Guadalupe National Park

1. Once again we find ourselves looking at a park on the edge of the Basin and Range province – this time the far southeastern edge. Guadalupe Mountains National Park lies within a distinctively different portion of the Basin and Range known as the Rio Grande Rift.
2. Recent seismic studies across the Rio Grande Rift near Albuquerque reveal its characteristic structure…
3. … which consists of closely spaced, steeply dipping normal faults. Unlike other parts of the Basin and Range, very little rotation on the fault blocks has occurred along the Rio Grande Rift, …
4. … such that strata like these in the Guadalupe Mountains have only a gentle ENE dip caused by rift normal faults.
5. Because the faults are virtually inactive today, many geologists consider the Rio Grande rift to be an allochogen, which you of course remember is a failed rift. The rift opened almost 30 million yeas ago, but the degree of extension here never got anywhere close to that of the rest of the Basin and Range.
6. Perhaps that explains why the normal faults have not rotated to more gentle dips as is the case elsewhere in the Basin and Range.
7. At any rate, normal faulting along the rift produced well over 20,000 feet of vertical offset in many areas. Streams flowing into the rift were therefore given an enormous amount of gravitational potential energy by which they could erode the rift’s shoulders.
8. Guadalupe National Park is situated on one of those eroded shoulders. Here, the erosion which accompanied the formation of the Rio Grande Rift exposed an amazingly well-preserved reef from the Permian period. The reef’s massive core outcrops majestically on the cliffs of El Capitan – the park’s signature landmark and type locality for the Capitan Reef,…
9. … which is exposed in the Guadalupe, Apache and Glass Mountains. Extensive oil exploration in the region has revealed buried portions of the reef that complete a nearly continuous circuit around what during the Permian period was a deep ocean basin …
10. … known as the Delaware Basin. It and several other basins comprise what is collectively known as the Permian Basin.
11. Apparently these basins formed during the final stages of Pangaea’s formation. The collision of North and South America forced the southwestern margin of North America under South America, thereby causing subsidence.
12. Because these basins were near the equator during Late Permian time, the warm tropical sea water promoted reef growth …
13. … much in the same way that modern reefs form on the Bahaman Banks. These two diagrams are the same scale, so except for being next to deeper basins, the Bahamas Banks are pretty good modern analogues to the reefs of the Permian Basins. The Capitan Reef which surrounded the 600-meter deep Delaware Basin …
14. … is best exposed in the Guadalupe Mountains because that portion of the reef is closest to the Rio Grande Rift where maximum erosion occurs.
15. The degree to which the reef has been exposed is dramatically illustrated from the low point at Salt Basin where about a mile of relief separates the basin from Guadalupe Peak. Mostly what was eroded here was a soluble gypsum unit which we will cover in greater detail later.
16. The big story here is the complete set of ancient reef “facies” exposed in the Guadalupe Mountains.
17. In geology, facies refer to rock mass characteristics that reflect depositional environment.
18. Depositional environments in and around reefs vary from deep water basinal deposits, to mid-depth fore reef, to shallow water reef, lagoon and back reef deposits. In the Guadalupe Mountains each of these facies is represented by a different geological formation …
19. … on the geological map of the area.
20. Different facies are often depositing at the same time but in different environments. For example: The Capitan Limestone represents the reef front, but the Tansill and Bell Canyon formations where depositing at the same time in the back reef and deep basin respectively.
21. Let’s look at the standard Guadalupian Facies Spectrum starting with the Basin facies where the calm, deep water …
22. … leads to the formation of thin, highly continuous layering.
23. A close-up view of this unit shows millimeter-scale laminations and extremely dark colors from abundant organic matter. Both characteristics are typical of deep, stagnant basins where oxygen depletion inhibits the decomposition of organic material.
24. Upon burial and heating the organic material is converted into oil which eventually migrates into more porous materials. Oil reservoirs are relatively common in the area, which, as we will see in the next lesson, will play an important role in the formation of Carlsbad Caverns.
25. Within the basin facies there are numerous sand lenses that are more resistant to erosion than the laminated basin limestone.
26. These were formed during periods of lower sea level when wind-blown sand was brought to the reef front where it was transported down the reef slope via sand slides and turbidity currents. Turbidity currents are mixtures of sediment and water that tumble down slope somewhat like underwater avalanches.
27. Because turbidity currents contain a variety of particle sizes and larger particles settle more quickly than finer ones, the deposits of turbidity currents, or “turbidites” , typically show graded bedding with finer particles above coarser. This one was deposited at the base of the reef slope and includes numerous shell fragments.
