Middle Pennsylvanian Paleogeography, by Ron Blakey

http://jan.ucc.nau.edu/~rcb7/ColoPlatPennDM.jpg *AND Blakey, R. and W. Ranney, 2008, Ancient Landscapes of the Colorado Plateau, Grand Canyon Association, 156pp.*

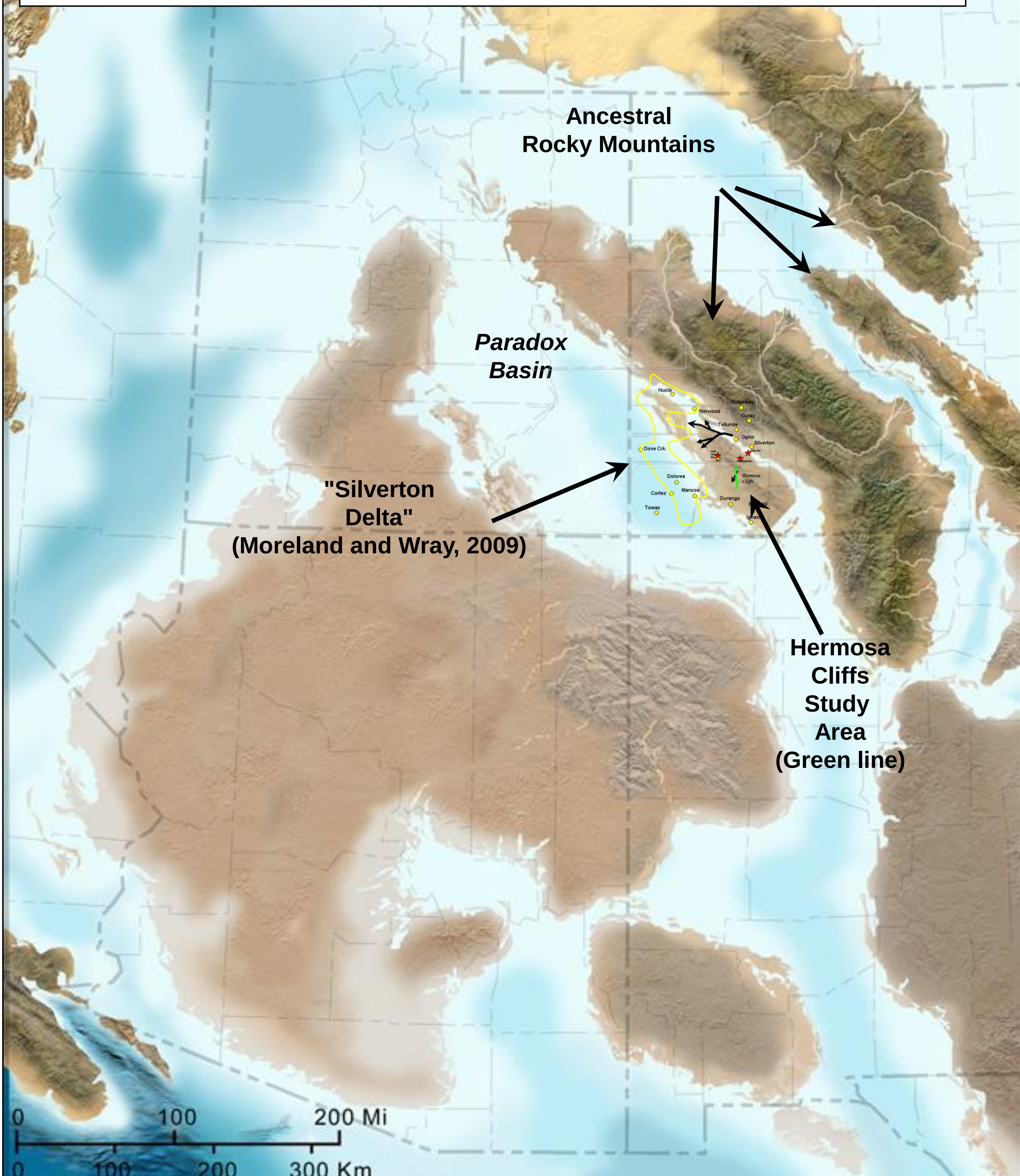


Figure 1. Location of Hermosa Cliffs study area with respect to the paleogeography of the Colorado Plateau and the location of the "Silverton Delta" from Moreland and Wray (2009). Miskell-Gerhardt, Gianniny and itter, 2010, RMS-AAPG 2010, Field Trip 1 Guidebook, The Pennsylvanian Hermosa Fm., from Shelf to Basin.

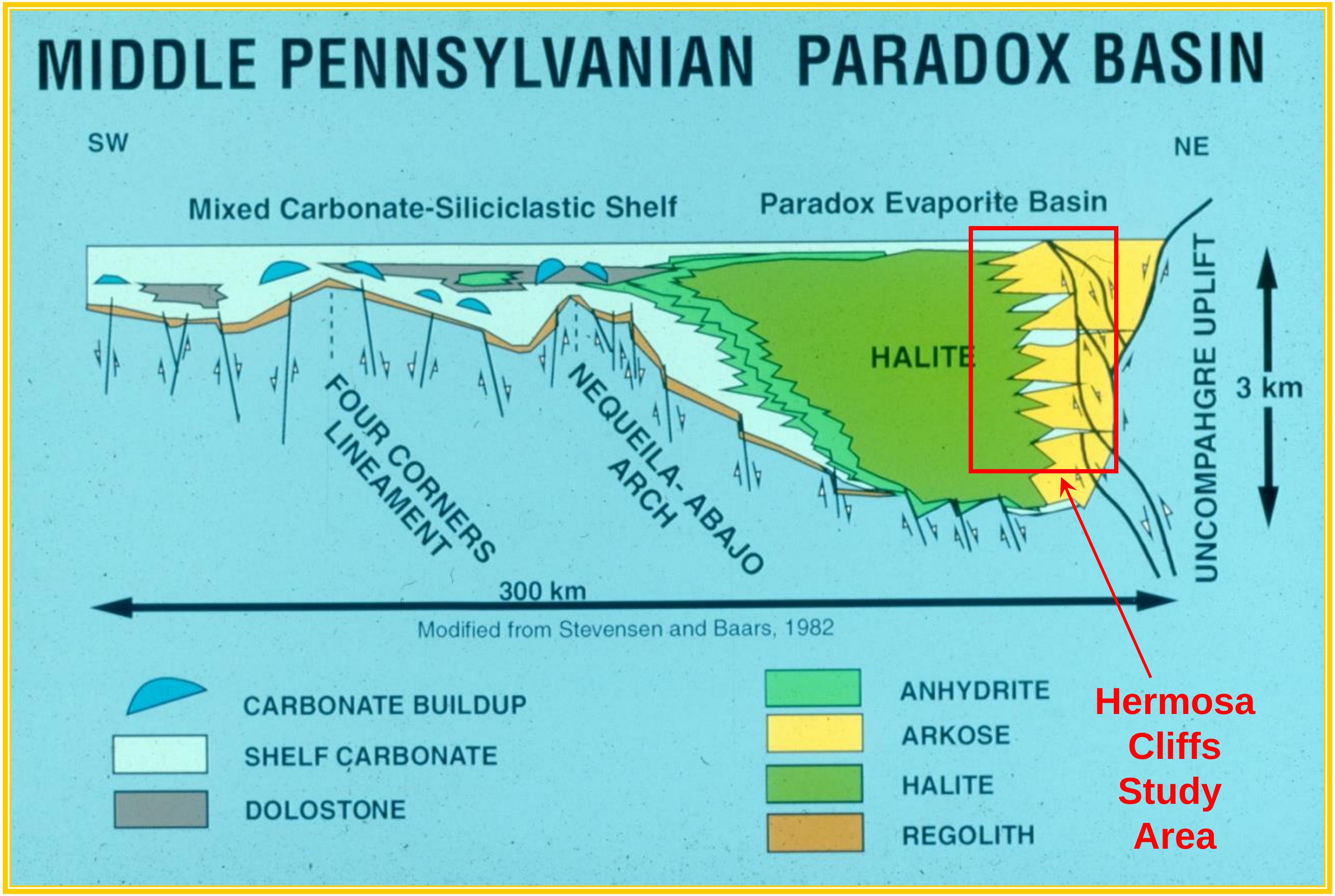


Figure 2. Cross-section through the Paradox Basin showing location the of the study area on the northeastern margin. Modified from Stevense and Baars, 1982.

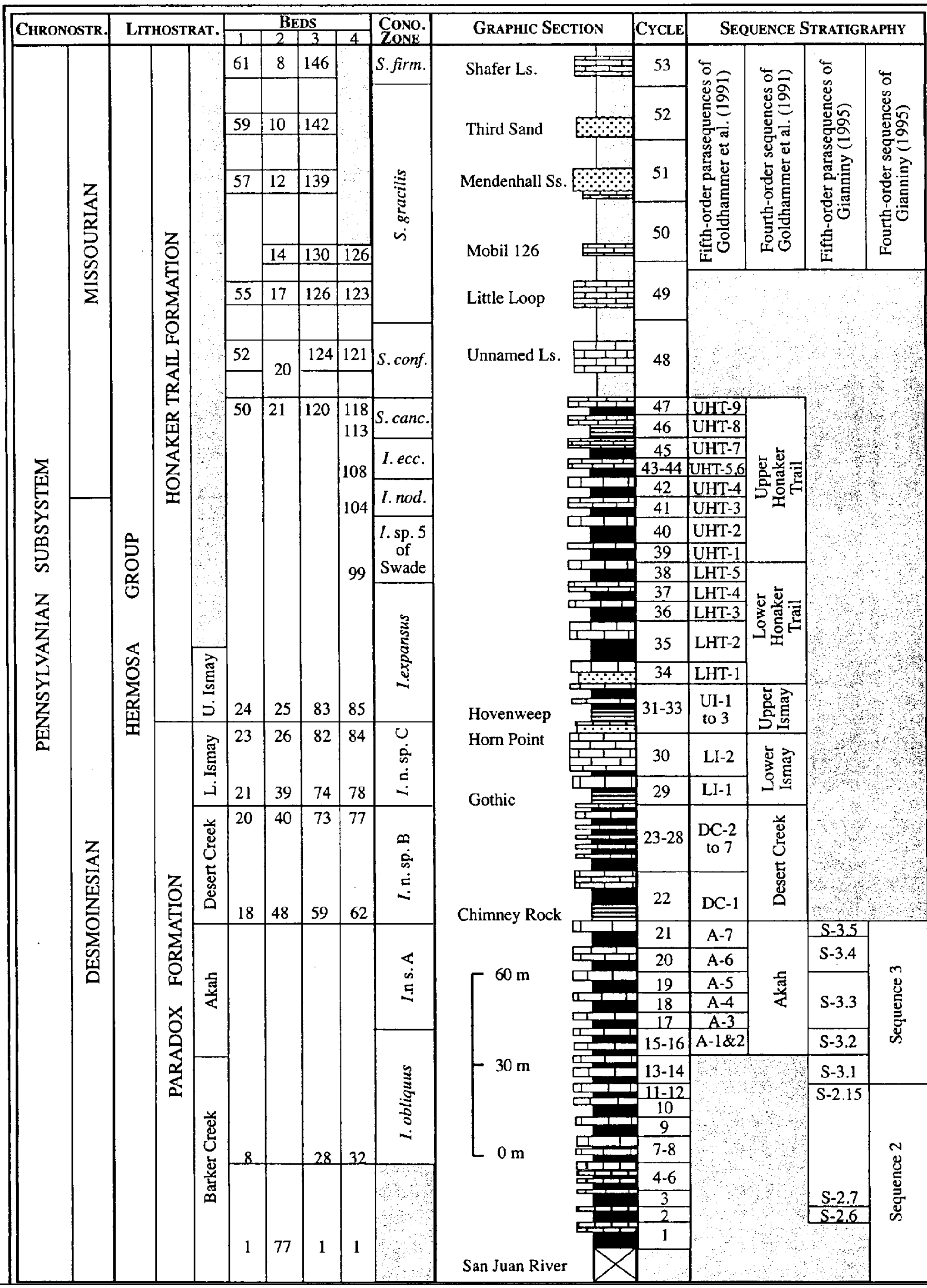


Figure 3. Biostratigraphic Chart of the Pennsylvanian Hermosa Group. From Ritter et al., 2002, Conodont Sequence Biostratigraphy of the Hermosa Group (Pennsylvanian) at Honaker Trail, Paradox Basin, Utah, Journal of Paleontology ,V. 76, No. 3, pp 495-517

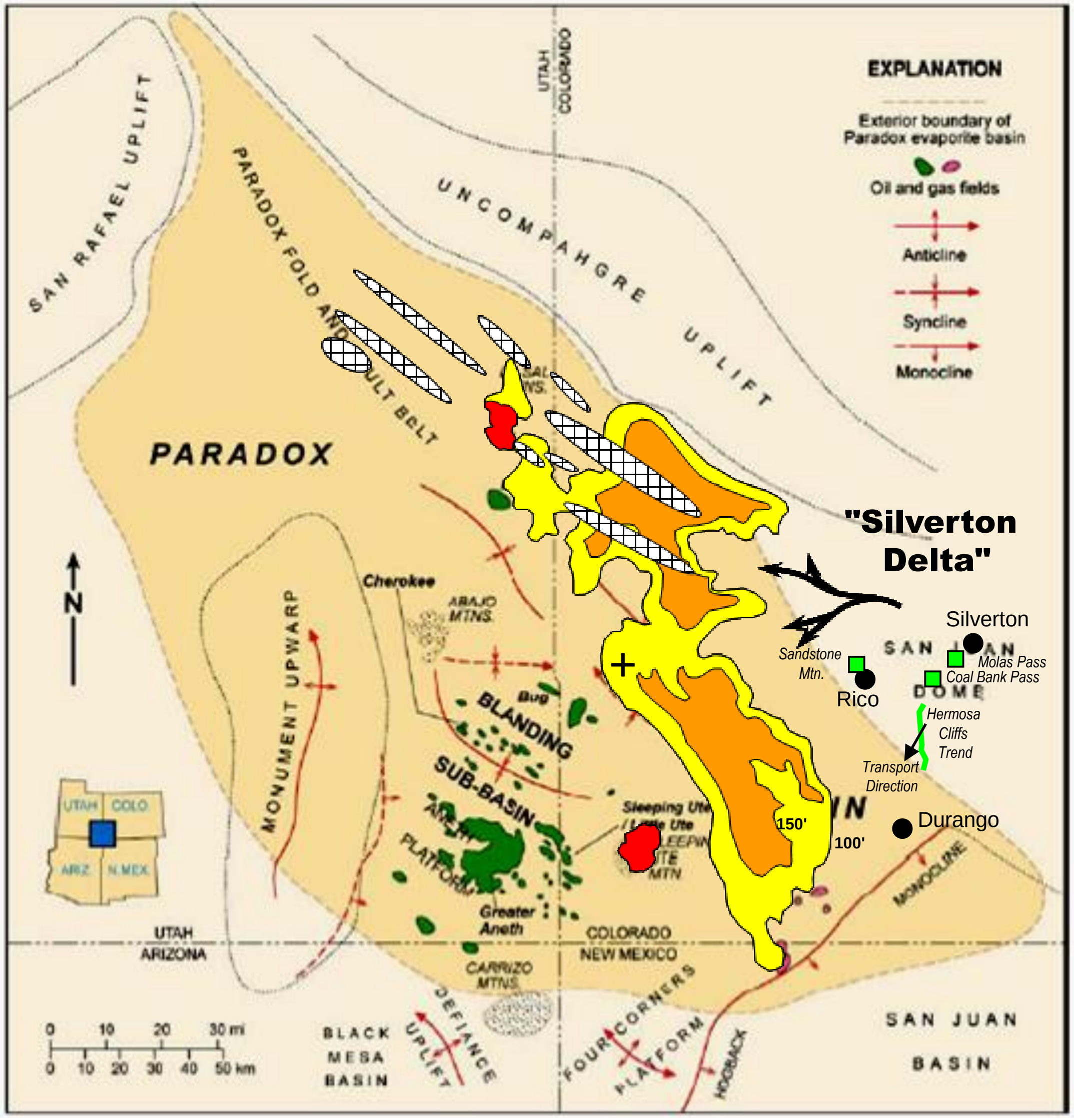


Figure 1. Location map of the Paradox Basin, Utah, Colorado, Arizona, and New Mexico showing producing oil and gas fields, the Paradox fold and fault belt, and Blanding sub-basin as well as surrounding Laramide basins and uplifts (modified from Harr, 1996).

