- I. Origin of Magma
 - A. Depth: 20 200 km
 - B. Temperatures: ~600°C ~1600°C
 - C. Composition
 - 1. molten rock
 - a. basaltic magma 40% 50% silica
 - b. andesitic magma 50%-60% silica
 - 2. gases water vapor, CO_2 , sulfur (SO₂ or H_2S), and other minor gases
 - D. Melting of rocks
 - 1. geothermal gradient 30° C/km
 - 2. pressure and water impact melting
 - E. Magma chambers/reservoirs
- II. Volcanic Eruptions
 - A. magma moves upward through fractures/ faults
- III. Products of volcanic or fissure eruptions
 - A. Liquids lava
 - 1. basaltic lavas flow in thin, broad sheets
 - a. pahoehoe and a'a
 - 2. andesitic lavas viscous, do not flow easily
 - a. associated with violent eruptions
 - B. gases
 - 1. 70% 95% water vapor and 14% $CO_{\rm 2}$
 - 2. role in violent vs quiet eruptions
 - C. solids pyroclastics
 - 1. upon release, superheated gases expand ~75X- pulverize rock & lava from vent
 - 2. dust, ash, cinders, volcanic bombs, and blocks
- IV. Volcanic eruptions and volcanoes
 - A. Successive eruptions from central vent resulting in mountainous accumulations of materials
 - B. Stratovolcano or composite volcano steep-sided
 - 1. alternating lava and pyroclastics
 - 2. andesitic lavas most violent
 - 3. Examples Mt. Rainier, Mt. St. Helens, Mt. Fuji, Mt. Pinatubo
 - D. Cinder cone almost exclusively pyroclastics
 - 1. pyroclastics
 - 2. not as steep as stratovolcano
 - 3. occur in groups; sometimes parasitic cone on flank of main volcano
 - 4. last phase of volcanic activity
 - 5. Examples: Paracutin (Mexico), Sunset Crater, AZ
 - E. Shield volcano tall and covers large area
 - 1. gently sloping sides 15^o slope or less
 - 2. successive lava flows with little pyroclastic
 - 3. Hawaii: Kilauea, Mauna Loa, Mauna Kea
 - a. quiet eruptions low silica and gas content

I. History

- A. called Tahoma Snow Mountain by Native Americans in the area
- B. 1792 Capt. Vancouver sailed into Puget Sound and named mountain after Rear Admiral Rainier
- C. 1899 became national park
- II. Geologic History
- A. Farallon plate: consumed except for Juan de Fuca plate subduction zone
 - 1. 40 mya landscape covered by episodes of volcanic eruptions, lava flows, and pyroclastics
 - 2. 12 mya base of Mt. Rainier formed by granodiorite (white granite with dark minerals)
- B. Mt Rainier
 - 1. alternating layers of lava and pyroclastics began to build in early Pleistocene
 - 2. reached its greatest height of 16,000' ~ 75,000 years ago
 - 3. continuous glacial erosion steepened the mountain
 - 4. 6,000 years ago eruptions blew off ~2,000' of summit; formed caldera 2 miles across
 - 5. 2,500 years ago eruptions built a new cone within the caldera
 - 6. few eruptions since 1800's but still high heat flow
 - 7. highest peak in Cascade Mountain Range ~14,410' above sea level
- C. Glaciers and activity
 - 1. 25 major active glaciers
 - a. Nisqually Glacier most accessible in park
 - b. Emmons 4.3 miles², largest area of any glacier in contiguous United States; advanced rapidly in early 1980's. That advance continues today, but at slower rate
 - c. Carbon greatest measured thickness (700 feet) and volume (0.2 cubic miles) and lowest terminus altitude (3,600 feet) of any glaciers in the contiguous 48 states
 - d. Glaciers are replenished at the high snowfall zone \sim 4000"
 - 2. Activity
 - a. 25,000 to 15,000 years ago, glaciers covered most of Mount Rainier area and extended to present Puget Sound Basin
 - b. Little Ice Age: 1650 1850, many glaciers on Mount Rainier advanced to their farthest extent since Pleistocene
 - c. between height of Little Ice Age and 1950, glaciers lost about 1/4 of length
 - d. 1950 to early 1980's Carbon, Cowlitz, Emmons, and Nisqually Glaciers advanced in response to cooler temperatures and higher snow fall
 - e. early 1980's to 1992 many glaciers, Emmons for example, have been thinning and retreating and some advances have slowed, in response to drier conditions
- D. Glacial features greatest single-peak glacial system in the United States
 - 1. moraines
 - 2. arêtes
 - 3. crags and ridges The Cleavers
 - 4. cirques and cirque lakes
 - 5. meltwater streams
 - 6. steam caves
 - 7. ice caves since 1990's they no longer exist

