November 13th – 14th, 2015, RioMAR Fieldtrip

MOUNTAIN CANYON AND THE WEST-SALTON SUPRADETACHMENT (Fish Creek – Valecito) BASIN, CALIFORNIA

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The field guide is using data from the MS Theses of Michael Cloos, Jeremy Slaugenwhite and Sarah Bateman

Main Fieldtrip Objective:

During the field trip we will examine the depositional fill of a small steep margined basins (Fish Creek – Valecito Basin) formed and filled during Late Miocene to Pliocene. In addition to (1) the overall stratigraphy and the basin fill evolution reflected by changing depositional environments, a special attention will be given to (2) slope to basin floor deposits which show spectacular 30 m thick mass transport deposits, large scale deformation turbidites, and possible supper critical flow large bedforms alternating with more “typical” sandstone-mudstone slope deposits.

Google map with coordinates showing the locations of the stops during the 2 day fieldtrip. During the first day most of the stop will be along the main wash (Fish Creek Wash). On the second day we will walk along Lycium Wash.
Fish Creek – Vallecito Basin Geology Overview

The Salton Trough, the northern-most part of the Gulf of California rift basin, is a half-graben formed as a result of middle Miocene (~12 to 14 Ma) regional crustal extension, crustal thinning, and sedimentation. Focused extension in a long, straight zone that paralleled the existing Miocene continental margin created a single rift basin and led to the detachment of Baja California from North America and the development of the Gulf of California (Winker and Kidwell, 1996; Abbott et al., 2002; Dorsey et al., 2011). Miocene extension and subsidence, controlled by the San Andreas Fault to the east and the now-inactive West Salton detachment fault to the west, and potentially numerous smaller synthetic normal faults in-between, created a paleotopography of small, tilted blocks and linked basins separated by some uplifted and tilted Cretaceous plutons and associated metamorphic rocks (Abbott et al., 2002; Dorsey et al., 2007). Progressive marine inundation from the south began ~13 Ma, and likely reached the northernmost part of the Salton Trough at San Gorgonio Pass by 6.5 Ma (Winker and Kidwell, 1996). The arrival of the Colorado River 5.3 Ma (Fig. 1, Dorsey et al., 2007) triggered the building of a large delta that dominated sedimentation through to the present day, and created the barrier that separates the non-marine Salton Trough from the rest of the marine Gulf of California.

The Fish Creek – Vallecito Basin (Figs. 1 and 2), located within Anza-Borrego Desert State Park in the Colorado Desert of southern California, is one such small supra-detachment basin created by the paleotopography related to extension of the western Salton Trough. Here a 5.5-km-thick package of late Miocene to early Pleistocene sediment was deposited on the hanging wall of the oblique, dextral-normal West Salton detachment fault (Kerr, 1984; Winker, 1987; Kerr and Kidwell, 1991; Winker and Kidwell, 1996; Abbott et al., 2002; Dorsey et al., 2007, 2011). Early subaerial rift-related coarse clastic sedimentation gave way to marine sedimentation as marine water abruptly entered the basin ~6.3 Ma (Dorsey et al., 2011). Soon after, the first evidence of Colorado River-derived sands appears in the basin, and the remaining basin history is controlled by the development and progradation of the Colorado River delta and its associated deepwater slope and basin floor sediments.
Figure 1. Present day tectonic setting of the Gulf of California (right) and reconstruction of the Gulf at the onset of the Colorado River delta progradation at 5.3 Ma. (modified from Dorsey et al., 2007).

Figure 2. Geologic map of the Fish Creek – Vallecito Basin in southern California. Modified from Winker (1986) and Dorsey et al. (2007).
Structural Setting and Geology

The Fish Creek – Vallecito Basin (Fig. 4) was formed as a result of extension in the Salton Trough region from ~8.0 to ~0.95 Ma. During this time, crustal extension and subsidence were controlled by low-angle slip on the West Salton detachment fault to the west and the strike-slip San Andreas Fault to the northeast (Axen and Fletcher, 1998; Dorsey et al., 2011). It is likely that a number of synthetic and antithetic normal faults existed to the east of the current western end of the West Salton detachment fault, giving rise to the apparent segmentation of the Fish Creek – Vallecito Basin into sub-basins as suggested by a late Miocene stratigraphic succession replete with rapid facies changes and steep basin margins.

The Fish Creek – Vallecito Basin is bounded to the west by the Peninsular Ranges, to the north-northwest by the Vallecito Mountains, to the east-southeast by the Fish Creek Mountains, and to the south by Coyote Mountains (Fig. 2).

Stratigraphy

The total thickness of the exposed Miocene to Pleistocene section in the Fish Creek – Vallecito Basin is ~5,500 m and encompasses ~7 M.y. of depositional history – from the coarse clastic alluvial material deposited during the initial extension to the unconformity on top of the Colorado River deltaic, fluvial, and lacustrine deposits caused by regional uplift over the past ~1 m.y. (Fig. 3) (Dorsey et al., 2011). On figure 3 is shown the stratigraphy mapped on figure 4. The stratigraphy in the basin starts with the Elephant Trees Formation of the Split Mountain Group that contains at its base the lower distal alluvial fan and axial braided stream sandstone member and the thick alluvial fan facies of the conglomerate member. The conglomerate member extends ~6.5 km from the southeastern flanks of the Vallecito Mountains to just east of Split Mountain. It achieves a maximum thickness of ~450 m just west of Split Mountain Gorge. The vertical transition from the upper conglomerate member to the Lycium turbidites can be gradational, as is the case in the west wall of Split Mountain Gorge, or sharp. Where the contact is sharp, predominantly to the northwest of the gorge, the upper conglomerate unit contains a series of distinct red beds within its top ~5 m. It is clear that the two conglomerate units are separated based on the larger transition that occurred in the basin at the time: alluvial fan conglomerates, sands, and gypsum deposited after the first major sturzstrom event and appearance of marine water (the upper conglomerate unit), and the alluvial fan conglomerates deposited before this transition (the lower conglomerate unit).

The Split Mountain Group lower megabreccia (Fig. 3) [also referred to as the lower boulder bed (Winker, 1987) or the Split Mountain sturzstrom (Kerr and Abbott, 1996; Abbott et al., 2002)] is a mass transport deposit exhibiting nearly all of the features that would suggest its classification as a sturzstrom. The lower megabreccia is overlain by a thick deposit evaporite, the Fish Creek Gypsum, though small lenses of sandstone or mudstone are present locally.

Imperial Group - Latrania Formation - Fish Creek Gypsum (Fig. 3): The Fish Creek Gypsum is a ~60 m thick deposit of nearly pure calcium sulfate (~90%-95% CaSO₄; 35% anhydrite, 65% gypsum) that is largely free of terrigenous clastic sediment. A few thin interbedded claystones appear within the base and top, but are rare in the bulk of the deposit.
(Dean, 1996; Abbott et al., 2002). It is the oldest evidence for marine incursion into the western Salton Trough and the Fish Creek – Vallecito Basin (Winker and Kidwell, 1996). Sulfate isotope ratios, the presence of calcareous nannofossils in claystones within the Fish Creek Gypsum, and a more detailed understanding of the stratigraphic relationships between transitional facies in the basin have confirmed that the evaporite deposit is of marine origin. **Imperial Group - Latrania Formation - Lycium Member (Fig. 3):** Overlying the Split Mountain Group subaerial deposits is a ~ 75m-thick section of locally derived ("L-suite") Latrania Formation marine mudstones, turbidites, grain-flow sandstones, and boulder-bearing sandstones (Kerr and Abbott, 1996; Bateman, 2015). The majority of the Lycium Member deposits are medium to thin-bedded, coarse-grained sediment-gravity flows, with graded beds and bioturbated tops, and other abundant trace fossils (Winker, 1987; Winker and Kidwell, 1996).

