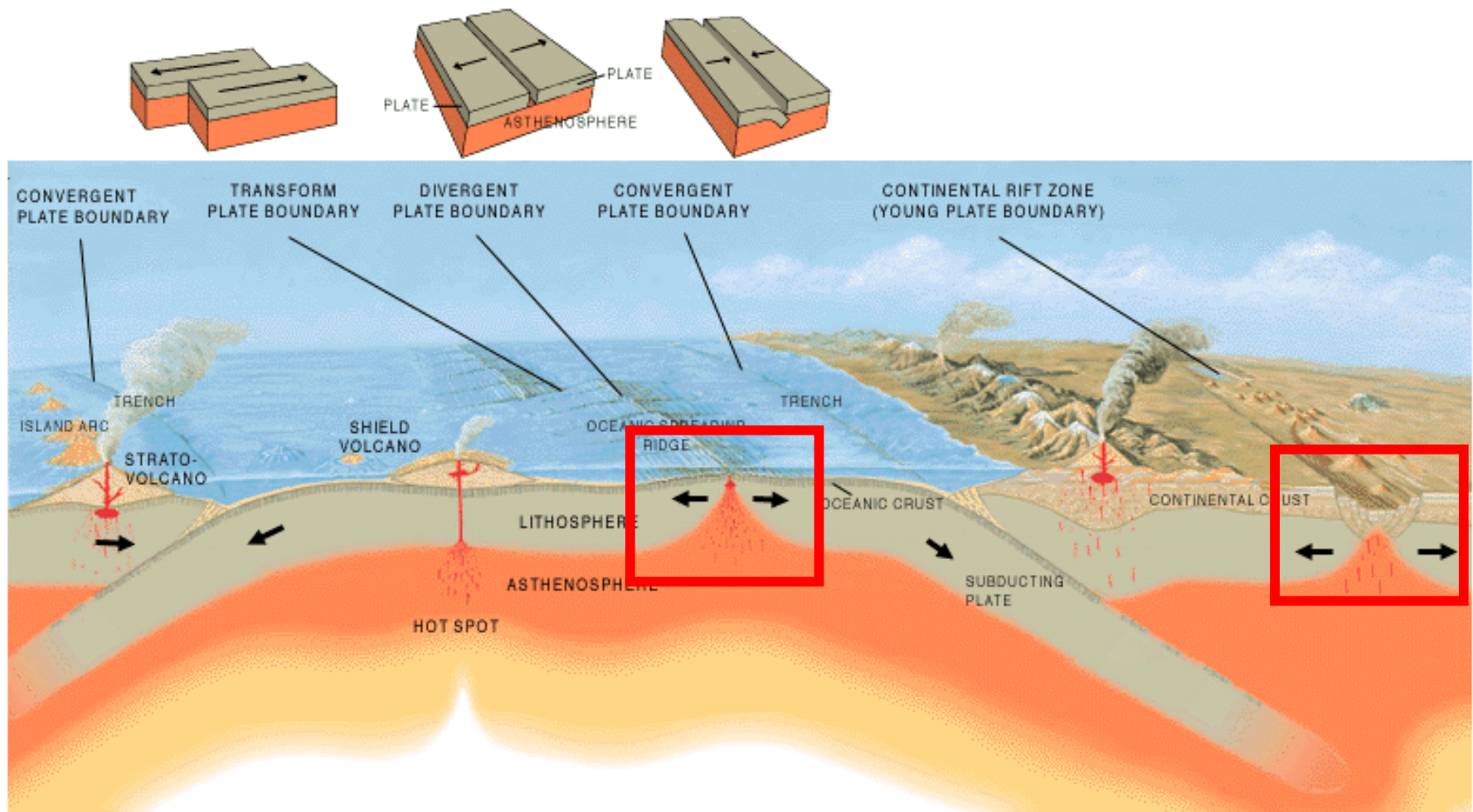


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Melting