

# **PS Grayburg Formation Reservoir-Scale Architecture and Sequence Stratigraphy, Permian Basin\***

**Robert F. Lindsay<sup>1</sup>**

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## **Abstract**

A regional study was conducted on the Lower Middle Permian (Guadalupian) Grayburg Formation, a mixed carbonate (dominant)-siliciclastic (subordinate) composite sequence. The Grayburg was studied in the: 1) type section, Northwest Shelf; 2) Guadalupe Mountains; 3) Apache Mountains; 4) Eunice Monument complex of unitized oil fields, northwest Central Basin Platform (CBP); and 5) McElroy Field, southeast CBP. All of these areas have been correlated in strike and dip view. Reference sections have been proposed for each area. Grayburg Formation is composed of six proposed members, which in stratigraphic order from base to top are: 1) Premier Sandstone Member; 2) Lower Dolostone Member; 3) Metex Dolostone and Sandstone Member; 4) Loco Hills Sandstone Member; 5) Upper Dolostone Member; and 6) Stone Canyon Dolostone and Sandstone Member. Hierarchy of Grayburg Formation sequence stratigraphy is: 1) one composite sequence; 2) two simple sequences; 3) 10 high frequency sequences; 4) 21+ cycle sets; 5) 82+ cycles; 6) numerous beds/lamina. Bedding, cyclicity, and rock types change systematically down-dip to up-dip via changes in accommodation space, wave/storm energy, and tectonics. High resolution sequence stratigraphy of one apparent cycle, utilizing 20 closely spaced measured sections in the Guadalupe Mountains, identified five shingled cycles from up-dip to down-dip in a distance of 3,333 m (10,935 ft), which identified more cyclicity than individual vertical measured sections suggest. Deposition was upon a tectonically modified, distally steepened ramp in an: 1) inner ramp (non-reservoir–lateral seal); 2) ramp crest shoal (reservoir); 3) middle ramp (reservoir), and outer ramp (non-reservoir) depositional setting. The inner ramp was evaporitic. The ramp crest contains peloid-oid dolopackstone-dolograinstone. The middle ramp contains fusulinid-poor and fusulinid-rich strata. The outer ramp contains solitary sponges, small sponge clusters (1 m, 3 ft), and massive sponge baffestone. Most of the outer ramp and part of the middle ramp was eroded during post-Grayburg Formation subaerial exposure in the Delaware Basin. Sequence stratigraphy has been found to be highly useful in helping solve day-to-day production-related problems in Grayburg Formation oil fields.

## **References Cited**

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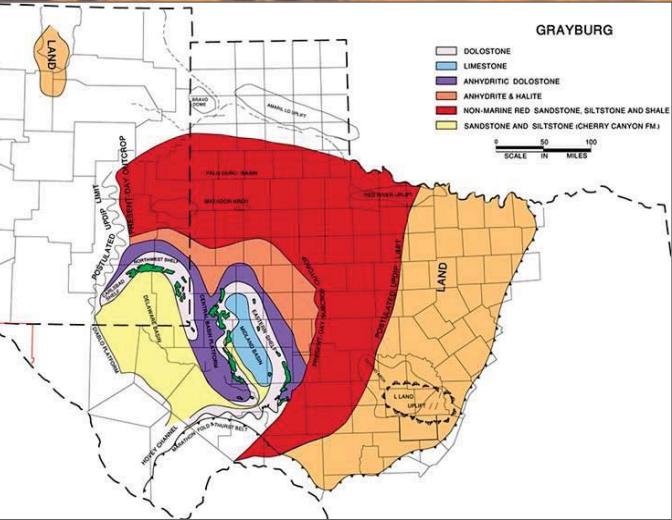
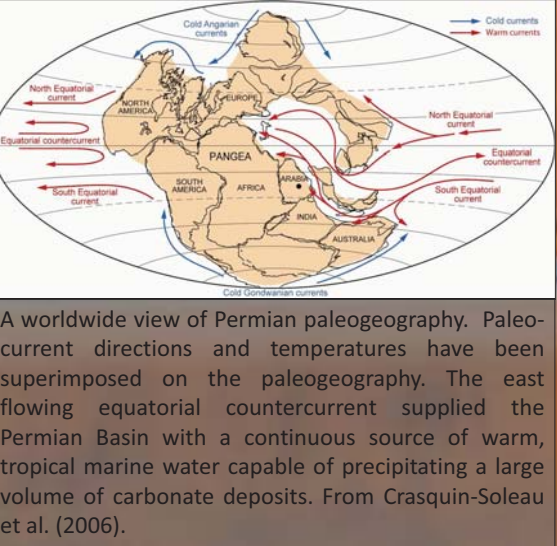
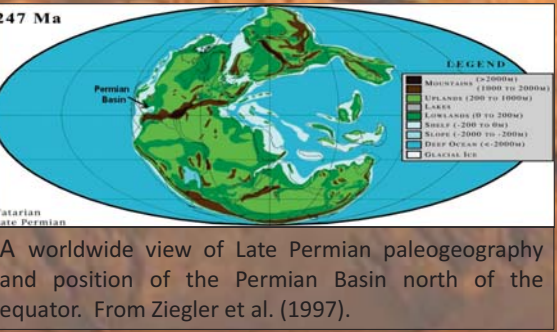
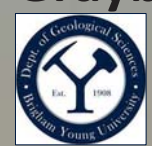
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Deposition was upon a tectonically modified, distally steepened ramp in an: 1) inner ramp (non-reservoir–lateral seal); 2) ramp crest shoal (reservoir); 3) middle ramp (reservoir), and outer ramp (non-reservoir) depositional setting. The inner ramp was evaporitic. The ramp crest contains peloid-oid dolopackstone-dolograinstone. The middle ramp contains fusulinid-poor and fusulinid-rich strata. The outer ramp contains solitary sponges, small sponge clusters (1 m, 3 ft), and massive sponge bafflestone. Most of the outer ramp and part of the middle ramp was eroded during post-Grayburg Formation subaerial exposure in the Delaware Basin.

