

12.110 Field Trip Report

(Photos courtesy of Sarah Slotznick and Augusta Dibbell. Used with permission.)

Stop 1 – Sunrise Mountain W., Tapeats Siliciclastics-Bright Angel Shale:

Setting: East of North Las Vegas and the easternmost thrust faults. We are in the autochthon. Across the valley, red and white sandstone is visible on the other side of the Keystone Thrust, which dips gently away from us. A marine transgression occurred from west to east, so sediments are younger going eastward.

Observations: Before us is an unconformity between Precambrian metamorphics and basal Cambrian marine deposits. The layers dip to the east at approximately 45°. The older metamorphic layer is a red and white colored granite with grains 1-5mm. The contact between layers is somewhat wavy. The granite appears altered close to the contact, implying a possible paleosol. Above the contact is quartz arenite with differential weathering and cross stratification.

About one meter above the contact is a layer of whitish arenite. The rock is poorly sorted with rounded clasts of mm order diameter.

A half meter above is more arenite without clasts. It is cross stratified and calcite cemented. One meter further above, the rock exhibits parting indicating a dip at an angle to the overall dip. A little further up the parting indicates a dip in the opposite direction. This could be caused by sand dunes filling in bowl shaped depressions—we're seeing opposite sides of the bowl with oppositely oriented dips. Clearly visible cross stratification supports the dune hypothesis and the truncation surfaces also indicated that we are moving up section into younger rock.

After a covered section we find very fine grained green sandstone/shale. In the midst of this layer is a thin bed 1-2 cm thick of red colored coarser grained sandstone. The rock has parting and many extracted samples have sole marks and trace fossil burrows on the bottom. This is probably an event bed. There are a large number of these event beds interbedded with the very fine grained rock. My interpretation is that the very fine grained rock is from quiet water deposition. The event beds could be either tempestites or turbidites. There is one bed that is particularly interesting. It grades upward from planar to cross stratified with hummocky cross stratification on the top surface. This suggest to me that it was likely a tempestite. As the storm settled the current velocity decreased, leading to the change from planar deposition to ripples.



Above: Tool marks

Upsection the sandstone event beds become thicker and more common, culminating in several meters of cross stratified sandstone. This could be caused by a marine regression. As the water got shallower, the sediment was more easily affected by storm waves. The cross stratified section could be evidence of a tidal environment with a tidal current.

Upsection we move abruptly into shale. I interpret this as a slow increase in water depth which abruptly cut off the supply of coarse grained siliciclastics, as the change in base level caused rivers to store sediment upstream to maintain their profile.



Above: As sea level rises, streams maintain their profile by storing sediment upstream.

Continuing upsection, we find a large sandstone event bed with the negative relief of flute marks on the bottom. This indicates that the current was first erosional and then depositional.

Upsection we move into carbonates. This would indicate a marine transgression—farther from shore the carbonate factory dominates over siliciclastic deposition from the land. Further up is ribbon rock. This rock has alternating tan and gray microfacies. An acid test indicates that the tan is dolostone, while rill marks on the gray microfacies clearly identify it as limestone. A possible explanation for the formation of ribbon rock is that certain lamellae are somehow preferentially dolomatized. The lamellae are also irregular indicated the rock underwent diagenesis.



Above: ribbon rock

We also find ooids! The ooids are preferentially dolomatized. At this point the section is mainly carbonates all the way up.

Large scale interpretations: The section is marine in nature and indicates allocyclicality in the water depth. The alterations in the thickness and frequency of event beds in the siliciclastics indicates small changes in water depth. The abrupt change to carbonates indicates a marine transgression. The signal is probably transgressive overall with small scale fluctuations and periods of regression.

Stop 2- Sunrise Mountain E, Permian Redbeds:

This is a large formation of quartz arenite with carbonate cement. Rock is red to salmon pink, probably due to hematite. Very large scale cross stratification is visible, as well as strange holes weathered into the rock forming large bowls and caves. The cross

stratification has a “swoopy” look in some places, which is characteristic of eolian dunes. Jointing occurs at 90° to the strata. The sets are dipping gently to the South.



