I. Basic concept of plate tectonics
   A. lithosphere is broken up into plates
      1. analogous to plates in skull
      2. except these move
   B. shifting of plates cause geologic activity
      1. volcanism
      2. earthquakes
      3. mountain building
   C. plate tectonics is a relatively recent theory
      1. accepted since the 1960’s
      2. not complete
         a) doesn’t explain the Rocky mountains
         b) doesn’t explain hot spots
            (1) explains why they seem to move
            (2) not why they exist
         c) driving mechanism is not known
      3. does explain the major features on earth
         a) provides a framework for study

II. Early puzzles
   A. young linear mountain ranges near oceans
      1. young implies not eroded
      2. jagged peaks, little soil or vegetation
      3. Rockies are an exception
   B. old eroded ranges in continental interiors
   C. cratons in continental interiors
      1. very old hard, inactive rocks
   D. ring of fire
      1. most volcanoes surround the pacific ocean
      2. appear to form curved lines
      3. some notable exceptions (Hawaii)
   E. hot spots
      1. isolated areas of volcanic activity
      2. show curvilinear trends
   F. distribution of earthquakes
      1. strong quakes
         a) near mountain ranges, volcanoes, islands
         b) along ring of fire
      2. weak quakes
         a) mid-ocean, continental interiors
G. apparent fit of Africa and South America
   1. coastlines seem to fit in some places
   2. fit is very poor in others
H. biologic life on different continents
   1. some strong similarities
   2. possible common ancestors that were separated
   3. fossils at unexpected latitudes
I. apparent continuity of rocks across continents
J. coal in high latitudes
   1. England, Pennsylvania
   2. believed to form in swamps
K. evidence of glacial movement near equator
L. apparent polar wandering
   1. lava retains magnetic orientation at cooling
   2. data implied that the north pole moved
M. mere existence of mountains, oceans
   1. should be eroded if earth is old
   2. sediment would have filled oceans

III. New evidence
A. accurate profiles of ocean bottoms
   1. spurred by WW2
   2. destroyed previous hypothesis of featureless deeps
   3. ocean bottom features
      a) mid-ocean ridges
         (1) volcanic activity
         (2) high heat flow
      b) continental shelves
         (1) give better fit than coastline
      c) submerged seamounts
         (1) dead volcanoes
B. magnetic reversals
   1. bands parallel to ridges
C. sediment thickness
   1. decreases close to ridge
D. radioactive dating
   1. younger rocks near the ridges
   2. no very old rocks have been found in oceans
E. accurate measurements of distance between continents

IV. Theory of plate tectonics
A. earth’s crust is broken into a number of plates
   1. different shapes, sizes
   2. some continental some oceanic
B. plates grow and shrink  
1. the size of the earth remains the same  
2. growth rates different in different places  
C. plates move around  
1. growth rates  
2. shape differences  
D. plate movement is root cause of most geologic activity  

V. Driving mechanism  
A. not known for sure  
B. convection currents appear to be involved  
1. hot magma rises  
2. spreads out laterally  
3. drags continents along  

VI. Types of boundaries  
A. divergent boundaries (spreading centers)  
1. plates move apart  
2. magma (molten rock) rises to fill the void  
   a) forms new lithosphere  
3. mostly located at mid-oceanic ridges  
4. divergent boundaries first form in mid-continent  
   a) forms a rift valley  
   b) rift may split continent and reach the ocean  
      (1) Red Sea  
      (2) Africa may split apart in this manner  
   c) rift may stop growing  
      (1) healed rift from KS to Lake Superior  
      (2) southern Oklahoma  
5. growth of a rift forms a new ocean  
   a) continental shelf  
      (1)  
   b) continental slope  
      (1) steep slope  
      (a) submerged continental crust  
      (2) connects crusts  
      (a) continent  
      (b) ocean  
   c) abyssal plain  
      (1) true oceanic crust  
   d) mid-ocean ridge  
      (1) actual boundary  
      (2) new crust is formed  
B. convergent boundaries
1. collision between plates
  
2. lithosphere is destroyed at these
   a) new lithosphere at divergent boundaries
   b) old lithosphere must be destroyed
   c) else the earth would continually expand

3. possible types of collisions
   a) continental and oceanic plates
   b) two continental plates
   c) two oceanic plates

4. collision between oceanic and continental plates
   a) oceanic plate always goes underneath
      (1) continental plate is less dense
      (2) forms a deep-oceanic trench
   b) region is called a subduction zone
   c) also characterized by volcanoes
      (1) sediments are melted at depth
      (2) rise to form volcanic ranges
         (a) called volcanic arcs
         (b) Cascades
         (c) Sierra Nevada