+ = Bill Barrett Corp., Johnson-Alkali Cyn #1

Traditional Paradox Basin Field Map (Harr, 1996), as reproduced by Eby et al, 2003.

WITH

- Gothic Shale contours (100' & 150') from Moreland and Wray (2009). Bill Barrett Corp. and Williams O&G interpret the Gothic Shale as pro-deltaic mudstones associated with the "Silverton Delta". Their shale gas play area is within the 100' contour (yellow).

- Location of the Hermosa Cliffs study area (green N-S trend), Coal Bank Pass measured section, Molas Pass (bioherms) and Sandstone Mountain measured section at Rico (Tadero et al., 2010). Note that transport Directions seen in the field along the Hermosa Cliffs trend are to the S/SW, suggesting the fluvio-deltaic systems described in this area did not drain into the Silverton Delta.

Figure 4. Location of Study Area with respect to Paradox Basin Oil and Gas Plays

RMS-AAPG 2010
Field Trip 1, Day 1, Route Map

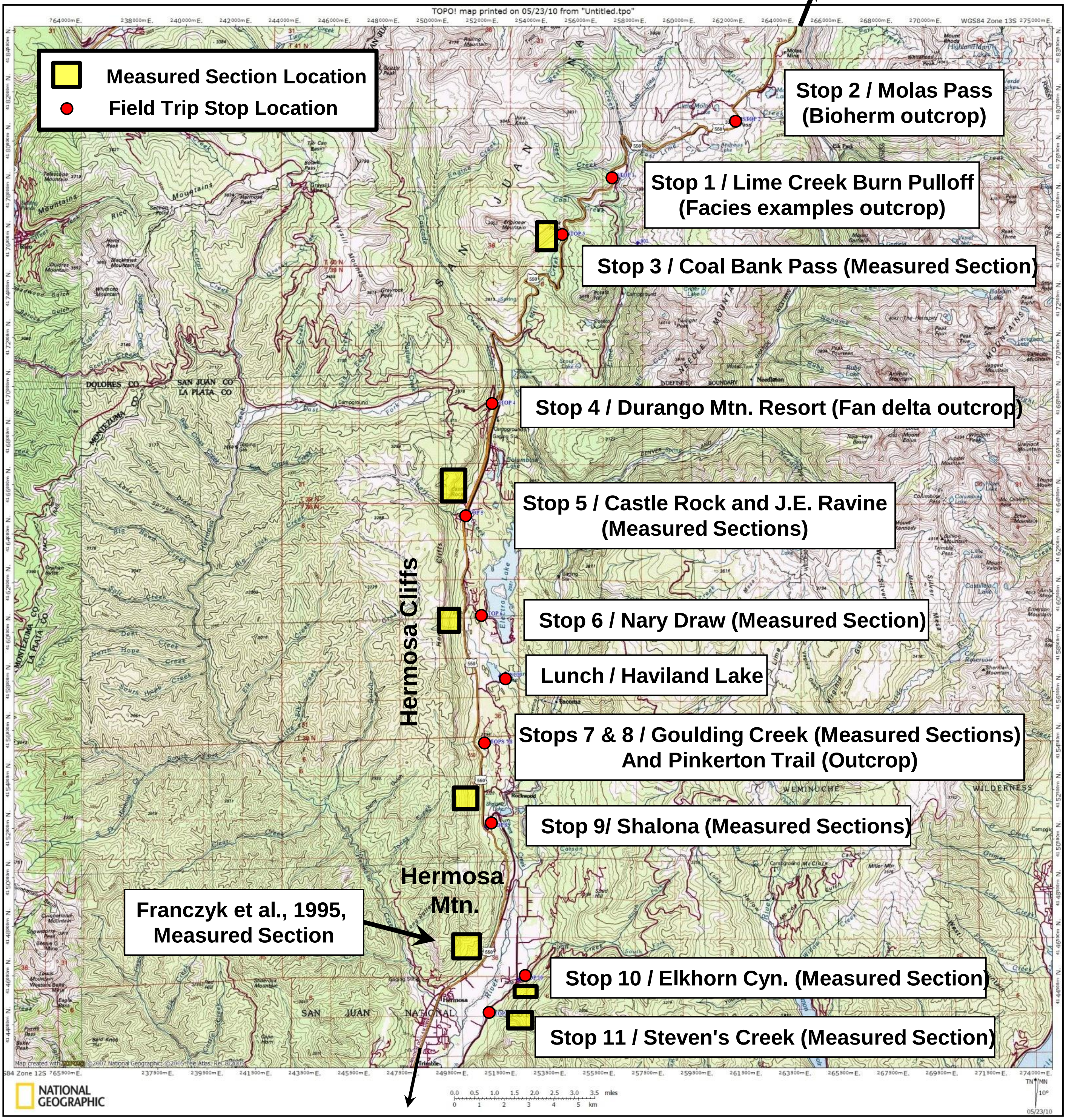
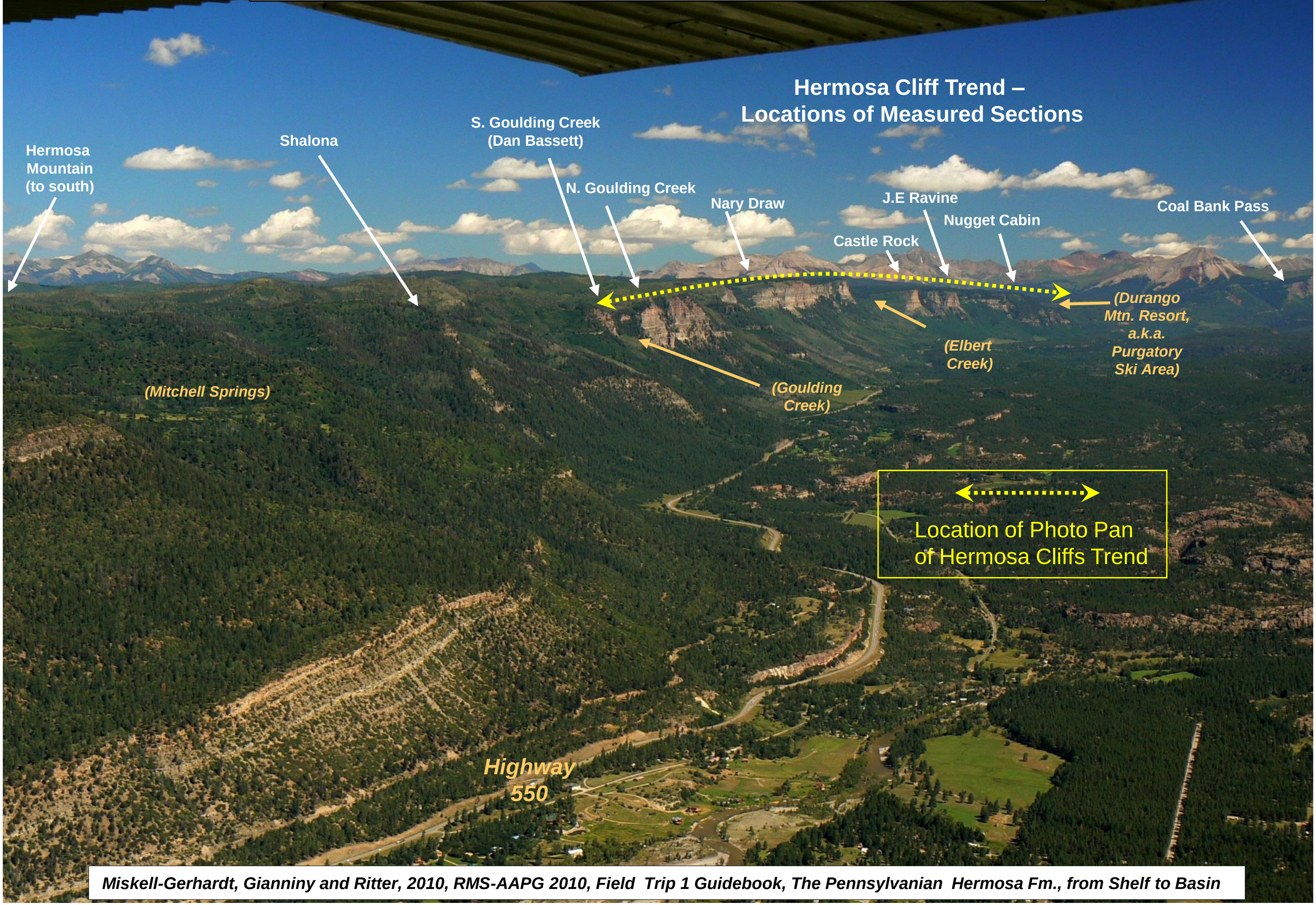


Figure 5, Locations of stops for day 1 of field trip 1, Miskell-Gerhardt, Gianniny and Ritter, 2010, RMS-AAPG 2010, The Pennsylvanian Hermosa Fm., from Shelf to Basin.

Figure 6, Location of Hermosa Cliffs trend and measured sections.
View North up Animas Valley from Hermosa to Coal Bank Pass



Miskell-Gerhardt, Gianniny and Ritter, 2010, RMS-AAPG 2010, Field Trip 1 Guidebook, The Pennsylvanian Hermosa Fm., from Shelf to Basin

Stratigraphic Summary of Hermosa Cliffs Trend from Measured Sections and Photo Panoramas

Kim Miskell-Gerhardt and Gary Gianniny, May 23, 2010

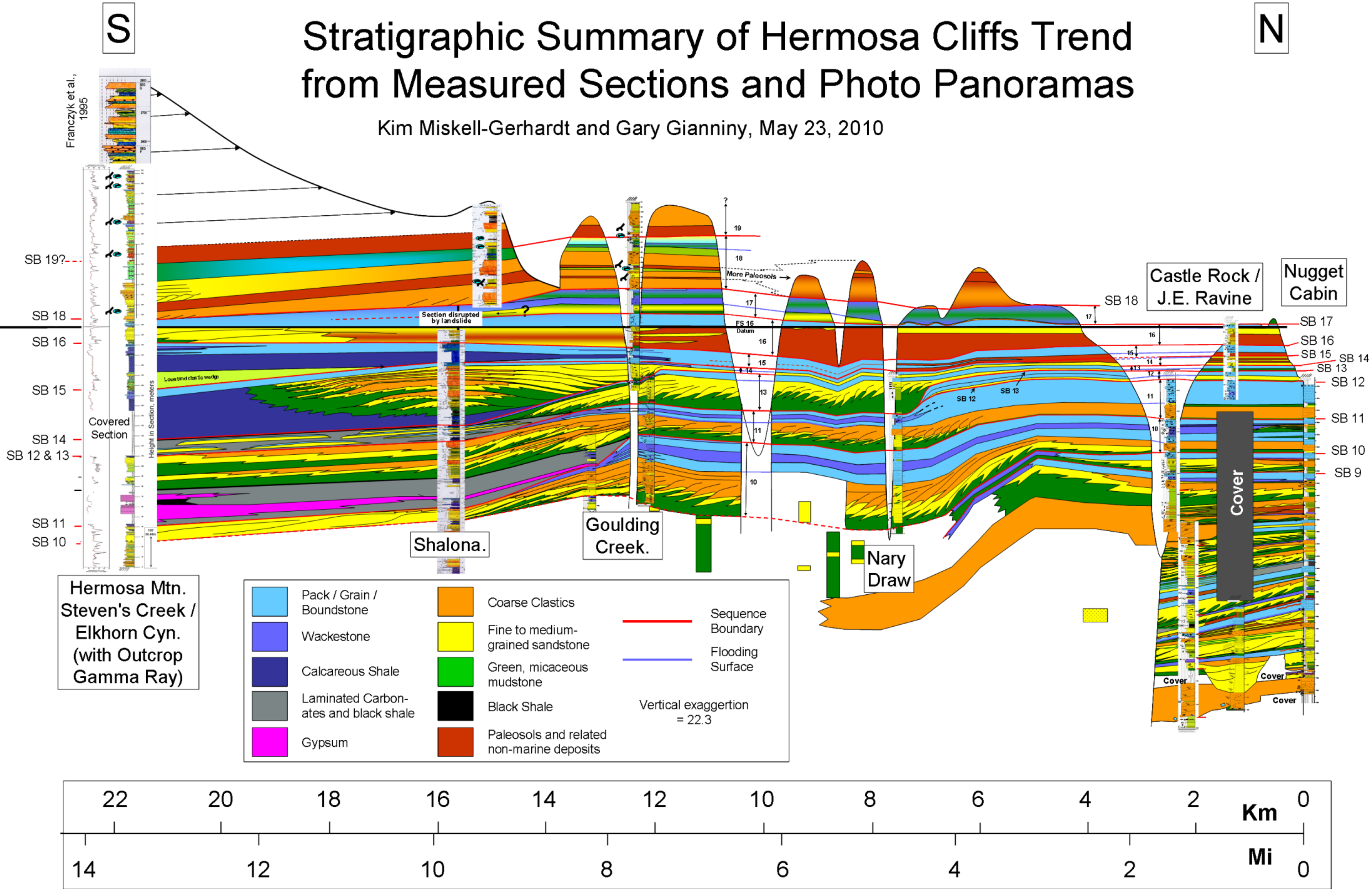
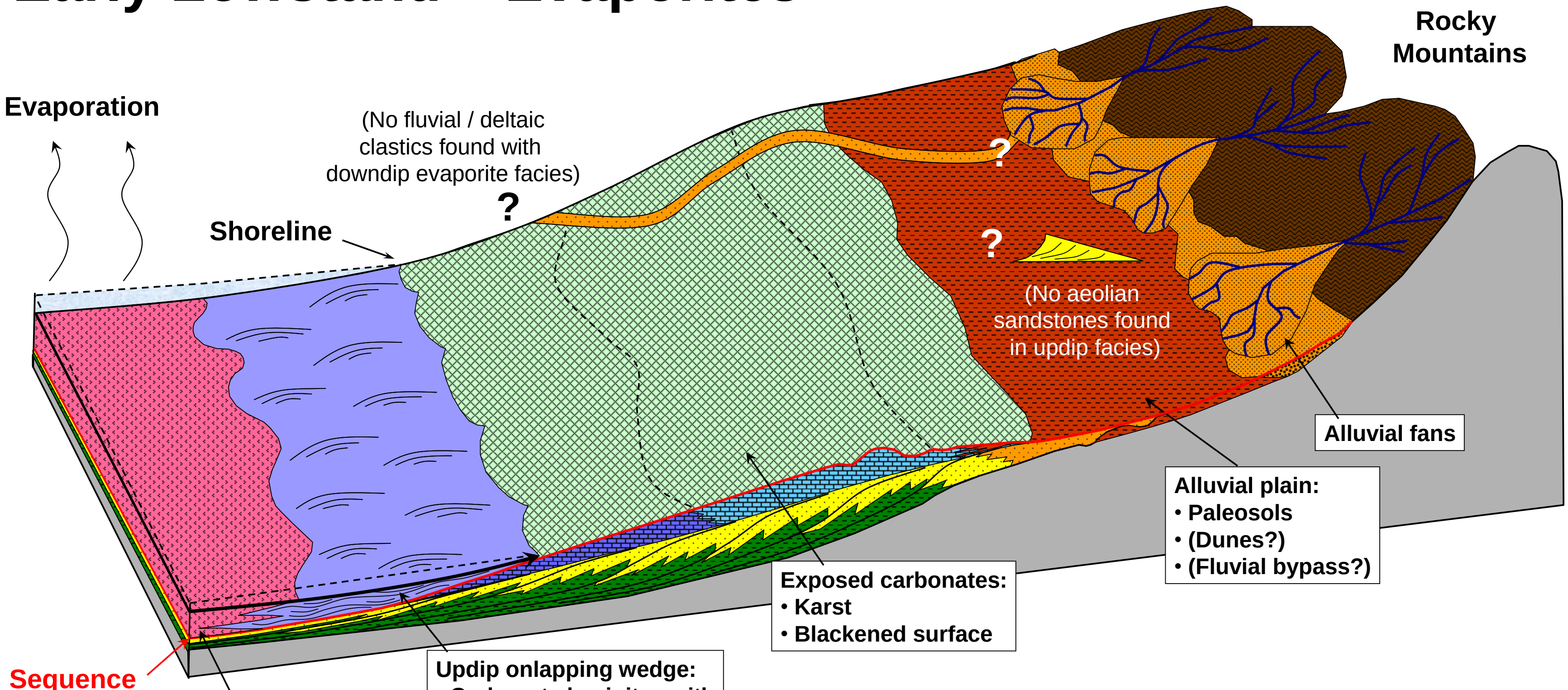


