Glaciers

I. Formation of glaciers
   A. Net accumulation of snow from season to season
   B. Compaction - 3 phases: snow -→ firn -→ glacial ice

II. Types of glaciers
   A. Alpine (mountain, valley) in previously formed stream valleys
   B. Continental - cover all land surface over extensive areas
   C. Tidewater - flow into ocean or bay

III. Anatomy of a Glacier
   A. zone of accumulation
   B. zone of ablation
   C. zone of fracture

IV. Movement of glaciers
   A. rate differs – fastest - Greenland: 82 - 100 cm/hour
   B. Overriding force is gravity
   C. Basal sliding
   D. plastic flow

V. Erosion and transportation
   A. Acquire load by:
      1. frost wedging
      2. landsliding
      3. avalanching
   B. Plucking and quarrying
   C. Abrasion

VI. Glacial erosional features
   A. glacial trough or valley; fjords
   B. hanging valley
   C. arete
   D. horn
   E. cirque
   F. roche moutonnee
   G. striations
   H. glacial polish

VII. Glacial deposits
   A. Drift - generic term for all glacial deposits
   B. Types
      1. till
      2. erratic

3. moraine
4. kame
5. kettle
6. esker
7. drumlin
8. proglacial
    a. outwash
    b. lake sediments
9. eolian deposits - sand dunes and loess

VIII. Pleistocene glaciation

A. Alternate glacial and interglacial times - 1.5 mya until ~10,000 years ago

IX. Effects of Pleistocene glaciation

A. change of drainage patterns
B. isostatic adjustment
C. change in sea level
D. lakes - Lake Bonneville, Great Lakes
E. Driftless area
F. Channeled Scablands
G. wind
H. Cape Cod and Long Island
I. Migration and selected extinction of plants and animals

X. Causes of glaciation

A. Milankovitch cycles - wobbling of Earth on axis - change in incoming solar radiation and change in shape of Earth's orbit

Glacier National Park

(Waterton – Glacier International Peace Park)

I. History

A. Blackfoot Indians lived in area
B. Railroad surveyors after the Civil War were looking for mountain passes for a northern route
C. George Bird Grinnell, early explorer, responsible for getting park protected
D. National Park in 1910
E. Biosphere Reserve in 1976
F. World Heritage Site in 1995

II. Geographic setting

A. straddles the continental divide – orographic effect

III. Geologic History

A. All Precambrian age rocks: 800 – 1,600 mya

B. Transgressing & regressing seas – near-shore shallow vs deep water environments

1. shallow water to east: Altyn Formation
   a. limestone and dolomite
   b. ripple marks
   c. mud cracks
   d. stromatolites
2. deeper water to the west: Pritchard Formation: silt and clay
3. tidal mud flats: Appekunny Formation: fine silt and clay
4. tidal mud flats: Grinnell Formation – most colorful and recognizable bed in park
   a. red and green mudstone: alternating oxidizing and reducing environments
   b. mud cracks
   c. ripple marks
5. transition to deeper water: Empire Formation: mud, sand, and silt
6. deeper water: Helena (Siyeh) Formation
   a. limestone and dolomite
   b. stromatolites
   c. upper part has diorite sill (10' – 200' thick) intruded 1,000 – 800 mya
7. return to shallow water: Snowslip Formation
   a. tidal mud flats
   b. silt and mud
   c. ripple marks
   d. mud cracks
   e. stromatolites
8. in some areas of the park – Purcell lava flows - 1,075 million years old
9. transgression of seas: Shepard Formation: limestone and stromatolites

C. Uplifts so that the region remained above sea level during Paleozoic and Mesozoic

D. Cretaceous

1. Laramide Orogeny – near end of Cretaceous – 65 – 70 mya
2. thrust faulting – Lewis Overthrust
   a. significant because of the extent of lateral displacement (up to 80 kilometers)
   b. overrode younger shales in park

3. increased stream gradients
4. eroded large stream valleys

E. Minor uplift brought Rockies to present height

IV. Glaciation

A. Four episodes of alpine glaciation during middle Pleistocene
1. valleys filled with up to 500’ – 1000’ of ice

B. very intense in Glacier National Park
1. sedimentary rocks that were very susceptible to erosion
2. intense erosion during interglacial times deepened valleys by as much as 300’
3. low snow line

C. warm interval ~7000 years ago followed by cooling ~ 5000 years ago (Little Ice Age)
1. responsible for the 26 alpine glaciers found today between 6000’ and 9000’

D. glacial features – in slides

YOSEMITE NATIONAL PARK

I. Introduction

A. History
1. 1851 - Bands of white men decided to force Yosemite Indians out of valley
2. State park in 1864 and National Park in 1890
3. Visit by Muir, Theodore Roosevelt, and Stephen Mather
4. 1913 – lost battle with flooding of Hetch Hetchy Valley for hydroelectric power
5. World Heritage site in 1984

