The Permian Basin Field Trip

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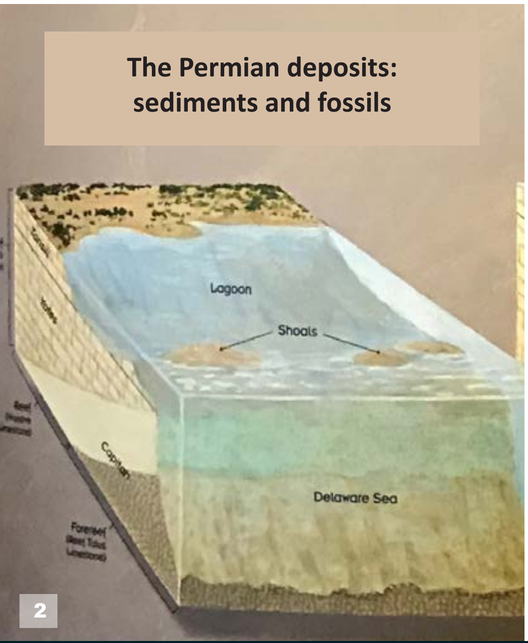
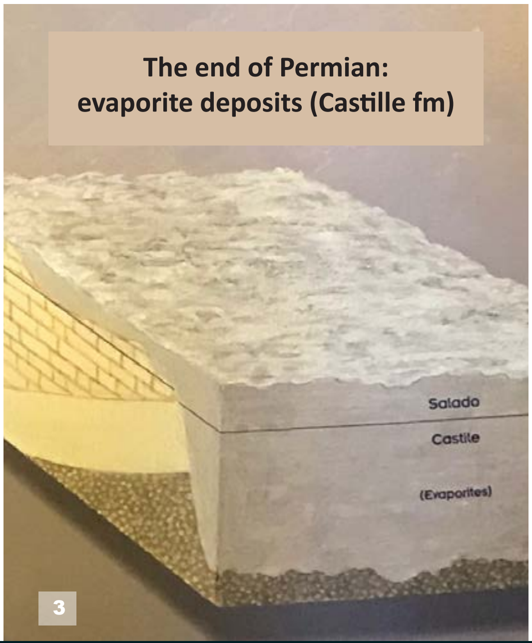
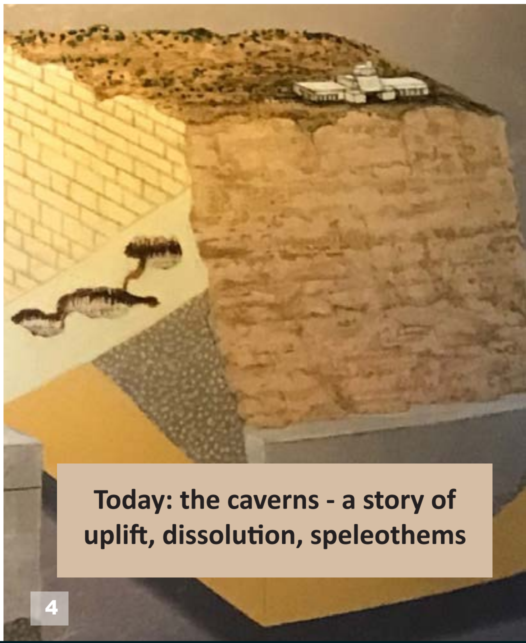
Thanks to industry donations to the LSU Department of Geology and Geophysics Applied Depositional Geosystems and funds from the American Association of Stratigraphic Palynologists Chair, 15 graduate students had the opportunity to go on a five-day field trip to the Permian Basin of West Texas and Southern New Mexico. The field trip was a joint project of GEOL 7900 Permian Basin (Warny) and GEOL 7061 Sequence Stratigraphy (Bart) classes and combined the paleontological and sequence stratigraphic expertise of both faculty. The trip was designed to look at various Permian outcrops in the Guadalupe Mountain National Park (GMNP), the Carlsbad Caverns National Park (CCNP), and the surrounding areas. We are grateful for both parks for granting educational fee waivers. Outcrops visited include Permian deep basin deposits, Capitan shelf margin carbonates, reef deposits, back reef environment and the evaporate deposits that filled the basin by the latest Permian. The cave at CCNP that formed after the basin was uplifted gave the group a chance to walk "inside" the reef deposits. The following pages are a summary of some of the outcrops visited, from the deep basin to the back reef environment, in geological order.