Figure 7, Summary of measured sections , geometries seen on photo pan and in field, facies, and sequence stratigraphic framework of the Pennsylvanian Hermosa Fm. along the Hermosa Cliffs tend north of Durango, Colorado. Miskell-Gerhardt, Gianniny and Ritter, 2010, RMS-AAPG 2010, Field Trip 1 Guidebook, The Pennsylvanian Hermosa Fm., from Shelf to Basin

Early Lowstand – Evaporites



LOWSTAND SYSTEMS TRACT

- Shallow-water.
- Restricted circulation, high salinity, reducing environment.
- Precipitation of gypsum and deposition of black shale in basin.
- Deposition of shallow-water laminites and black shale updip of gypsum.
- Deposition, or alteration to, or chemical precipitation of, dolomite from basin to laminites.
- Abundant breccias formed by multiple episodes of deposition of evaporites, carbonates, and shale followed by exposure and dissolution.

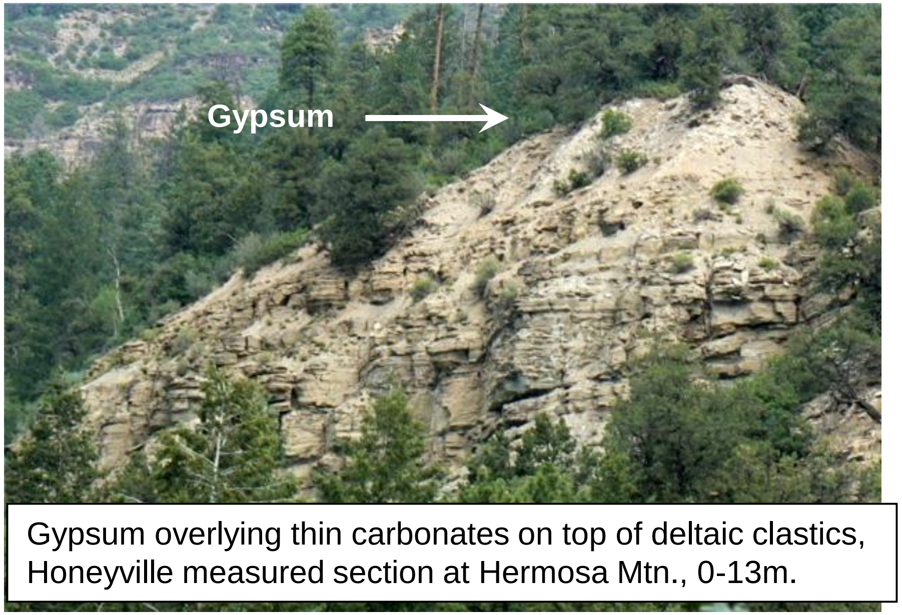
Figure 8. Block diagram of early lowstand systems tract. From Gianniny, G.L., Miskell-Gerhardt, K.J. and S.M. Ritter, 2008, Basin Margin Evolution in Mixed Carbonate-Siliciclastic-Evaporite Sequences, Eastern Margin of the Pennsylvanian Paradox Basin, Southwestern Colorado. American Association of Petroleum Geologists, 2008 Annual Meeting, San Antonio, Texas.

Evaporite Facies – Elkhorn Cyn. and Hermosa Mtn.

5 meter-thick, laminated gypsum with darker dolostone laminae. Elkhorn Cyn, 72m.

Brecciated carbonate boundstone, Elkhorn Cyn. 52m.

Interlaminated gypsum and carbonaceous black dolomitic siltstone. Elkhorn Cyn. 65m.



Gypsum overlying thin carbonates on top of deltaic clastics, Honeyville measured section at Hermosa Mtn., 0-13m.

Figure 9. Examples of evaporite facies seen at Hermosa Mountain and Elkhorn Canyon. From Gianniny, G.L., Miskell-Gerhardt, K.J. and S.M. Ritter, 2008, Basin Margin Evolution in Mixed Carbonate-Siliciclastic-Evaporite Sequences, Eastern Margin of the Pennsylvanian Paradox Basin, Southwestern Colorado. American Association of Petroleum Geologists, 2008 Annual Meeting, San Antonio, Texas.

Evaporite Associated Facies - Shalona

Organic rich, dissolution breccia of laminated dolostone. Shalona section 140.4 m.

Brecciated dolomite (evaporite dissolution?) Shalona section, 146m.

Calcareous boundstone “laminite” with fenestral porosity (Shalona section, 144 m.)

Brecciated calcareous boundstone with black shale chips (evaporite dissolution? Shalona section, 150m.

Figure 10. Examples of evaporite associated facies seen at the Shalona measured section location. From Gianniny, G.L., Miskell-Gerhardt, K.J. and S.M. Ritter, 2008, Basin Margin Evolution in Mixed Carbonate-Siliciclastic-Evaporite Sequences, Eastern Margin of the Pennsylvanian Paradox Basin, Southwestern Colorado. American Association of Petroleum Geologists, 2008 Annual Meeting, San Antonio, Texas.

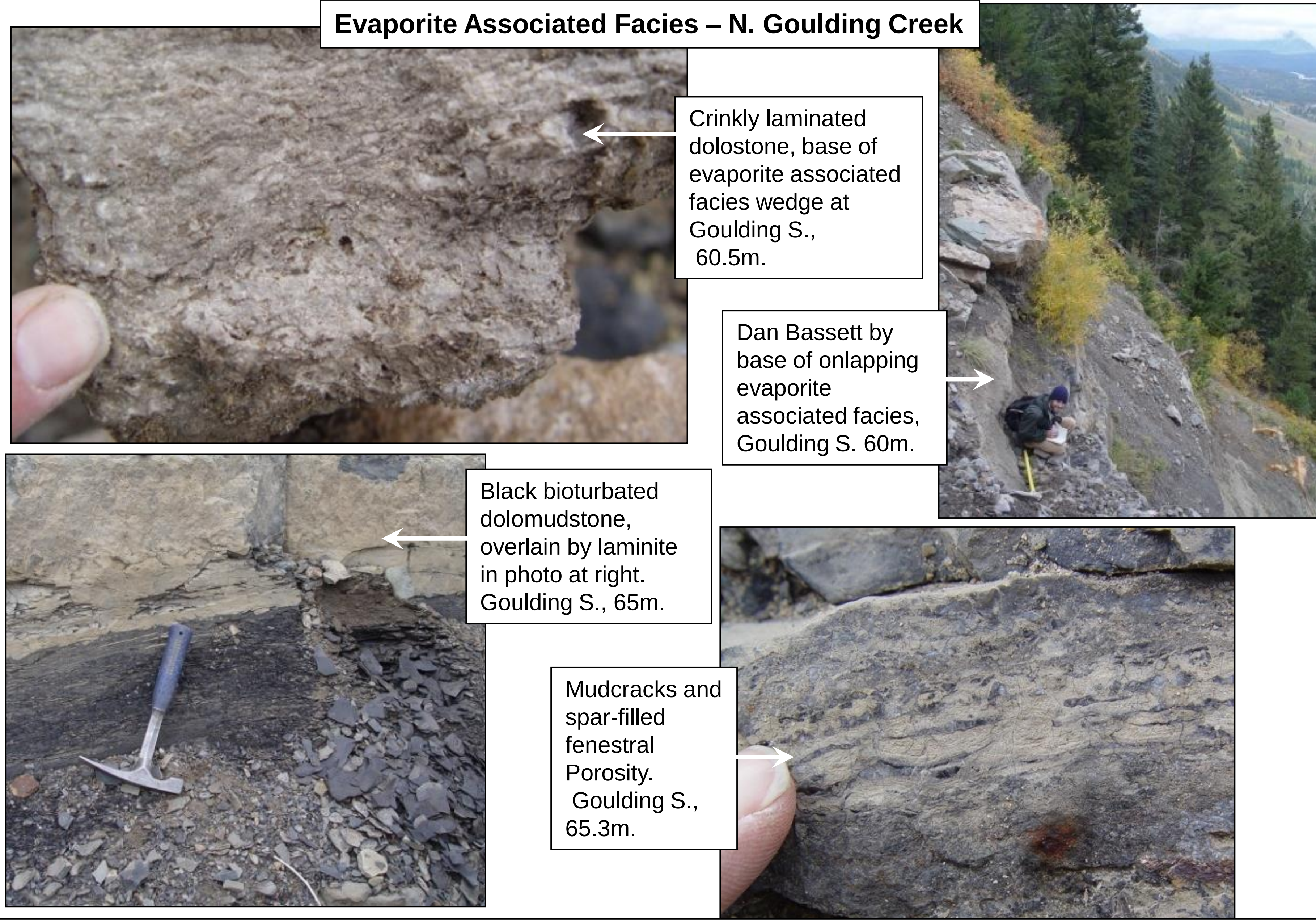


Figure 11. Examples of evaporite associated facies seen at the S. Goulding Creek measured section location. From Gianniny, G.L., Miskell-Gerhardt, K.J. and S.M. Ritter, 2008, Basin Margin Evolution in Mixed Carbonate-Siliciclastic- Evaporite Sequences, Eastern Margin of the Pennsylvanian Paradox Basin, Southwestern Colorado. American Association of Petroleum Geologists, 2008 Annual Meeting, San Antonio, Texas.

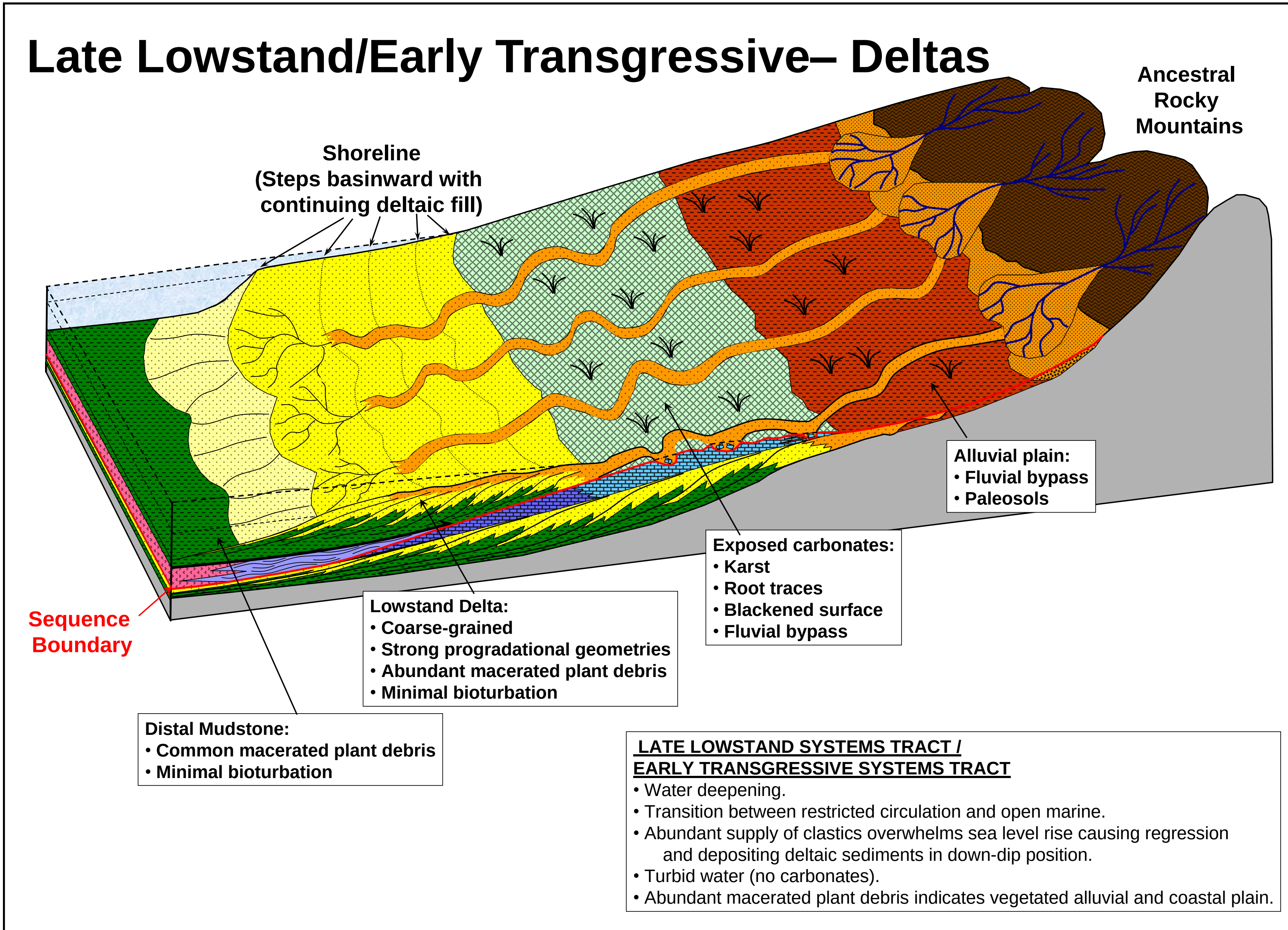


Figure 12. Block diagram of late lowstand to early transgressive systems tract. From Gianniny, G.L., Miskell-Gerhardt, K.J. and S.M. Ritter, 2008, Basin Margin Evolution in Mixed Carbonate-Siliciclastic-Evaporite Sequences, Eastern Margin of the Pennsylvanian Paradox Basin, Southwestern Colorado. American Association of Petroleum Geologists, 2008 Annual Meeting, San Antonio, Texas.

