Geology Field Extravaganza - Spring 2014
San Diego Mesa/Miramar Colleges
Peninsular Ranges Batholith
Sat/Sun May 3rd & 4th 2014
“It’s all about the plutons…”

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Student Name(s): ____________________________
Course Name: ____________________________
Campus: ____________________________
Instructor: ____________________________
A. Tectonic History of San Diego County

1) List the four tectonic stages of San Diego’s 400 million year geologic history. (mya = million years ago)
   a) Initial Stage 1 = ________________________________________________ (from 500 to 200 mya)
   b) Stage 2. = _____________________________________________________ (from 200 to 30 mya)
   c) Stage 3. = ______________________________________________________ (from 30 to 10 mya)
   d) Present Stage 4. = ________________________________________________ (from 10 to 0 mya)

2). Define "Pluton": __________________________________________________________________

Define "Country Rock": _____________________________________________________________

Define "Batholith":  _________________________________________________________________

San Diego, Orange, and Riverside Counties and much of Baja California are underlain by a complex, three-dimensional mosaic of intrusive igneous plutons and older pre-batholithic metamorphic country rocks. This province is called the ____________________________________________________________.

3). Development of the extensive batholiths of California (Peninsular Ranges, Sierra Nevada, and Klamath) occurred during much of the Mesozoic Era - a time span of around 150 million years.

   What major tectonic process created these batholiths?  Hint: Oceanic convergent plate boundaries.

   __________________________________________________________

4) There are two general types of subduction systems, based on the type of crust that makes up the overlying plate, beneath which the oceanic slab subducts. Name those two subduction types.

   Ocean - ______________________ Subduction; and Ocean- _______________________ Subduction

5) There are two general types of trench-volcanic arc systems; each arc type is associated with one of the two types of subduction system listed in #4. Name those two volcanic arc types.

   O-O Subduction =: ______________________ and O-C Subduction = ______________________

6) The Peninsular Ranges batholith is divided into two plutonic provinces – an older western zone and a younger eastern zone – based on the observed rock types, ages, and mineral/chemical characteristics.

   a) Which subduction type (see #4 above) formed the western-zone of the PRB? _________________
   b) Older Western-zone is interpreted as which type of volcanic arc? (see #5 above) _________________
   c) Which subduction type (see #4 above) formed the eastern-zone of the PRB? _________________
   d) Younger Eastern-zone is interpreted as which type of volcanic arc? (see #5) _________________

7). What are the two likely factors that caused the change from fringing island arc to continental margin arc?
   Note: During that time, North American plate accelerated westward and the subduction angle shallowed.

   1) ___________________________________________  2) ___________________________________________

B. Characteristics of the Plutonic Rocks of the Western Zone of the PRB
1) The four major plutonic rock types of the older **western-zone** of the PRB are: ____________________, _________________________, _______________________, and ____________________________

2) Which iron-rich magnetic mineral is **present** in nearly all western-zone PRB plutons? ________________

3) What are the ages of the western PRB plutons? Ages range from _______myo to _______myo.

4) How deep in the earth did these plutonic rocks form? Emplaced ________km to ________km down

**C. Characteristics of the Plutonic Rocks of the Eastern Zone of the PRB**

1) The three major plutonic rock types of the **eastern-zone** of the PRB ________________, ________________, and ________________

2) Which major plutonic rock type is mostly missing here that the western zone has? ________________

3) Which iron-rich magnetic mineral is **absent** in nearly all eastern-zone PRB plutons? ________________

4) What are the ages of the eastern PRB plutons? Ages range from _______myo to _______myo.

5) How deep in the earth did these plutonic rocks form? Emplaced ________km to ________km down

**D. The Pre-Batholithic Metamorphic Country Rocks of the of the PRB**

1) The four major types of pre-batholithic metamorphic rocks that the PRB magmas intruded into are: ________________, ________________, ________________, and ________________

2) What are the ages of these metamorphic rocks? Ages range from _______myo to _______myo.

3) Which stage of SD’s tectonic history did the meta rock’s protoliths get metamorphosed? ________________

4) What are the inferred protoliths (parent rocks) for these various metamorphic rocks, respectively? ________________, ________________, ________________, and ________________

5) What are the ages of the pre-metamorphozed protolith rocks? Ages range from _____myo to _____myo.