Captions: 1. Sunset view over what was formerly a coastline of the Delaware Basin during the Permian Period (viewed from Carlsbad Caverns visitor center). 2-4. Block diagrams from the exhibits at the CCNP showing the map and cross section views of the northern end of the Delaware Basin as it evolved through time. In the late Permian, shallow lagoons were fronted by shoals on the outer margin adjacent to the Capitan reef at the platform margin that transitioned to a steep fore-reef slope (2). At the end of the Permian, the evaporites filled the shoaling Delaware Basin as a result of restricted connection to the global ocean during an interval of relatively low sea level (3), and today (4) after the Permian basin was uplifted, the exposures partly eroded and the caverns formed. The field trip was designed to look at the deposits from these three stages. All photos are from Warny unless photo credits (PC) are otherwise indicated.

The following information is taken from the Guide to the Permian Reef Geology Trail by Bebout, Kerans and Harris (available online at www.nps.gov).

The Permian Reef Geology Trail in the McKittrick Canyon, Guadalupe Mountains National Park, traverses 610 vertical meters (2,000 ft, or 1,520 to 2,130 m [5,000 to 7,000 ft] topographic elevation) of Permian (upper Guadalupian) sediment facies through one of the world's finest exposed examples of a rimmed carbonate platform margin. The present-day topography approximates that originally formed by the Capitan reef along the edge of the Delaware Basin. Encouraged by geologists from geological societies, universities, the petroleum industry, and the U.S. Geological Survey, the U.S. National Park Service constructed the Permian Reef Geology Trail in the early 1980's to provide better access to the depositional facies and diagenetic features of this shelf margin.

The Capitan reef and its associated upper Guadalupian carbonate platform define the margin of the Delaware Basin of West Texas and New Mexico. Most of the reef that rims the Delaware Basin is buried; however, Basin and Range-related tilted fault blocks in the Guadalupe, Apache, and Glass Mountains provide Capitan reef outcrops along parts of the western and southern sides of the basin. The Guadalupe Mountains exposures are the most accessible.

The west flank of the southern Guadalupe Mountains is a fault scarp that exposes the reef and its basin equivalents in cross section view more than 300 m (>1,000 ft) in the vertical dimension and several miles in the dip dimension.

The east side represents an erosionally modified depositional profile of the shelf-to-basin system that was exhumed during late Cenozoic uplift of the Mountains. Canyons, such as McKittrick Canyon, that cut into the platform give access to cross-sectional views. South of McKittrick Canyon, topset beds are largely eroded; north of McKittrick Canyon, most canyons do not incise deeply enough to expose bottomset beds. However, McKittrick Canyon exposes nearly the complete platform and basin cross section.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Captions: 5. View of the southern-most peak of the Permian reef, named El Capitan. This is the best view driving from Van Horn, TX towards the GMNP (PC Oscar Molina). 6. Outcrop showing the contact between deposits of toe-of-slope in the deep basin. The section contains debris flows and other mass flows intercalated with carbonate deep deposits (PC Joseph Honings). 7. Group looking at the first slope deposits in the GMNP McKittrick Canyon Permian Trail.

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Captions: 8. View of the slope and reef deposits in the Permian Reef Trail (PRT) in the McKittrick Canyon (PC Oscar Molina). 9. Hiking towards stop 4 of the PRT. This outcrop shows several limestones, including wackestones and packstones representing the toe-of-slope sedimentation. These units are rich in fossils originated from the reef formation, and some brought there by mass flow processes. 10-12. A variety of fossils encountered during the hike. 10. Bryozoan. 11. Horn coral (PC Oscar Molina). 12. Sponge.