28. The basin facies can be seen at the mouth of Pine Spring Canyon just west of the Visitor Center and …
29. … a few miles north at the mouth of McKittrick Canyon. The hike up McKittrick Canyon is rated “best in Texas” and although that may not mean much, the “Geology Trail”, which you can just make out on the north wall of the canyon, offers a world-class tour through the ancient reef.
30. At the mouth of McKittrick Canyon you can see the graded sandstone so characteristic of turbidite deposition.
31. On the steep reef slope turbidity currents flowed fast enough to erode submarine canyons into the carbonates that were deposited during intervals of higher sea level. During low sea level intervals virtually all sedimentation occurred in the basin.
32. Occasionally large blocks of carbonate slope material were carried into the basin via debris flows. Note the rock hammer for scale.
33. Moving from the basin to the forereef facies, note that, although exaggerated in this diagram, the forereef has by far the steepest slopes of all reef environments. Periodically blocks of the reef will break off and tumble onto the forereef.
34. Looking north from McKittrick Canyon along the Capitan reef escarpment you can see the cemented fractures that formed parallel the reef escarpment as gravity pulled it towards the forereef. These formed at the same time sedimentation was occurring.
35. The forereef is dominated by carbonate debris flows derived from unstable, fragmented reef material.
36. Such debris flows would inevitably have buried Capitain fore-reef inhabitants, like this fenestrate bryozoan. This sample is from the Geology trail on north wall of McKittrick Canyon.
37. Forereef strata were deposited parallel to the surface of the reef slope. Thus the modern slope here must pretty much coincide with that of the ancient reef slope.
38. Now let’s look at the heart of the matter – the reef facies itself.
39. El Capitan shows clearly the massive character of the reef facies limestone. In geology the term massive means without structure or layering.
40. The most common reef building organism here was not coral, but extinct forms of calcareous algae known as Tubiphytes.
41. Tubiphytes lived on and alongside lace-like bryozoans,
42. … calcareous sponges, …
43. … and many other organisms - with the notable exception of coral.
44. This diorama of the Capitan reef displayed at the Permian Basin Petroleum Museum in Midland, Texas emphasizes the tall framework sponges and the abundant encrusting fauna.
45. Wave action was most intense on the reef, but as we move towards the back-reef the water becomes calmer.
46. The fact that this fossil crinoid, an ancient relative of the starfish, is virtually intact indicates that at least local pockets of low energy and/or high rates of marine cementation of sediment existed in the near back-reef.
47. As we move into the back-reef notice that some of it is exposed above sea level as small barrier islands.
48. These islands consisted essentially sand made of broken-up shell material. Here the carbonate sand has seaward-dipping cross-beds that are probably of beach origin.
49. Carbon dioxide is driven out of solution by warm lagoon temperatures, thereby lowering the concentration of carbonic acid which holds carbonate in solution. Conditions in the lagoon therefore promote the inorganic precipitation of carbonate.
50. Inorganic carbonate precipitation coats grains rolled about by wave action producing pisolites in the near back-reef where some wave action is felt.
51. In the extremely clam water of the lagoon facies …
52. … fine carbonate mud deposits along with carbonate secreted by algal mats known as stromatolites. Some of the larger voids here are the result of evaporite mineral dissolution.
53. The proximity to land and high salinity and of the lagoon favors the precipitation of Mg carbonate over Ca carbonate, so dolomite is the dominant carbonate here. Note the abundant voids left by the dissolution of evaporites.
54. Finally, in near-shore tidal flats evaporites deposit with rain-water oxidized clastic sediments, known as redbeds.
55. The dominant evaporite here is massive nodular gypsum.
56. Red beds and evaporites become interbedded as shorelines shift with climate and sea level changes. Note the gully-formation in the soluble evaporite and presence of a capping layer of dolomite which has preserved this outcrop from complete erosion.
57. Red siltstone and nodular gypsum are indicative of the back-reef facies, but …
58. … laminated evaporite is indicative of the basin facies during the time when the basin became restricted from the open ocean. Dark laminae are calcite plus organic matter; light laminae are gypsum. Laminae are considered to be annual layers reflecting variations between summer (evaporitic) and winter (less evaporitic) conditions.
59. The laminated evaporites are represented by the Castile Formation whose thickness of up to 600m, …
60. … is enough to completely bury the reef.
61. Due to it’s high solubility the Castile Formation has been almost completely eroded from the basin leaving the relatively resistant reef intact.
62. I would like to acknowledge the resources and support of Dr. Peter Scholle, which contributed enormously to this lesson. Thanks Peter!