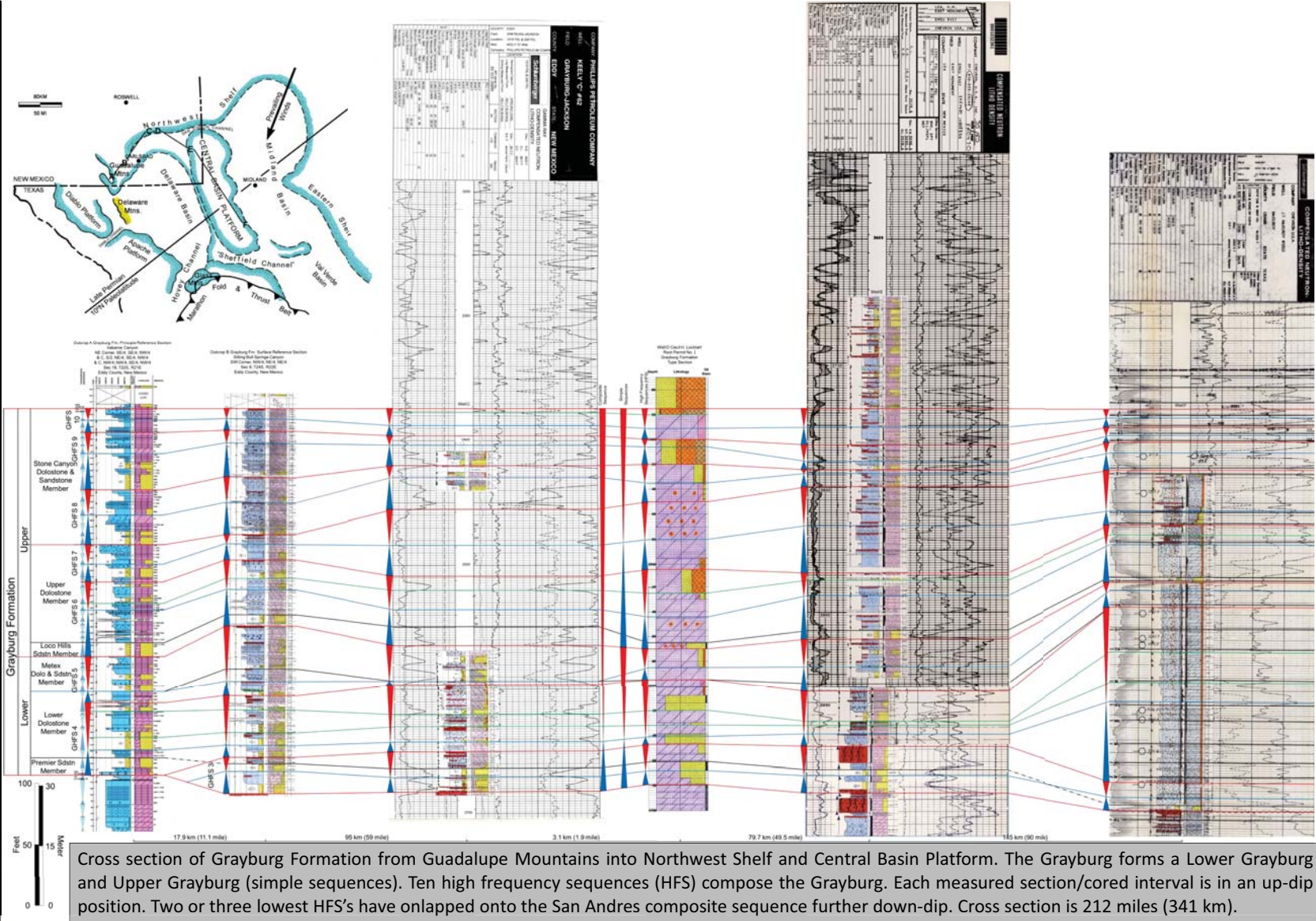
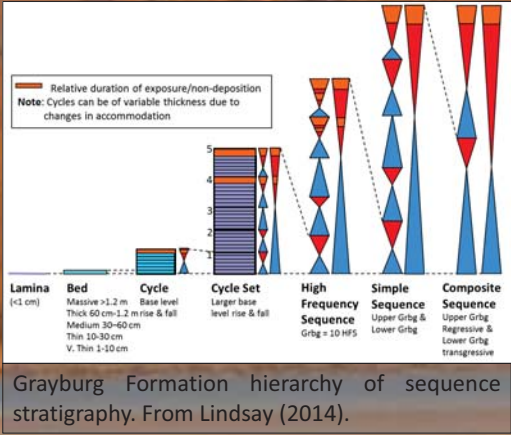
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# Grayburg Formation Reservoir-Scale Architecture and Sequence Stratigraphy, Permian Basin