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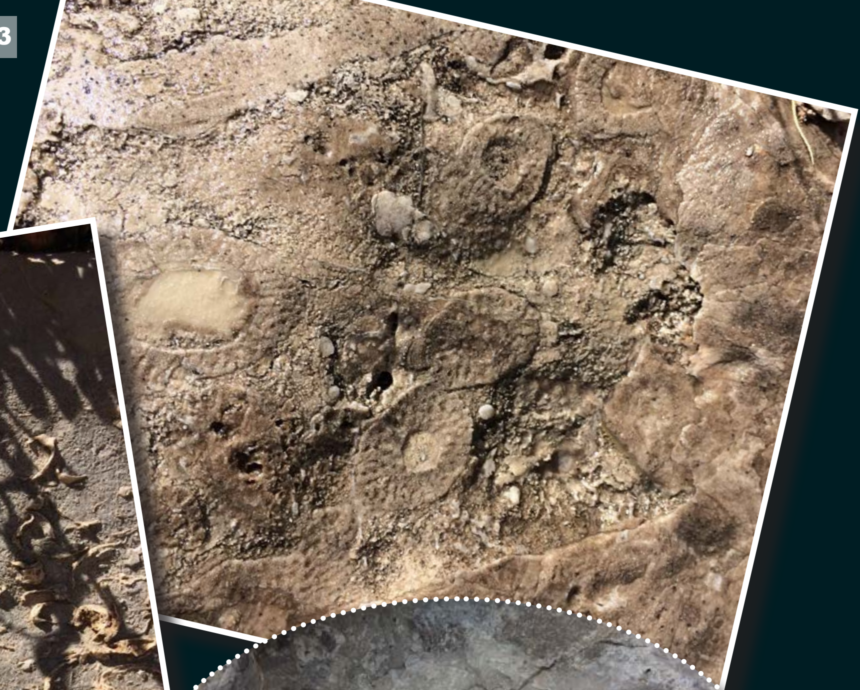

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Captions: 13-17. A variety of fossils photographed from the slope and reef deposits. 13. Sponges. 14. A slope-derived debris flow full of broken fossils, mostly brachiopods that are visible in outcrop. 15. Most likely a trilobite. These arthropods seem rare in the reef, which might not be surprising as they were not the most abundant life form in the Permian and became extinct at the Permo-Triassic (P/T) boundary. 16. Beautiful ammonoid in cross section. 17. Hundreds of fusulinid foraminifers. These single-celled organisms are excellent biostratigraphic markers for the Permian. They too became extinct at the P/T boundary.

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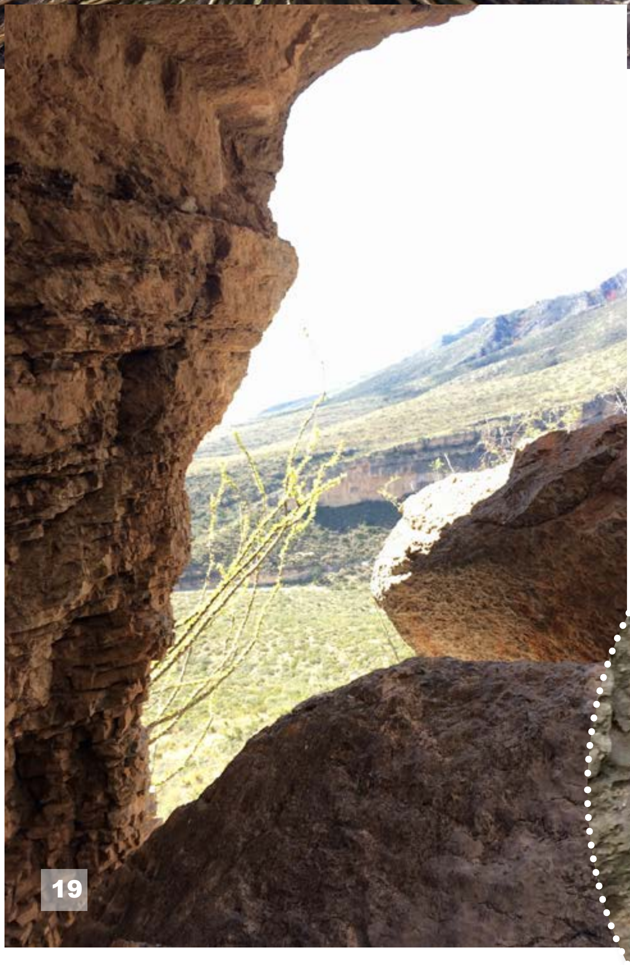