**Imperial Group - Latrania Formation - Upper Megabreccia (Fig. 3):** The upper megabreccia is similar to the lower megabreccia, and exhibits all of the qualifying attributes of a sturzstrom. It differs from the lower megabreccia in clast composition, and due to its subaqueous emplacement over unconsolidated or semi-lithified sediment, in the way that it deforms and disrupts the sub-stratum. In the southeast near Cairn Canyon, the upper megabreccia overlies the thin, fine-grained Lycium Member package. In the area of Split Mountain Gorge, the upper megabreccia occurs between the thick turbidites of the Lycium and Wind Caves members. Further northwest it overlies proximal Lycium Member facies and is in turn overlain by the conglomerates of the Stone Wash Member.

**Imperial Group - Latrania Formation - Wind Caves Member (Fig. 3):** The Wind Caves Member turbidites are significant because they mark the earliest influx of Colorado River derived “C-suite” sediments. The base of the Wind Caves Member begins with “L-suite” turbidites similar to those of the Lycium Member. The fine-grained, well-rounded, hematite-coated quartz sand that marks the arrival of the Colorado River in the basin occurs ~5 – 10 m above the contact with the underlying upper megabreccia (Winker and Kidwell, 1996; Dorsey et al., 2007, 2011; Cloos, 2014). The remainder of the member is a ~200 m thick package of “C-suite” turbidites that occasionally alternates with minor, thin, locally derived “L-suite” turbidites. Towards the northwest, the Wind Caves Member laterally grades into the Stone Wash Member.

**Imperial Group - Deguynos Formation - Mud Hills, Yuha, and Camels Head members (Fig. 3):** The Mud Hills Member is a ~700 m-thick package of regionally extensive deepwater slope claystones and siltstones. The middle and upper portion of the slope succession in the vicinity of Fish Creek Wash has conspicuous rhythmic banding that has been interpreted as decadal Colorado river flood cycles on the deepwater slope driven by El Nino forcing (Robinsen, 2014). The Yuha and Camels Head members, fossiliferous shallow-marine sands of the prograding Colorado River delta, overlie these marine rhythmrites (Winker, 1987; Winker and Kidwell, 1996; Dorsey et al., 2011).

**Palm Springs Group.** The deepwater margin slope and delta deposits of the Imperial Group give way to Colorado River and coeval locally derived fluvial sediments (Arroyo Diablo Formation and Olla Formation), basin margin alluvial fan conglomerates (Canebrake Conglomerate), lacustrine mudstone and sandstones (Tapiado Formation), and transitional
locally derived fluvial sandstones and conglomerate (Hueso Formation) of the Palm Springs Group (Winker, 1987; Winker and Kidwell, 1996, Dorsey et al., 2011).

Figure 3. Fish Creek – Vallecito Basin stratigraphic column. Modified from Winker (1986) and Dorsey et al. (2007).
Figure 4. Geologic map of the Split Mountain Gorge area of the Fish Creek – Vallecito Basin. Modified from Winker (1986) and Dorsey et al. (2007).
Age of Fish Creek – Vallecito Basin Section

Based on stratigraphic, paleomagnetic, and micropaleontologic analysis presented by Dorsey et al. (2007) and Dorsey et al. (2011), the Fish Creek – Vallecito Basin section ranges in age from ca. 8.0 ± 0.4 Ma at the base of the Elephant Trees Formation to 0.95 Ma at the top of the Hueso Formation (Fig. 5). The age of the oldest conglomerate in the Split Mountain Group is ca. 7.4 Ma, which at a minimum marks the beginning of strong extension in the region and movement on the West Salton detachment fault. Based on the conformable nature of the contacts within the Elephant Trees Formation, however, Dorsey et al. (2011) believe that deposition of the lower sandstone member likely coincides with tectonic activity starting ca. 8.0 ± 0.4 Ma.

The lower megabreccia was emplaced between 6.57 Ma and 6.27 Ma. The oldest marine deposits in the basin, at the base of the Lycium member turbidites, are ca. 6.3 Ma and similar in age to other latest Miocene marine deposits found in the Salton Trough and Gulf of California region (Dorsey et al., 2007). The upper megabreccia between 5.89 Ma and ~5.33 Ma, and sands from the Colorado River first appear in the Wind Caves Member at 5.33 Ma.

Figure 5. Measured section at Split Mountain Gorge showing results of stratigraphic, paleomagnetic, and micropaleontologic analysis. Species indicated are benthic foraminifers. m-breccia—megabreccia. (From Dorsey et al., 2007).
Day 1 – Overview Stratigraphy of the Fish Creek – Valecito Basin and large scale turbidite beds deformation caused by mass transport deposits

Stop 1: Alluvial Fans (Elephant Tree Formation)

At this stop we will examine a hundreds of meters thick succession of non-marine alluvial fan deposits which are at the base of the stratigraphy in the Fish Creek – Valecito Basin. The dominant facies is represented by debris flow deposits with variable grading structures (normal, inverse, inverse to normal) of structureless (Figs. 1.1 to 1.5) and secondary by thin stream flow deposits and occasional channels (Fig. 1.6). Individual beds are commonly dm to metres thick (Figs. 1.7, 1.8).

Alluvial fans of Elephant Tree Formation prograded toward NE (Fig. 1.9) sourced from basement in the Valecito Mountains. Channels seems to be more common in the proximal part of the deposits. Sheet flood deposits are more abundant distally.

Figure1.1. Structureless conglomerate beds. The left example seems to have a lower inverse graded base and a normal graded top.
Figure 1.2. Normally graded beds with upward increasing matrix percent

Figure 1.3. Inversely graded conglomerate beds

Figure 1.4. Inverse-to-normal graded beds

Figure 1.5. Small channel 3-4 meters thick, 10 m wide willed with debris flows. The channel can be followed on multiple cliffs and is oriented NE-SW.
Figure 1.6. Vertical variability of debrite facies.

Figure 1.7. Measured section through the alluvial fans; Composed of interbedded debrites, braided stream, and sheetflood deposits.
Figure 1.8. Bed thickness and maximum clast sizes up through 220m succession

Figure 1.9. All aluvial Fan paleocurrent measurements (n=26). Red- imbricating clasts and cross-strata. Black - channels orientations.
Stop(s) 2: Lower “Megabreccia” / “Debris flow” / “Sturgesztrom” deposits

What are Sturzstroms?