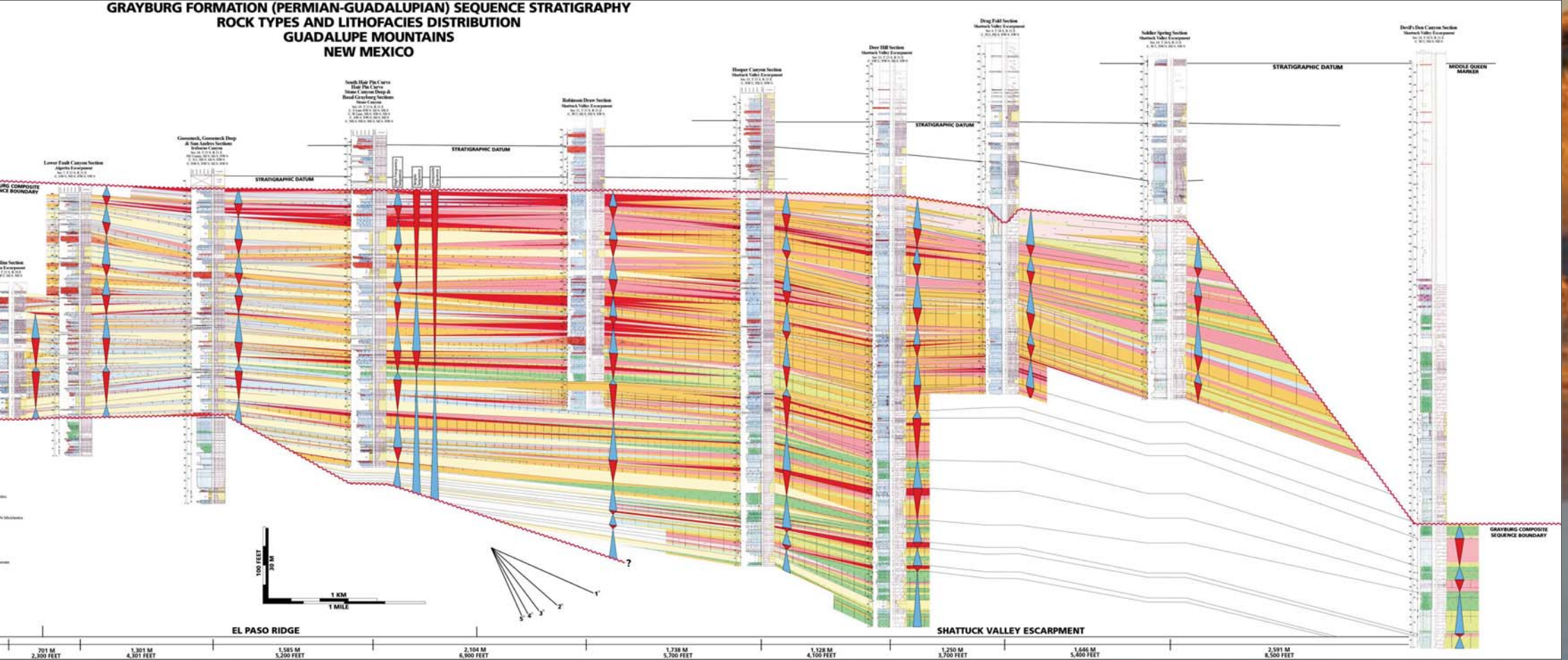
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Grayburg Formation paleogeography during the Middle Permian. Grayburg oil fields (green) are shown and are combination structural-stratigraphic traps. Blue=basin limestone (Midland Basin). Light purple=ramp margin dolostones. Dark purple=inner ramp anhydritic dolostones. Orange=inner ramp anhydrite and halite. Red=non-marine red beds. From R.F. Ward et al. (1986) and Lindsay (2014).



Grayburg Formation dip-oriented cross section, with Grayburg high frequency sequences 1-10 (GHFS's 1-10) across the west side of Queen Plateau (Guadalupe Mountains). Measured sections are along Algerita Escarpment (up-dip, left), El Paso Ridge, and Shattuck Valley Escarpment (down-dip, right). GHFS's 1-10 contain an excellent record of inner ramp, ramp crest shoal, middle ramp, and potential outer ramp lithofacies. In the up-dip most areas covered slopes have hidden up-dip most inner ramp lithofacies. Lithofacies have been correlated and walked out between the measured sections. Note that GHFS's 1-3 onlap onto the Upper San Andres Formation composite sequence. GHFS 4 was the first to flood onto the ramp top. Distal inner ramp areas contain evaporite crystal molds in carbonate strata. Maximum flooding surfaces (MFS) were picked for each GHFS, with the MFS for the Lower Grayburg and Grayburg Formation composite sequence in GHFS 5. During highstand to lowstand time evaporite strata was deposited further up-dip in the proximal to medial part of the inner ramp. A series of datums within Grayburg Formation and lower Queen Formation strata were utilized. From Lindsay (2014).