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Captions: 18. Group picture (PC Chang Liu). 19. Outcrop showing a thick section of densely burrowed wackestone. 20. Close up view of the weathered bedding plane showing filled cavity of worm-burrowed features called *Planolites*.

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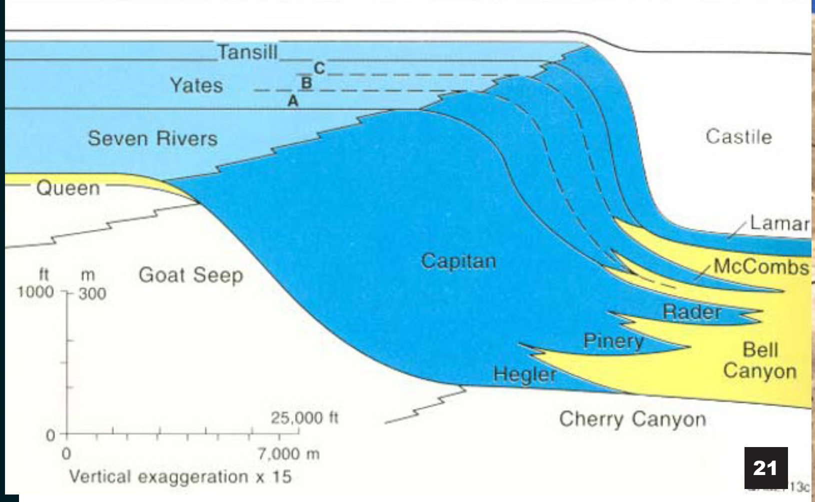
Captions: 21. Illustration from the “Guide to the Permian Reef Geology Trail” by Bebout and Kerans, 1993 (available on the UT BEG website).

This diagram features a cross section showing shelf-to-basin correlations of the Capitan Formation and equivalents.

Blue areas are dominantly carbonates and evaporites, and yellow areas are mostly siltstone and sandstone (modified from Garber and others, 1989).

22-23. These outcrop views are taken in the Tansill/Yates Formations in the back reef environment. The deposits are particularly visible in the CCNP. Clues to a shallower environment of deposition include teepee structures (22) and oolitic limestone full of ooids coarsening up-section. These grains are known to form in shallow environment, under wave action, in warm waters.



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This information is taken from a guidebook by Scholle and others for an AAPG Field Seminar from El Paso to Carlsbad. The guide states that “Excellent exposures of the Castile Formation can be found in deep roadcuts” (such as the one we indeed examined near Whites City). The guide adds that “This unit is the oldest true Ochoan sediment in the region and conformably overlies the Guadalupian Bell Canyon Formation. The Castile is entirely confined to the Delaware basin and does not extend onto the adjacent shelf areas. It overlies a thin, limestone and siltstone/shale zone which may be a lateral facies equivalent of the very youngest part of the Capitan and Tansill Formations. The bulk of the Castile Formation itself consists of a thick section of laminated anhydrite with intervals of laminated halite. The Castile Formation has been reported to reach a maximum preserved thickness of 470 to 600 m (1,550 to 2,000 ft) in subsurface sections in the northeastern part of the Delaware basin (King, 1948, p. 89). The Castile Formation, then, represents an evaporite filling of the approximately 550 m (1,800 ft) deep basin existing at the end of Guadalupian time. Although there may have been some drop in basinal water levels, most of the Castile evaporites clearly were deposited in deep water (at least well below wave base) as indicated by the absence of shallow-water sedimentary structures in most intervals and the presence of fine-scale lamination. The laminae consist of regular (although variable thickness) alternations of white anhydrite laminae and darker laminae containing a mixture of organic matter (circa 1.5 percent average) and calcite.”