6) Which stage of SD’s tectonic history did the pre-metamorphic protolith rocks form? ________________

**E. The Great Mystery of the Missing Pile of PRB Volcanic Overburden Rocks**

1) What happened to the 2 to10+ kilometer-thick pile of volcanic rocks that originally covered the PRB? __________________________________________

2) Where is the displaced pile of overburden rock (sediment) now? Hint: Largest depositional site on earth __________________________________________

3) When did most of the thick volcanic overburden of the PRB get removed? Which tectonic stage(s)?

4) What happened, isostatically, to San Diego’s crust when the thick volcanic overburden got removed? Hint: Imagine what a big container cargo ship does as it’s tall stack of containers are unloaded dockside.

**Stop 2. Plutonic Rocks of the Western PRB – Pine Creek Trailhead**

*Latitude:* 32.83638889 N  *Longitude:* 116.5408333 W  *Elevation:* 3600 ft.
Outcrop #1 (Close to trailhead)

A. Describe the Pine Creek plutonic rock here:  
1) Texture: ____________________________

2) Mineral composition: ________________, ________________, ________________, & ________________

3) Color Index: ________  

5) Name the Rock: ____________________________

B. Are these rocks foliated (layered texture)? ______ If so, what’s the foliation orientation? ________________

C. The magnetic susceptibility (MS) of a rock is proportional to its magnetite content. MS is measured with a hand-held MS meter. 

What is the MS of the Pine Creek Gabbro? ________ SI units  Volume percent magnetite? ____%

D. What’s the inferred age of the Pine Creek Gabbro? ______ myo - Age based on __________________

E. Based on age and MS, Is the Pine Creek Gabbro a western or eastern zone PBR rock? ___________

F. What is the most dominant mineral in these gabbroic rocks? Why so much? Hint: from stewed ocean slab 
__________________________________________________________________________________
__________________________________________________________________________________

Outcrop #2 (Further away from trailhead)

A. Describe the Pine Creek plutonic rock here:  
1) Texture: ____________________________

2) Mineral composition: ________________, ________________, ________________, & ________________

3) Color Index: ________  

5) Name the Rock: ____________________________

B. Are these rocks foliated (layered texture)? ______ If so, what’s the foliation orientation? ________________

C. What is the MS of the Pine Creek Tonalite? ________ SI units  Volume percent magnetite? _______%

D. What’s the inferred age of the Pine Creek Tonalite? ______ myo - Age based on __________________

E. Based on age and MS, Is the Pine Creek Tonalite a western or eastern zone PBR rock? ___________

F. What is the most dominant mineral in these tonalitic rocks? ___________________________

Intrusive Contact Between Outcrops #1 and #2

A. There appears to be an intrusive contact between the two rock types (plutons) of the two respective outcrop stops. There are several aspects of the rock characteristics notable within and between the two outcrop stops that support the likelihood of an intrusive contact. List three lines of observable evidence:

1) ____________________________, 2. ____________________________, & 3 ____________________________

B. Are there any cross-cutting features within the contact region that suggests which pluton intruded the other?  
_________ If so, what are they? ____________________________

Stop 3. Cuyamaca-Laguna Mountain Shear Zone – Sunrise Highway

A. What is the Cuyamaca-Laguna Mountain Shear Zone (CLMSZ)? ____________________________
B. What is the orientation of the Cuyamaca-Laguna Mountain Shear Zone in this vicinity, as shown by the local fault (scarp) that runs through the dirt parking lot here? Make several measurements and average them.

Average Strike: ____________    Average Dip: ____________

C. Is this fault a dip-slip or strike-slip fault? ____________ How did you figure it out? ____________

D. Observe the local metamorphic rocks: Foliated? Yes or No?: Type of foliation?________________________

Mineral composition? __________________, __________________, __________________, & __________________

Based on texture and composition, name the rock: __________________

E. These metamorphosed rocks are from an igneous tonalite protolith. Tonalite protolith age? ______ myo

F. These metamorphosed rocks have a special name: Lineated "S-C" mylonite. What’s a mylonite? How does it form?

G. You can analyze the fabric of an “S-C” mylonite to determine the motion direction along the shear zone.

Below is a sketch of a typical S-C mylonitic fabric. Can you tell which way it sheared? Label the "C" and "S" surfaces, and draw arrows to show relative shear motion directions. What do lineations also tell you?

H. Determine the timing of when the Cuyamaca-Laguna Mountain Shear Zone was active. You can do this by comparing the ages of the pre- and syn-tectonic (deformed) rocks versus the post-tectonic (undeformed) rocks found within and next to the shear zone.