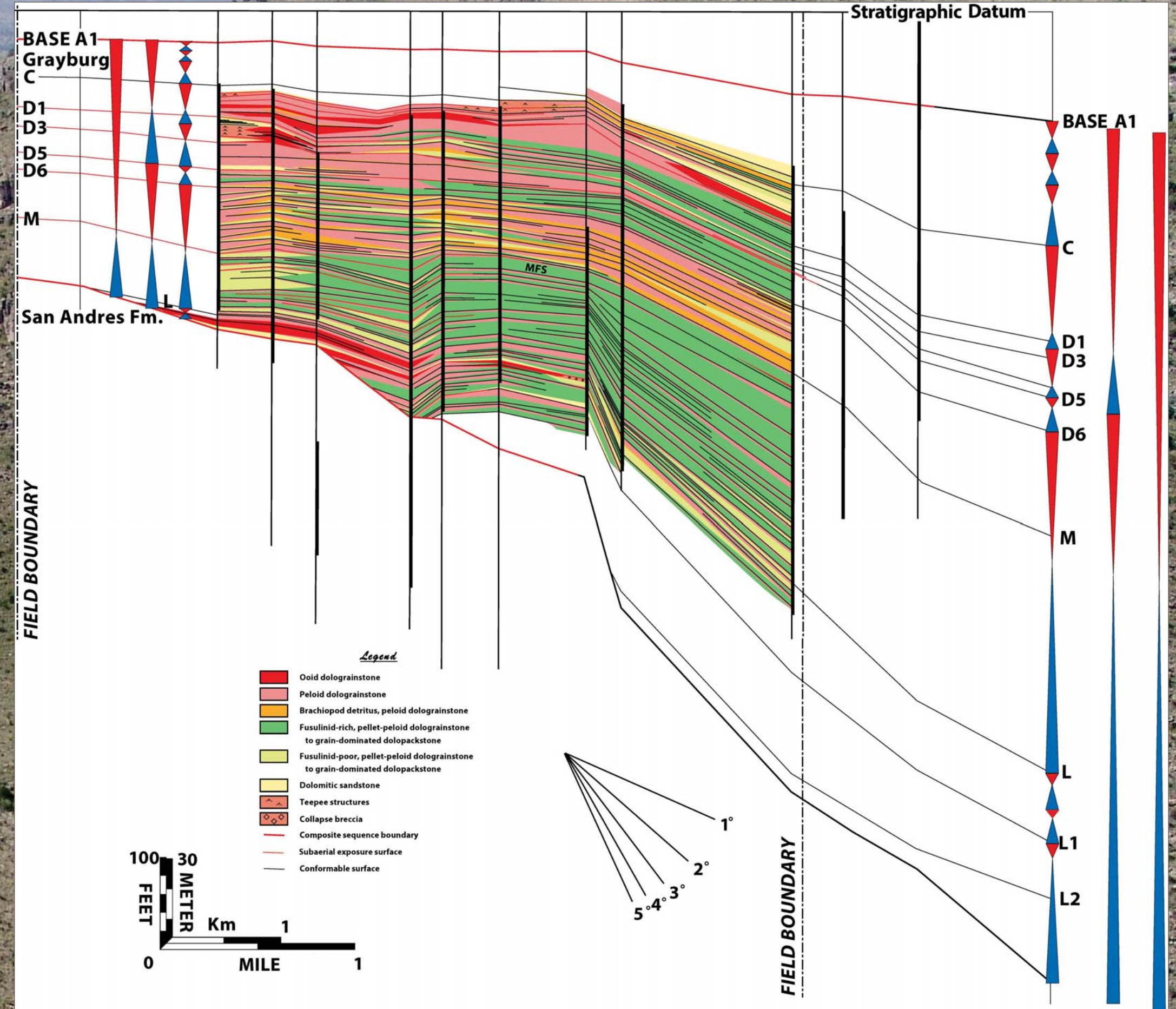
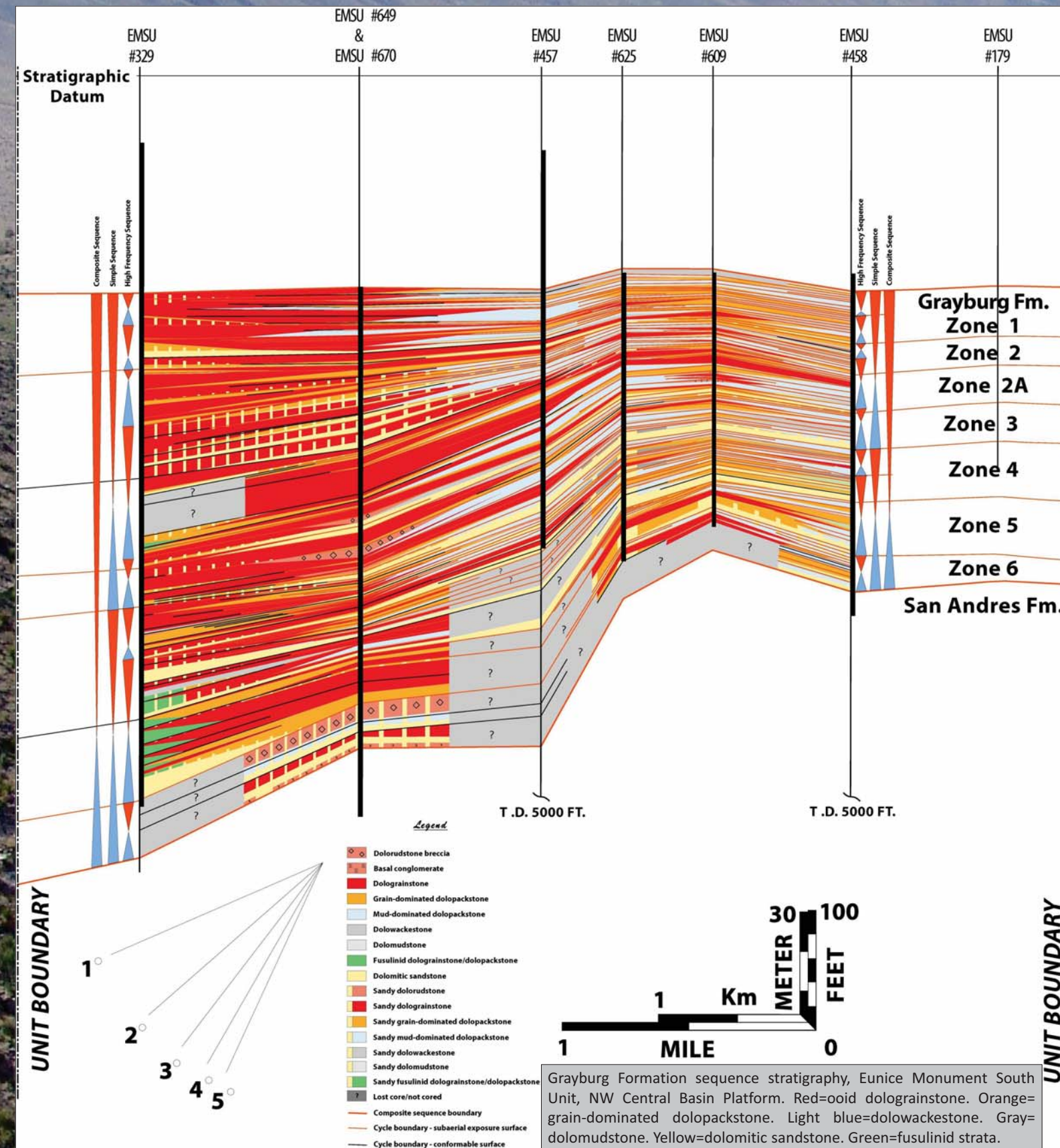