Shelfal Clastic Facies

Channelized, conglomeratic sandstone. This facies is comprised of 30cm-thick beds of trough cross-bedded to planar-bedded, coarse-grained, arkosic sandstone to conglomerate. White spots in lower right are feldspars altered to kaolinite. Individual beds amalgamate into deposits which may be tens of meters thick. Fines are rare, but when present, often contain plant debris. Note the cut-and-fill geometries highlighted in the yellow box. These photographs are from the 273-287m interval at Castle Rock.

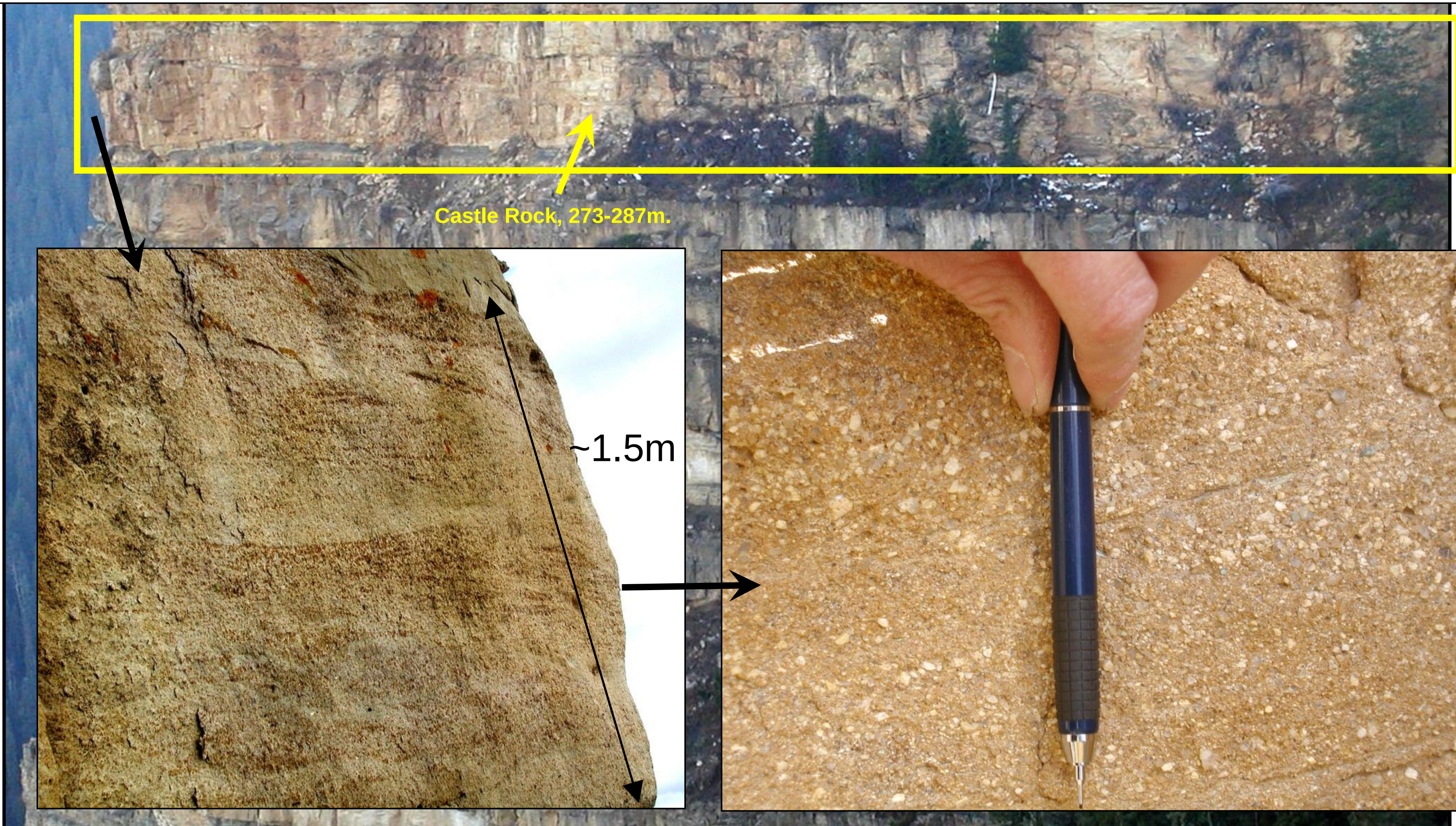
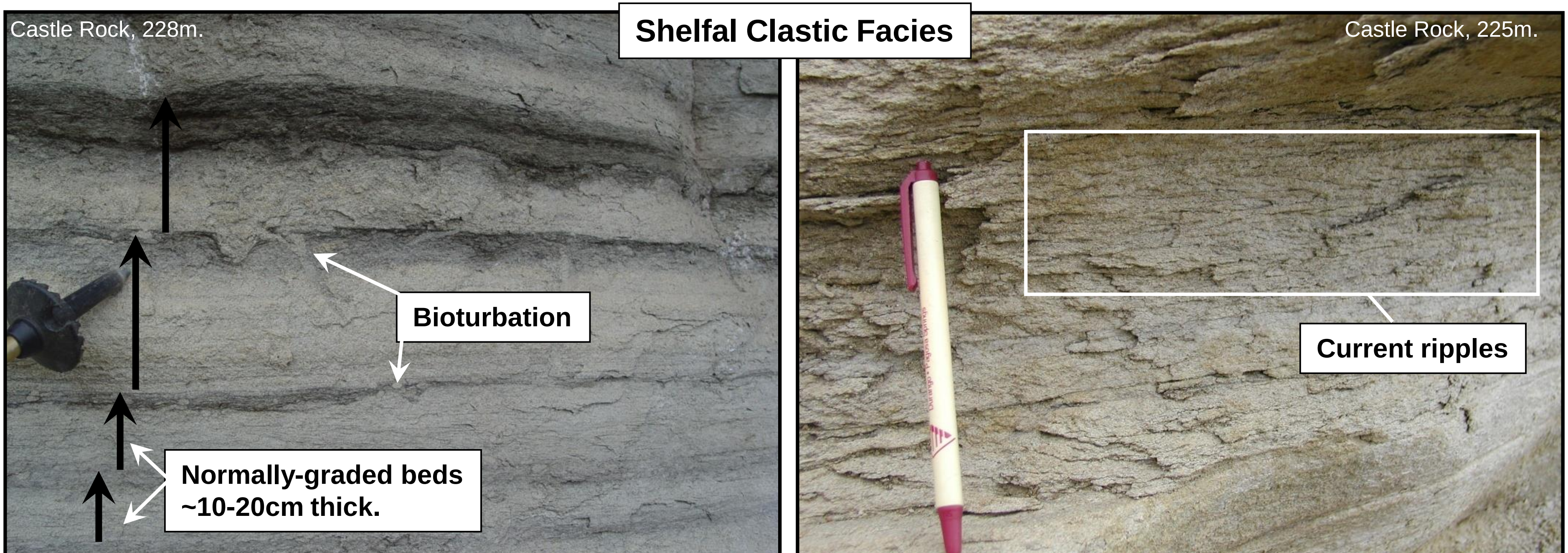


Figure 13. Shelfal clastic facies examples. From, Gianniny, G.L. and Miskell- Gerhardt, K.J., 2009, Progradational mixed siliciclastic / carbonate sequence sets on the tectonically active eastern margin of the Pennsylvanian Paradox Basin, Southwestern Colorado, in: Houston, W.S., Wray, L.W. and Moreland, P., (eds.), The Paradox Basin Revisited – New Developments in Petroleum Systems and Basin Analysis, pp.310-380. RMAG 2009 Special Publication.

Shelfal Clastic Facies



Clinoform sandstone facies. Details of the clinoform sandstone facies include rhythmic, normally-graded beds with bioturbated tops (upper left), current ripples (upper right), soft-sediment deformation (lower left) and macerated plant debris (lower right).

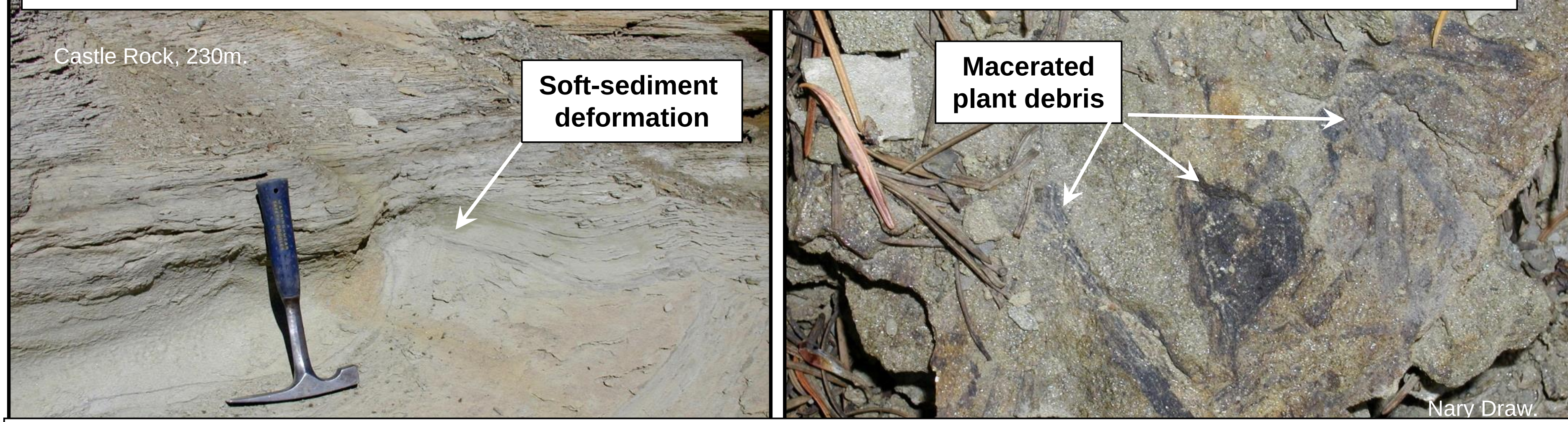
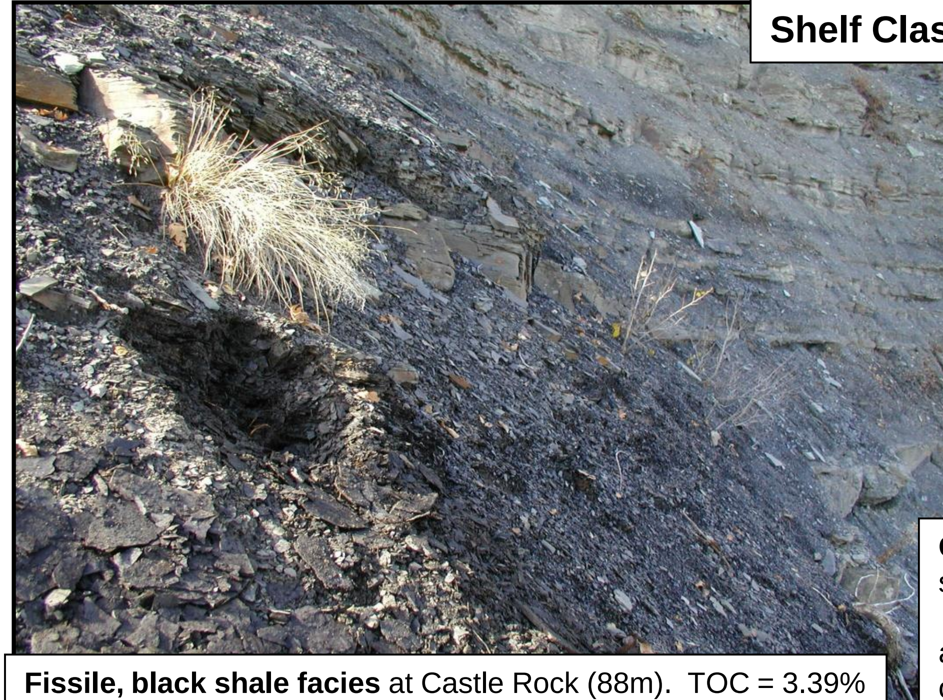
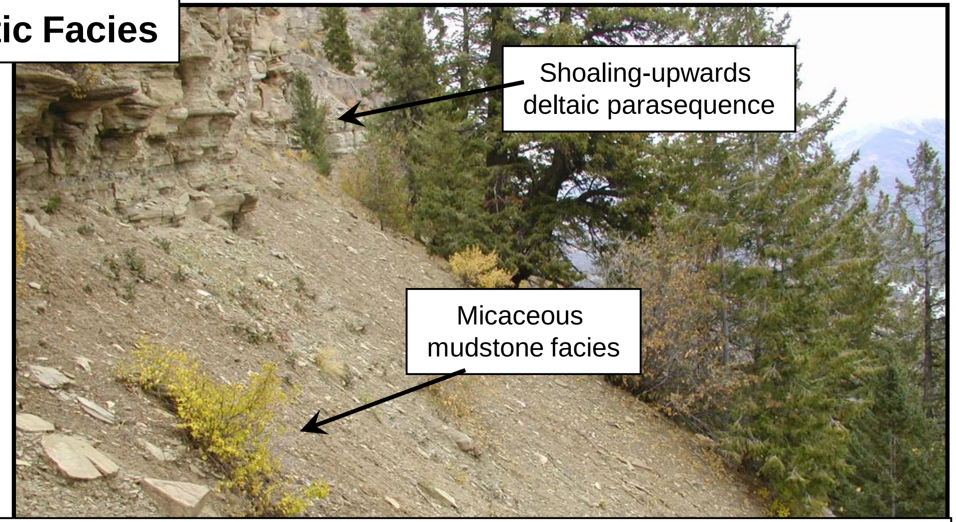


Figure 14. Shelf clastic facies examples, ctd. From, Gianniny, G.L. and Miskell- Gerhardt, K.J., 2009, Progradational mixed siliciclastic / carbonate sequence sets on the tectonically active eastern margin of the Pennsylvanian Paradox Basin, Southwestern Colorado, in: Houston, W.S., Wray, L.W. and Moreland, P., (eds.), The Paradox Basin Revisited – New Developments in Petroleum Systems and Basin Analysis, pp.310-380. RMAG 2009 Special Publication.