Geologist Albert Heim investigated the aftermath of a singularly devastating 1881 rock avalanche in Elm, Switzerland. Ten million cubic meters of crushed slate dropped 600 m, and then flowed 2.23 km as a dry mass moving at an estimated speed of 180 km/hr. Heim noted that the debris flow still showed some of the original mountainside stratigraphy, and, like a jigsaw puzzle, the broken pieces might be put back together. Heim called this unique rock avalanche deposit a sturzstrom – German for “fall stream” (Shreve, 1968; Hsü, 1975; Abbott, 1996). Hsü (1975) proposed that the term sturzstrom be adopted and defined as “as a stream of very rapidly moving debris derived from the disintegration of a fallen rock mass of very large size; the speed of a sturzstrom often exceeds 100 km/hr, and its volume is commonly greater than 1x10^6 m^3.”

Sturzstroms are unsorted and unstratified breccia of angular grains ranging in size from silt to boulders (Fig. 2.1), and have been reported to show both normal and inverse grading among the finest fraction of matrix. It is common, however, for the largest clasts to gradually increase in size with height above the sturzstrom base, but abruptly coarsen at the top of the flow as the largest shattered boulders often armor the surface of the deposit. Sturzstroms can be matrix-supported and/or grain-supported, and a switch between the two can occur vertically within the same deposit. The debris provenance is from local bedrock, and the composition at a single sample site is often monolithologic. Sturzstroms often are marked by compositional zoning, where the matrix is closely related to the clasts it surrounds (Figs. 2.1 B, 2.2). The clasts and associated matrix often form the jigsaw-puzzle fabric reported by Heim.

Figure 2.1 Fish Creek – Vallecito Basin sturzstroms. (A) Large clast at top of upper megabreccia west of Oyster Shell Canyon #1. (B) Boulder clast and compositional zoning in matrix, lower megabreccia in east wall of Split Mountain Gorge. (C) Lower megabreccia in east wall of Split Mountain Gorge.
The lower mega breccia is typically ~45 m – 50 m thick, but increases to ~180 m thick against the Fish Creek Mountains. Its general uniform thickness can be seen in the prominent 5.2 km-long northeast-facing cliff that it forms from the entrance to Split Mountain Gorge in the north to the Fish Creek Mountains in the south (Kerr, 1984; Winker, 1987). The megabreccia is extremely poorly sorted, and includes essentially an entire range of clast sizes – from silt included in the finest matrix fraction to truck-sized boulders at the top of the flow (Fig. 2.3). It is matrix-supported, especially near the base, but locally may be clast-supported in the upper portions of the deposit. Clasts are angular to sub-rounded, and the sturzstrom is inversely graded in the coarsest fraction of the deposit (Fig. 2.3). The size of boulders increases toward the top of the deposit, with the very largest boulders (a few in excess of 5 m) located on the hummocky top surface of the deposit.
Figure 2.3. Schematic lower megabreccia section. Note the large clasts near top of Lower Megabreccia

Along with its stratigraphic position on top of the subaerial Elephant Trees Formation alluvial fans, other features suggest that the lower megabreccia was emplaced subaerially as a high-velocity, non-turbulent laminar flow. The megabreccia has a sharp, undulatory basal contact across the underlying alluvial fans (Fig. 2.4). As described above, the lower megabreccia did not disturb the substrate, but rather abraded it as it cut across the ground.
Figure 2.4 Lower megabreccia contact with Elephant Trees Formation alluvial fans in the east wall of Split Mountain Gorge. (A) Sharp, undulatory contact. (B) Channel cut into the deformed alluvial fan deposits. (C) Deformed alluvial fan deposits below the lower megabreccia contact.
Stop 3: Lower Turbidites (Lycium Member) in Split Gorge Canyon

Lycium Member turbidites is part of Latrania Fm. that has 4 members: the Fish Creek Gypsum, Lycium Member turbidites, Upper Mega breccia and Wind Caves Member turbidites (Fig. 3.1). Thickness measurements are difficult to obtain due to complexity in the field, but previous work by Dorsey et al. (2011) and Winker (1987) constrain oldest marine deposits in the formation are the coarse-grained Lycium turbidites which account for 75 m of the total formation thickness and at times interfingers laterally with the Fish Creek Gypsum. Lycium turbidites at different location are overlying the Elephant Tree alluvial fans, Fish Creek Gypsum or Lower Mega-breccia deposits (Fig. 3.2).

![Figure 3.1. Map with distribution of the Latrania Formation four members. The white wash “road” in the middle of the image is the Split Mountain Gorge.](image)
Depositional environments of Lycium turbidites varies spatially with an overall trend of fining and thinning from NW to SE (Fig. 3.2). Channelized turbidites are common throughout the NW (Lycium Canyon) and medial portions of the system (Split Mountain Gorge) and are absent in the SE (Cairn Canyon). Debris Flow Lobes. Debris Flow lobes are only found in the NW portions of the system, specifically Lycium Canyon and Oyster Shell Wash 2. Sheet turbidites are the most common facies association throughout the system, they interfinger with debris flow lobes, channelized turbidites and heterolithics. Heterolithic interbedded sandstones and siltstones. Facies Association 4 is most common in the southern most portions of the system (Cairn Canyon) and can be seen at the base of Section 1 in Split Mountain Gorge.

Coarse-grained, normal and inverse to normally graded beds are characteristic of the locally derived sediment gravity flows of the Lycium member turbidites. Previous work by Winker (1987) suggests that the Lycium member was deposited as a slope apron, sourced by the coeval Elephant Trees alluvial fan system with paleo-flow direction to the east. There is no field evidence for an intermediate shoreline or delta system, possibly indicating that a ‘true shelf-slope morphology was probably not developed’ at the time of deposition (Winker, 1987). Paleoecology of the Lycium suggests deposition in water depths less than 200m (Winker, 1987). The present sedimentological and paleocurrent analysis argues that the thick turbidite succession was not sourced from the alluvial fans but originated from a NW-SE oriented valley running parallel to the edge of the West Salton Detachment Fault, debouching into the Fish Creek Basin to the east northeast, with locally derived alluvial fans from the Vallecito Mountains separately spilling into Fish Creek from local slopes along strike from the turbidite feeder system (Fig. 3.3).
Figure 3.3 Paleogeographic interpretation of basin before marine incursion (~6.4-6.3 Ma). Alluvial fans were shedding into the basin from the neighboring Peninsular Ranges and Vallecito Mountains and a sturzstrom deposit entered the basin; B) Paleogeographic interpretation of deposition into the basin from 6.3 Ma to 5.6 Ma. Rapid marine incursion followed by progradation of an axial fluvial feeder system into the basin along the West Salton Detachment fault depositing basin floor fans.

In Split Mountain Gorge the Lycium turbidities start with an interval of thin (cm thick beds) sandstone beds which is about 10-15 m thick (Fig. 3.4). The thin bedded interval coarsens and thickens into dm thick sandstone beds alternating with thinner mudstone beds or amalgamated. Higher up in the succession the sandstone beds become amalgamated and have been interpreted as channels (Fig. 3.5).

Figure 3.4 Basal succession of Lycium Member in Split Mountain Gorge dominated by thin sandstone beds.
Figure 3.5. Outcrop image of steep cliff face in Split Mountain Gorge; B) Illustration of bed type distribution throughout the panorama. There are 7 identified channel complex packages. Packages widen and thicken as you move up in section. The top of the unit is capped by the Upper Mega Breccia. Complexes are broad and less erosive than those found in Lycium Canyon and feed into lobe complexes. Thin-bedded normally graded sands are found in between channel packages.

