PRESENTATION GROUP #1 - WESTERN ZONE OF THE PENINSULAR RANGES BATHOLITH

Question Sets that Group #1 needs to know the answers to for a successful presentation:

STOP 1: SUNRISE HIGHWAY AND FREEWAY 8

A. List the four stages of tectonic development for San Diego County, including their age ranges.

B. The PRB is divided into a western zone and an eastern zone based on differences in rock type, age and structure. What is the age range for each zone?

C. What is the tectonic origin (setting) for the western zone rocks (plutons) of the Peninsular Ranges Batholith?

D. What stage of tectonic activity does the western zone of the batholith represent?

E. What is the depth of emplacement for the plutons in the western zone of PRB?

F. List the three major plutonic rock types of the western zone of the PRB.

G. Describe the Pine Valley granite's mineralogy (4 most common minerals) and rock texture.

H. What is the absolute age of the Pine Valley granite and how was this age determined?

I. Describe the Pine Valley gabbro's mineralogy (4 most common minerals) and rock texture.

J. What is the most dominant mineral in these gabbroic rocks? Why so much?

K. What is the absolute age of the Pine Valley gabbro and how was this age determined?

L. Where did all the overlying rock, that once covered these Mosozoic-aged plutons, go to?

STOP 2: SUNRISE HIGHWAY

A. What is the Cuyamaca-Laguna Mountain Shear Zone? It's general tectonic significance in the PRB?

B. What is the tectonic origin and age for the Cuyamaca-Laguna Mountain Shear Zone?

C. Describe the Harper Creek rock's mineralogy (4 most common minerals) and rock texture.

D. Are these rocks foliated? If so, then describe the type of foliation and determine the strike and dip of the foliation and lineation in the metamorphic rocks with your compass.

E. What is the parent (protolith) rock for the Harper Creek Schist? How can you tell?

F. What is the age of the Harper Creek rocks and how was this age determined?

G. These metamorphosed rocks have a special name called "mylonite". What's a mylonite?

H. Determine the orientation of the prominent fault found here in the CLMSZ with your compass.

I. Can you determine whether this is a dip-slip or strike-slip fault? If so, then how? Relative motion?

J. Determine the timing of when the Cuyamaca-Laguna Mountain Shear Zone was active. You can do this by comparing the youngest-aged deformed (pre- and syn-tectonic) rocks (hint: western zone PRB rocks) in the CLMSZ with the oldest-aged undeformed (post-tectonic) rocks (hint: eastern zone PRB rocks) that terminate (cross-cut) the shear zone.

PROFESSOR'S COMPILED INFORMATION ON WESTERN ZONE OF THE PENINSULAR RANGES BATHOLITH (PRB)

A. Tectonic Origin of the Western Zone of the Peninsular Ranges Batholith

1. Initiation of an island arc system when the ancient oceanic Farallon plate began subducting beneath the fringing oceanic crust of Southwestern North America around 200 Ma.

a) Change from passive margin to island arc subduction system around 200 Ma

b) Subduction of relatively old, cold, dense Farallon plate created a relatively steep subduction angle

c) <u>Western zone of PRB was created during the early subduction stage</u> of San Diego's tectonic development (200 Ma to 100 Ma)

2. Birth and development of a fringing island arc system (western zone of PRB)

a) Large volumes of magmas form in the subduction zone

- ✓ **Due to the dewatering of the down-going ocean slab**
- ✓ **Dewatering of slab into the mantle wedge acts like a flux for melting**
- ✓ **Water flux lowers melting temperature of subduction zone rocks (melting of the asthenosphere mantle wedge and/or the oceanic slab itself).**

b) Subduction-generated magmas are water-rich and gabbroic in composition.

c) These volatile-rich gabbroic magmas rise up and begin to collect and pool beneath overlying plate (fringing ocean crust adjacent to continent)

d) Over time, these gabbroic magmas intrude up into the overlying plate (fringing ocean crust) and form crustal magma chambers

e) The magma chambers feed an overlying system of conduits that feed the growth of volcanoes

f) A linear belt of volcanic islands grow, made up mostly of stratovolcanoes, which lie close to the edge of the continent.

g) Between the newly established island arc system and the continent is a narrow "back-arc" seaway floored by ocean crust.

3. Evolution of a fringing island arc system

a) Over time (from 200 Ma to 100 MA) the fringing island arc became wider and thicker, due to the

B. Structure of the Western Zone of the PRB

1) Areal extent of the western zone of the PRB:

a) Length is from Riverside to half-way down Baja California

b) Locally, the width is from coast to halfway across San Diego county

2) The crust is comprised of lava flows and several hundred plutons that form a shoulder-to-shoulder mosaic of intrusions - older intrusions intruded by younger intrusions

3) Average size of the plutons range from one to ten kilometers across.