Shelf Clastic Facies



Fissile, black shale facies at Castle Rock (88m). TOC = 3.39%

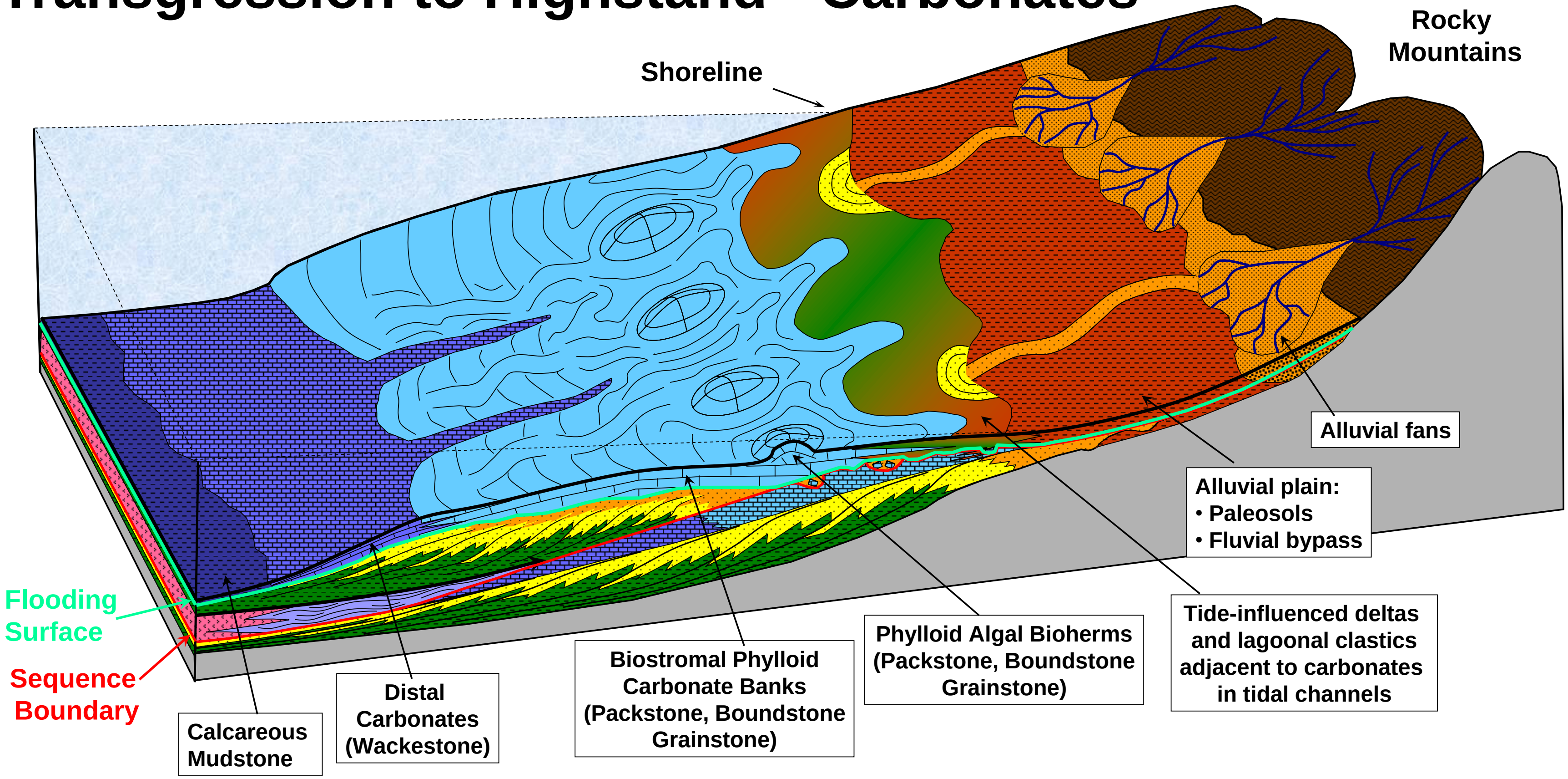


Green, micaceous mudstone, with thin interbeds of very fine-grained sandstone, is found in Nary Draw, at the base of a shoaling-upwards parasequence. The mudstones contain carbonaceous plant debris and rare, indistinct, trace fossils. The parasequences stack in an offlapping – downlapping geometry, indicating progradation to the south.

This sandstone unit is stacked in a clinoform geometry characterized by off-lapping at the top and downlapping at the base. The direction of progradation is to the southwest. The beds coarsen and shoal upwards within the unit, sometimes repeating as multiple parasequences, above a base of green, micaceous mudstone. Normally-graded beds, current ripples, bioturbation of the fines, soft-sediment deformation and macerated plant debris are common features of the finer-grained sands which occur in the toes of the clinoforms. Upper fine to coarse-grained sandstones in the upper clinoforms to top sets are typically planar-bedded to trough cross-bedded. This unit is found at Castle Rock, north of the measured section, but corresponding to the interval of 128-140m.

Figure 15. Shelf clastic facies examples. From, Gianniny, G.L. and Miskell- Gerhardt, K.J., 2009, Progradational mixed siliciclastic / carbonate sequence sets on the tectonically active eastern margin of the Pennsylvanian Paradox Basin, Southwestern Colorado, in: Houston, W.S., Wray, L.W. and Moreland, P., (eds.), The Paradox Basin Revisited – New Developments in Petroleum Systems and Basin Analysis, pp.310-380. RMAG 2009 Special Publication.

Transgression to Highstand - Carbonates

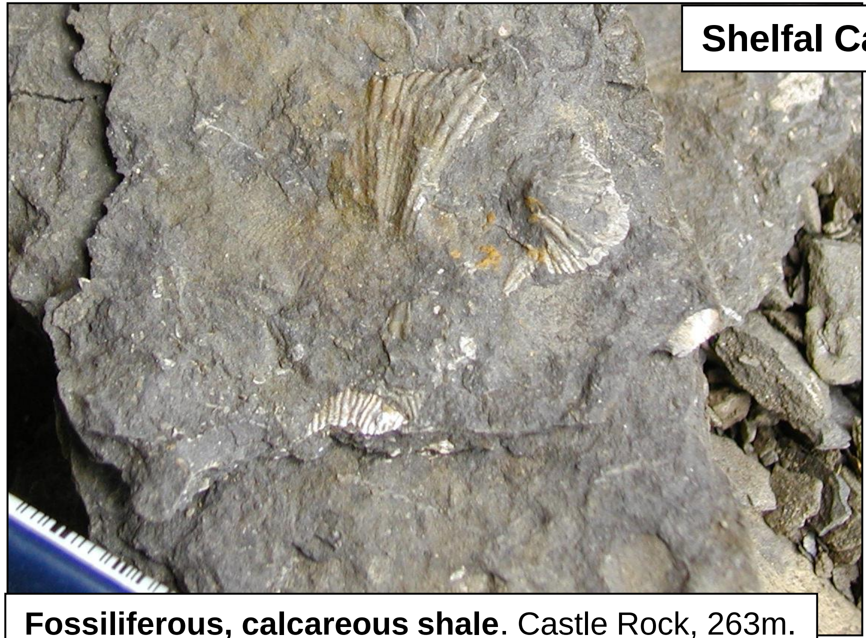


TRANSGRESSIVE TO HIGHSTAND SYSTEMS TRACT

- Rapid to slowing sea level rise.
- Clastics trapped updip.
- Open marine circulation, normal salinity.
- Broad phylloid algal carbonate banks developed in photic zone, supported downdip by underlying lowstand delta and updip by underlying fluvial deposits.
- Thinner banks with bioherms updip; thicker, biostromal character downdip.
- Banks characterized by phylloid algae, crinoids, brachiopods, fenestrate and ramose bryozoans, pelloids, chaetides, fusulinids and gastropods.
- Banks shoal-upwards from nodular to boundstone and are capped by cross-bedded grainstones.

Figure 16. Block diagram of late transgressive to highstand systems tract. From Gianniny, G.L., Miskell-Gerhardt, K.J.and S.M. Ritter, 2008, Basin Margin Evolution in Mixed Carbonate-Siliciclastic-Evaporite Sequences, Eastern Margin of the Pennsylvanian Paradox Basin, Southwestern Colorado. American Association of Petroleum Geologists, 2008 Annual Meeting, San Antonio, Texas.

Shelfal Carbonate Facies



Fossiliferous, calcareous shale. Castle Rock, 263m.

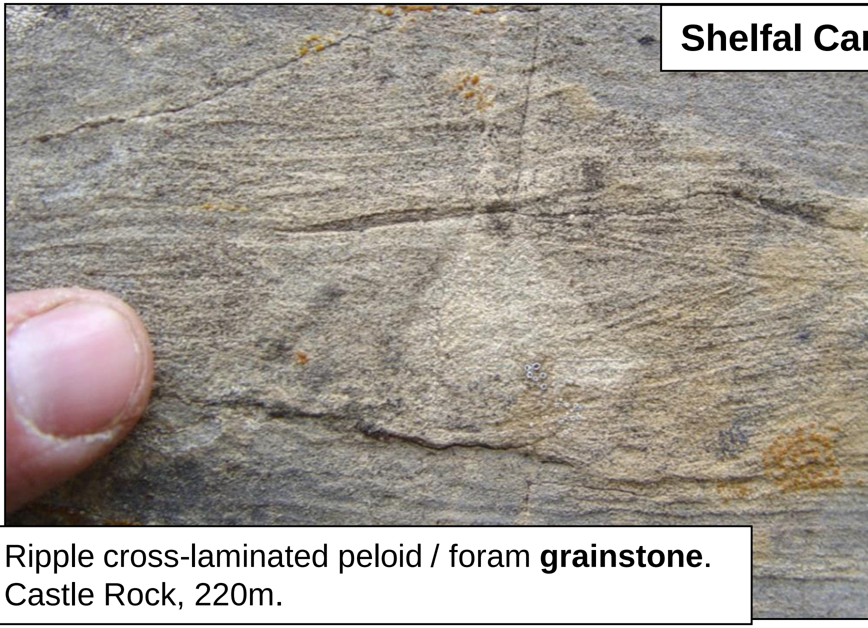
Mud-supported, silty, fossiliferous **wackestone**. From Nary Draw recon section, sequence 12.

Grain-supported skeletal **packstone**. J.E. Ravine. Sequence 15.

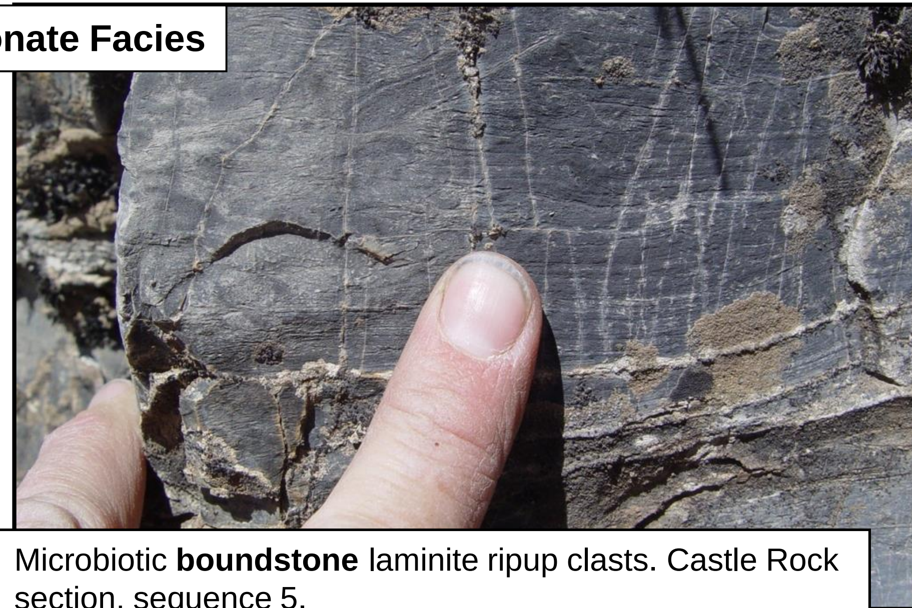
Phylloid **bafflestone** with extensive cement (pendant?) and geopedal brachiopod.

Figure 17. Shelfal carbonate facies examples. From, Gianniny, G.L. and Miskell- Gerhardt, K.J., 2009, Progradational mixed siliciclastic / carbonate sequence sets on the tectonically active eastern margin of the Pennsylvanian Paradox Basin, Southwestern Colorado, in: Houston, W.S., Wray, L.W. and Moreland, P., (eds.), The Paradox Basin Revisited – New Developments in Petroleum Systems and Basin Analysis, pp.310-380. RMAG 2009 Special Publication.

Shelfal Carbonate Facies

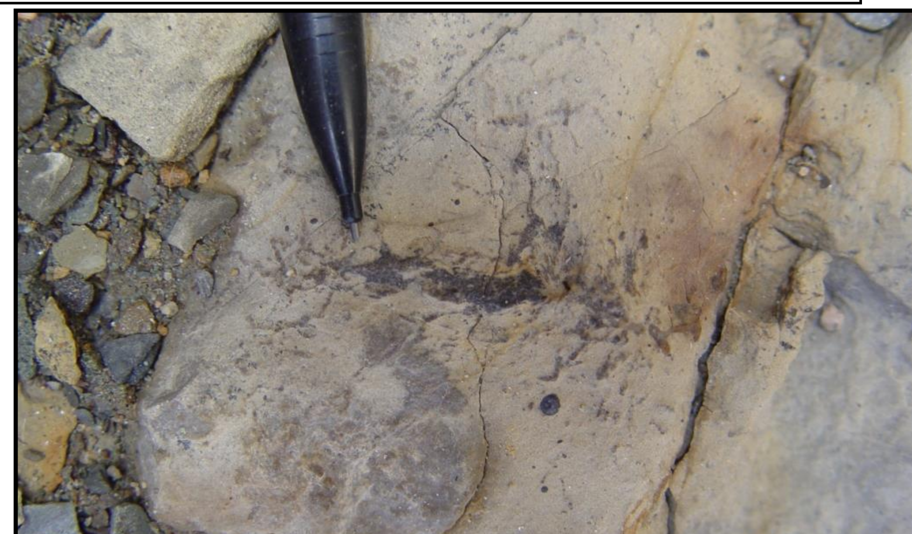


Ripple cross-laminated peloid / foram **grainstone**. Castle Rock, 220m.



Microbiotic **boundstone** laminite ripup clasts. Castle Rock section, sequence 5.

Black pebble lag on exposure surface on top of carbonate bank. Castle Rock, 219m.



Bedding-plane view of **rhyzolith** (root trace) on top of facies peloid / foram grainstone in J.E. Ravine, sequence 12.

Figure 18. Shelfal carbonate facies examples, ctd. From, Gianniny, G.L. and Miskell- Gerhardt, K.J., 2009, Progradational mixed siliciclastic / carbonate sequence sets on the tectonically active eastern margin of the Pennsylvanian Paradox Basin, Southwestern Colorado, in: Houston, W.S., Wray, L.W. and Moreland, P., (eds.), The Paradox Basin Revisited – New Developments in Petroleum Systems and Basin Analysis, pp.310-380. RMAG 2009 Special Publication.