at spreading ridge

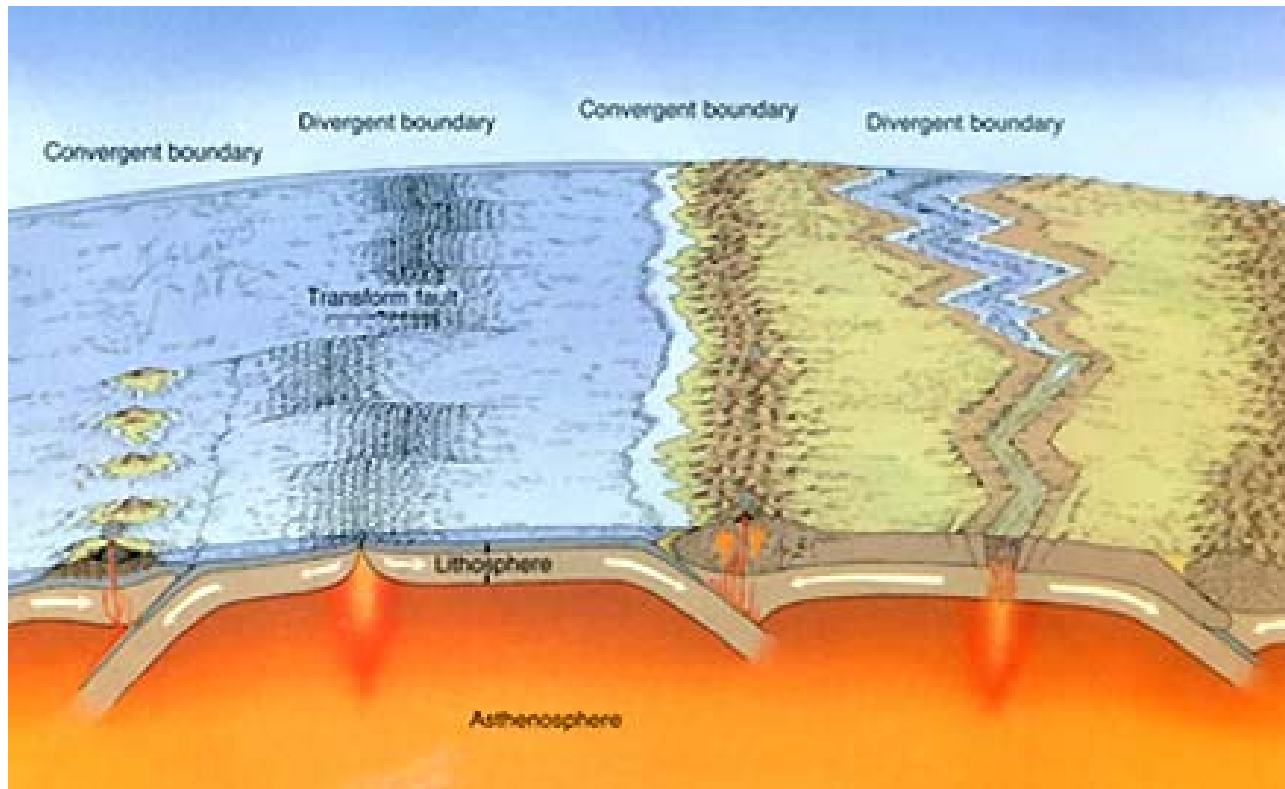


Image courtesy of NASA.