Captions: 24-25. At the end of the Permian, massive amount of evaporates were deposited and filled the Delaware and Midland Basins. These two photographs show a general view of a road-cut outcrop between the two parks (GMNP and CCNP) where some of the preserved Castile evaporites have been exposed(24), and a close up view of the fine-scale laminations within the Castile Formation at the same outcrop (25).

The following information was provided to us by the park: Carlsbad Caverns National Park was designated a World Heritage Site by the United Nations in 1995, confirming the worldwide significance of its spectacular natural resources. Caves of the Guadalupe Mountains are extraordinary in that a very aggressive “sulfuric acid bath” played a major role in cave development by dissolving limestone from the top downward through the water table. The Permian Basin of western Texas and southeastern New Mexico contains some of the country’s most prolific oil fields. During the late Tertiary period (perhaps as late as 12 million years ago), hydrogen sulfide began migrating upward from these petroleum reservoirs deep under the Capitan Limestone. When the upwelling hydrogen sulfide rich water met with groundwater, it combined with oxygen in the water table to form sulfuric acid. Highly aggressive dissolution of limestone thus occurred at the water table. This unusual sulfuric acid mechanism is responsible for time-transgressive erosion of these very large connected chambers that were progressively eroded as the region was uplifted. One of the clues which led geologists to the development of the sulfuric acid theory is the presence in most caves here of the mineral gypsum. Gypsum is produced as a chemical by-product of the reaction between the sulfuric acid and limestone during dissolution. This soft white mineral coats the walls in many parts of the cave.

A more recent episode of uplift placed the flooded cavity well above the water table, and speleothems start precipitating. The widespread and ongoing growth of cave decorations, or speleothems, found in Carlsbad Caverns did not begin to form until the cave chambers were well drained of the “acid bath.” The natural entrance to the cave formed within the last million years by erosion and collapse of the hillside. The entrance allowed air from the surface to circulate through the cave. As rainwater and snowmelt percolates downward, it picks up carbon dioxide from the air and soil to form a mild carbonic acid. The mild acidity of the surface water allows it to dissolve some of the limestone it encounters on its way down. When the mineral-laden water reaches the open void of a cave, it forms a drop on the ceiling. The carbon dioxide in the water is released, making the water saturated with respect to the dissolved calcite. In order to reach equilibrium with the cave air, the water must unload the mineral. When the water evaporates or drops off the ceiling, a small mineral deposit is left behind. Drip by drip, these deposits will form a stalactite on the ceiling. The water that falls to the floor may also carry minerals which are precipitated on the floor, eventually creating stalagmites.