The Lycium Member is dominated by spectacular and abundant well-bedded, fine to coarse-grained sandstones that are interpreted as sandy, submarine sediment gravity flows (turbidites) because of the flute casts along the soles of some of the beds, their sharp and sometimes slightly erosive bases and the common graded nature of beds. These turbidites can be subdivided into: normally graded sandstone beds, inversely graded sandstone beds and inverse- to- normally graded sandstone beds (Fig. 3.6).
Figure 3.6. Well Bedded Sandstones; A) Normally graded sandstone bed, beds generally have flat, unscoured bases; B) Inversely graded sandstone, grades from medium/coarse at base to very coarse gravel at top of bed; C) Inverse to normally graded sandstone, beds grade from medium to very coarse gravel sand at the middle, and then normally grade from very coarse to medium sand in the upper portion of the bed

Tabular, normally graded sandstone beds are prevalent throughout the Lycium member. Average bed thickness is 20 cm, with a maximum thickness of 45 cm. ‘Beds’ thicker than 45 cm are generally an amalgamation of several thinner ones. Individual beds are poorly to moderately sorted and grade vertically from coarse to medium-grained sand up to a very-fine sand capping. Occasional plane parallel lamination is focused in the upper portion of the bed. (Fig. 3-6A)

Transitional flow deposits (Kane & Ponten, 2012) are also present in the system but make up less than 5% of the well-bedded sandstones and are thus not included as a major bed type, but are similar in character to the normally graded sandstones. The transitional flow deposits in the Lycium Member are comprised of medium sandstone beds with basal grading topped with a mud clast horizon within a muddier matrix. Inversely graded sandstone beds are interspersed throughout the section, with bed thicknesses ranging from 5 to 20 cm. Beds grade crudely from medium or coarse grained at the base to very coarse sand and even pebbles higher in the bed. Beds have irregular bases suggesting scour into the underlying substrate. (Fig. 3-6B). The inverse grading and generally associated slightly coarser grain size suggest that these beds represent flows with a higher sediment concentration and higher density than the normally graded beds associated with highly turbulent currents.

Inverse to normally graded sandstone beds are also scattered throughout the Lycium Member. Average bed thickness is 44 cm, with a maximum thickness of 80 cm. These beds are interspersed within thick, normally graded sandstone intervals. The basal portion, bottom 2/3, of the bed grades from medium or coarse sand and gravel, which then rapidly grades to medium sand in the upper 1/3 portion of the bed and then is capped with fine silty sand. Occasional ripple laminae are found in the fine sand/silt capping. (Fig. 3-6C)
On the bedding planes, drag marks and flute casts can be found. Horizontal trace fossils are common and at some locations highly intense. *Cruziana* (Fig. 3.7) was found abundant along some bedding plain in Split Mountain Gorge.

Similar to facies associations, lithofacies also vary from NW to SE from coarser lithologies to finer (Fig. 3.8).

**Figure 3.7.** Highly bioturbated fine sediments between sandstone beds with *Cruziana.*
Figure 3.8. Facies variability of the Lycium Member turbidite system; A) Location of outcrop measured sections and NW to SE transect; B) Distribution plot of lithofacies throughout the 10 outcrop measured sections; C) Normally graded sandstone bed; D) Inversely graded sandstone; E) Inverse to normally graded sandstone; F) Sandstone dominated heterolithics; G) Sandy debris flow, boulder rich; H) Sandy debris flow, mud clast rich; I) Amalgamated sandstone; J) Siltstone dominated heterolithics
Stop(s) 4: Upper “Megabreccia” / “Debris flow” / “Sturgesztrom”

The upper megabreccia is similar to the lower megabreccia, and exhibits all of the qualifying attributes of a sturzstrom. It differs from the lower megabreccia in clast composition, and due to its subaqueous emplacement over unconsolidated or semi-lithified sediment, in the way that it deforms and disrupts the sub-stratum (Figs. 4.1, 4.2).

The upper megabreccia is an unsorted, chaotic, polymictic breccia containing clasts of granodiorite, tonalite, granite, pegmatite, and an assortment of metamorphic rocks including mica and biotite schist, biotite gneiss, and marble. Like the lower megabreccia, clast range from silt to boulder size, and the dark gray to olive matrix takes on the composition of surrounding clasts. In places it has jigsaw-puzzle fabric, compositional zoning, and abundant streaks of white comminuted pegmatite. Geochemical analysis reported by Kerr and Abbott (1996) and Abbott et al. (2002) confirms that little mixing took place during the flow, though the uppermost meter or so in the Gorge shows a normally graded sandstone top, indicating turbulence during the waning stages of sturzstrom emplacement. Due to the polymictic nature of the upper megabreccia, workers have proposed as the source the Fish Creek Mountains to the east – southeast, or a now-buried basement block to the south – southwest (Winker and Kidwell, 1996). The upper megabreccia attains a maximum thickness of ~40 m at the southern entrance to Split Mountain Gorge, and thins to the northwest and southeast.

Figure 4.1 Tongue of Lycium member turbidite incorporated into the base of the upper megabreccia in Oyster Shell Canyon #2.
Figure 4.2 Turbidite–upper megabreccia interactions along the left side of the Split Mountain Gorge. (A) Injection of upper megabreccia into Lycium member turbidites in Split Mountain Gorge resulted in thrusts and imbricate horses in the green Lycium transitional member. (B) Injection of upper megabreccia caused ~30 m of Lycium member turbidites to fold in Split Mountain Gorge.
Figure 4.3. Megabreccia top characteristics. (A) Fining-up sands cap the compositionally zoned upper megabreccia at the southern entrance to Split Mountain Gorge. (B) Upper megabreccia compositional zoning and fining-up sand cap near Oyster Shell Canyon #3.
Stop 5: Turbidite deposits of Wind Cave Member, Latrania Formation

Wind Caves Member of Latrania Fm. is a 200 m succession of sandy to muddy beds deposited primarily by turbidity currents and extends from from the second megabreccia to the top of the succession which was defined as the last 2 cm sandstone bed as the unit graded into the Mud Hills Member of the Deguynos Formation.

Outcrops of exposed Wind Caves Member occur over ~6km lens-like with sandstones pinching out to the NW and SE. Lithologies present include graded and structureless sandstones, claystones and silty mudstones, as well as sandstone/mudstone heterolithic units. The sections measured (Fig. 5.1) show a vertical and lateral trend of fining toward the NW and SE margins of the outcrop extent as well as vertically upsection (Fig. 5.2). Paleocurrent directions were recorded from flute and groove casts oriented obliquely to the outcrop belt, i.e. SW to S to SE.

Sandstones of both “local” sourcing (L-Suite) and Colorado River sourcing (C-Suite) were documented by Winker (1987) and occur within the Wind Caves Member. L-Suite and C-Suite sandstone are differentiated in hand sample mainly by mineralogy and texture. L-Suite sandstones have medium to coarse grains with abundant biotite while C-Suite sandstones are generally medium to fine grained and have abundant quartz. L-Suite sandstones occur just above the second megabreccia for up to tens of meters prior to the appearance of C-Suite sandstones. An interval of silty mudstone/cover ranging from ~1 m to tens of meters thick separates the lower L-Suite sandstones from the C-Suite sandstones which make up most of the sandstones within the Wind Caves sandstones. LSuite sandstone beds are also found as thin beds (up to 20 cm) interbedded with silty mudstones higher in the section.