Above: Cross stratification

The rock is thinly laminated in some parts while other thick bands have no lamination. The laminated parts are likely caused by grain fall while the unlaminated bands are grain flow. A top surface is exposed with rib and furrow formation, indicating a principle wind direction from the North.



Above: Rib and Furrow

Stop 3- North Shore L. Mead unconformity

. The bottom red layer is sandstone. This is an angular unconformity—as can be seen from the photo. The red layer has undergone significant deformation and has a complex structure. In some places it dips steeply toward while in others steeply away. It is very fine grained and poorly consolidated.

The top layer is siliciclastic conglomerate sandstone. It is mostly grain supported, but an acid test fizzes slightly indicating some carbonate cement. The clasts are 1-5cm in diameter. It is somewhat stratified, with bands of varying grain size and clast size, and is gently dipping.

Interpretation: The lower layer was deposited first. It then underwent significant deformation and erosion before the deposition of the upper layer. The size of the clasts in the upper layer suggests a fluvial environment. The variations in clast and grain size could be caused by changes in current velocity.

Stop 4 – Moenkopi Formation

Layers are cut by a wash allowing for fantastic viewing. The layers are dipping at about 45°. Layers moving downsection:

- 1) Cross stratified sandstone
- 2) Dark colored conglomerate
- 3) Cross stratified shale

Interbedding of green sandstone and red shale. The sandstone are probably event beds. They have a sharp base indicating erosion and a rippled surface, suggesting they are tempestites. The shale grades upward to mudstone.

4) Veins of gypsum are introduced. These veins are up to a few cm thick. They conform with the strata in some places and in other places they cut through it. This indicates that they are post depositional features, deposited as veins in later diagenesis. In a few places there are large nodular deposits of gypsum as well. The gypsum veins are folded in some places. Differential weathering is exhibited where the cross the wash—the mudstone erodes more easily than the gypsum.

In some places the mudstone exhibits climbing ripples with oscillation ripples on top. This suggests a possible combined flow. In addition, the negative relief of ripples is visible on the underside of a slab! In some places there are ripples with a low climb angle so that the stoss sides are not preserved. They come in long sets that don't die out, suggesting they are oscillation ripples.

Up one of the side slopes, we discover some “photographites”. Soft sediment deformation in one bed indicates liquifaction and flowage. The bed plane below it has ripples on its surface, some of which are classic tuning fork ripples.



Above: Soft sediment deformation

On the other side of the wash, the layers are cut on top by an angular unconformity with overlying sediment.

5) Cross stratified sandstone

The ripples change their direction of climb in several places. A side view and front view of the cross stratification indicates a current direction.

Interpretation: the depositional environment was probably marine. The gypsum suggests a hypersaline environment and the presence of tempestites suggests marine deposition. Since the deposits are siliciclastic they must have been near shore in shallow water.

Stop 5 – Red Rock Park, Aztec Siliciclastics



Swooping cross stratification suggests eolian dunes. This is caused when dunes overlap while moving. The cross stratification climbs to the East and the sets are very large (some up to 10 meters thick). Since only a small fraction of dune height is preserved in sets, we can assume the dunes must have been hundreds of feet tall. In places the sets appear to change their direction of climb, but this could also be opposite sloped sides of troughs between dunes that were filled in by migrating dunes.

There are three layers to the formation. The bottom layer has alternating stripes of red and white. The middle section is all red but it is a darker red than that in the stripes. The top layer is entirely white. The colors are due to hematite in the rock, but why it makes these three distinct layers is unclear. The stripes in the lowest layer could be caused by differences in porosity that allow water to preferentially flow in certain strata, leaching out the hematite.

Stop 6 – Eagle Mountain

The section has three Cambrian formations (from oldest to youngest): Zabriskie Quartzite, the Carrara Formation, and the Bonanza King Formation.

The Zabriskie is a well cemented upper medium to lower coarse arenite. The rock has a purple tint. The strata alternate between more and less purple tint. The strata are dipping at $\sim 45^\circ$ with parting and jointing perpendicular to the strata. The formation is planar stratified. The combination of coarse grain size and planar strata suggests it is upper regime planar deposited by a strong current.