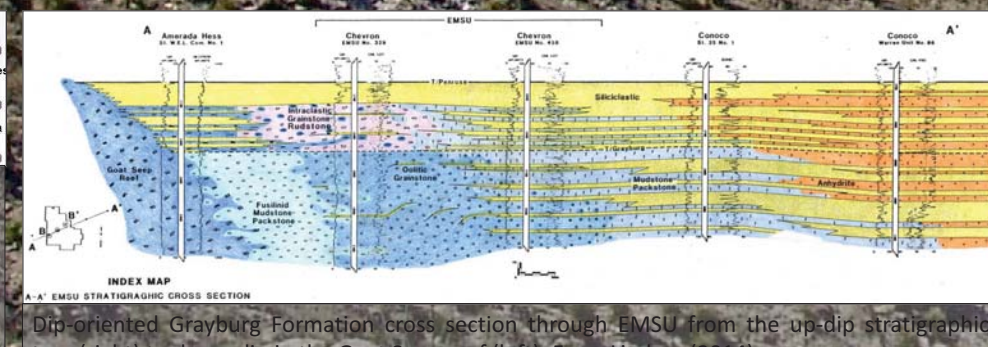
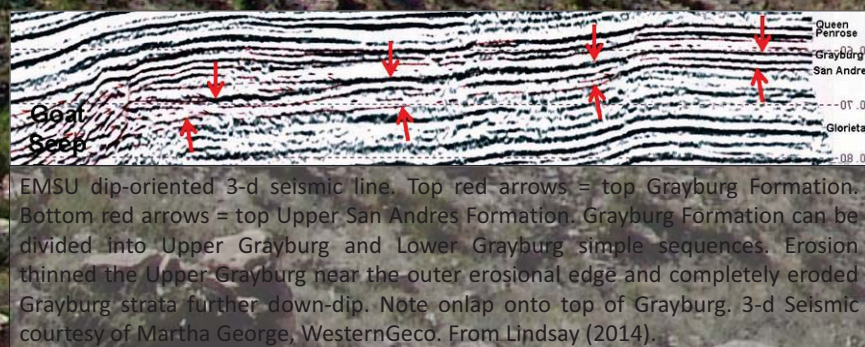
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Grayburg Formation dip-oriented sequence stratigraphic cross section, McElroy field, SW Central Basin Platform. Datum = McElroy marker. The Upper San Andres Formation composite sequence boundary (bottom line) downlaps (right) into the Midland Basin. Lower Grayburg Formation onlaps the Upper San Andres Formation composite sequence boundary. Top of the Upper San Andres Formation was subaerially exposed and karstified. Grayburg Formation composite sequence boundary is the top line beneath the stratigraphic datum. Note how the Grayburg Formation ramp distally steepened, with thicker strata down-dip. All of the stratigraphic markers are local markers used within McElroy field. The D5 stratigraphic marker can be correlated regionally and subdivides the Grayburg Formation into a Lower Grayburg simple sequence and Upper Grayburg simple sequence. There are three reservoir intervals within McElroy field. The lower reservoir is associated with onlapping strata. The main reservoir is in the upper part of the Lower Grayburg simple sequence. The upper reservoir is in the lower part of the Upper Grayburg simple sequence. Reservoir quality strata does not exist in the upper three high frequency sequences and form the initial vertical stratigraphic trap. From Lindsay (2014; 2016).