Detrital zircon taken from the last thick bedded L-Suite sandstone and the first C-Suite sandstone show a distinct shift in U-Pb ages with the LSuite bed dominated by Cretaceous age grains while the C-Suite bed contains grains of Miocene-Archean age. Zircon U-Pb ages (n=375) from four samples throughout the Wind Caves Member section show the age range to be Pliocene to Archean (Fig. 5. 3). This broad age range would be expected of a fluvial system sourcing from a large area encompassing diverse terranes, such as the Colorado Plateau. Erosion from a source area such as this would involve recycling of previously deposited sediment and give a wide spread of U-Pb ages in downstream deposits.
Figure 5.1 Locations of vertical measured sections taken throughout the outcrop extent of the Wind Caves Member.

Figure 5.2 Measured section correlation along the Wind Caves Member outcrop belt. Central sandstone beds are often thick bedded and amalgamated deposited in a basin floor setting. Bedding thickness decreases off axis of the thick bedded sheet sandstones and channels. Going up section, bedding also becomes thinner with increased silty mudstone and heterolithic interbedded sandstones and mudstones.
Figure 5.3. Outcrop A shows the Second Megabreccia/Wind Caves contact. Locally sourced (L-Suite sandstone) can be discriminated from Colorado Riversourced (C-Suite sandstone) by its coarser texture and common biotite. U-Pb age distributions show C-Suite sandstones to have a Miocene-Archean age spread. This larger age spread would be expected from deposits of a larger river system sourcing from more geologically diverse areas. Sandstone clast at top of megabreccia is ~2 m.
Wind Cave Turbidites Lithofacies

Six lithofacies were identified from vertical sections measured throughout the Wind Caves Member and these tend to form larger scale architectural elements. Lithofacies identified were linked to process-based interpretations of deposition. These lithofacies include Thick bedded, structureless sandstone (Fig. 5.4); amalgamated, normally graded sandstone (Fig. 5.5); non-amalgamated, normally graded sandstone (Fig. 5.6); heterolithic interbedded sandstone and silty mudstone (Fig. 5.7); and silty mudstone. The dominant architecture along the Fish Creek Wash is channels (with amalgamated sandstone beds) and thick sandstone beds alternating with thin mudstone beds (Fig. 5.8).

Figure 5.4. Thick bedded, structureless sandstone in outcrop (A). Flutes and groove casts (B and C). Structureless bed with weathered out mudclasts (circled in D). These beds are common within ~1 km of Fish Creek Wash. Structureless sandstone indicates rapid deposition from suspension in high concentration flow (Lowe, 1982).
Figure 5.5 Amalgamated beds in outcrop (A). Bedding planes are often difficult to distinguish but tops of beds are recognized by being finer grained than bottoms. (B) shows irregular base of amalgamated bed. These are interpreted to be deposited within the axis of flow.
Figure 5.6. Non-amalgamated sandstone beds ~30 cm thick with heterolithic and silty mudstone units between beds (A). Beds typically have flatter, less scoured bases. Beds outcrop with slightly rounded top due to finer grained portions of beds being more easily eroded (B).
Figure 5.7. Heterolithic interbedded sandstone and mudstone and silty mudstone intervals are interpreted to be deposited by dilute turbidity currents off-axis of main flow or by hemipelagic sedimentation (Talling, 2012). Intervals of these units are often thin in central outcrops within the Wind Caves Member and increase in thickness laterally and also up section.
Figure 5.8. Outcrop B shows thick bedded structureless and normally graded sandstones exposed on the right side along Fish Creek Wash. On the left side of the picture sandstone beds are highly amalgamated with decreasing amalgamation to the right. The zone of amalgamation is interpreted to be the channel axis with amalgamation decreasing off axis. The measured section is taken from the right hand portion of the photo.
Stop(s) 6 (optional): Slope (or prodelta?) “rythmites” of Mud Hills Member of the Imperial Formation

The Mud Hills Member is a ~700 m-thick package of regionally extensive deepwater slope claystones, siltstones and thin beds of very fine sandstones. The middle and upper portion of the slope succession in the vicinity of Fish Creek Wash has conspicuous rhythmic banding that has been interpreted as decadal Colorado river flood cycles on the deepwater slope driven by El Nino forcing (Robinsen, 2014).

Figure 6.1. Alternation of 5-10 cm thick very fine sandstone to silt beds with mudstone beds. The Mud Hills Member is hundreds of meters thick composed of similar beds.
Figure 6.2. “Rytmites” 5-10 cm thick very fine sandstone beds. Beds are mostly rippled and low angle to flat laminated. Occasionally bioturbated.

Figure 6.3. The upper part of the Mud Hills a few meters thick sharp based sandstone units can be interpreted as channels.
Stop(s) 7 (optional): Shoreline deposits of Elephant Knees Member of the Imperial Formation

The Yuha and Camels Head members, fossiliferous shallow-marine sands of the prograding Colorado River delta, overlie these marine rhythmites (Winker, 1987; Winker and Kidwell, 1996; Dorsey et al., 2011). The typical coarsening and upward units (Fig. 7.1) indicate the deposits are formed in a shallow water/ delta environment. The facies contain cross-strata (Fig. 7.2), cross-strata with mud drapes, symmetrical ripples, *Ophiomorpha* borrows. Some of the units are exclusively build from oyster shells forming large cross-strata within shallow channels (Fig. 7.3).

Figure 7.1. Coarsening and thickening upward 10-15 m thick units interpreted as tidal dominated delta.
Figure 7.2. Cross-stratified sandstone beds with bioturbation (*Ophiomorpha*).

Figure 7.3. A few meters thick, strongly cemented unit built of high percentage (over 90%) of oyster shells. The deposits are locally erosional forming channels and formed of large cross-strata.
Stop 8: Deformation of the turbidites by megabreccia in Crazy Kline Canyon; Megabreccia interactions with underlying and overlying turbidites

Spectacular deformation of the Lyceum turbidites by the upper megabreccia can be observed in Crazycline Canyon. With tens of meters high folds of the underlying beds (Fig. 8.1.).

Fig. 8.1. Upper megabreccia basal characteristics. (A) Eroded and folded Lycium member turbidites in Crazycline Canyon. (B) >10 m fold in the Lycium member turbidites in Oyster Shell Canyon #2.
Upper megabreccia, in addition to plunging into the underlying turbidites deposits and creating large folds (Fig. 8.1.) also generates “channelization” at the top where the overlying turbidite deposits interacts with the irregular top of the megabreccia (Fig. 8.2.). The upper meggabreccia has a variable thickness with maximum thickness in the Split Mountain Gorge of about 40 m (Fig. 8.3.) and is thinning toward the NW and SE where is ending abruptly. Most of the deformations under and above the megabreccia was observed in the thicker parts (Fig. 8.3.).
Figure 8.3. Upper megabreccia thickness variation, degree of underlying sediment erosion and deformation variation, and upper megabreccia impact on lateral continuity of overlying and underlying sediment.
Day 2: Lycium Canyon – Turbidites of Lycium Member, Latrania Formation, Slope Channels or Slope “Cyclic Steps” Upper Flow Regime Bedforms?

