GEOL 252**, HISTORICAL GEOLOGY –** fall 2016
Professor: Dr. **Alessandro Grippo**, Ph.D.
FIELD TRIP: ***Friday, November 18, 2016:*** *Cadiz, CA*

YOUR NAME _____

stop 1a: <u>before entering the Mountains</u>

At this location you can observe (from a distance) a tilted sequence of Cambrian sedimentary rocks overlying an eroded crystalline basement (granites) dated at about 1200 my ago. If we had time we might go into a gully at the base of the outcrop and observe that the first rocks on top of the basement are conglomerates, followed by sandstones.

1. What is the relative age of the crystalline basement?
2. How much time is missing between the crystalline basement and the conglomerates?
3. If time is missing, there must be an unconformity! What kind of unconformity is present at this location?
4. In terms of sea-level, what does a basal conglomerate indicate?

1. The crystalline basement is Precambrian in age. But I gave you a date (1200 my ago), so you can be more specific and say its age is Proterozoic
2. If the conglomerates have been dated as a Lower Cambrian, you know their age (around 550 million years, give or take, depending on sources). The missing time between the basement and the Cambrian is then 650 million years
3. An unconformity that separates a sequence of sedimentary rocks from crystalline (non-sedimentary) rocks is called a non-conformity
4. A basal conglomerate forms with a rising sea level

stop 1b: <u>reading the landscape</u>

When you look behind you, you see a desert landscape with alluvial fans coalescing into sedimentary bodies called bajadas, and flatter valley bottoms. In one of these valley bottoms, past the railroad tracks, there is a green patch in the middle of nowhere. That is the Cadiz Farm orchard.

5. How would you explain the presence of such a patch of green if there is no visible water at the surface?

5. There could be a variety of reasons for this. Ultimately, there is no evidence of rivers, lakes, abundant precipitation, so the answer lies in the presence of an underground aquifer

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stop 2: <u>at the foot of the Mountains</u>

We are now getting closer to the outcrop. From where we park our cars we can see a sequence of sedimentary rocks on top of the crystalline basement that includes, from bottom to top, sandstones, shales, limestones, then shales again.

6. What does such a sequence indicate in terms of changing sea level?
7. During the Cambrian this part of the world was a passive continental margin. Does what you see at the outcrop fit your idea of a passive continental margin deposit? Explain why
8. During our labs we discussed sedimentation in orogens and cratons. Is this part of the world an orogen or a craton today? And what about Cambrian times? Explain
9. What sediment would you expect in an orogenic area, and what sediments would you expect in a cratonic area?

6. Such a sequence, in general, indicates a relative rise in sea-level, followed by a drop in sea-level (indicated by shales on top of limestones)
7. Yes it does. In particular, the description of rocks includes very mature quartz sandstones that can only form on a passive continental margin: in order for such a mature sediment to form, several cycles of erosion, transportation, deposition must have occurred. Possibly, deposition on a wide siliciclastic shelf enhanced the maturity of such a sediment (see Lab Chapter 5)
8. Today this area is part of the western margin of the North American plate. Tectonic and volcanic activity is frequent (albeit this last one is not common in the area of study), and rapid uplift followed by rapid subsidence are common. In Cambrian times, as discussed in the answer to the previous question, this area used to be part of a craton, a craton that was relatively stable, with very slow uplift and slow subsidence (see Chapter 5)
9. In an orogenic area I would expect immature sediments, including graywacke sandstones (turbidites, within a flysch facies association) at the foot of the continental slope, and conglomerates and arkose sandstones on land. In a cratonic area I would expect progressively more mature sediments with distance from the sediment source, such as quartz sandstones and, past the continental rise, shales and limestones

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stop 3: <u>at the foot of the Mountains</u>
Hiking at the base of a cliff, we first cross coarse sediments (gravels and sands) at the mouth of two small gullies, then arrive at the Cambrian outcrop

10. What is the origin of the coarse sediments at the foot of the outcrop?
11. Can you tell their approximate age?
12. Can you describe composition, sorting, and rounding of the sediments?
13. Would you define this sediment as mature or immature? Explain
14. What is the name of sediment and sedimentary rock forming this deposit?
15. What is the name of the sedimentary body these deposits are forming?

10. These materials are clastic, coarse sediments, from very angular to subrounded, indicating a high-energy environment, and proximity to source. Very likely it was a stream that carried these sediments to the location of stop 3
11. The sediment is fresh and unconsolidated, their age is Recent (Holocene)
12. a. The composition of these clasts reflects the composition of the surrounding rocks (sandstones, shales, limestones, granites, dolostones)
    b. The sediment is unsorted
    c. The sediment is angular to subrounded
13. This sediment is immature because it is not sorted, not rounded and compositionally it shows the original minerals of the source rocks from where it was eroded
14. The sediment would be gravel. The rock forming out of it would be called a conglomerate. You may argue for breccia, but many grains are already subrounded, indicating a minimal amount of transportation away from the source
15. These gravels are currently forming what would be called an alluvial fan

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stop 4: the sandstones

Proceeding towards the outcrop, we encounter the lowermost formation above the crystalline basement, a sandstone.