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Melting at subduction zones

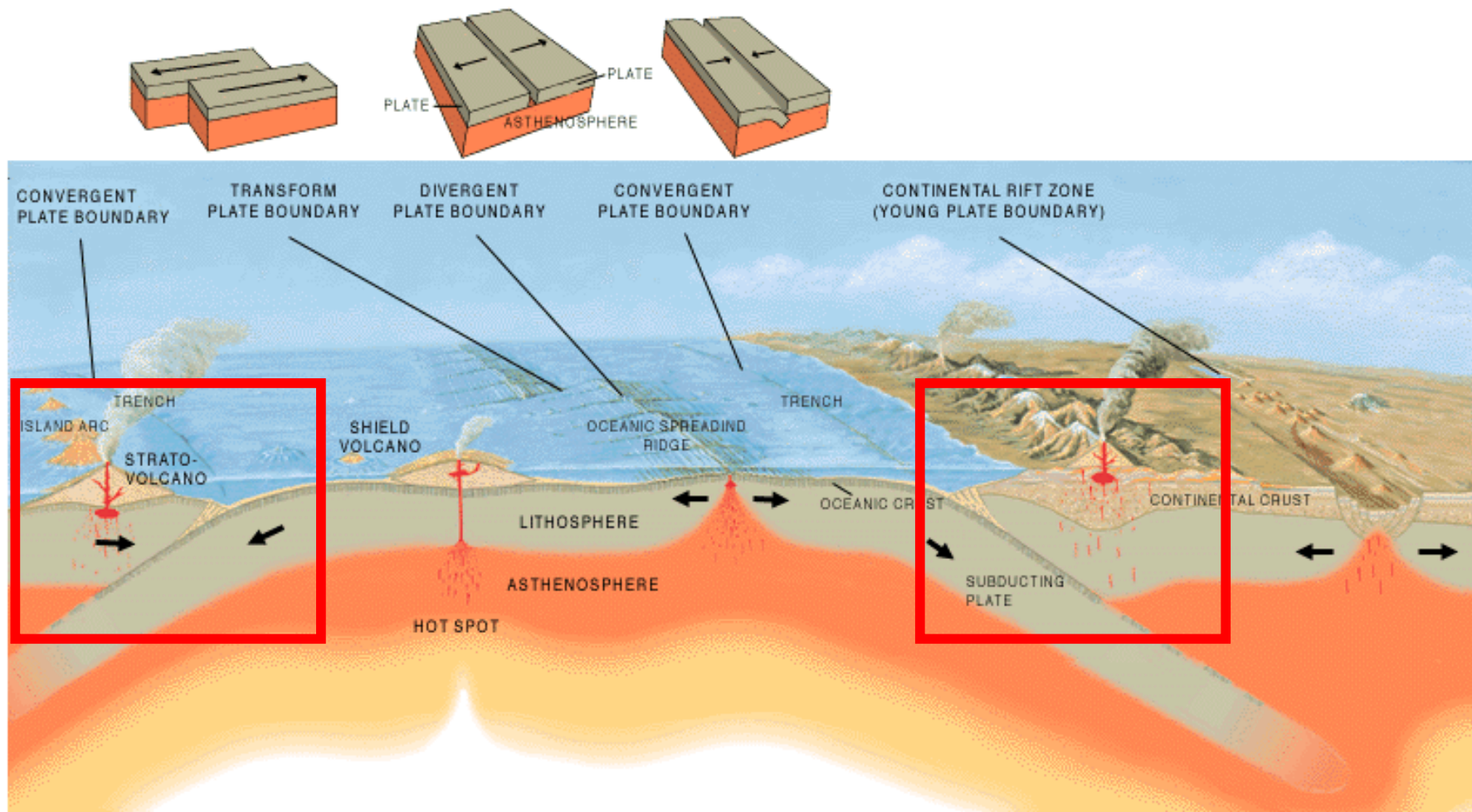


Image courtesy of NOAA.

Melting at subduction zones

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Melting at subduction zones

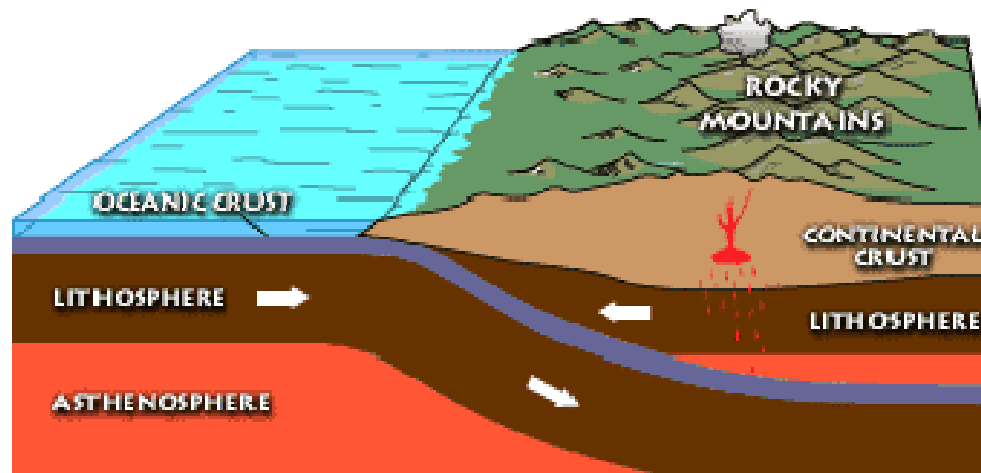


Image courtesy of USGS.