Moving up section several meters we find a coarse to very coarse red arenite. It is less well cemented and grain supported with rounded grains. This is followed by several meters of covered section. When the outcrop reemerges it is a fine siliciclastic with shale-like parting. Some lamellae have very coarse clasts. This abrupt upward fining could be explained either by autocyclicality (such as a shifting river) or allocyclicality (such as rising sea level). Roy D. Adams did a thesis on this formation and concluded that a combination of both allocyclicality and autocyclicality were at work, the former as changing sea levels and the latter as shifting tidal currents.

There is a slow coarsening upward. The parting gets thinner and the rock gets redder. Eventually we find low angle cross stratification. Then we find an abrupt upward fining to red shale. This facies alternates between red and greenshale interbedded with coarser grained event beds. Moving upsection, these event beds are thicker, coarser, and more frequent. This suggests that the section is shallowing upward. We find some lenses of coarse rock, most likely deposited by event beds that filled only local lows in the underlying bed. Some event beds have tracks, flute marks, and burrows.

We now reach the Carrara. They are weathered tan and an HCl test identifies them as dolomitic. They are upper medium grained and contain flute marks and elliptical shaped objects that may be oncoids or microfossils.

Moving up we find a dolostone conglomerate event bed. There's a floatstone with a trilobite. Although it is a floatstone this supports the hypothesis of a marine depositional environment.

At this point we move across a Bonanza King scree and into a wash to continue working upsection. The background sedimentation is a bluish-black siltstone. There are some sandstone event beds with sharp bases and rippled tops which are clearly tempestites. There is a general coarsening upward of the section and we reach some hummocky cross stratification.

Next is a large section of ribbon rock (described in stop 1). The rock has ooids and is stratified, in some places planar and in others low angle cross stratified. There is also some minor faulting. The transition to carbonates and the presence of ooids suggests a very shallow marine environment.

Interpretations: This section represents marine transgressions and regressions, but the overall signal is transgressive. The transitions from sandstones to shales represent transgressive periods. The general shift from siliciclastics to carbonates could be caused by mountains weathering down and shutting off the supply of siliciclastics, or by climate change that turned on the carbonate factory. It could also be caused by a marine transgression, however the presence of ooids shows that the carbonate section was deposited in shallow water. It is possible for water to remain shallow during a transgression if there is a shelf off shore.

Stop 9 – Tecopa Lake Beds

The lake bed deposits are primarily siliciclastics and evaporates. They are mostly planar stratified with some cross stratification and are interspersed with datable ash beds. There are some good examples of soft sediment deformation as well. The lake drained 186,000 years ago and subsequent alluvial deposits were laid down on top of the lake bed. The deposits were then incised and exposed.

Stop 8 – Eagle Mountain W

There's a large orthoconglomerate with well rounded carbonate clasts. It is poorly sorted and unstratified. It has a sharp contact with sandstone above, indicating that it is an event bed, probably a landslide or debris flow of previously rounded clasts. The conglomerate has a fine grained carbonate cement at the bottom, but at the top it has a matrix of sandstone that is exactly the same as the sandstone above. It's possible that after the event, sand that was deposited on top of the rocks filtered down in between the rocks. The clasts include arenites from the Zubrisky Formation and ribbon rock from the Carrara Formation, both of which are situated up the mountain.