II. Geologic History

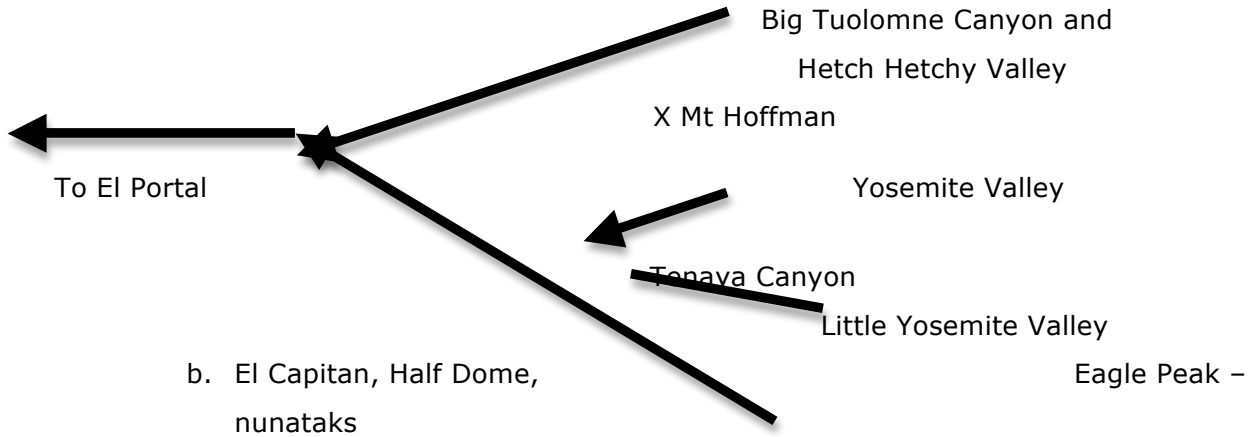
A. Paleozoic: Farallon Plate subducting under continental plate

B. Mesozoic
1. 120 – 90 mya - formation of Sierra Nevada batholith
a. series of intrusions so rocks are of different ages
i. El Capitan Granite – 103 my old
ii. Half Dome granodiorite – 90 my old
b. massive rock with widely spaced joints
c. Intrusive formations – 4 important “granite” units
i. Granite – El Capitan - 20 – 60% quartz, very resistant to erosion
ii. Diorite – 5% quartz, more dark minerals
iii. Grandiorite – Silica 5 - 20%; Sentinal Rock, Half Dome, Mt. Hoffman
iv. Tonolite- similar to diorite but more quartz; Gateway is only exposure
2. Late Mesozoic - magma activity ceased

C. Cenozoic: 25 mya Sierra Nevadas began continuous uplift and tilting towards west

D. Pleistocene – 2 mya

1. first and second glacial advances (interglacial times)



b. El Capitan, Half Dome, nunataks

c. Shaped valleys according to joint patterns

i. unjointed – polished and scraped

ii. jointed – quarried and plucked

iii. stairstep pattern – Nevada Falls and Vernal Falls steps

2. Third glacial advance 30,000– 60,000 years ago

a. most of park to foot of Bridal Veil Falls

b. finalized glacial features of valley

3. 20,000 – 15,000 years ago the glaciers began to melt back

a. many lakes formed after each episode of glaciation

b. Lake Yosemite formed behind moraine at Bridal Veil Falls

c. 3 glaciers left in park – Lyell, Maclure, and Dana

4. Glacial features

a. roches mountonee – asymmetrical dome - steep side in direction of movement

ii. Liberty Cap, Mt. Broderick

b. exfoliation

c. water falls – over ½ of tallest waterfalls in US: smallest = 2x times Niagara Falls

ii. Yosemite Falls – three falls controlled by joints

d. subalpine meadows: tarn or cirque lakes that silted up

e. moraines

f. glacial polish

g. glacial lakes

h. Pater nostre lakes

III. Geologic Features

A. Joint system – resulted from stresses imposed on batholith during tilting

1. controlled landforms
2. The more quartz-rich/silica-rich rocks have more widely spaced joints
3. Weathering/erosion along joints = straight and narrow canyons - Tenaya Canyon
4. Massive, unjointed – El Capitan
5. Vertical joints – Glacier Point, Upper and Lower Yosemite Falls, Lost Arrow, Ribbon Falls, Sentinel Rock, front face of Half Dome, Washington Column
6. Joint sets
    a. Closely-spaced – Cathedral Spires, Rockslides (why have so much talus)
    b. widely-spaced –Three Brothers (incline at 45^0), Cathedral Rocks
    c. sheet jointing – expansion that forms sheet joints and reflects topography
        i. Sentinel Dome, North Dome, Royal Arches, back side of Half Dome
    d. Domes – only 2 of 7 types of granite in Yosemite form domes
        i. El Capitan and Half Dome