Intraplate magmatism

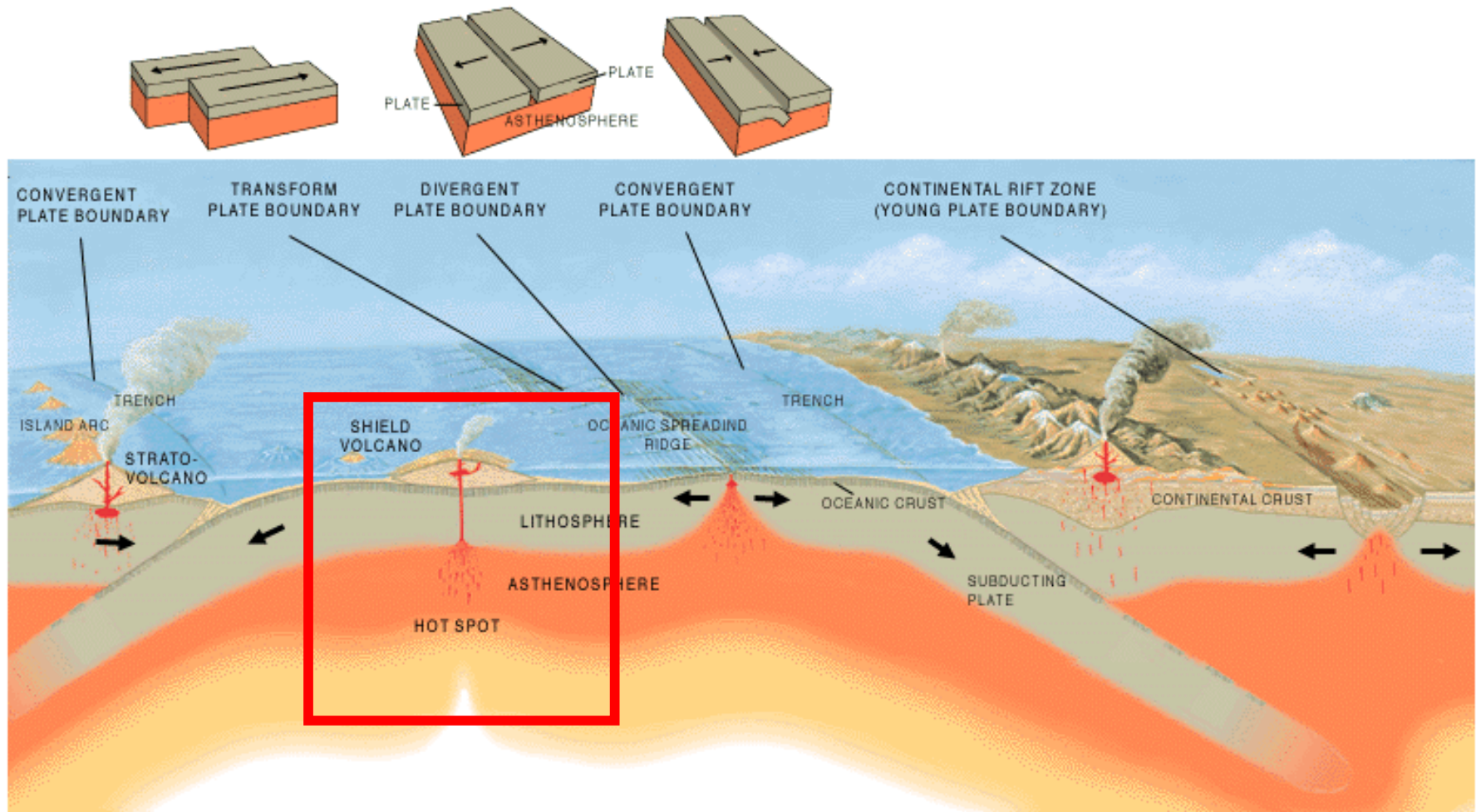


Image courtesy of NOAA.