16. Describe sorting, rounding, and maturity of the sandstone
17. Describe all the sedimentary structures you see
18. What do these kinds of sedimentary structure indicate?
19. It looks like that this sandstone has almost been partially metamorphosed. If that were the case, what would the (metamorphic) name of this rock be?

16. This sandstone is rounded, very well sorted, and rich in quartz; hence it can be defined as very mature
17. You can see horizontal bedding, cross-bedding, herring-bone cross-bedding. In some parts, even hints of ripple marks
18. These sedimentary structures indicate a coastal environment on a passive margin (shelf), possibly in shallow waters, with waves and currents, and also strong tides (herring-bone cross-bedding)
19. The metamorphic equivalent of a quartz sandstone is a quartzite

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stop 5: <u>the shales</u>

Past the sandstones, shales are cropping out. These shales are dark, thinly laminated, and at times rich in trilobites. Trilobites are Paleozoic arthropods that became extinct at the Permian/Triassic boundary. Trilobites have commonly been used as guide fossils for selected intervals of the Paleozoic because they were numerous, ubiquitous and rapidly evolving.

20. Based on what you see in the shales, and considering the relative abundance of fossils (even if you do not see many of them, there are plenty of fossils in these shales), describe the possible ancient sedimentary environment in which the rocks were deposited and the trilobites used to thrive

21. These shales include levels of siltstone and levels of limestone. What would these two different kinds of rocks indicate?

20. It was probably a shallow to medium depth ocean, on a shelf, away from sources of sands. Sands would not be deposited below wave-base, so it must have been a depth where the trilobites could still be thriving but deep enough not to be disturbed by wave motions

21. A siltstone would indicate a shallowing ocean (a relative, momentary fall in sea level), a limestone would indicate the opposite (a relative, momentary rise in sea level)

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stop 6: <u>the limestones</u>

Climbing up the cliff, we come to the base of the limestone units. The layers of limestone begin with relative big *oncolites*. Oncolites are small algal structure that develop by concentric growth of algal mats, comparable to small stromatolites if you want. Oncolites decrease in size towards the top of the limestone unit. Other fossils are found in between the stromatolites

22. Limestones usually indicate a deep marine facies. Do your observations on this outcrop confirm this general idea?
23. What kind of limestones would develop in shallow waters?
24. Based on what you see, what was the approximate depth of the ocean at this location? On what do you base your observation?
25. Why do you think are the oncolites, at each single level, more or less all of the same size?
26. What would muddier levels within the limestone indicate?
27. Why would some level be so "red" (rich in hematite)?
28. Do you think the oncolites were fossilized in place, or where they moved by some current?

22. While in general a limestones is deposited far away form a coastline, there are several locations today where limestones are deposited in fairly shallow waters (for instance, the Caribbean region in Central America). The deposits at stop 6 show broken fossils, oncolites, micritic deposits, evidence for oxidation (hematitic levels). all this points towards a shallow environment
23. Among the limestones we have seen, oolites (not present here), reefs (present here), fossiliferous limestones (present here), coquina (not present here) can form in shallow waters
24. Depth here must have been shallower than the previous case, because this limestone structure represents a reef and shows evidence of wave action (for instance, levels with fossil fragments, oncolites that are not in place and at times are very well sorted – as if from wave action). Also, oncolites are algal in origin, so sunlight for photosynthesis is required (photic zone)
25. Probably because of the sorting action of wave motion
26. That sea level changed. Muddier levels seem to be devoid of fossils
27. It could be because of temporarily high levels of oxygen in water, but it could also be a secondary alteration
28. Some of them seem in place, others seem to have "rolled" up and down the ocean bottom. Some present concentric growth rings, others do not

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stop 7: <u>at the top of the outcrop</u>

At the top of the outcrop, several levels show deep weathering of the limestones. Weathering could be recent, but could also have formed in geological time.

29. What kind of indications would you be looking for to make your case, in one sense or the other?
30. The limestones are followed stratigraphically by layers of shales again. What does that mean in terms of sea-level change?

29. If weathering is recent, it would be effective on exposed surfaces. If it were older, it could be found between layers, or in other intervals
30. Sea-level in general would have dropped. But, if this was an ancient reef, it could simply signify the passage from a reef to its outer margin. In this case, the previous shales (stop 5) might represent a protected lagoon

stop 8: <u>along the fault</u>

At a location by the dry waterfall it is possible to see that you are along the trace of a fault. Tension gashes, filled with calcite, are evident in the limestone. The layers of limestones are thinner and more frequent than they were at the base of the outcrop.

31. Look toward where we parked our vehicles. Look at the rocks, and try to correlate the two blocks across the fault. Would you say the right side is higher than the left, or the opposite?

31. What we have defined as the right side seemed to have moved upward

From here you can see the whole sequence form another point of view. The same sequence shows up at the bottom of the Grand Canyon, Arizona.

32. Would the rocks here in California and those in Arizona possibly belong to the same Formation?
33. Whether they do belong or not to the same formation, would they be of the same age? Explain?

32. Possibly so, since they represent the same environments at a similar time junction, and would show continuity throughout the whole area
33. They cannot be of the same age since the facies would have moved inland over time, thus creating a Formation that is time-transgressive