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## Conclusions

### Proximal Inner Ramp Stacking Pattern:

Top-Capped by a subaerial exposure surface  
Evaporite composed of anhydrite and halite  
Anhydritic, mud-dominated dolopackstone  
Base-Dolomitic sandstone

### Distal Inner Ramp Stacking Pattern:

Top-Capped by a subaerial exposure surface  
Sparsely sandy to non-sandy, mud to grain-dominated dolopackstone, anhydrite cemented, cross bedded to bioturbated, laminated to thin bedded  
Sparsely sandy to sandy, dolomudstone to dolowackestone, cross bedded to bioturbated, laminated to thin bedded  
Base-Dolomitic sandstone, cross bedded to bioturbated, laminated to thin bedded

### Ramp Crest Shoal Stacking Pattern:

Top-Capped by a subaerial exposure surface  
Sandy to non-sandy, teepee-intraclast-peloid-coated grain-oid grain-dominated dolopackstone to dolograinstone w/some dolorudstone, cross bedded to bioturbated, laminated to thick bedded

Peloid grain-dominated dolopackstone, cross bedded to bioturbated, laminated to thick bedded  
Sandy to non-sandy, peloid mud-dominated dolopackstone, cross bedded to bioturbated, laminated to thick bedded  
Base-Dolomitic sandstone, cross bedded to bioturbated, laminated to thick bedded

### Middle Ramp Stacking Pattern:

Top-Capped by conformable to occasional subaerial exposure surface  
Sparsely sandy, peloid grain-dominated dolopackstone to dolograinstone (proximal middle ramp)  
Fusulinid-poor, peloid grain-dominated dolopackstone to dolograinstone (down-dip part proximal middle ramp)  
Fusulinid-rich, peloid grain-dominated dolopackstone to dolograinstone (distal middle ramp)  
Base-Occasional dolomitic sandstone (less common)

### Outer Ramp Stacking Pattern:

Top-Capped by a conformable surface  
Peloid grain-dominated dolopackstone to dolograinstone  
Brachiopod detritus, peloid mud to grain-dominated dolopackstone to dolograinstone  
Fusulinid-poor, peloid grain-dominated dolopackstone to dolograinstone  
Sparse fusulinid-rich, peloid grain-dominated dolopackstone to dolograinstone  
Base-Sponge dolobafflestone to doloframestone to dolorudstone

Grayburg Formation high frequency sequences (GHFS's) and associated relative sea level fall:

Top Grayburg, GHFS 10; minimal fall=72 ft, maximum=205 ft

GHFS 9; minimal fall=18 ft, maximum fall=25 ft

GHFS 8; minimal fall=25 ft, maximum fall=95 ft

GHFS 7; minimal fall=32 ft, maximum fall=110 ft

GHFS 6; minimal fall=19 ft, maximum fall=110 ft

Top Lower Grayburg, GHFS 5; minimal fall=6.5 ft, maximum fall=135 ft

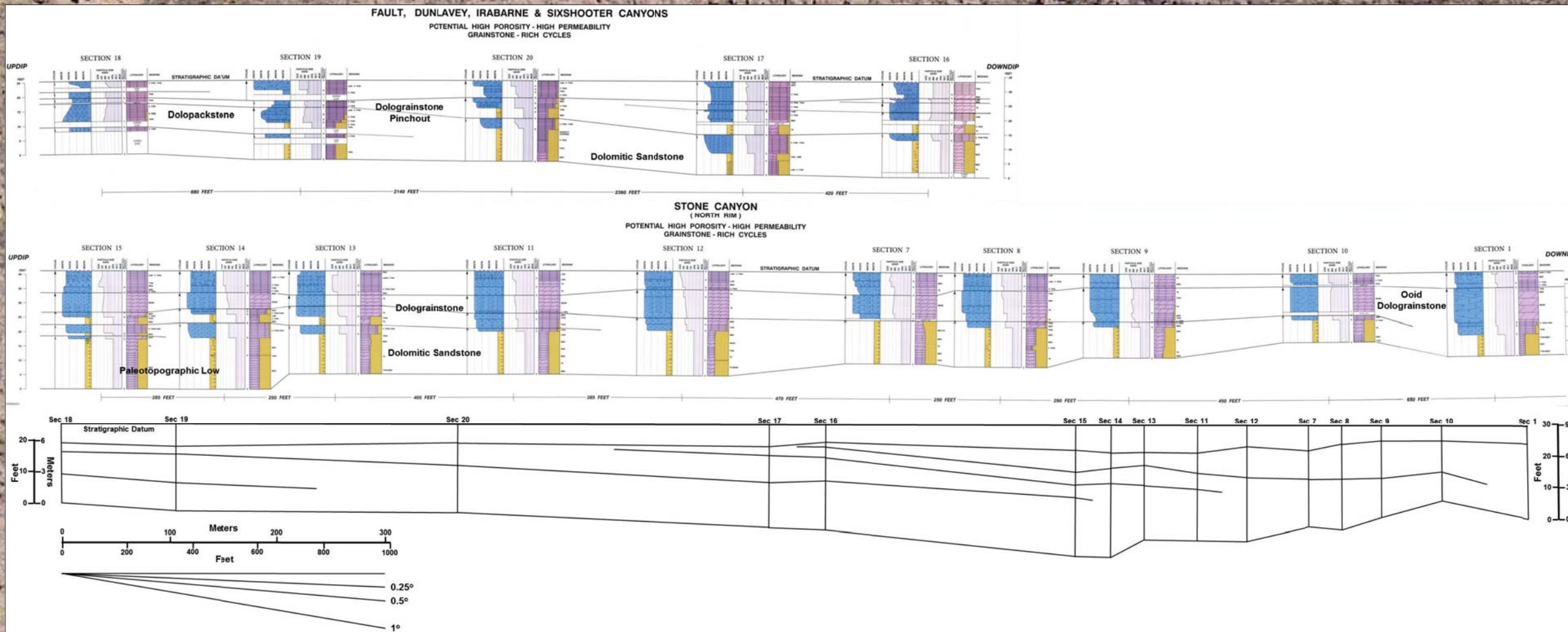
GHFS 4; minimal fall=6 ft, maximum fall=60 ft

GHFS 3; minimal fall=11 ft, maximum fall=31 ft

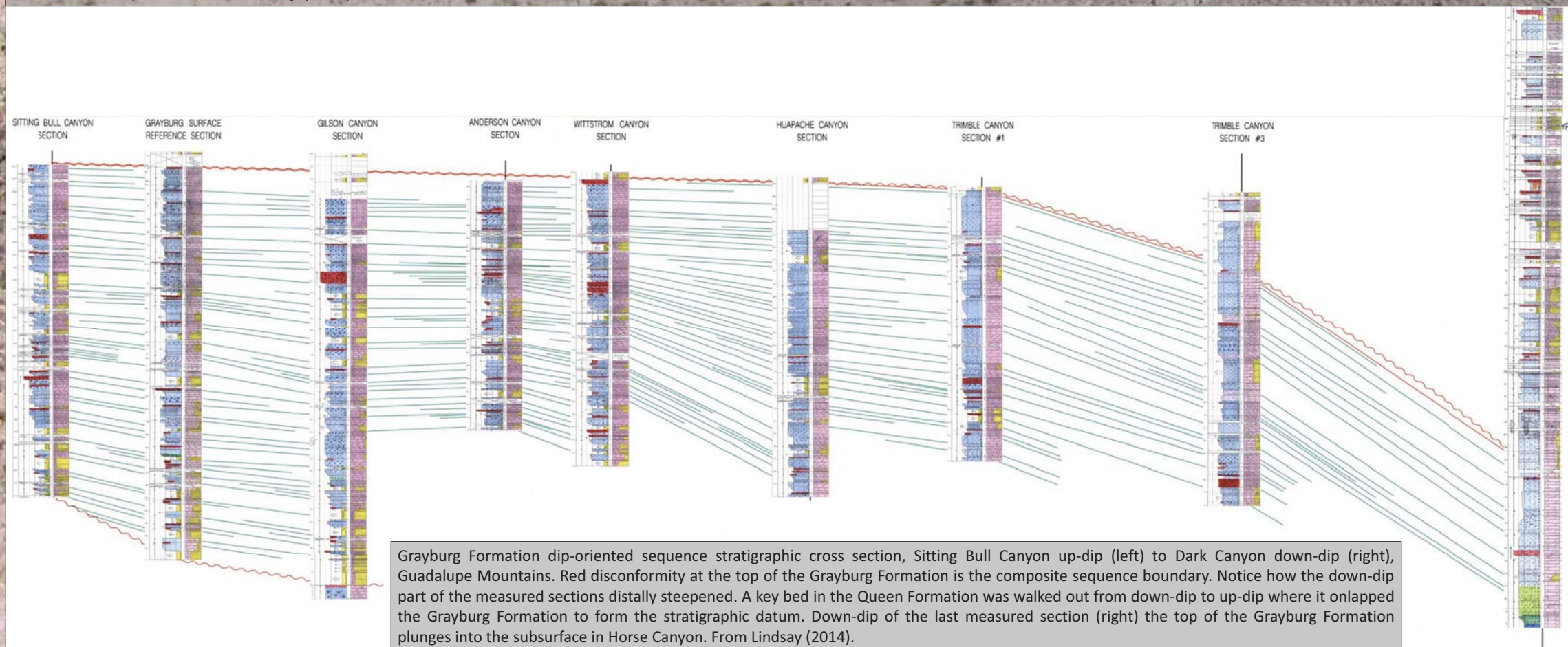
GHFS 2; minimal fall=36 ft, maximum fall=88 ft