4) Exposure of plutons, in terms of original crustal depth when the bodies formed is relatively shallow

a) From near surface (on the western side, near coast) to about 10 kilometers deep (eastern side, near Sunrise Highway)

5) Western zone is differentiated (longitudinally along the center of the batholith) from the eastern zone of the PRB by several distinct differences in rock structure and composition

a) The boundary roughly coincides with Sunrise Highway and the CMLMSZ

b) The western zone rocks are older, magnetite bearing, broad compositional spectrum; but overall, more mafic, less silicic, and chemically of purely oceanic origin

c) On eastern zone rocks are younger, magnetite- free, narrow compositional spectrum (overall of granodiorite composition), and chemically of mixed oceanic/continental origin

C. Rocks of the Western Zone of the PRB

1) There are Three Major Plutonic Rock Types in the Western Zone of the PRB -

a) Gabbros and Diorites

- ✓ **Found all over the western zone of the PRB (little to none found in the eastern zone of PRB)**
- ✓ **Rocks rich in hornblende and Ca-rich plagioclase; also substantial amounts of pyroxene, olivine and magnetite.**
- ✓ **Parent magmas generated by partial melting of hydrated (water-enriched) mantle-wedge asthenosphere in island arc subduction zone.**

- ✓ **Considered the most primitive/immature of the three rock types in the entire PRB, and appear to associated with the tonalites as nested plutonic complexes.**
- ✓ **The parent magma of the gabbros most likely formed an extensive under-plating of the entire western zone of batholith during its development**
- ✓ **Gabbroic under-plate in the western zone of PRB crust most likely the parent material that partially melted to form the more silicic rock types**
- ✓ **Absolute age determination of these rocks is difficult, but scarce ages ranges from 120 Ma to 100 Ma (= wide age range)**
- ✓ **Forms topographic high relief (pointy-looking peak tops with low-standing, homogenous-looking chaparral cover.**
- ✓ **Example is found in Pine Valley and along the Sunrise Highway at stops #1 and 2.**

b) Tonalites and Granodiorites

- ✓ **Found all over the western zone of the PRB (substantial amounts also found in the eastern zone of PRB)**
- ✓ **Rocks rich in quartz and Ca/Na-rich plagioclase; also accessory amounts of hornblende, pyroxene, and/or biotite.**

- ✓ **Low amounts of potassium feldspar in the western zone tonalites (low potassium rocks).**
- ✓ **Parent magmas generated by partial melting of either subducting hydrated (water-enriched) oceanic basalt slab, or the gabbroic under-plate (see above)**
- ✓ **The most abundant of the three rock types in the entire PRB, and appear to associated with the gabbros as nested plutonic complexes.**
- ✓ **The eruptions of these magmas probably created stratovolcanoes.**
- ✓ **Absolute age determination of these rocks are abundant; ages ranges from 120 Ma to 100 Ma (= wide age range)**
- ✓ **Forms mostly topographic mid- to low geographic relief (rolling hills and broad valleys) with moderate to thick chaparral cover.**
- ✓ **Example is found all along Freeway 8 on the way to stops 1 and 2.**

c) Monzogranites

- ✓ **Found all over the western zone of the PRB (substantial amounts also found in the eastern zone of PRB)**

- ✓ **Rocks rich in quartz, Na-rich plagioclase, and potassium feldspar; also accessory amounts of hornblende and biotite.**
- ✓ **Low amounts of potassium feldspar in the western zone tonalite rocks (low potassium rocks).**
- ✓ **Parent magmas generated by partial melting of either, the subducting hydrated (water-enriched) oceanic slab sediments, or the tonalite rocks, or prebatholithic country rock, or a mixture.**
- ✓ **The eruptions of these magmas probably created stratovolcanoes.**
- ✓ **Absolute age determination of these rocks give ages ranging from 120 Ma to 110 Ma.**
- ✓ **Forms mostly topographic high geographic relief (blocky peaks with steep boulder-rich slopes); heavy chaparral cover.**
- ✓ **Examples are found in Pine Valley and along the Sunrise Highway at stops #1 and 2.**

ADDITIONAL INFORMATION ON THE WESTERN PRB:

1) San Diego Natural History Museum -
http://www.sdnhm.org/research/geology/geo_westpluton.html

2) Peninsular Ranges Batholith – Ray Rector - http://www.terrasonics.com/The Peninsular Ranges Batholith.mht

3) Peninsular Ranges Batholith Illustrations - http://www.terrasonics.com/ Peninsular Ranges Batholith Figures.mht

C. The Cuyamaca Laguna Mountain Shear Zone (CLMSZ)

1) Tectonic Origin

a) The CLMSZ is a brittle-ductile shear zone that separates rocks of the western and eastern zones of the PBR

- ✓ **It formed at mid-crustal depths (10 to 12 km down) in response to trans-batholithic tectonic forces.**
- ✓ **The shear zone extends for 10's of kilometers in length (strike is NW-SE), and is several kilometers in width.**
- ✓ **The shear zone, and accompanied fault surfaces, dips steeply (60 to 80 degrees) to the east**
- ✓ **The shear zone was active in the mid- to late Cretaceous period, and experienced two distinctive episodes of deformation**
  - o **Early compressional episode (120 to 110 Ma); East side (hanging wall) up over west side (footwall)**
  - o **Later extensional episode (105 to 95 Ma); East side (hanging wall) down off of west side (footwall)**