Age of youngest rock that is deformed in the CLMSZ (pre/syn-shear): ___________ myo

Age of oldest rock that is undeformed in the CLMSZ (post-shear): ___________ myo

Therefore, active shearing along CLMSZ occurred between ___________ myo to ___________ myo

I. Which stratigraphic principle did you use in answering question I above? __________________________

Stop 4. Youngest Rocks of Western-zone of PRB – The Lake Morena Pluton

A. Describe these Lake Morena pluton rocks: Texture: __________________

Mineral composition: __________________, __________________, __________________, & __________________

B. Age of the Lake Morena Tonalite, as determined by radiometric U-Pb dating of zircons? _______ m.y.o

C. Do you observe a foliation in these rocks? Yes? No? Intensity? Weak, Moderate, or Well-developed? How did it most likely develop? ________________________________

D. Measure the orientation of the rock’s magmatic foliation: Strike: _______ Dip: _______

E. Check out the mafic enclaves in the tonalite. Do the long axes of the mafic enclaves line up with the strike and dip of the host rock’s foliation? Yes? No? _______

F. What are a couple of possible explanations for how these enclaves originated in the host tonalite rock?
________________________________________________________________________________________
________________________________________________________________________________________

Stop 6. Southeast side of the Lake Morena Pluton - Entrance to Lake Morena Campground

A. Find and mark your location on your topo map. What are the GPS coordinates? _______ _______

B. Describe the Lake Morena pluton rocks at this outcrop. Texture: ________________________________

Mineral composition: ______________, ______________, ______________, & ______________

Color Index: ____ Magnetic susceptibility: ____ SI units Rock name: ___________________________

C. Do you observe a foliation in these rocks? Yes? No? Intensity? Weak, Moderate, or Well-developed?

D. Measure the orientation of the rock’s magmatic foliation: Strike: _______ Dip: _______

E. Check out the mafic enclaves in the tonalite. Do the long axes of the mafic enclaves line up with the host rock’s foliation? Yes? No? Estimate 3-D aspect of the most typical enclave: ___ : ___ : ___ Sketch them.

F. Estimate number of enclaves per 9 square meter area: ____ / 9 m² Estimate average enclave size: ____ cm

G. Compare and contrast your observations of this outcrop with that of Stop #5. _______________________
________________________________________________________________________________________
________________________________________________________________________________________

❖ Lunchbreak – At Lake Morena County Park Group Campsite

Stop #7 - Hilltop NW of Lake Morena Cabins – Center of Lake Morena Pluton

A. Find and mark your location on your topo map. What are the GPS coordinates? _______ _______

B. Describe the Lake Morena pluton rocks at this outcrop. Texture: ________________________________

Mineral composition: ______________, ______________, ______________, & ______________
C. Do you observe a foliation in these rocks? Yes? No? Intensity? Weak, Moderate, or Well-developed?

D. Measure the orientation of the rock’s magmatic foliation: Strike: _________ Dip: __________

E. Check out the mafic enclaves in the tonalite. Do the long axes of the mafic enclaves line up with the host rock’s foliation? Yes? No? Estimate 3-D aspect of the most typical enclave: ___ : ___ : ___ Sketch them.

F. Estimate number of enclaves per 9 square meter area: ____ / 9 m² Estimate average enclave size: ____cm

G. Compare and contrast your observations of this outcrop with that of Stop #5. _______________________
________________________________________________________________________________________
________________________________________________________________________________________

H. How far away is Los Pinos Peak? ________ Miles What is the bearing to the peak? __________________

I. What type of rock underlies Los Pinos Peak? ______________ Where did you get that info? ______________

Saturday Trip Reflection
Write a reflection of your fieldtrip experience (about two paragraphs). 1) What did you discover and learn on Saturday’s excursion? And how did this trip contribute to what you learned in the classroom? 2) What did you enjoy most about today's fieldtrip and/or find interesting? 3) How could the fieldtrip today have been better planned and/or designed?
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________________________________________________________________________________________
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Sunday 5-8-11  Lake Morena Pluton  - Eastern Edge of Western PRB

❖ After Breakfast – 4-mile roundtrip Hike to the Dam along the Pacific Crest Trail

Stop #1 - Hilltop South of Lake Morena Campground – South Central Lake Morena Pluton

A. Find and mark your location on your topo map. What are the GPS coordinates? __________ _________
**Stop #2 - Hilltop Northeast of Morena Butte – Southernmost region of Lake Morena Pluton**