5. collision between two oceanic plates
   a) one descends
   b) arc of volcanoes forms on the ocean floor
      (1) several hundred miles away
      (2) parallel to the oceanic trench
      (3) crust below the volcanic arc
         (a) becomes less dense
         (b) moves upward
      (4) island arc (Aleutians) results from
         (a) crustal buoyancy
         (b) volcanic activity
         (c) accumulation of sediments

6. collision between two continents
   a) continental rocks are lighter than oceanic
   b) subduction is likely to be minimal,
   c) causes an unusually tall mountain range
      (1) Himalayas (young)
      (2) Appalachians (old)

C. transform boundaries
   1. allow for sliding motion between plates
   2. most are located in ocean basins,
   3. few major ones go through continental crust
      a) San Andreas
VII. Arid lands
   A. about 30% of the earth’s land surface is considered dry
      1. ~20% desert
      2. ~10% semi-arid
   B. desert
      1. so barren of vegetation it is inhospitable to life
   C. semi-arid
      1. transition zone
      2. separates true desert from sub-humid
      3. western Oklahoma, Texas
      4. useful as rangeland
      5. crops require irrigation

VIII. Characteristics of deserts
   A. limited vegetation
      1. lack of soil, which requires organic material
      2. lack of water
   B. extreme temperature variation
      1. moisture and clouds insulate, retain heat
      2. vegetation also retains heat
   C. sand dunes are the exception rather than rule
   D. rock formations tend to be angular
      1. rounding is caused by chemical weathering
         a) lack of water
         b) low average temperature
      2. freeze-thaw cycles tend to break rocks sharply

IX. Types of deserts
   A. low-latitude (sub-tropical) deserts
      1. result from global air circulation patterns
         a) warm air rises at the equator
         b) circulates back downward around latitude 20-30
            (1) north and south
         c) descending air masses produce high pressure
            (1) air mass warms and contracts
            (2) lots of evaporative power
         d) not favorable to cloud formation and precipitation
      2. characterized by little rain, high evaporation, clear skies
      3. Australia, Sahara (north Africa), southern Africa
   B. continental deserts
      1. usually occur on high plateaus in the continental interior
         a) far from any source of moisture
         b) air expands and cools as it travels from the sea
            (1) rains at lower elevations
(2) doesn’t pick up new moisture
2. characterized by warm summers, cold winters
3. mostly in Asia (Gobi)
   a) long distance from any water
   b) high average elevation
C. coastal deserts
   1. occur near coastal upwelling of deep ocean waters
      a) upwelling cold water cools air
      b) cold air
         (1) lowers evaporation from the ocean
         (2) produces onshore fog
      c) some of the driest places on earth
   2. characterized by little rain, extreme dryness, evening fog
   3. Peru, west Africa, Baja
D. rain shadow deserts
   1. occur inland from coastal mountain ranges
      a) oceanic evaporation produces humid air
      b) onshore winds force air over the mountains
         (1) orographic uplift
      c) rising air expands and cools
      d) tremendous precipitation occurs
         (1) dries out the air mass
      e) on the leeward side
         (1) air descends
         (2) contracts and warms
         (3) increased evaporative power
   2. characterized by little rain, high evaporation, clear skies
   3. Sierra Nevada, Cascades, Himalayas, Andes mountains
E. polar deserts
   1. result from descending cold dry air
      a) air warms and contracts
      b) high pressure region with little moisture
   2. may have lots of snow and ice
      a) whatever falls doesn’t melt
      b) air temperatures rarely exceed freezing
   3. Greenland, parts of Antarctica

X. Wind erosion and transport
   A. transport
      1. like water, wind has a suspended load (mostly silt)
      2. also has a bed load (sand)
         a) sand moves by a process called saltation
         b) basically rolling and bouncing
      3. wind velocity decreases near the ground
a) wind is not as powerful as water
   (1) has difficulty breaking particles loose
   (2) often unable to pick particles up
   (3) wet particles stick together
   (4) wind erosion requires very dry particles
b) wind transport requires particles be lifted off ground
   (1) impact from saltation
   (2) wind blown tree branches
   (3) biologic perturbation

B. erosion
   1. water is the most important erosional agent in deserts
      a) intermittent flash floods
      b) highly powerful
   2. deserts are the only places where wind has any significance as an erosional agent
   3. windblown sand can be an abrasive force
      a) local significance, but is not a major erosional process
   4. wind is a much more important depositional agent than erosional agent

