I. Normal Faults

A. Characteristics

1. Defined

a. Inclined dip-slip faults in which hanging wall has moved down relative to footwall

(1) younger rocks placed on older rocks by fault

(2) Crustal extension = driving process

2. Separation and Normal Faulting

a. Relative stratigraphic offset of normal fault a function of:

(1) strike and dip of fault plane
(2) strike and dip of bedding

(a) controls outcrop and cross-section rock patterns

3. Folds Associated with Normal Faults

a. Drag Folds
b. Listric normal faults and roll-over anticlines

(1) listric fault: angle of dip decreases with increasing depth

(a) concave upward normal fault

(2) Roll-over Anticline

(a) As hanging wall block downdrops, beds deform to maintain contact with footwall

4. Associated Deformation
a. drag folds
b. slickensides
c. cataclastites
d. ducile shear at deeper levels

B. Shape and Displacement of Normal Faults

1. Surface Trace

a. Sinuous vs. straight fault trace
b. Mountain front geomorphology

2. Shape at Depth

    a. listric normal
    b. high-angle normal faults: constant dip at depths
    c. Detachment faults: major fault surface of "rock detachment"
        (1) commonly low angle
    d. Imbricate Faults: parallel fault sets

    e. rotational vs. non-rotational normal faults

C. Structural Associations

1. small scale vs. large scale faulting

    a. outcrop vs. mountain front size faults

2. synthetic vs. antithetic faults

    a. synthetic: smaller scale faults parallel to major faults

    b. antithetic: smaller scale faults oriented with dip in opposite direction of major faults

3. Horsts and Grabens (fault bounded blocks)

    a. Horsts: uptrown fault-bounded blocks
    b. Grabens: down-thrown fault-bounded blocks

        (1) Half-grabens: normal faulting on one side of block, with net downward rotation

    c. Basin and Range of Western U.S.

        (1) Grabens as tectonic sediment traps

4. Regional Fault Systems

    a. Rift-Extension Systems

        (1) Basin and range of Western U.S.
        (2) Triassic Rift Basins of Eastern U.S.

    b. Gulf Coast

        (1) Extensive sedimentation by sediment delivered to coast
        (2) Growth Faults

            (a) Normal faulting that develops contemporaneously with sedimentation

i) gravity-sliding vs. differential compaction mechanisms

ii) result = fault that grows through time as more sediment is deposited

c. Metamorphic Core Complexes

(1) Intense crustal extension

(a) low angle detachment faults
(b) mylonite development, ductile deformation
(c) uplift of meta-plutonic complexes from beneath detachment zone

II. Thrust Faults

A. Definitions and Terminology

1. Thrust = low-angle reverse fault (dip < 45 degrees)
a. hanging wall over up and over relative to footwall

2. Thrust-fault Mountain Complexes

a. Zones of regional compression and crustal shortening
(1) scale: 100's of km, regional mountain complexes

(a) e.g. northern Rockies of U.S., Canada
(b) Himalaya Mtns of Asia

3. Terms

a. Thrust Sheet or Thrust Nappe: hanging wall block above thrust plane

(1) Allochthon: blocks of rock that have undergone serious thrust displacement
(a) e.g. hanging wall complex

(2) Autochthon: blocks of rock that have NOT undergone thrust displacement
(a) e.g. footwall complex

b. Foreland: direction towards which thrust blocks have moved
c. Hinterland: direction from which thrust blocks have moved

B. Recognition of Thrust Faults

1. Stratigraphic
    a. place older rocks on top of younger rocks
        (1) repetition of stratigraphic sequences
        (2) mismatched facies sequences
            (a) e.g. marine over fluvial

2. Thrus-fold relations

C. Shape and Displacement of Thrust Faults

1. Shape of Thrusts
    a. Common patterns:
        (1) thrusts listric at depth
        (2) occur in branching networks that connect back to single main fault at depth
        (3) thrust faults have irregular surface geometry with up and down ramps common
            (a) front ramps
            (b) side ramps

    b. Klippe: isolated erosional remnant from allochthon

    c. Fenster (window): erosional hole through hanging wall thrust block, into footwall thrust block

D. Structural Environments and Thrusting

1. Local Thrusts

    a. Diapiric Structures

        (1) less dense rock bodies that are uplifted by buoyant isostatic forces through more dense rock

            (a) e.g. Salt Domes
            (b) Diapiric igneous intrusives

        (2) Up-thrust systems common in strata above diapiric intrusion

    b. Thrust Systems

        (1) Foreland Fold and Thrust Belts

            (a) major orogenic belts characterized by compression, thrusting and folding

        (2) Terms and concepts

(a) salient: convex wedge of thrust toward foreland

(b) Reentrant: concave bend in thrust toward foreland

(c) Decollement: surface of detachment, above which = thrust sytem, below which = undeformed basement rocks

(d) Thrust Duplex
- i) imbricate thrust faults that form horses between them
- ii) horse = blocks of rock bounded by thrust faults

(e) Tear Faults
- i) vertical high-angle faults, that form perpendicular to thrust trace
- ii) accommodation of deformation of rock sheet

III. Strike Slip Faults

A. Definitions and Terminology

1. Strike Slip Faults

a. offset parallel to strike of fault plane

(1) commonly high angle faults
(2) dextral vs. sinistral strike slip faults

b. Tear faults: secondary strike-slip faults associated with thrust systems

c. Wrench fault: another term for high-angle strike-slip fault

d. Transform or transcurrent faults: major strike slip faults, some of which form tectonic plate boundaries

(1) hundreds of km of displacement, e.g. San Andreas

B. Characteristics of Strike-Slip Faults

1. horizontal strike separation of strata along fault plane
   a. mismatched stratigraphy
   b. exotic terranes

2. Geomorphic expression
    a. offset streams
    b. sag ponds

C. Shape and Displacment

1. single Faults

    a. En echelon strike-slip fault array

    b. Bending strike slip faults

        (1) transpression: local zones of compression associated with bend in strike-slip fault

        (2) transtension: local zones of extenstion associated with bend in strike-slip fault

2. Strike-slip Duplexes

    a. stacked horses bounded by strike slip faults

        (1) branching and coverging at depth

    b. Flower structures: vertical shape of strike-slip duplexes

        (1) Normal or Negative Flower Structure

            (a) transtensional strike-slip duplex, with downdropping of horses in fault strands (ie. normal component to faults)

                i) concave up fault strands

        (2) Reverse or Positve Flower Structure

            (a) transpressional strike-slip duplex with uplfting of horse wedges in fault strands

                i) convex up fault strands

    c. Scissor Faults: accommondate motion of horses in strike-slip compex
    d. Pull-apart basins: downdropped blocks form sedimentary basins in trantensional tectonic zone

        (1) lake or fluvial sedimentary basins

3. Terminations

a. branching and bending terminations

(1) thrust terminations
(2) normal termination

D. Structural Associations

1. Transform Tectonics

a. e.g. San Andreas system