…Stop 9 …along the Lycium Wash

Lycium Member in Lycium Wash contain the coarsest deposits (boulder sized within sandstone beds, debris flows) which gradually fines and pinch out toward the southeast (Fig. 9.1), see also the Stop 3 of Day 1. Sandstone beds thickness varies from cm to a few meters with common boulder sized clasts (Fig. 9.1) or mud clasts (Fig. 9.2).

Figure 9.1. Thick-bedded amalgamated sandstone units(LF-2); A) Outcrop scale, amalgamated sandstones; B) Mud clasts highlighting amalgamation surfaces; C) Spaced laminations (~10 cm thick); D) Amalgamated beds with boulder inclusions (up to 1m).

Figure 9.2. Meters thick sandstone bed with mud clast conglomerates. Note erosion to the left >0.5m.
Large (dm to m) clasts are concentrating in general parts of the beds and are matrix supported. Beds are in general thicker than the boulder diameter (Fig. 9.3), but there are also beds with the thickness approximate the same as the large clasts diameter. The “coarse” boulder beds are in general erosional (Fig. 9.3).

Figure 9.3. TOP) Outcrop image of debris flow lobe; BOTTOM) Illustration of bed type distribution in the above image. Thick debris flow beds are intermixed with amalgamated sandstones. Boulder inclusions are large and can reach sizes greater than 1 meter in diameter. Debris flow beds are plug like, with rapid lateral pinchout and thinning.
Deposits in Lycium Wash have been interpreted to be slope deposits mainly channel elements which are composed of coarse (bouldary) beds which erode the substrate and also migrate laterally forming LAP (Fig. 9.4).

The intervals which are thinner (dm thick) bedded and have undulatory geometries with the wavelength of meters to tens of meters were interpreted as shallow channels with lateral accretion units (Fig. 9.5). The gently dipping lateral accretion units are formed of dm thick sandstone beds alternating with cm-dm thick mudstones which locally are highly bioturbated.

Figure 9.4. TOP) Outcrop image of channel complex; BOTTOM) Illustration of bed type distribution in the above image. Thick amalgamated sandstones are interbedded with conglomeratic debris flows and sandstone dominated heterolithics. Channel bodies are broad and lenticular with minor scouring bases.
Figure 9.5. A) Outcrop example of lateral accretion packages found in Lycium Canyon; B) Illustration of bed type distribution throughout the outcrop example. Lateral accretion packages (LAPs) suggest slight channel sinuosity in a lower energy environment.

However, the thick sandstone beds with locally clustered boulders or the “thin bedded” undulatary sandstone units can be also alternatively be interpreted as upper flow regime bedforms (antidunes, cyclic steps) formed by highly energetic flows on the slope. The upper flow regime (or supper critical flow) bedforms forms at relative high velocities (Fig. 9.6) when Froude number is higher than 1. The hydraulic jump, or the dynamic of it (Fig. 9.7) is controlling the formation of the bedforms. The supercritical flow bedforms commonly recognized are cyclic steps and antidunes (Fig. 9.8) which are characterized by large meters to tens of meters wavelengths and internal laminations which are inclined in an upstream direction (Fig. 9.8).
Extended bedform stability diagrams of: (A) the diagram of Southard & Boguchwal (1990; for a 0.06 to 0.1 m water depth and water temperature of 10°C) from Cartigny et al., 2014.

Figure 9. 7. Geometric and dynamic configurations of hydraulic jumps (From Cartigny et al., 2014). (A) The central diagram shows the theoretical relations between outgoing Froude number (Fr2), the dimensionless energy loss expressed in metres of water column (DH/h1) and the ratio of conjugated depths (h2/h1) as a function of the incoming Froude number (Fr1). Experiments have shown that different kinds of hydraulic jumps (B) to (F) occur at different incoming Froude numbers (Bradley & Peterka, 1955; Chow, 1959; Lennon & Hill, 2006).
Figure 9.8. Representative idealized overview of four stages in unidirectional supercritical flows, corresponding to the development of the four kinds of bed configurations presented and defined here (flow directed from right to left; vertical scale exaggerated for clarity). Additional insets for unstable antidunes and chutes-and-pools illustrate the dynamics of associated cyclic processes. (From Cartigny et al., 2014)
Examples of sandy waves (cyclic steps) formed by supercritical flows in modern environments are similar with paleo-environments envisioned for Lycium deposits, strong flows on steep slopes. Deposits formed in front of a delta on steep slopes of lake Chelan in Washington State show tens of meters bedforms in tens to hundreds of meters water depth (Fig. 9.9). The bedforms (cyclic steps) develop from a depth of 60 m to 130 m where the gradient decreases (Fig. 9.10). The bedfoms have wavelengths of 10-20 m most proximal and increase to 40 m in the distal deeper parts. The height of the bedforms is a few meters with higher 3-4 m in the proximal, shallower parts while the distal bedforms have amplitudes of 1-2 m (Fig. 9.11).

Figure 9.9. Bathymetric chart of the northern 5 km of Lake Chelan. The Stehekin River enters the north end of the lake where it builds a delta. Bathymetry is shown over a USGS basemap. Insets A–D identify selected artifacts in the bathymetric surface and features interpreted to be bedforms.
Figure 9.10 Raw and annotated CHIRP profile through the bedform field on the foreset of the Stehekin River delta. The position of the bedforms on the foreset is noted in Figure 5. The vertical axis in each plot is depth in meters calculated from two-way travel time assuming a sound velocity of 1500 m s\(^{-1}\). A) Raw CHIRP profile showing the bedforms and the transition to flat-lying sediments marked by parallel reflectors at 1300 m distance. B) Annotated copy of the CHIRP line in panel Part A showing the bedform–water interface traced with a black line, and the location of 41 bedform troughs marked with red flags.
Figure 9.11. CHIRP cross sections through the bedform field at six locations between 70 and 860 m from the delta rollover. Each cross section is nearly perpendicular to the trend of the bedform field and is displayed at the same scale (200 m x 7.5 m). The cross sections are arranged from most proximal (top) to most distal (bottom). Triangles mark the approximate location of the transition between the bedform field and lateral flat-lying sediments with parallel reflectors.
New data is collected on slope deposits of Lycium turbidites (Fig. 9.12) along longs sections as long as detail short sections along the same sandstone unit. The detail mapping of the grainsize variability, internal laminae distributions, occurrence of the large boulder clasts and the 3-D geometry of the sandstone body will be collected (Figs. 9.13 and 9.14). The scope is to understand the differences and typical characteristics and architectures of supercritical bedforms versus lateral accretion within channels.

![Figure 9.12. Photopanel with location of measured sections in Lycium Wash.](image)

![Figure 9.13. Photopanel with measured section 3 (on previous figure). Note the succession is build of alternation of thin sandstone beds and thicker (over one meter) sandstone beds with boulder clasts.](image)
Figure 9.14. Detail with one potential supercritical bedform. A few meters thick sandstone with undulatory internal laminae and large boulder size clasts.
References


Johnson, SD, S Flint, D Hinds, and H De Ville Wickens. 2001. “Anatomy, Geometry and Sequence Stratigraphy of Basin Oor to Slope Turbidite Systems, Tanqua Karoo, South Africa.”