Types of volcanic eruptions

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Hawaiian eruption

basaltic eruption with very low viscosity magma (10-100 Pa s), comprising lava fountains and lava flows

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Please see:

<http://www.firstscience.com/images/articles/self/flow.jpg>

Strombolian eruption



Image courtesy of USGS.

basaltic eruption with low viscosity magma (100-1000 Pa s), comprising lava fountains and lava flows and series of explosions

Vulcanian eruption



Image courtesy of USGS.

small to moderate-sized volcanic outbursts that eject material to heights $<20\text{km}$ and last on the order of seconds to minutes

Plinian eruption

large, explosive events that form enormous dark columns of tephra and gas high into the stratosphere (>20km)



Image courtesy of USGS.

Surtseyan eruption



violent explosions caused by rising basaltic magma that come into contact with abundant surface water (or shallow groundwater)

Image courtesy of NOAA.

Types of volcanic eruptions

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Volcanic intensity

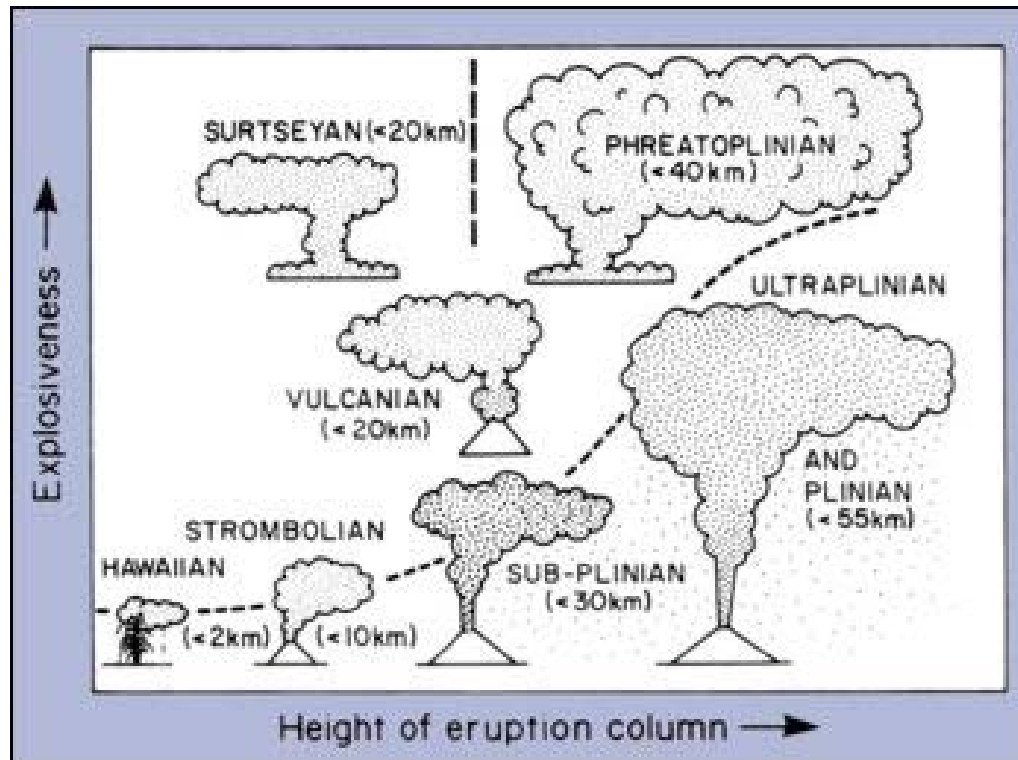


Image courtesy of USGS.