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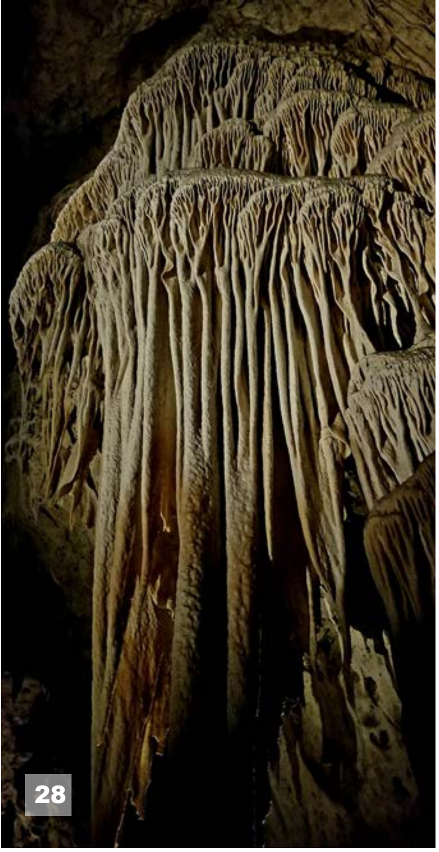
Captions: 26. View of the natural entrance of the Carlsbad Caverns (PC Oscar Molina). This entrance is also famous for the “bat flight” that occurs every evening during the summer and fall as the bat fly out of the cave by the thousands. 27. Close up view of some of the speleothems deposited in the cavern (PC Connor Matherne). A variety of columns, stalagtites, stalagmites, soda straws, and popcorn structures are visible.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Captions: 28. Photograph of the draperies, a sheet-like speleothem structure (PC Connor Matherne). 29. One of the rare areas in the cavern where water still forms ponds (PC Connor Matherne). 30. Students working together to photograph some of the Capitan Reef fossils visible in some areas of the cavern not covered by the many speleothems (PC Oscar Molina). 31. A rare trilobite visible in the cavern. 32. A cephalopod in the wall of the cavern, near the natural entrance (PC Vann Smith).


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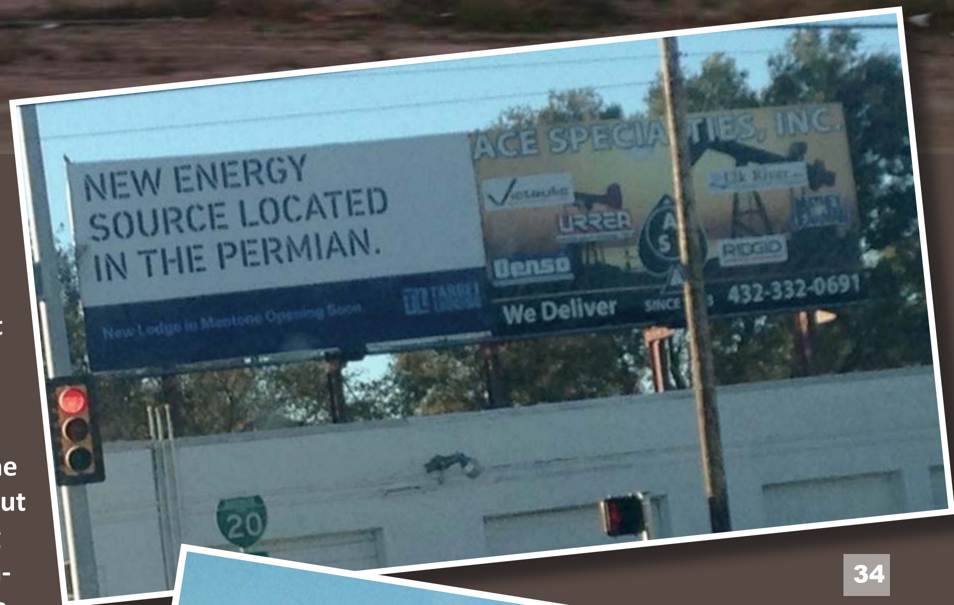
Captions: 33-36. Various views of oil and gas operations along the drive from Whites City, NM to Pecos, TX. These photographs were taken along RM652. The images depict the more applied side of the geology of the region. In a June 2018 report, CNBC journalist Tom DiChristopher wrote: “Today, the Permian Basin in Texas and New Mexico is the nation’s biggest shale oil producing region. But in just a few years, drillers could be pumping enough Permian crude to outmatch every nation in the world except Russia and Saudi Arabia. Output from the region is forecast to more than double between 2017 and 2023, jumping to 5.4 million barrels a day, according to a new estimate from IHS Markit.”

On their website, Chevron, one of the companies committed to the Permian for a longtime, indicates that their Permian production amounted to 119,000 net (Chevron share) barrels of crude oil, 383 million cubic feet of natural gas and 45,000 barrels of natural gas liquids daily in 2017.



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