Safety instructions for Vallecito - Fish Creek Basin Fieldtrip
November 13-15, 2015, Borrego Springs Fish Creek California

Recommended Accommodation:

PALM CANYON HOTEL & RV RESORT
221 PALM CANYON DRIVE, BORREGO SPRINGS, CALIFORNIA 92004
Local: 760-767-5341
(See attached driving directions)

1. Does the operator carry communication that works at all stops -- Sat Phone \\ Cell Phone
(if not, we will carry our own)

The operator will not have a satellite phone. Some networks (AT&T cover most of
the field area). You should carry your own satellite phone.

2. Does the operator have an emergency response plan with contact numbers for each
area (if not we prepare a contact list and will carry it with us)

For the emergency use the fieldtrip leader phone: Cornel Olariu: 512 917 4133

Close Hospital / Medical   Emergency: 911
Borrego Medical Clinic & Pharmacy 760-767-5051
Gordon T. Wimer, DDS       760-767-5112
Eisenhower Medical Center, Rancho Mirage 760-340-3911
Pioneers Memorial Hospital, Brawley 760-351-3333
Palomar Medical Center, Escondido 760-739-3000
Pomerado Medical Center, Poway 858-613-4000

REGIONAL HOSPITALS
Desert Regional Medical Center (PALM SPRINGS)
1150 N INDIAN CANYON DR, PALM SPRINGS, CA 92262
Emergency Department phone (760) 323-6251

UC San Diego Health System (SAN DIEGO)
200 West Arbor Drive
San Diego, CA 92103
Main Line: 858-657-7000

Hillcrest Emergency       La Jolla Emergency
UC San Diego Medical Center Sulpizio Cardiovascular Center
200 W. Arbor Drive         9434 Medical Center Drive
3. Does the operator carry first aid equipment and have training (if not we will carry our own 1st aid kits)

   The operator will not have a first aid equipment. You should carry your own first aid kit.

4. Does the operator supply PPE if needed (if not we will carry our own - example reflective vests for road exposures, life jacket, etc.)

   There is no need of specific PPE equipment. The outcrops to be visited are in Anza-Borrego State Park (see attached figure) and away from busy roads.

   However, if the company regulation require reflector vest or hard hat you should have them.

5. Does the operator require drivers training for anyone driving on the field activity (if not we will drive our own vehicle)

   Drivers are “safety certified” by the University of Texas. However, you can drive your own car in the field. Driving is relatively close (20 miles) from Borrego Springs hotel to the park where the outcrops are. In the park there are a few miles of “rough” unpaved roads.

6. If boat transportation is included in the activity, who is the vessel registered under and what license / certifications do they carry?

   No boats or vessels will be involved during the trip.

7. If boat transportation is included in the activity, do the boat operators have all of the required PPE and safety equipment? (Life vests, life boats, ship to shore comms, etc.)

   No

8. Is aviation (helicopter, charter plane) involved as part of the field trip? If so, we will need to check that the Helicopter or plane complies with/passes ExxonMobil Aviation guidelines.

   No aviation will be involved during the trip.
9. Are there any special risk considerations? (Example bears or other wild animals, in water activity such as snorkeling/diving, camping as part of the activity, river rafting, etc)

No large (predatory) animals are in the area. Venomous snakes might be present. Anti- venom kit recommended but not mandatory (see comments below).

Additional Safety Instructions

For emergency contact you can use Cornel Olariu's cell phone number: 512 917 4133.

The main possible hazards during the trip are (1) driving, (2) falling (loose) rocks, and (3) Heat/wind/wildlife.

(1) The traffic/driving is the main risk. The distance is relative short (80 miles from Palm Springs and 90 miles from San Diego airports) roads are paved but in the field close to the outcrops and some roads are paved with gravel. Extra attention to road traffic and slow driving speed is required on unpaved roads. 4 wheels drive vehicles will be used in the field to be sure we can get out in case it rains. We will drive in convoy and make sure that at road bifurcations everyone takes the right road. Extra attention and slow speed is needed while driving on dirt roads.

In case we will stop by side of the road. Please watch careful both ways of the traffic even if it is a small road or a park road.

(2) Some of the locations are close to steep cliffs. You will have to pay extra attention to loose rocks under your feet and above you head. If close to a cliff please look over to see if there are any obvious loose rocks.

We will have to walk on uneven terrain and occasionally on inclined slopes strong, good quality hiking boots with good ankle support (sneakers/training shoes are not acceptable) are required!

Please stay with the group and do not remain far back (alone) along trails. If you have to walk over wet rocks (or soil) pay extra attention as these can be slippery.

Wind can be extremely strong at times.

(3) Temperature in Anza-Borrego desert can be very high over the day and in general is very dry but be prepared for changing weather. We also recommend you to have a hat, sunscreen and insect repellant.

At most of the locations there is relative short walk distances (hundreds of meters to 1-2 km). Because we will be times when you will be away from the car for hours/ most of the day, we recommend that you have with your personal or satellite phone, food and plenty of water (at least 2 liters).

Wildlife is not a specific danger. However, like anywhere in the nature there are some specific insects and animals needed to be avoided such as fire ants, spiders, snakes. Please watch where
you step and put your hand. Have with you a tool that can also be used as a "weapon" such as a stick, hammer, etc.

If you have BEEN ALLERGIC IN THE PAST at insect bites or snake bites have an allergy emergency kit or have an anti-venom kit with you.

General Geologic Field Safety Protocols (from SEPM)

1. Field safety is a shared responsibility for which each participant is accountable. Your action to address a safety concern may save a life or prevent a hospital stay.

2. Observe and follow all safety warnings and instruction from trip leaders.

3. Participants should immediately inform the excursion leaders and, if appropriate, other group members of any safety concerns that arise.

4. Participants should inform the excursion leader (in confidence) of any relevant medical condition which may affect their performance in the field (e.g. asthma, diabetes, epilepsy, vertigo, heart conditions, back problems, allergies, medication requirements, etc).

5. Strictly adhere to any clothing/equipment/hydration requirements: these are essential safety requirements specific to the weather and terrain for each field excursion.

6. Do not leave the field party group without first informing a field excursion leader.

7. Roadside Stops Protocols:
   - Always be vigilant of traffic: avoid causing an obstruction, distraction or other danger to other road users.
   - On roads with infrequent traffic, alert others of approaching vehicles or cyclists.
   - Take steps to warn other road users of your presence. Wherever appropriate, wear reflective jackets and make use of warning triangles.
   - Remain behind safety barriers if present: only cross the road in a safe manner at an appropriate location.
   - Do not touch protective rock-fall netting on road-cut exposures: any movement could disturb loose rocks above.