Volcanoes and volcanic structures

Types of Volcanoes				
	Volcano Type	Characteristics	Examples	Simplified Diagram
Increasing Violence Increasing Viscosity 	Flood or Plateau Basalt	Very liquid lava; flows very widespread; emitted from fractures	Columbia River Plateau	
	Shield Volcano	Liquid lava emitted from a central vent; large; sometimes has a collapse caldera	Larch Mountain, Mount Sylvania, Highland Butte, Hawaiian volcanoes	
	Cinder Cone	Explosive liquid lava; small; emitted from a central vent; if continued long enough, may build up a shield volcano	Mount Tabor, Mount Zion, Chamberlain Hill, Pilot Butte, Lava Butte, Craters of the Moon	
	Composite or Stratovolcano	More viscous lavas, much explosive (pyroclastic) debris; large, emitted from a central vent	Mount Baker, Mount Rainier, Mount St. Helens, Mount Hood, Mount Shasta	
	Volcanic Dome	Very viscous lava; relatively small; can be explosive; commonly occurs adjacent to craters of composite volcanoes	Novarupta, Mount St. Helens Lava Dome, Mount Lassen, Shastina, Mono Craters	
	Caldera	Very large composite volcano collapsed after an explosive period; frequently associated with plug domes	Crater Lake, Newberry, Kilauea, Long Valley, Medicine Lake, Yellowstone	



Image courtesy of USGS.

fissure



Image courtesy of USGS.

definition: elongate fracture or crack at the surface from which lava erupts

common environments: spreading ridges and intraplate

photo: flank of Kilauea, Hawaii

Cinder cone



definition: steep, conical hill of volcanic fragments that accumulate around and downwind from a vent

common environments: various

photo: flank of Mauna Kea, Hawaii

Image courtesy of USGS.

Shield volcano



definition: Volcanoes with broad, gentle slopes and built by the eruption of fluid basalt lava

common environments: various (esp. spreading ridges and intraplate)

photo: Mauna Loa, Hawaii

Image courtesy of USGS.

Stratovolcano (composite)



definition: steep, conical volcano built by the eruption of viscous lava flows, tephra, and pyroclastic flows

common environments: subduction zones

photo: Rainier, WA

Image courtesy of USGS.

Volcanic (lava) dome



Image courtesy of USGS.

definition: rounded, steep-sided mounds built by very viscous magma

common environments: subduction zones

photo: Novarupta vent, Valley of Ten Thousand Smokes, Alaska

Caldera



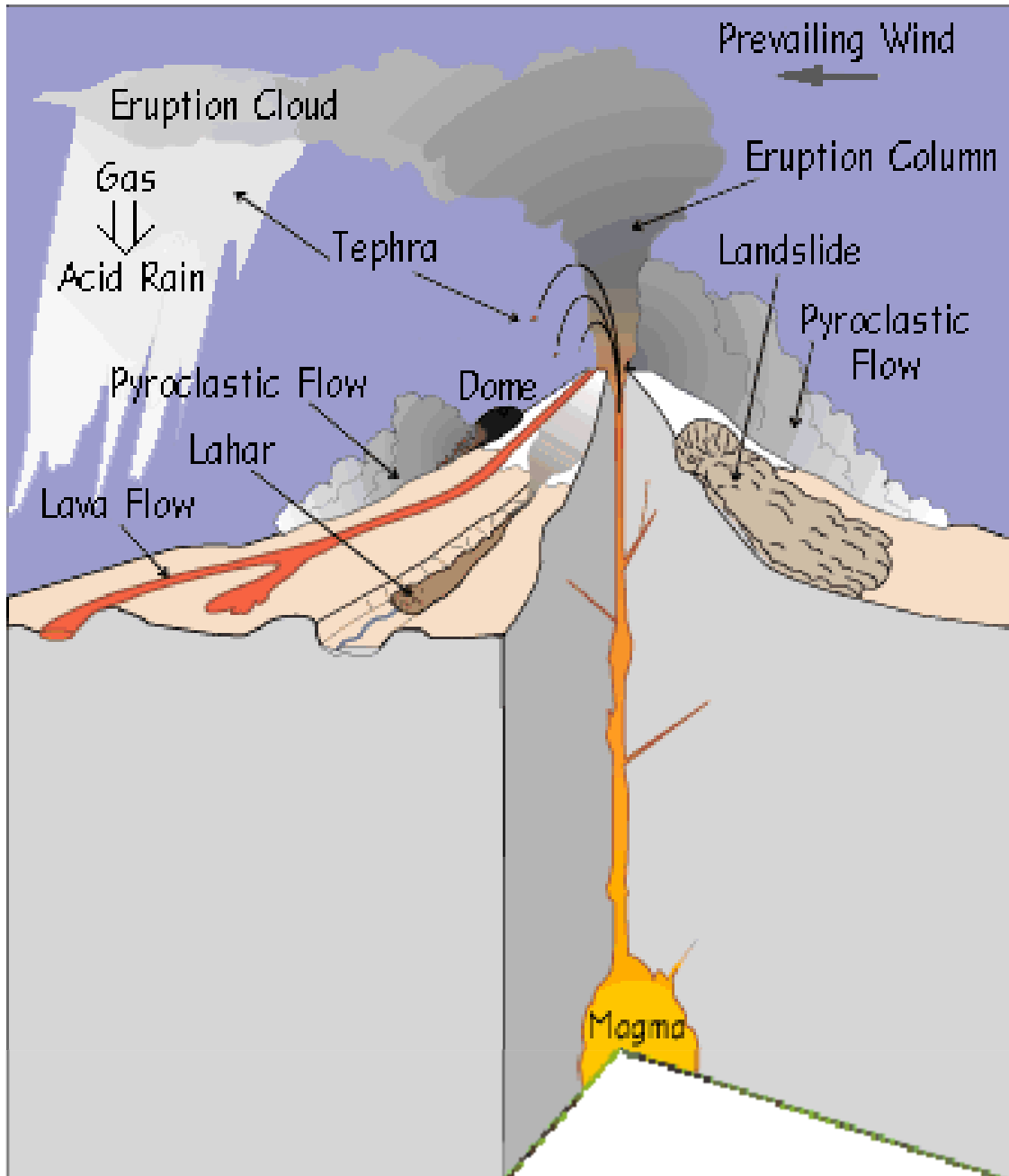
definition: large, usually circular depression at the summit of a volcano formed when magma is withdrawn or erupted from a shallow underground magma reservoir