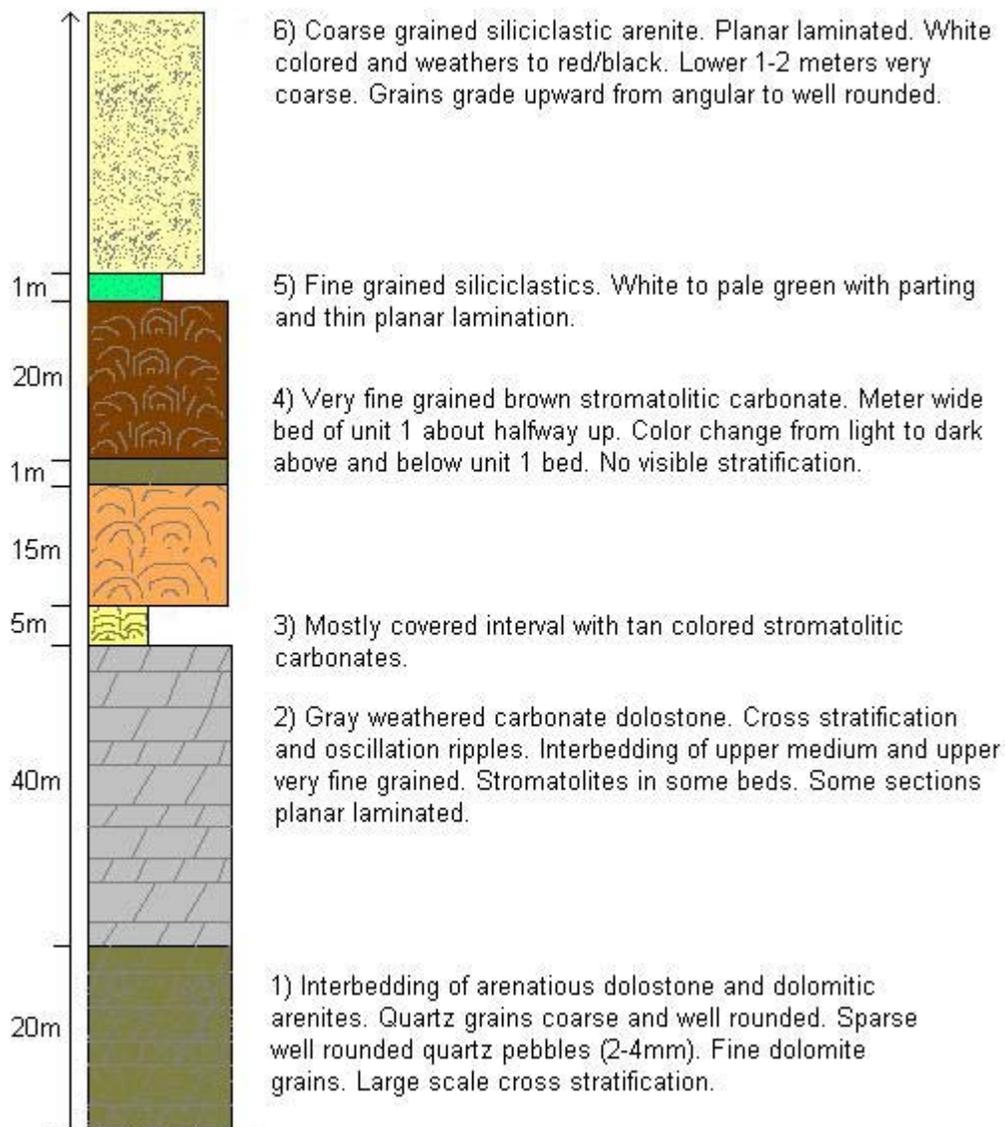
The sandstone layer above has quartz grains in dolomite cement. It is grain supported and has conformable contact with the conglomerate. It is planar stratified. There's a thin layer of conglomerate a few cm above the contact, indicated a second small event.

The rock fines upward into thinly laminated red shale, and then coarsens again to a medium grained cross stratified sandstone. We next reach a layer of yellow limestone, clearly identified by solution rills. Following this is another layer of medium grained cross stratified sandstone. Then there's an interbedding of three rock types: a tan colored

quartz arenite, a yellow dolomitic sandstone, and a bright yellow dolomitic shale. This layer is cross stratified and has undergone soft sediment deformation, made particularly visible by the color contrast of yellow and tan.

Interpretation: We can rule out marine deposition because we know from the literature that the rock is Cenozoic and postdates the most recent marine transgression. It could be fluvial deposition. There are no channels or overbanks, indicating a braided stream. Changes in water speed and course account for the cross stratification and planar stratification. The carbonate deposits must have been eroded and carried down stream from older formations. The conglomerate is a debris flow from a subaerial period.

Stop 11 – Johnnie section



Interpretation: The carbonates must be shallow water marine, due to the presence of stromatolites. The planar siliciclastics could be marine or coastal. For example, they could be from a coastal plain that is occasionally flooded.