8. Protocols for cliffs, slopes and rocky terrain:
   - Wear walking boots with good grip and proper ankle support to reduce chances of slips and sprains.
   - Check your footing: step carefully and continually assess footing.
   - Do not climb rock faces or unsafe slopes. Always be guided by the leaders for the safest routes up slopes.
   - Be aware of falling rock beneath steep or overhanging cliffs: hard hats must be worn in quarries. Avoid areas of the rock face that are heavily cracked, have recent debris at the base or are overhanging.
   - Avoid passing up- or down-slope of other members of the group (to reduce the risk from dislodging rock).
   - Take care not to dislodge rocks. If by accident you do dislodge loose material, shout loudly “ROCK” whether or not you are aware of others below.
   - Avoid passing others on narrow ledges and paths: be patient and walk in single file.
   - Be extra vigilant when a path leads to an area with high exposure.
- Stay back from cliff edges and be aware of unstable areas near edges.
- Be aware of the possibility that wildlife (birds, deer, etc) may dislodge rocks from above.
- Wear walking boots with good grip and proper ankle support to reduce chances of slips and sprains.
- Be aware of the risk of slipping on wet rocks, particularly rocks covered with seaweed or algae.
- Be aware of the risks of tides, waves and currents.

9. Driving Protocols:
- Where available, seat belts must be worn at all times.
- Drive safely and observe driving regulations and local laws (speed limits etc)
- If driving in convoy, keep a safe distance from the vehicle in front and keep visual contact with the vehicle behind. When driving in convoy it is the responsibility of the vehicle in front to slow down or wait for the vehicle behind, rather than the vehicle behind feeling the need to keep up with the vehicle in front
- The use of inexpensive FRS radios can be useful to maintain communication when driving in convoy, but as their range is limited (2 to 3 km) they should not be relied upon. Passengers, not the driver, should operate the radios.

10. Environment & Property Protocols:
- Respect private property and machinery.
- Do not litter: check area for left litter before leaving a site; encourage participants to leave the site cleaner than it was found.
- Avoid undue disturbance to wildlife. In national parks it is the illegal to disturb wildlife and take flora.
- Avoid use of geologic hammers. If you do need to hammer, warn others to stand clear and do not hammer indiscriminately. In national, state and provincial parks it is as a rule illegal to remove any material including rocks.
- Refrain from making any unnecessary permanent marks on rocks.
MAP with the Location of the recommended hotel and the location of the outcrops
(for larger map see attached files)
MAP with the Location of the the outcrops in tsplit mountain Gorge area (Anza-Borrego State Park) (for larger map see attached files)
Directions from San Diego International Airport to 221 Palm Canyon Dr

- **San Diego International Airport**
  3225 North Harbor Drive, San Diego, CA 92101

Get on N Harbor Dr from Airport Terminal Rd

1. Head northwest on Airport Terminal Rd
   - 0.2 mi
2. Keep left to stay on Airport Terminal Rd
   - 0.2 mi
3. Take the ramp to I-5/Downtown
   - 0.5 mi

Take CA-163 N, Pomerado Rd, Scripps Poway Pkwy, CA-67 N, ... and Montezuma
Valley Rd to Palm Canyon Dr in Borrego Springs

1. Merge onto N Harbor Dr
2. Turn left onto W Grape St
3. Take the Interstate 5 S ramp
4. Merge onto I-5 S
5. Take the exit onto CA-163 N toward Escondido
6. Merge onto I-15 N
7. Take the Pomerado Road exit toward Miramar Road
8. Turn right onto Pomerado Rd
9. Turn right to stay on Pomerado Rd
10. Turn right onto Scripps Poway Pkwy
11. Turn left onto CA-67 N
12. Continue onto Main St
13. Continue onto CA-78 E/Julian Rd
14. Turn left onto Hwy 79 N
15. Turn right onto San Felipe Rd
16. Turn left onto Montezuma Valley Rd
17. Turn right onto Palm Canyon Dr

Destination will be on the right

221 Palm Canyon Dr
Borrego Springs, CA 92004
Horses are excluded from all hiking trails. Equestrian trails in Coyote Canyon and on the Equestrian Area are open to bicycles, but remember, horses are excluded from all hiking trails. Cross country travel is not permitted.
Anza-Borrego Desert State Park

To the first-time visitor, the space, the light, and the silence of Anza-Borrego Desert State Park can be awesome. But the far horizons mean freedom, the clear light makes seeing an adventure, and the silence speaks solitude and peace. Anza Borrego, California's largest state park, is a treasury of wildlife and plants, and provides a refuge for the many native species of people and wildlife within a few hours' drive. The park's impotence as a protected refuge becomes greater each year.

From its underground visitor center to its highest pine-clad peaks, Anza Borrego Desert State Park shines as the diversity of life and terrain makes this 560,000-acre desert park one of the liveliest in the country. Almost one million visitors make the trip each year, pausing, camping, and breathing in the fresh air.

Points of Interest

The park is open year-round, but there is one point to which all the visitor centers at the top of the park and the National Park Service must pay attention: the desert's vast, open spaces. It is a place that demands respect and understanding. Here, where the sun beats down with a vengeance, it is wise to wear sunscreen, carry plenty of water, and be prepared for unexpected storms.

VISITOR CENTER

An excellent place to begin your park visit. Maps, books, brochures, exhibits on the flora and fauna, and a gift shop provide information and souvenirs.

BORREGO PALM CANYON

Located one mile from the visitor center, this canyon offers a great opportunity to explore the desert's unique vegetation. The palm trees and fan palms are especially striking. The canyon is also home to a variety of wildlife, including the desert tortoise and the Kit Fox.

COYOTE POINT

Located at the western end of the park, this viewpoint offers panoramic views of the desert and the mountains. The visitor center is nearby, and there is a great place to picnic.

POINTS OF INTEREST

Located one mile from the visitor center, the Borrego Palm Cottonwood includes a variety of desert plants and animals. The visitor center is nearby, and there is a great place to picnic.

SPLIT MOUNTAIN

A massive rock formation in the center of the park, Split Mountain rises to a height of 2,000 feet. The rock is a popular spot for rock climbers and hikers.

MOUNTAIN PALM SPRINGS

A cluster of giant cacti, this oasis is located on the western edge of the park. The cacti are surrounded by a variety of desert plants and animals. The visitor center is nearby, and there is a great place to picnic.

CARRIZO BADLANDS OVERLOOK

On County Highway 82 just a few miles south of the park, this viewpoint offers a great view of the desert and the mountains. The visitor center is nearby, and there is a great place to picnic.

Wildflowers

One of the most popular attractions in Anza Borrego is the spring wildflower bloom. Flowering varies from year to year, and the desert is carpeted with color the day and night. In the spring, wildflowers are abundant. The peak bloom is usually in late March or early April. Wildflowers that are found here are the desert sunflower, the brittlebush, the hedgehog palo verde, and the agave. The wildflowers are also available in the visitor center.

Rule of Law and Order

All visitors are encouraged to respect the park's boundaries and protected areas, including the desert, the mountains, and the rivers.

Vehicles

The park offers a variety of vehicle access, including boats, bicycles, and horses. Bicycles are required on all trails.

Camping

For information on desert camping, contact the park's Visitor Center. Campsites are available on a first-come, first-served basis.

Firearms

The park is a wildlife refuge and a protected area. Firearms are prohibited.

Desert Services

To ensure the safety and enjoyment of all visitors, the park provides a variety of services, including information, education, and interpretation. The park offers ranger-led programs, including bird-watching, nature walks, and outdoor activities.

Information

For more information about the park, contact the park's Visitor Center. The Visitor Center is located at the eastern end of the park.