GHFS 1; minimal fall=18 ft, maximum fall=29 ft

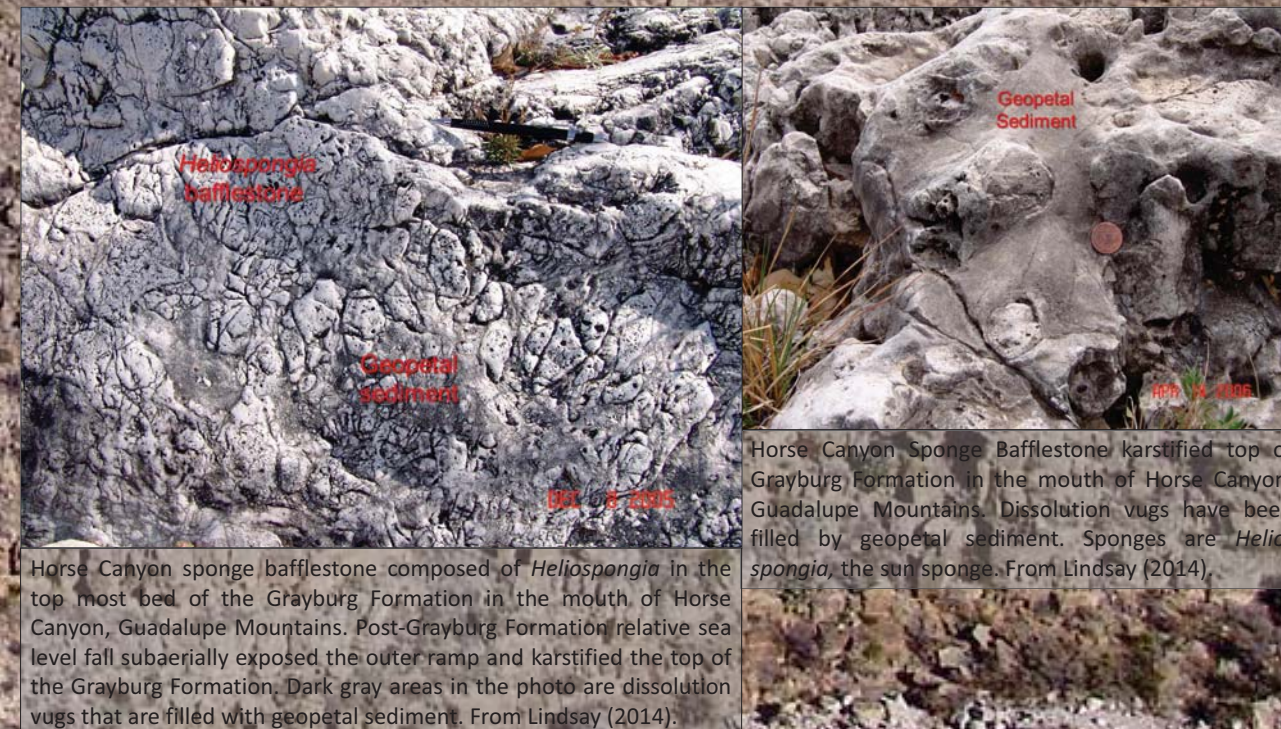
Top Upper San Andres; minimal fall=49 ft, maximum fall=147 ft



Dip-oriented Grayburg Formation measured sections through Lower Fault, Dunlavey, Irabarne, Sixshooter, and Stone canyons, Guadalupe Mountains. Measured sections are in GHFS 9-highstand systems tract of what appeared to be a few carbonate cycles. Up-dip is left. Down-dip is right. The lower "cycle" was studied in detail. The upper "cycle" was the stratigraphic datum. Gaps between the measured sections are canyons. Five down-lapping, low-angle carbonate cycles were identified in 10,935 ft. In any one location only one or a few cycles can be identified when in reality there are a series of cycles. One measured section only contains the minimum number of cycles and the total number of cycles is a larger number. The top and middle cross sections contain lateral variable scales. The bottom cross section contains a uniform lateral scale, with dip shown. Dolomitic sandstones (yellow) were deposited upon subaerial exposure surfaces and were reworked down-dip (right) during transgressions. During highstand deposition a series of low-angle clinoforms of grain-rich carbonate strata, five in total, were deposited. From Lindsay (2014).



Grayburg Formation dip-oriented sequence stratigraphic cross section, Sitting Bull Canyon up-dip (left) to Dark Canyon down-dip (right), Guadalupe Mountains. Red disconformity at the top of the Grayburg Formation is the composite sequence boundary. Notice how the down-dip part of the measured sections distally steepened. A key bed in the Queen Formation was walked out from down-dip to up-dip where it overlapped the Grayburg Formation to form the stratigraphic datum. Down-dip of the last measured section (right) the top of the Grayburg Formation plunges into the subsurface in Horse Canyon. From Lindsay (2014).



Horse Canyon sponge bafflesstone composed of *Heliospongia* in the top most bed of the Grayburg Formation in the mouth of Horse Canyon, Guadalupe Mountains. Post-Grayburg Formation relative sea level fall subaerially exposed the outer ramp and karstified the top of the Grayburg Formation. Dark gray areas in the photo are dissolution vugs that are filled with geopetal sediment. From Lindsay (2014).