Stop 11b – farther up on the Johnnie

We start with a unit of interbedded fine grained sandstones and siltstones. Some beds exhibit pinch and swell cross stratification. The unit contains some individual beds that are hummocky stratified on top and planar on the bottom, indicating they are storm

event beds. The beds are thick, on the order of decimeters, and some make “gutter casts” – they only filled the local lows of the bed below. This unit is from deeper water than the lower Johnnie, but the presence of storm waves means it was still on a shelf.

Moving up we find carbonates, indicating shallower water. Sea level must have changed by some tens of meters.

Next we come to a large bed of unstratified paraconglomerate. It is poorly sorted with a matrix of upper medium to lower coarse dolomite. The conglomerate contains gray carbonate clasts that are rounded to subrounded. The matrix looks a lot like unit 1 and the clasts look like unit 2 of the lower Johnnie. There are also a few arenite clasts. Many of the clasts are rod shaped and show a slight horizontal preferential orientation. There is one huge dolostone clast the size of a truck. It looks like lower Johnnie unit 3 and is irregularly shaped with some veins of quartz. Some of the carbonate clasts have large ooids and some of the arenites have cross stratification. The conglomerate is about 50m thick at its thickest and 600 – 700m in total length. It thins out to the SE but remains thick and ends rather abruptly to the NW.

This conglomerate is an incised valley fill. A valley was incised in the Johnnie formation and then filled with a conglomerate debris flow. This incision could be caused by a drop in sea level, causing a river to incise upward to maintain its profile. Later, more Johnnie was laid down on top of the conglomerate.

Stop 12 – Kingston Peak Formation

The first thing to catch our eyes is a turbidite: a paraconglomerate bed with both angular and rounded clasts. The bed is graded upward from very coarse to very fine and is unstratified—this is the Bauma Sequence A. Flute marks on the bottom indicate

erosion. The whole bed is about 1.5 m thick. It is bounded above and below by fine grained siliciclastics with planar lamination, probably from quiet water deposition.

Moving upward in the section we find a number of event beds with planar and cross stratification—Bauma B and C beds.



Above: event beds. Below: dropstone



Another interesting feature is a large lonestone. The strata curve around under and arch up over the lonestone. It must be a dropstone that fell from pack ice or an ice berg, because it's too large to be transported by other means. We also know from the literature that this unit is Neoproterozoic, and the extent of glaciation was great during that time.

Stop 14 - Dumont Dunes

The sand has larger ripples with smaller ripples superimposed at about 90° orientation. We can tell that the last sand moving wind came from the west, indicated by the smaller ripples. The larger ripples indicate a previous wind from the north. We are also treated to the sight of a beautiful saltation cloud off the tip of one of the dunes.

Stop 15 - Afton Canyon

The Mojave river flows through this valley. At one time, a natural dam created a lake, but the river cut through the lake and drained it. Side rivers also incised because of the change in base level caused by the draining lake. Before us is a landscape of alluvial fans and incised terraces.

At the start of our hike up the wash, we are surrounded on both sides by semi consolidated planar stratified stream deposits. Some of these beds are cobble sized while others are fine gravel. Each bed represents a separate flood event with either differences in current strength or differences in the size of the source sediment available to the river. Most of the clasts are arenites but a few are granite. The clasts are imbricated, indicating current direction. Berms and undercuts at the river base of the walls indicates that the river is currently incising.

The planar stratification indicates a fast flowing current. In a few places there are some traces of low angle cross stratification, but it is rare. The rarity of cross

stratification can be explained either by a current dying out quickly before cross stratification could form, or by a very high concentration of sediment. There is a theory that dune formation is suppressed in high concentration sediment flows.

We also find one unusually large clast, about 30 cm in diameter, that seems out of place. It is rounded and may have been rolled by the river current before it was deposited.

Up on the left bank there is a large bank of finer grained tan colored deposit with bits of the "normal" gray bank plastered against it as a buttress unconformity. This tan material is older than the standard gray sediment. It was incised to make the canyon, and then the canyon filled with the gray sediment. The canyon was later incised again, and in this place the gray material was completely removed to expose the older tan wall. The color difference between these two deposition events could be explained by differences in the source sediment or by reworking of the sediment to remove certain finer components.