common environments: various

photo: Aniakchak Caldera, Alaska

Image courtesy of USGS.

Volcanic hazards

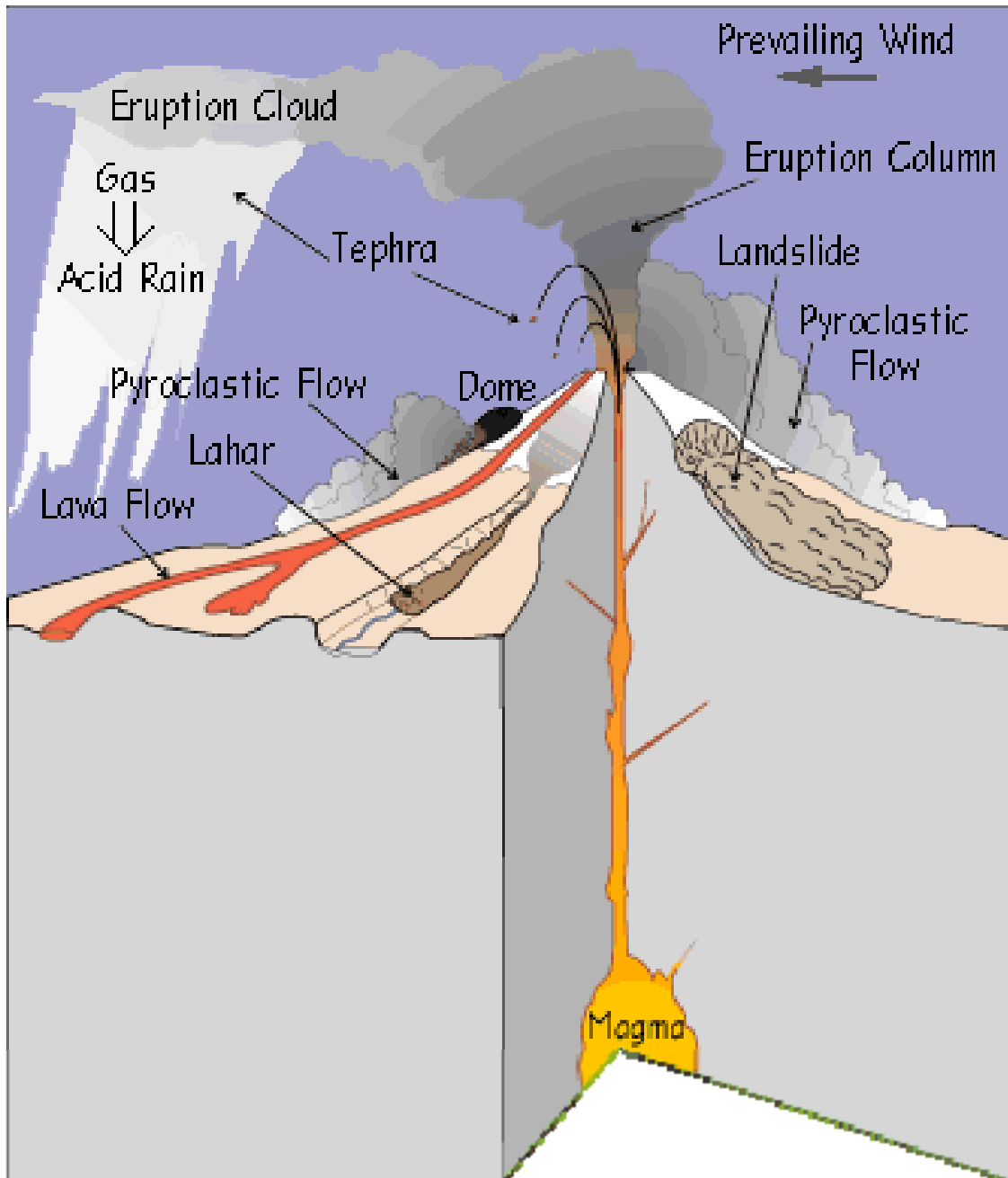


direct hazards:

- tephra and ballistic projectiles
- pyroclastic flows/surges
- lateral directed blasts
- debris avalanches
- debris flows/lahars, floods
- lava flows
- earthquakes

Image courtesy of USGS.

Volcanic hazards



indirect hazards:

- tsunami
- debris flows/lahars, floods
- air pollution
- post-eruption famine and disease
- aerosols and global atmospheric effects
- aircraft encounters with volcanic ash
- biotic extinctions (?)

Image courtesy of USGS.

Volcanoes as a hazard

Type of Hazard	No of Events
Drought	782
Earthquake	899
Extreme temperature	240
Famine	77
Flood	2389
Landslide	448
Strom surge	18
Tornadoes (non-US)	84
Tornadoes (US)*	9476
Tsunami	986
Tropical ctyclone	1337
Volcano	168
Wind (other)	793
Wild fire	269

** for F2-F5 Tornadoes 1950 - 995*




Figure by MIT OpenCourseWare.

Volcanoes as a hazard

Type of Hazard	Deaths	Injuries	Homeless	Largest Death Toll Event and Date	Death Toll