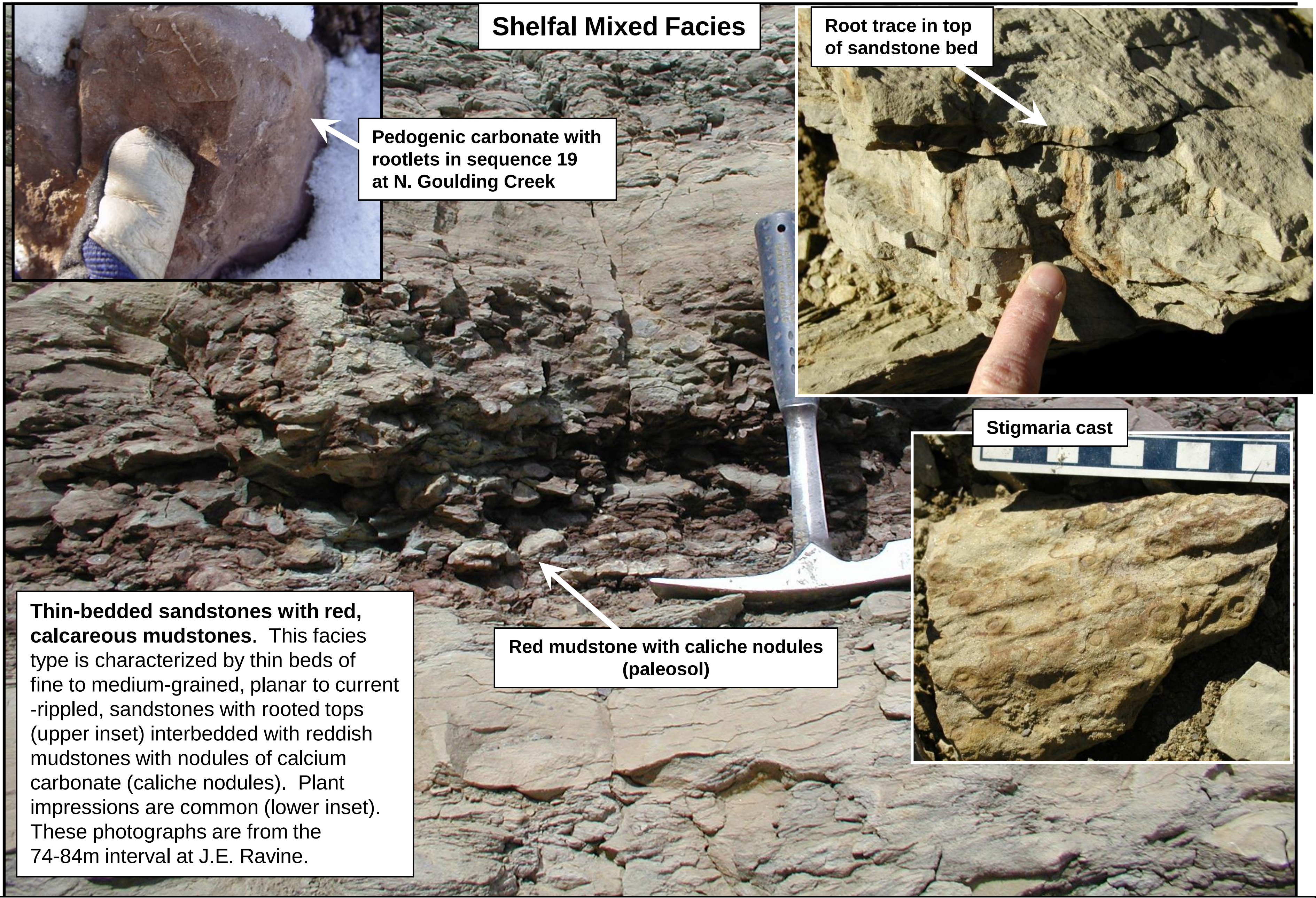


Figure 19. Shelfal clastic and carbonate facies. From, Gianniny, G.L. and Miskell- Gerhardt, K.J., 2009, Progradational mixed siliciclastic / carbonate sequence sets on the tectonically active eastern margin of the Pennsylvanian Paradox Basin, Southwestern Colorado, in: Houston, W.S., Wray, L.W. and Moreland, P., (eds.), The Paradox Basin Revisited – New Developments in Petroleum Systems and Basin Analysis, pp.310-380. RMAG 2009 Special Publication.

Molas Pass Bioherm – Facies Pics

An oblique view of the Syringopora sp mats that cap and drape the south flank of the bioherm. *Syringopora* and *Cheatetes* are often interlaminated suggesting competition on the bioherm crest

Dome-shaped *Chaetetes* heads encrust and bind crinoidal packstones and grainstones in the top 75cm of the exposed mound.

Basal phyloid algal packstones also contain abundant *Komia*, crinoid, brachiopod and fusulind bioclasts.

Basal phyloid algal packstones (Phyl) are overlain and encrusted by *Chaetetes* boundstones (Ch)with rugose corals and abundant crinoid bioclasts

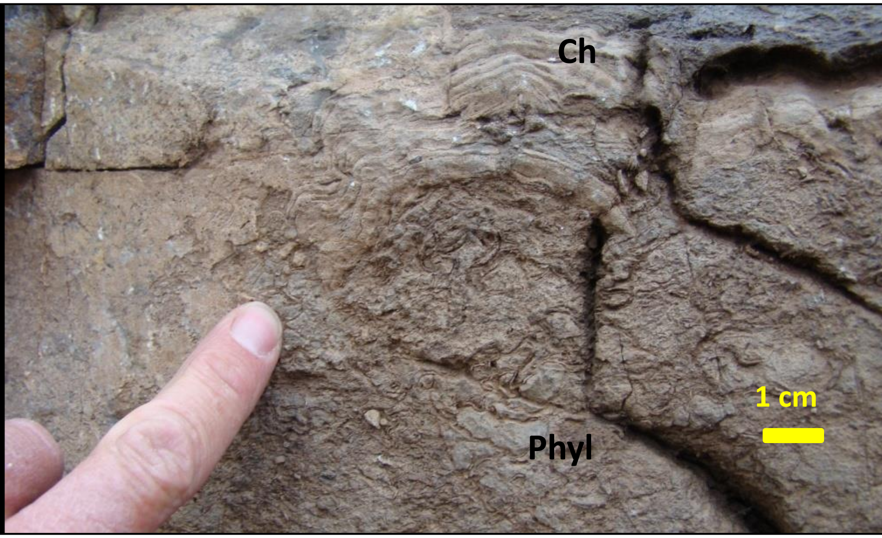


Figure 22. Digital images of major faunal components of the bioherm at the Molas Pass overlook in the Desmoisian lower Hermosa Group. Within the 6 meter thick mound, phyloid algae form the wackstone base, while packstones, boundstones, and grainstones form the upper meter. The estimated position of this buildup is at 278-384m in section 4 of Spoelhof (1974), which is probably equivalent to the Barker Creek, or less likely, the lower Akah interval.

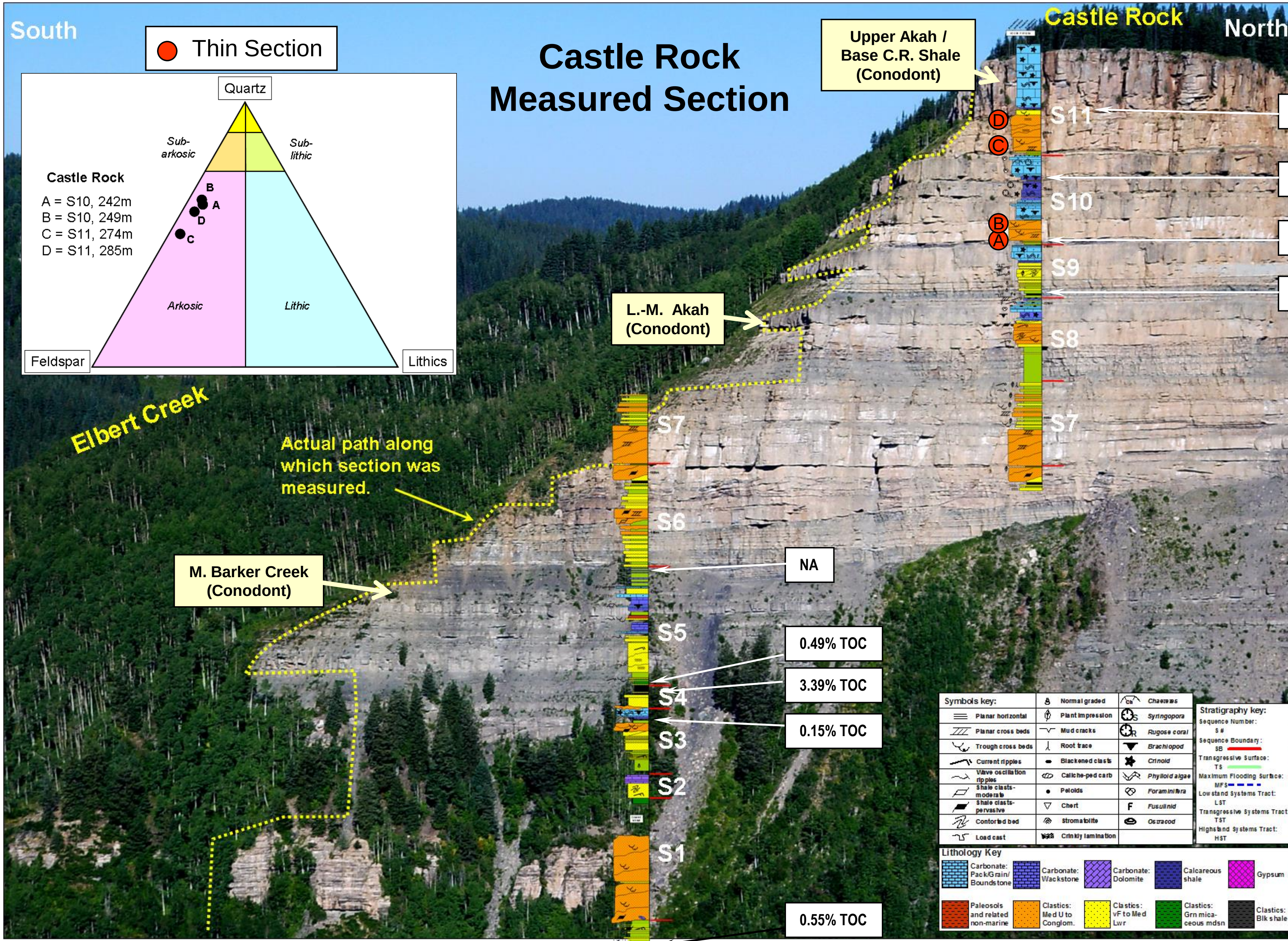


Figure 27. Castle Rock measured section posted on the outcrop. From, Gianniny, G.L. and Miskell- Gerhardt, K.J., 2009, Progradational mixed siliciclastic / carbonate sequence sets on the tectonically active eastern margin of the Pennsylvanian Paradox Basin, Southwestern Colorado, in: Houston, W.S., Wray, L.W. and Moreland, P., (eds.), The Paradox Basin Revisited – New Developments in Petroleum Systems and Basin Analysis, pp.310-380. RMAG 2009 Special Publication. Petrology by K. Miskell-Gerhardt, added 2010.

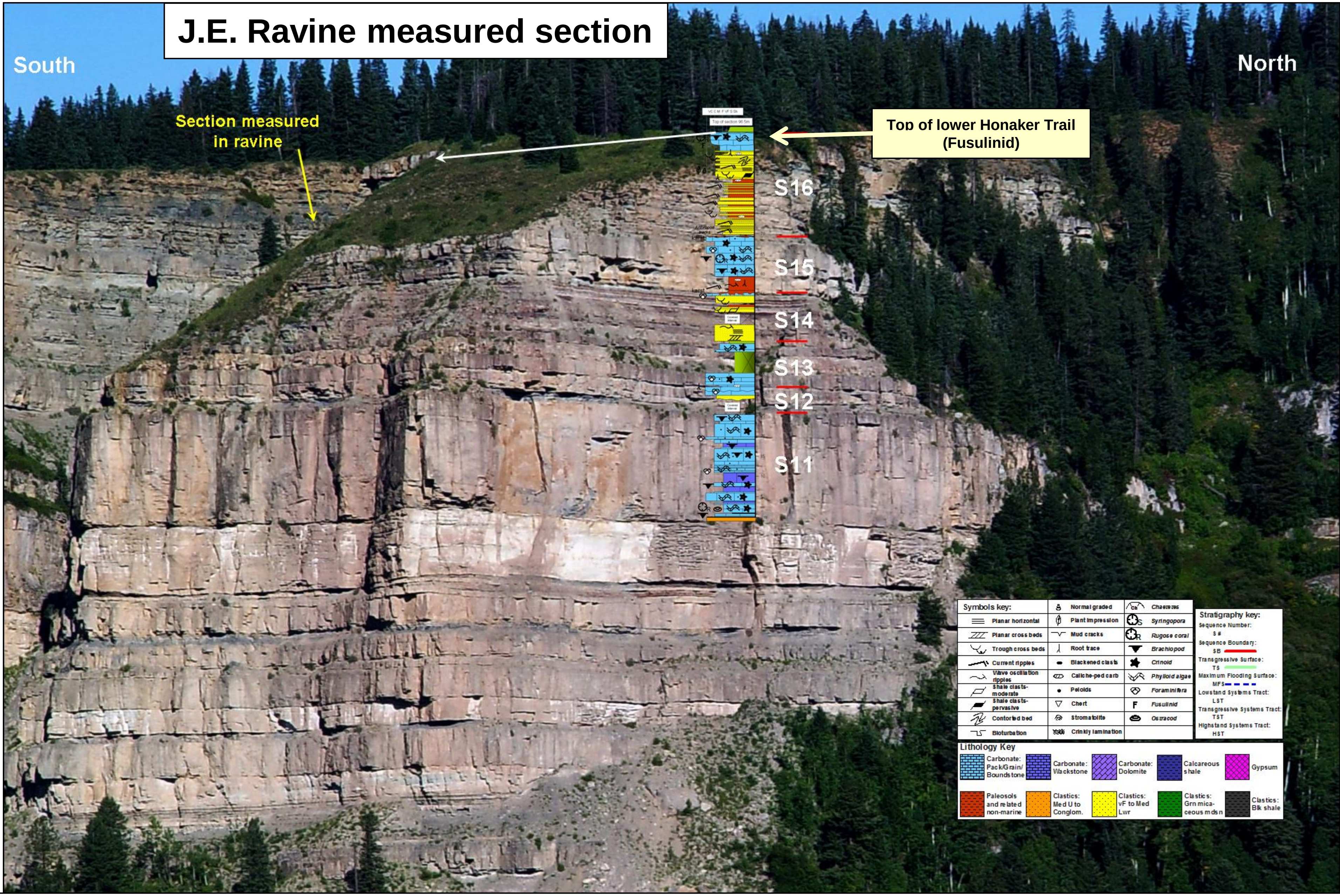


Figure 28. J.E. Ravine measured section posted on the outcrop. From, Gianniny, G.L. and Miskell- Gerhardt, K.J., 2009, Progradational mixed siliciclastic / carbonate sequence sets on the tectonically active eastern margin of the Pennsylvanian Paradox Basin, Southwestern Colorado, in: Houston, W.S., Wray, L.W. and Moreland, P., (eds.), The Paradox Basin Revisited – New Developments in Petroleum Systems and Basin Analysis, pp.310-380. RMAG 2009 Special Publication. Petrology by K. Miskell-Gerhardt, added 2010.