Moving on we find a butte. It is composed of younger gray sediment capped by greenish colored lake deposits. The lake deposit cap is stronger material and allows for the tall vertical walls of the butte without collapse or sloping at the top.



Above: Butte

Continuing up the wash, we find a paleosol. It is an angular unconformity that is dark brown on top and light tan underneath. The color grades downward to dark brown again and the clast size grades larger downward. Both the color change and clast size change indicate weathering, and therefore a paleosol.

We soon find another interesting unconformity. It consists of three layers. The bottom layer is planar stratified, tan colored, and slightly dipped. It makes an angular unconformity with a gray layer on top. The gray layer has solution rills and differential weathering and is not dipping at all. On top of this is a section of the greenish colored lake deposits again. Moving just a little farther up the canyon, the green lake deposits are replaced by an interbedding of gray and tan siliciclastics—we have reached the edge of the ancient lake bed.

The youngest gray conglomerate deposits reappear and the sides of the channel narrow. We've reached a kickpoint—the highest point of incision of the river. The

knickpoint has worked its way upstream as the river tries to respond to a change in base level.

Just past the knickpoint are some interesting features. There's a green colored material, interspersed with red and purple rock. It consists of small rounded quartz grains imbedded in a very fine grained siliciclastic. This is a felsic tuff, and the quartz grains indicate it has been reworked. The contact between the conglomerate and the tuff looks like a buttress unconformity, but it could also be a fault. There is a basalt flow on top of the tuff, complete with amygdules that are filled with a green colored mineral. There's an eroded waterfall chute in the basalt too.



Above: basalt flow

On the way back to the van, we find some true photographites! There's a sand bank with absolutely classic climbing ripple and oscillation ripple cross stratification.

Stop 16 – Bird Spring Formation

This last stop consists of a series of units on a ridge. We start at the bottom in a calcareous marine layer. The top part of the layer has lots of burrowing while the bottom has none. This bioturbation indicates that the layer was a hardground—the carbonate

factory must have shut down for some time to allow burrowing deep into the layer. The layer has medium quartz grains in a limestone cement and is planar laminated.

Moving up section we reach a layer of limestone mudstone. It is pinkish colored and unstratified. This mudstone would have formed from quiet water deposition.

The next layer is an arenaceous cherty limestone wackestone. It contains fossil fragments and medium sized quartz grains.

Next is a dolomite sandstone. It is medium grained and matrix supported and has large scale cross stratification. This could be formed either from tidal current or coastal dunes. The differences between laminae thickness suggests an eolian origin, although it lacks the classic “swoopy” look.

Next is a sharp contact with more arenaceous limestone wackestone. It is unstratified and has burrows filled with sandy sediment. This layer becomes planar stratified farther up and has microfossils. The sharp contact between this layer and the dolomite below suggests it was brought about by an autocyclic process, possibly a shifting tidal current.

Next is a brown weathering quartz sandstone that is thinly planar laminated and carbonate cemented.

Next is a thinly planar laminated fine grained carbonate layer with burrows at the bottom and microfossils.

Next are two distinguishable units of limestone. The bottom unit is a fine grained unstratified fossiliferous limestone. The upper unit is limestone grainstone, also with fossils.

Next is a cross stratified sandstone with carbonate cement. It is very similar to previous sandstone units in the section but is interbedded with arenaceous limestone with varying proportions of quartz to carbonate sediment.

Next is a medium grained unstratified limestone with foram fossils and some unusually large quartz grains.

Next is a cross stratified medium grained calcareous sandstone.

Next is a fine grained limestone with chert veins that grades upward from packstone to grainstone. It is planar stratified at the bottom and unstratified at the top. It has some fossil fragments at the top.

The final layer is an unstratified poorly sorted carbonate grainstone that ranges from upper medium to very coarse.

Interpretations: The sequence suggests changes in sea level and current velocity. The regular cyclicity from siliciclastics to carbonates suggests allocyclic processes are mostly at work, although an autocyclic process such as a shifting tidal current could account for some of the sharp contacts.