**A.** Find and mark your location on your topo map. What are the GPS coordinates? ________  ________

**B.** Describe the Lake Morena pluton rocks at this outcrop. Texture: ________________________________

Mineral composition: ________________, ________________, _______________, & _______________

Color Index: ____  Magnetic susceptibility: _____ SI units  Rock name: __________________________

**C.** Do you observe a foliation in these rocks?  **Yes? No?**  Intensity? **Weak, Moderate, or Well-developed?**

**D.** Measure the orientation of the rock’s magmatic foliation:  Strike: _________  Dip: _________

**E.** Check out the mafic enclaves in the tonalite. Do the long axes of the mafic enclaves line up with the host rock’s foliation? **Yes? No?**  Estimate 3-D aspect of the most typical enclave: ___ : ___ : ___  Sketch them.

**F.** Estimate number of enclaves per 9 square meter area: ____ / 9 m²  Estimate average enclave size: ____cm

**G.** Compare and contrast your observations of this outcrop with that of Stop #8.  _______________________

________________________________________________________________________________________

________________________________________________________________________________________

**H.** How far away is Lake Morena dam? ________ miles  What is the bearing to the dam? ______________

**I.** What type of rock underlies Morena Butte? ______________  Where did you get that info? ______________

**Lunchbreak – At Lake Morena Dam**
Stop #3 - Lake Morena Dam – Central region of Morena Butte Pluton

A. Find and mark your location on your topo map. What are the GPS coordinates? __________ __________

B. Describe the Morena Butte pluton rocks at this outcrop. Texture: _________________________________
   Mineral composition: ______________, ______________, ______________, & ______________
   Color Index: ____ Magnetic susceptibility: _____ SI units Rock name: _____________________________

C. Do you observe a foliation in these rocks? __________
   Intensity? _______ Weak, Moderate, or Well-developed?

D. Measure the orientation of the rock’s magmatic foliation: Strike: __________ Dip: __________

E. Compare and contrast your observations of this outcrop with that of Stop #9. ______________________________________________________________________________
   ______________________________________________________________________________

F. What is the structural term used for the boundary between the Lake Morena and Morena Butte plutons?
   Answer: __________________________ Are there any exposures of the above contact in this area? ________
   If not, why might that be? ____________________________

G. Is there a radiometric age for the Morena Butte pluton? _______. If not, could you still decipher the relative age for this pluton in relation to its adjacent neighbors? __________
   Briefly describe how one would do this using a familiar stratigraphic principle).
   ______________________________________________________________________________
   ______________________________________________________________________________

H. How far away is our campsite? ________ miles What is the bearing to the campsite? __________

Stop #4 - Dam Area Pegmatite Dike

A. Rock and Mineral Identification of Morena Dam Pegmatite
   1. The term pegmatite refers to what characteristic of the rock? _________________________________
   2. Observe and list the dominant texture and minerals observed at this outcrop:
      Mineral composition: ______________, ______________, ______________, & ______________
   3. Which mineral is most abundant in the pegmatite? _________________________________
   4. What makes the quartz pink in color? _________________________________

B. What is the most likely origin for this pegmatite? _________________________________

Sunday Trip Reflection

Write a reflection of your fieldtrip experience today (about two paragraphs). 1) What did you discover and learn on Sunday’s excursion? And how did this trip contribute to what you learned in the classroom? 2) What did you enjoy most about today’s fieldtrip and/or find interesting? 3) How could the fieldtrip today have been better planned and/or designed?

_______________________________________________________________________________
_______________________________________________________________________________
Figure 1: Geologic time scale of San Diego County showing the temporal distribution of the geologic rock units, including the western and eastern zones of the PRB.

Figures 2 and 3: Simple geologic maps of San Diego County showing the distribution of the geologic zones and plutons, including the western and eastern zones of the PR batholith.
Two-Stage Tectonic Development of the Peninsular Ranges Batholith

Older Western-Zone Fringing Island Arc

Younger Eastern-Zone Continental Margin Arc

Figures 4 and 5: Time-transgressive cross-sections of Peninsular Ranges Batholith and its changing eastward-dipping subduction zone. Panels A through E show the changes in the subduction system - from the time of the formation of the fringing volcanic arc of the older western zone, to after the formation of the younger continental margin arc of the eastern zone of the batholith - from 160 to 75 million years ago.
Figure 6: Geologic map of El Cajon 30' x 60' Quadrangle of the Peninsular Ranges batholith, showing the distribution of the western and eastern zone plutons, and the CLMSZ.