C. deflation
   1. general lowering of the land surface by wind erosion

D. desert pavement
   1. locations where the desert floor covered by pebbles
   2. two hypothesis
      a) both start with a parent material of mixed fines and pebble
   3. removal of fine particles by wind erosion
      a) general lowering of land surface
      b) pebbles are left behind to over the surface
      c) falling out of favor
         (1) little gravel is found beneath the pavement
         (2) pavement particles are of similar age
   4. pebbles rise to the surface
      a) wind blown dust containing clay and calcite lands on desert
      b) particles work downwards with rain
      c) shrink and swell with moisture
      d) push pebbles to the surface
      e) newer hypothesis

E. blow out
   1. occurs in fragile semi-arid lands
   2. damage to the surface vegetation can lead to deflation
   3. resulting depression is called a blowout
   4. often occurs where tree branches rub against the ground

XI. Sand dunes
   A. movement of sand sized particles
1. usually, but not always quartz sand
   a) quartz is durable (resists weathering)
   b) most common sand size particle
2. move in a rolling and bouncing manner called saltation
   a) air velocity is low near the ground
   b) impact of bouncing particle elevates others into wind
3. windblown sand rarely gets elevated by more than a meter
4. when wind velocity drops, the sand stops moving
5. obstructions tend to have dead air spots on the lee side

B. dune formation
1. sand tends to be deposited in mounds
   a) shallow slope on the windward side
   b) a steeper slope (angle of repose) on the lee side
2. individual mounds tend to migrate
   a) sand blows up the shallow face
   b) deposited on the lee slope
3. cross beds
   a) dune sand is deposited on an inclined surface
   b) forms a distinctive sedimentary structure

C. barchan dunes
1. solitary crescent shaped features
2. points face downwind
3. occur in locations where
   a) there is minimal sand
   b) wind direction is constant
4. often found on top of desert pavement
5. rarely over 30 m high

D. longitudinal dunes
1. elongated solitary features, often look like a stretched “J”
2. essentially stretched out barchan dunes
3. occur in locations where
   a) wind direction varies, but remains in one quadrant
   b) there isn’t lots of sand
4. usually small (3-4 m high)
5. can be 100 m high, in fields 100 km long (Australia)

E. transverse dunes
1. parallel rows of extensive dunes
   a) perpendicular to the prevailing wind
   b) this is the classic motion picture dune
2. occur in locations where
   a) there is lots of sand
   b) wind direction is constant
3. individual dunes can be over 200 m high, 1-3 km wide
4. some dune fields (Sahara) extend for 100 km
F. parabolic dune
   1. looks like a reverse barchan
   2. points face upwind
   3. occur in coastal locations where
      a) lots of sand
      b) shoreline dunes are anchored by vegetation
      c) damage to the plant cover can lead to a blowout

G. star dunes
   1. look like star fish with 3-5 arms
   2. found principally in the middle east
   3. wind comes from all quadrants
   4. can reach 100m high

XII. Loess
   A. deposits of windblown silt
      1. can be 100 m thick
      2. deposited primarily by repeated dust storms
      3. consists largely of rock flour (ground up fragments)
   B. origin of silt
      1. deserts
      2. glacial outwash
      3. lack of chemical weathering in this environment (no clay)
   C. this material covers much of Iowa, Illinois, Idaho, and Nebraska
   D. loess forms some of the productive farmland in the world

XIII. Water in the desert
   A. flash floods
      1. desert storms tend to be infrequent, short, and intense
         a) localized orographic storms
         b) controlled by weather and topography
      2. water runs-off rather than infiltrates
         a) lack of vegetation
         b) lack of soil
         c) steep slopes
      3. leads to floods in dry stream beds (wash, wadi, arroyo)
      4. flash floods carry lots of solid material
         a) powerful erosional force
         b) junk builds up in washes between floods
      5. floods can happen far away from rain storm
         a) tough on desert campers
   B. alluvial fans
   C. playa lakes
      1. bed load of mountain streams is dumped on alluvial fans
      2. suspended load may be washed into the valley
3. also dissolved chemicals from mountain rocks
4. playa lakes are salty and muddy
5. called simply a playa when they dry out
6. buried playas are often mined for dissolved salts
   a) borax
   b) lithium

XIV. Desertification
   A. expansion of desert like conditions into semi-arid land
      1. difference between desert and semi-arid is small
      2. the land in both is fragile, soil is thin
   B. soil damage can make land inhospitable to plant growth
      1. destruction of natural vegetation
      2. extensive erosion
   C. direct causes
      1. over cultivation or grazing are the prime causes
      2. over pumping of groundwater for irrigation
   D. feedback driven process
      1. drought reduces farm yield
      2. farmers work the land harder in order to survive
      3. damage fragile lands
      4. overpopulation is root cause
   E. happens on every temperate continent
      1. most extensive in northern Africa
      2. occurring in west Texas, New Mexico
      3. extensive research in Australia
         a) highest % of desert of any continent