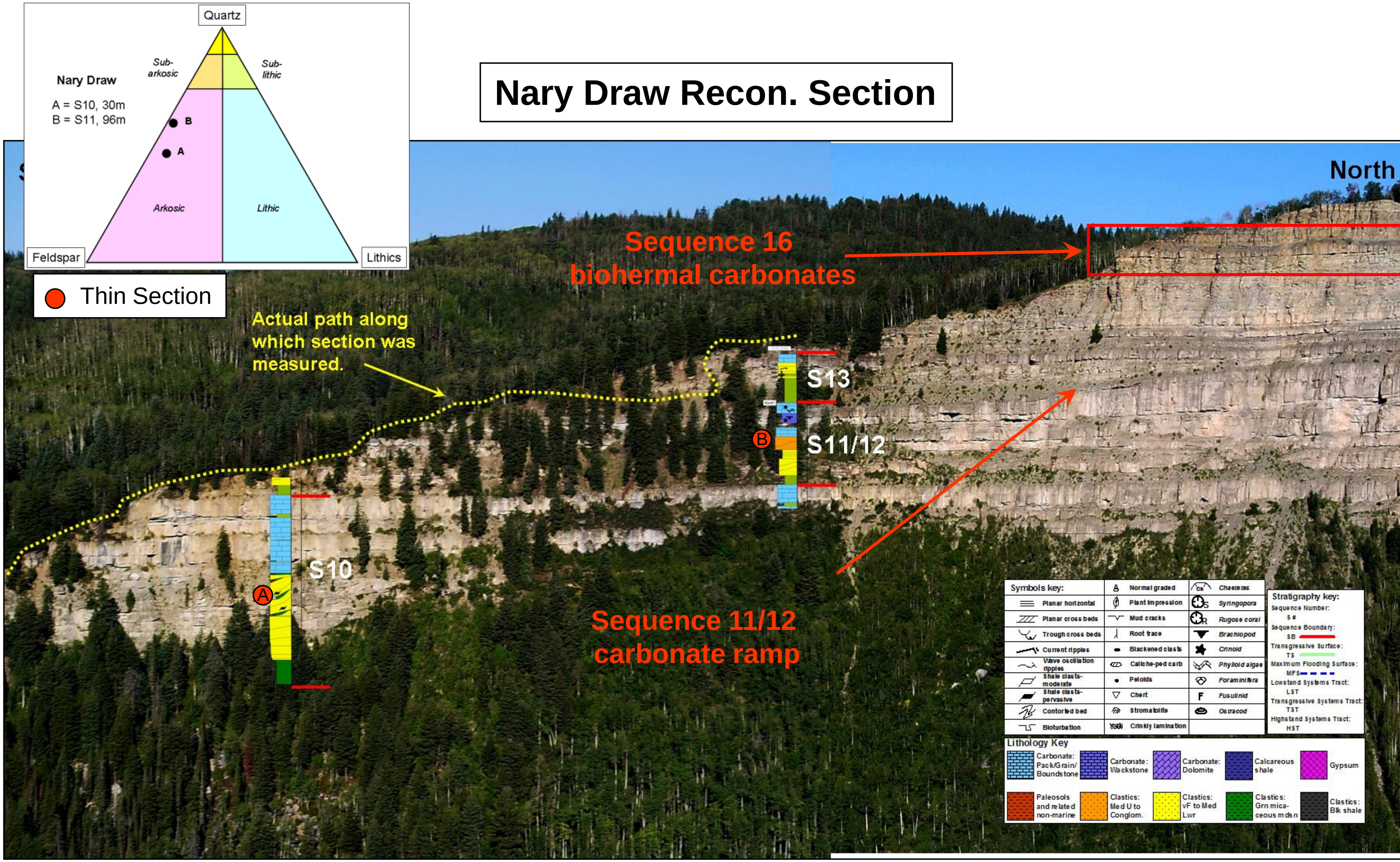


Figure 29, Nary Draw recon section posted on the outcrop. From, Gianniny, G.L. and Miskell- Gerhardt, K.J., 2009, Progradational mixed siliciclastic / carbonate sequence sets on the tectonically active eastern margin of the Pennsylvanian Paradox Basin, Southwestern Colorado, in: Houston, W.S., Wray, L.W. and Moreland, P., (eds.), The Paradox Basin Revisited – New Developments in Petroleum Systems and Basin Analysis, pp.310-380. RMAG 2009 Special Publication. Petrology by K. Miskell-Gerhardt, added 2010.

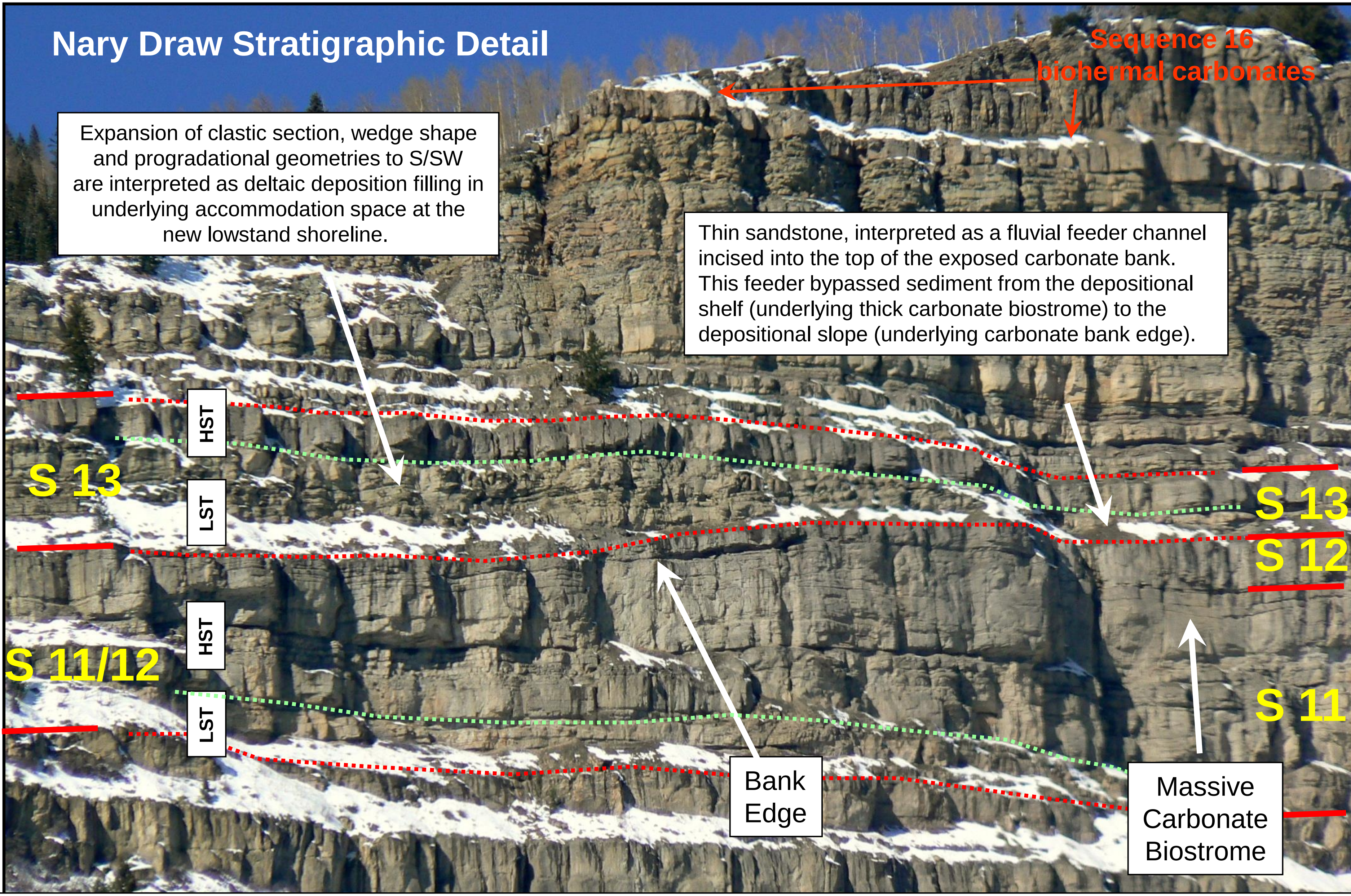


Figure 30. Detail of sequences eleven through thirteen just north of Nary Draw. Red lines are sequence boundaries, green lines are transgressive surfaces. LST = lowstand systems tract. HST = Highstand systems tract. The underlying geometry of the sequence 11/12 highstand carbonate bank edge controls the position of the overlying sequence 13 lowstand fluvial – deltaic transition. From, Gianniny, G.L. and Miskell- Gerhardt, K.J., 2009, Progradational mixed siliciclastic / carbonate sequence sets on the tectonically active eastern margin of the Pennsylvanian Paradox Basin, Southwestern Colorado, in: Houston, W.S., Wray, L.W. and Moreland, P., (eds.), The Paradox Basin Revisited – New Developments in Petroleum Systems and Basin Analysis, pp.310-380. RMAG 2009 Special Pub.

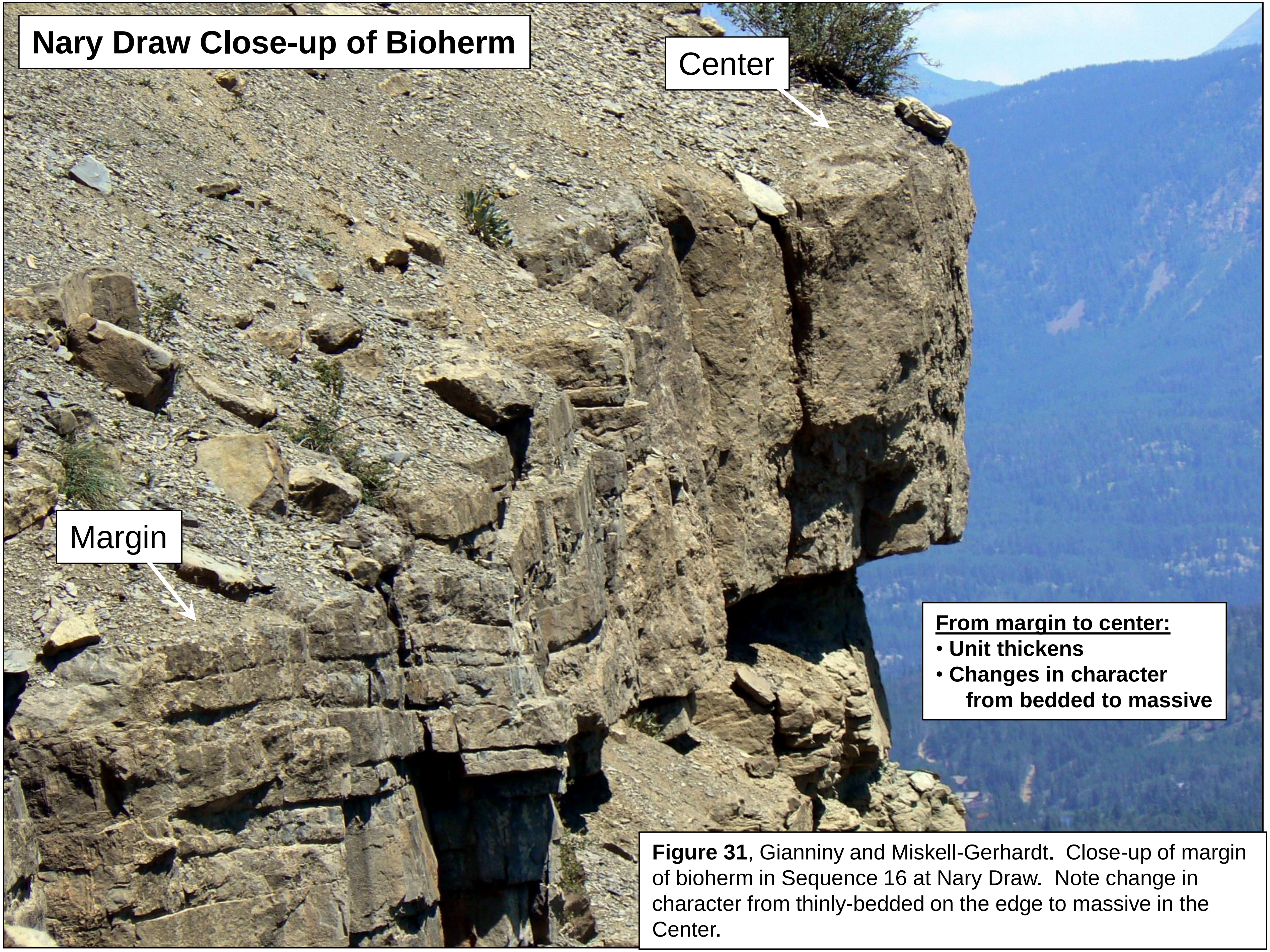
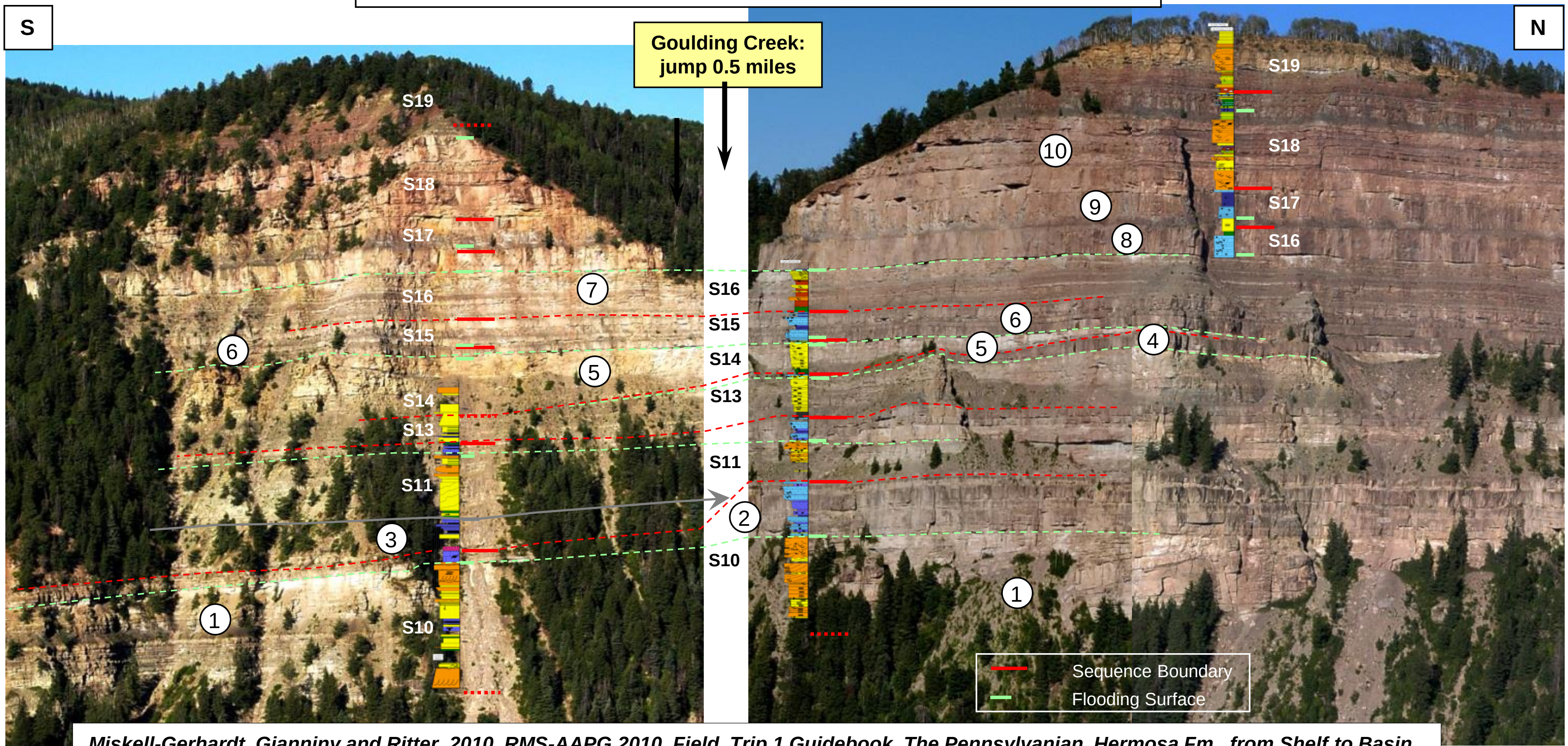


Figure 31, Gianniny and Miskell-Gerhardt. Close-up of margin of bioherm in Sequence 16 at Nary Draw. Note change in character from thinly-bedded on the edge to massive in the Center.