Avalanches, Landslides, Mud flows	60,501	8,071	3,759,329	Soviet Union, 1949	12,000
Cold wave	6,807	1,307	17,340	India, Dec 1982	400
Extra-tropical storms	36,681	117,925	12,606,891	Northern Europe, Feb 1953	4,000
Earthquakes	1,846,119	1,147,676	8,953,296	Tangshan, China, July 1976	242,000
Fires	2,503	1,658	140,776	USA, Oct 1918	1,000
Floods	6,851,740	1,033,572	123,009,662	China, July 1931	3,700,000
Heat wave	14,732	1,364	0	India, May 1998	2,541
Tornado	7,917	27,887	575,511	Bangladesh, Apr 1989	800
Tsunami	10,754	789	-	Sanriku Japan, Mar 1933	3,000
Tropical cyclones	1,147,877	906,311	34,272,470	Bangladesh, Nov 1970	300,000
Volcano	96,770	11,154	197,790	Martinique, May 1902	30,000
Total	10,052,401	3,257,714	183,533,065		

Figure by MIT OpenCourseWare.

Volcanoes as a hazard



Type	Cost
Cold wave	\$9,555,000,000
Drought	\$16,800,000,000
Earthquake	\$248,624,900,000
Flood	\$206,639,800,000
Heat wave	\$5,450,000,000
Tropical storm	\$80,077,700,000
Wild fire	\$20,212,800,000
Wind storm	\$43,890,000,000
Total	\$631,250,200,000

Figure by MIT OpenCourseWare.

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