Hawaii Volcanoes National Park

- I. History
 - A. Polynesian voyagers ~ 2000 years ago
 - 1. volcanoes were center to their culture and religion abodes of deities a. Maui and Hawaii were especially sacred
 - b. Pele lived in Halemaumau carried stick for digging to start eruption to build island
 - B. Captain James Cook 1778
 - C. series of kings and then became American territory in 1900.
 - D. 1840 was first scientific investigation noticed degrees of erosion from SE to NW concluded that islands were older to NW
 - E. Both islands became national park in 1916 but later separated
 - 1. Haleakala on Maui 1960 (2 surrounding watershed areas added in 1999 and 2009)
 - 2. Volcanoes 1961
 - F. International Biosphere Reserve (1980) and a World Heritage Site (1987).
 - G. Volcanoes National Park encompasses 333,086 acres from sea level to 13,677' and the summits and rift zones of Kilauea and Mauna Loa.
- II. Geologic History
 - A. Hot spot
 - 1. lava associated with Hawaiian eruptions
 - B. Pleistocene
 - 1. initial eruption on ocean floor
 - 2. Mauna Loa summit and rift-zone eruptions
 - a. Largest eruption 1950 600 million cubic yards of lava in 3 weeks
 - b. Last erupted in 1984
 - 3. Kilauea rift-zone, summit, lava lakes, and some violent eruptions
 - a. East Rift Zone lava flowing through the upper portion of the lava tube system and heading for the coast; not currently (January 25, 2010) entering the ocean.
 - b. Lava lake in fire pit at summit Halemaumau
 - i. Level of lava has fluctuated since first appeared in 1790
 - ii. Just recently erupted for the first time since 1982
 - c. Kilauea Iki 1959
 - d. Kapoho 1960
 - e. Pu'u 'O'o continuous since 1983
 - 4. Glaciation small ice caps on Mauna Kea and Mauna Loa
 - C. presently Loihi is forming on ocean floor off SE coast of Hawaii

Yellowstone National Park National Park in 1872 International Biosphere Reserve in 1976 World Heritage site in 1978

- I. History of Yellowstone area
 - A. John Colter expedition 1806-1808
 - B. Jim Bridger first "geographer" of the region
 - C. Washburn party 1870
 - D. Dr. Ferdinand Hayden heard lecture by members of Washburn party
- II. Geologic history
 - A. Hot spot
 - 1. Crust is extraordinarily thin and allows for high heat flow
 - 2. Plate moves over the hot spot
 - 3. Accounts for hydrothermal features and volcanic eruptions in ancient times
 - B. Volcanic eruptions
 - 1. Huckleberry Ridge Caldera Event 2 million years ago
 - 2. Mesa Falls Caldera Event 1.3 million years ago, smallest of the eruptions
 - 3. Yellowstone Caldera Event 600,000 years ago: central portion of the park exploded
 - a. collapse of the volcano created a caldera 28 by 47 miles across
 - b. ejected 600 cubic miles of material including ash, and hot gasses
 - Calderas basin-shaped volcanic depressions remnants of explosive volcanic activity
 - d. Created fractures which provided route for lava of plateau rhyolite
 - e. Younger inner caldera occupied by West Thumb of Yellowstone Lake
 - 4. Smaller lava flows 150,000 years ago, 110,000 years ago, and 70,000 years ago
 - C. Glaciation intermittent over last 2 million years
 - 2. most recent glaciation began 50,000 years ago and ended 13,000 years ago Pinedale stage
 - 3. moved from Absaroka and Beartooth Mountain ranges into Yellowstone area
- III. Geothermal features
 - A. contains over 10,000 features including 300 500 active geysers (55% of world's)
 - B. Fracture zones provide underground channels for circulation of hot water in thermal system
 - C. Geysers constriction in plumbing
 - D. Hot springs no constriction
 - 1. Colors are result of microbes/algae living in different temperature waters of the hot springs
 - 2. Blue color is optical effect of sky
 - 3. Mineral content from acidic lavas high in silica
 - 4. Mammoth Hot Springs differs from others on plateau
 - E. Fumaroles
 - 1. Gas and steam are emitted
 - F. Paint Pots
 - 1. Limited hot water; acidic water dissolves surrounding rock clay makes it thick and bubbly
- III. Other features
 - A. Yellowstone Canyon
 - 1. related to fracture zones and alteration of rhyolite by geothermal waters
 - a. hydrothermal alteration
 - i. changes mineral composition of the rhyolite K and/or Na feldspar and quartz
 - a.) formation of clay products (mud and paint pots)

- ii. physical changes
 - a.) increase in porosity and permeability
 - b.) soft & friable
 - c.) change in color: lighter; formation of red & yellow (pyrite -> hematite and limonite)
 - d.) change in texture finer grained than original
- 2. waterfalls are found at point of fracture ring and varying degrees of hydrothermal alteration
 - a. Upper Falls outer ring very little alteration
 - b. Lower Falls inner ring highly altered
- B. Obsidian Cliff
 - 1. Fault with 180,000-year-old lava flow forming noncrystalline volcanic glass
 - a. Extremely low water content and/or very rapid cooling (former is more accepted theory)
 - b. Presence of columnar joints indicating slow cooling
 - c. Swirling in obsidian indicates flow
 - d. Obsidian used by Native Americans as far back ago as 10,000 years
- C. Buried Forests
 - 1. Specimen Ridge
 - 2. Petrified tree trunks, some with root system intact
 - 3. 20 or more successive forests buried 55 33 mya by lava flows
 - 4. silica in lava replaced the wood cells and petrified the trees
- D. Earthquakes (www.seis.utah.edu/req2webdir/recenteqs/Maps/Yellowstone.html)
 - 1. 1,500 to 2,500/year occur within Yellowstone National Park and its immediate surroundings
 - a. 1,008 in last week of July 2021
 - b. 2,773 in 2021
 - c. most are too small to be felt
 - 2. causes
 - a. rising magma and hot groundwater movement
 - b. ancient regional faults from Teton, Madison, and Gallatin Ranges pass through park
 - c. large earthquakes >7 are unlikely within the Yellowstone Caldera itself
 - d. distance earthquakes can have an effect on Yellowstone
 - 3. effects on geothermal features
 - 4. Hebgen Lake earthquake August 1959
 - a. Magnitude 7.5
 - b. Caused Madison Canyon landslide
 - c. Killed 28 people