- ✓ **The two distinctive episodes of deformation in CLMSZ preserve a record of when the PRB experienced significant tectonic duress.**
  - **Early episode when the batholith was compressed (shortened and thickened); due to when the North Atlantic started to open up? Or a change in subduction angle/slip rate?**
  - **Early episode of deformation probably coincided with the collapse of the back-arc seaway, thereby suturing the island arc against the margin of the North American continent.**
  - **Later episode when the batholith was extended (stretched and thinned); due to collapse of gravitationally unstable arc welt? Or a change to strong oblique subduction angle?**
  - **Later episode of deformation probably coincided with the climax emplacement of eastern zone La Posta plutons, and gravitational collapse of an over-inflated crustal arc welt.**
- ✓ **The CLMSZ deforms pre-batholithic rock (Julian Schist), earliest western zone plutonic rocks (Harper Creek Gneiss)**

and younger western zone rocks (Pine Valley granite and gabbro).

- ✓ **The CLMSZ does not appear to deform the eastern zone PBR rocks; instead the CLMSZ appears to be truncated into those intrusions.**
- ✓ **The brittle-ductile deformation is a combination of regional and dynamic metamorphism that produces a rock fabric termed a "Mylonite"**
  - **Mylonites look like a schist or gneiss**

2) Rocks of the CLMSZ

- ✓ **PRB rocks deformed (pre- and syn-tectonic) in the CLMSZ include:**
  - **Pre-batholithic meta-sedimentary Julian schist (Late Triassic to Early-Mid Jurassic age - 210 to 160 Ma)**
  - **Meta-igneous western zone rocks: Cuyamaca Gneiss (180 Ma?) Harper Creek Gneiss (154 Ma);**
  - **Pine Valley Granite (118 Ma)**
  - **Las Blancas Tonalite (105 MA)**
  - **Pine Valley Gabbro (101 Ma?)**
- ✓ **PRB rocks not deformed (post-tectonic) in the CLMSZ include:**
  - **La Posta Pluton (94 Ma)**

- **Granite pegmatites (100 to 94 Ma?)**

✓ **Harper Creek Gneiss (154 Ma)**

- **Meta-igneous schistose gneissic to gneissic schist**
- **Mylonitic S-C fabric; brittle-ductile deformation**
- **Composed of mostly quartz, feldspar, muscovite and biotite**
- **Strong to moderate light-dark mineral layering**
- **The mica in the rock is highly foliated, giving is a schistose appearance**
- **Absolute age determined by Uranium-Lead isotopic dating of Zircons**

✓ **Pine Valley Granite (118 Ma)**

- **Western zone PRB plutonic rock**
- **Monza-granite (low-quartz granite)**
- **Composed of mostly quartz, potassium and orthoclase feldspars and biotite**
- **Contains low to moderate amounts of magnetite (low to medium magnetic susceptibility)**
- **Undeformed rock has a coarse-grained phaneritic texture, with a mild magmatic foliation**
- **Moderately to highly mylonitzed where in contact with the CLMSZ**

- **Absolute age determined by Uranium-Lead isotopic dating of Zircons**

✓ **Pine Valley Gabbro (101 Ma?)**

- **Western zone PRB plutonic rock**
- **Hydrated gabbro (hornblende-rich gabbro)**
- **Composed of mostly hornblende, plagioclase feldspar, pyroxene and olivine**
- **Contains moderate to high amounts of magnetite (high magnetic susceptibility)**
- **Undeformed rock has a fine- to coarse-grained phaneritic texture, with or without magmatic banding.**
- **Mylonitzed where in contact with the CLMSZ**

3) Evidence and Timing of the CLMSZ deformation

✓ **Evidence of brittle-ductile deformation (and kinematic sense of displacment) recorded in the S-C mylonitic rock fabric**

✓ **Timing of the deformation events constrained by examining all rock types involved in the CLMSZ using the crosscutting principle**

✓ **Rocks older than 110 involved in the first episode of deformation (contain a first-order and overprint S-C imprint)**

- ✓ **Rocks 105 Ma to 95 Ma involved in the second episode of deformation (only contain the overprint S-C imprint)**
- ✓ **Rocks younger than 95 Ma have no S-C imprint - (completely postdate the CLMSZ)**

Additional Information on Cuyamaca-Laguna Mountain Shear Zone (CLMSZ) of the Peninsular Ranges Batholith

1) San Diego Natural History Museum - http://www.sdnhm.org/research/geology/geo_oldrocks.html

2) Phil the Geo-Guy Website: http://field-trips.geology-guy.com/prb99trip/prb99stop3.htm

3) Article in Tectonics Journal: http://www.agu.org/journals/ABS/1994/94TC01649.shtml

4) CLMSZ Garnet Mountain area: http://www.terrasonics.com/CLMSZ Garnet Mountain area.htm

5) Peninsular Ranges Batholith – Ray Rector - http://www.terrasonics.com/The Peninsular Ranges Batholith.mht

6) Peninsular Ranges Batholith Illustrations **-** http://www.terrasonics.com/ Peninsular Ranges Batholith Figures.mht