Figure 32a. Correlation from North to South Goulding Creek.



Miskell-Gerhardt, Gianniny and Ritter, 2010, RMS-AAPG 2010, Field Trip 1 Guidebook, The Pennsylvanian Hermosa Fm., from Shelf to Basin

1 Sequence 10 LST/TST: Decrease in angle of clinoform to south interpreted as change from more proximal to more distal deltaic environment.

2 Sequence 10 HST: Decrease in thickness of carbonate biostrome to south interpreted as edge of platform, induced by the change in the inherited deltaic topography.

3 Sequence 11 LST: Onlapping wedge of dolostone, fissile black shale and laminated, mudcracked carbonate. These "Evaporite Associated Facies (EAF) correlates southwards (downdip) to gypsum at Hermosa Mtn.

4 Sequence 13 HST: Thinning and downlap of carbonate biostrome to south following similar thinning in underlying clastics.

5 Sequence 14 LST/TST: Expansion of thin sandstone fluvial feeder into a thick deltaic wedge, from N-S, into the accommodation space provided by the thinning of underlying sequence 13. Fills in basin forming a large, flat, shallow platform. Note autocyclic lobe switching in southern face.

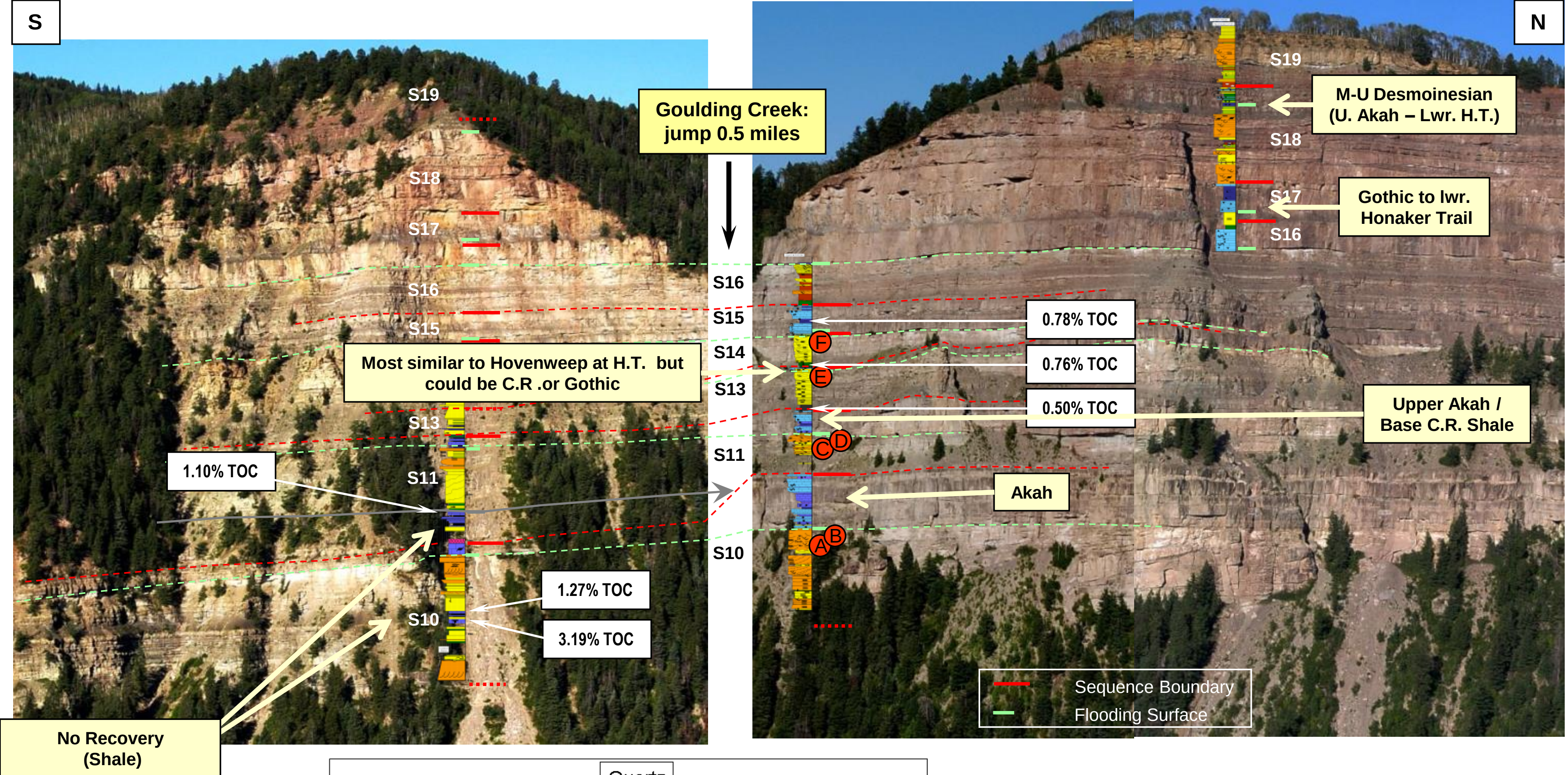
6 Sequence 15: All carbontate / major transgression. Notice increase in interbedded shaley beds (more distal) to south.

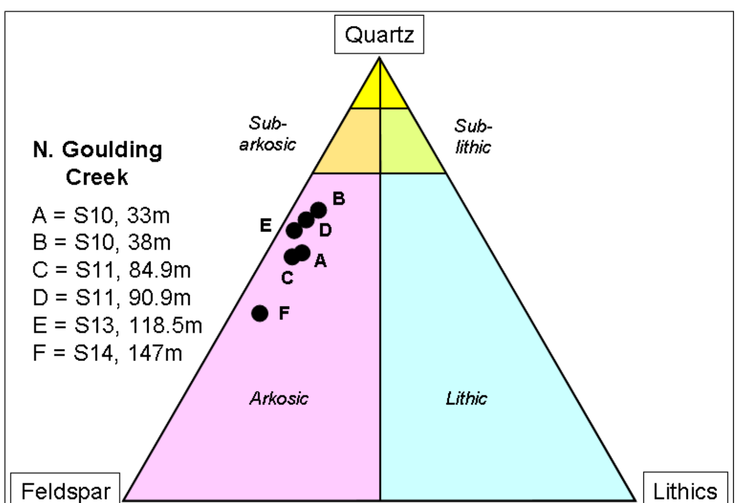
7 Sequence16 LST/TST: Tidal deposits (NOT fluvio-deltaic). No underlying shelf edges so no deltas when SL falls.

8 Sequence 16 TST/HST: Widespread carbonate biostrome, again capping a wide platform. This flooding surface is the datum for the cross-section.

9 Sequence 17 HST: Green, micaceous, silty – possibly lagoonal(?) carbonates is the transition from underlying dominantly marine to overlying dominantly non-marine deposition.

10 Seq 18: Fluvial, paleosols and restricted, lagoonal marine complete shoalling trend started at top of sequence 14. "Basin" in this location filled.





Thin Section

Age = Conodont Results

Figure 32b. TOC, biostratigraphy and petrology data from Goulding Creek. Miskell-Gerhardt, Gianniny and Ritter, 2010, RMS-AAPG 2010, Field Trip 1 Guidebook, The Pennsylvanian Hermosa Fm., from Shelf to Basin

Shalona Measured Section

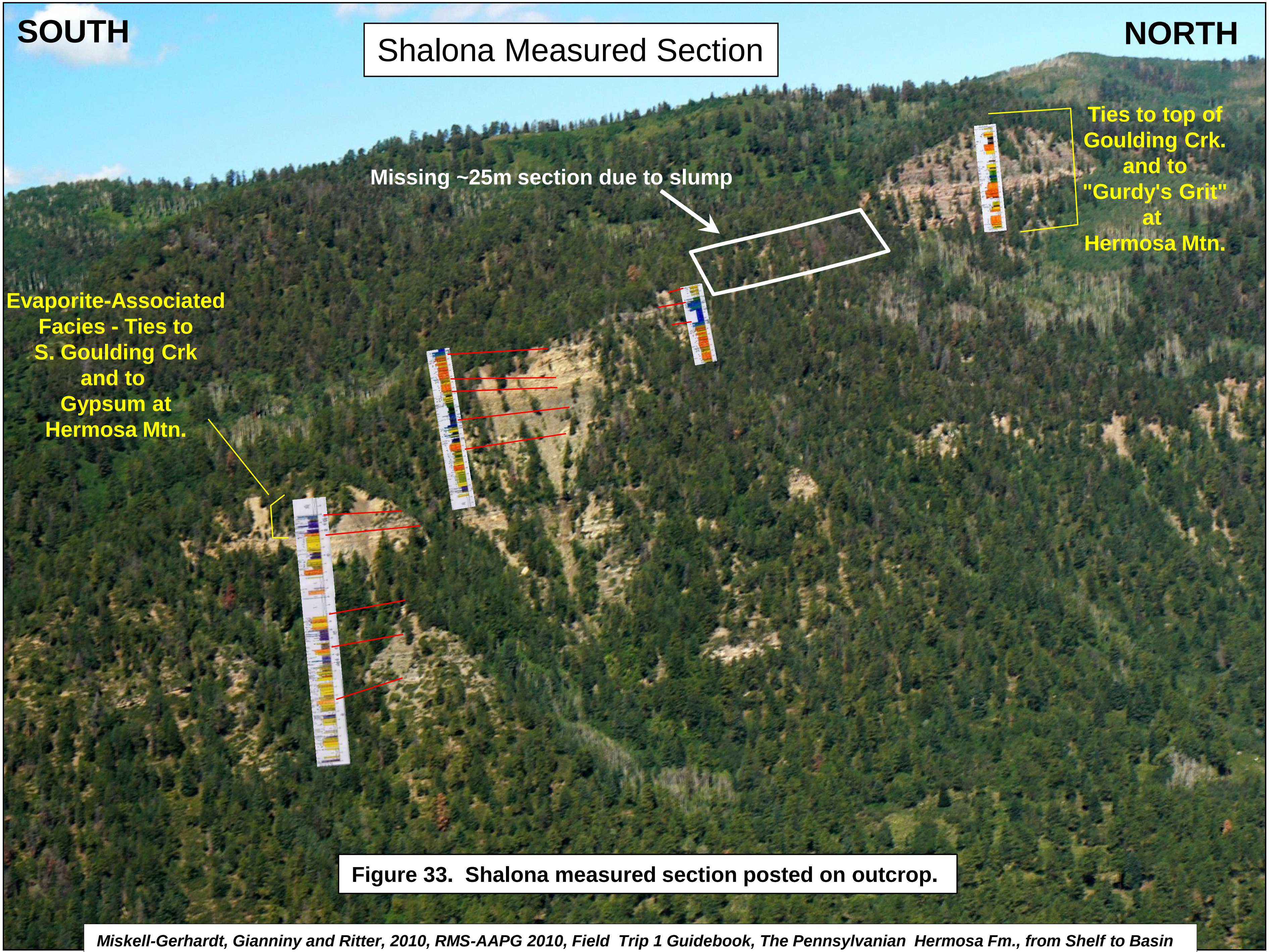
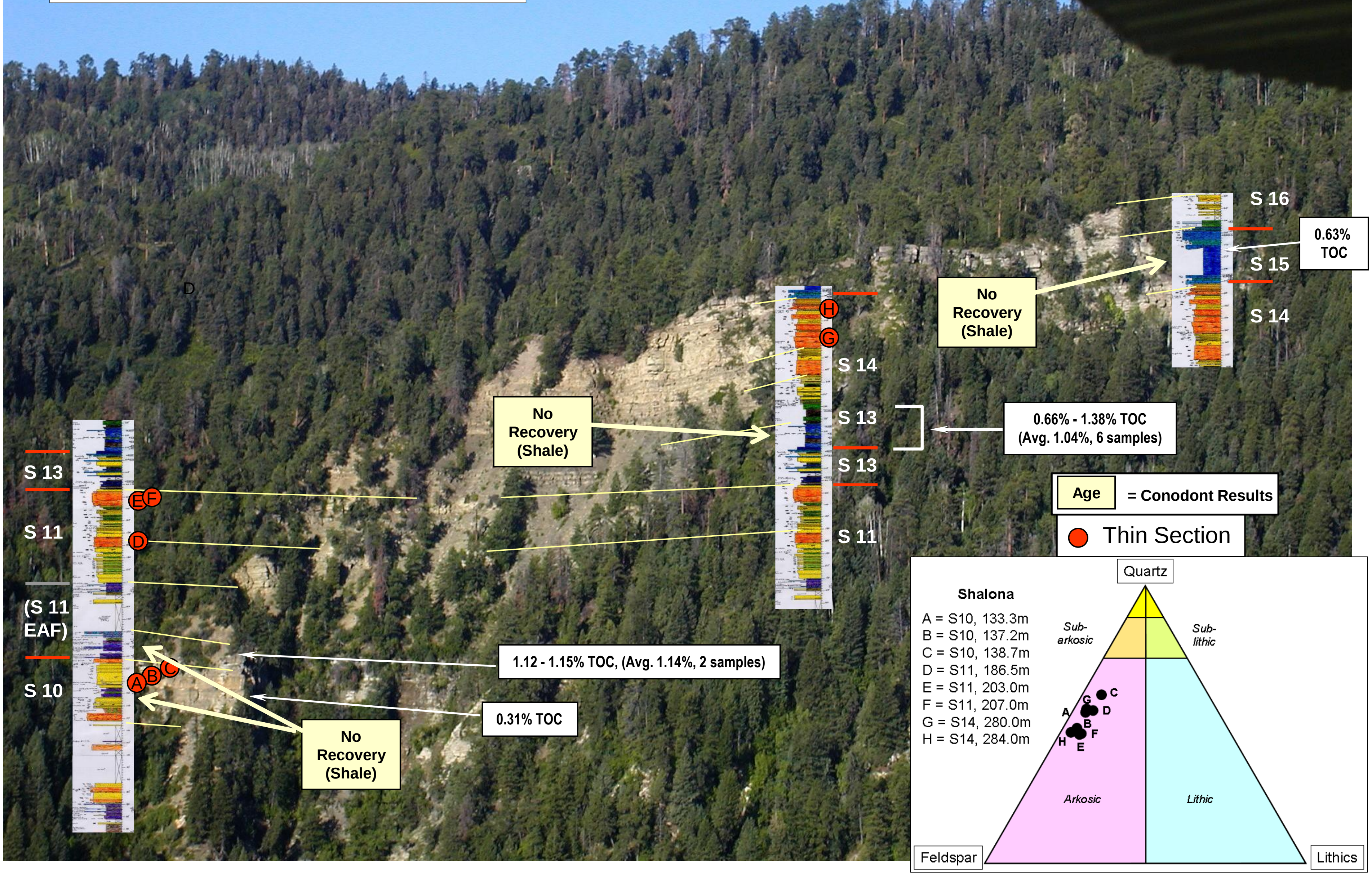


Figure 33. Shalona measured section posted on outcrop.

Miskell-Gerhardt, Gianniny and Ritter, 2010, RMS-AAPG 2010, Field Trip 1 Guidebook, The Pennsylvanian Hermosa Fm., from Shelf to Basin

Figure 34. Sequences 10-16 at Shalona. TOC, biostratigraphy and petrology data posted.

Miskell-Gerhardt, Gianniny and Ritter, 2010, RMS-AAPG 2010, Field Trip 1 Guidebook, The Pennsylvanian Hermosa Fm., from Shelf to Basin



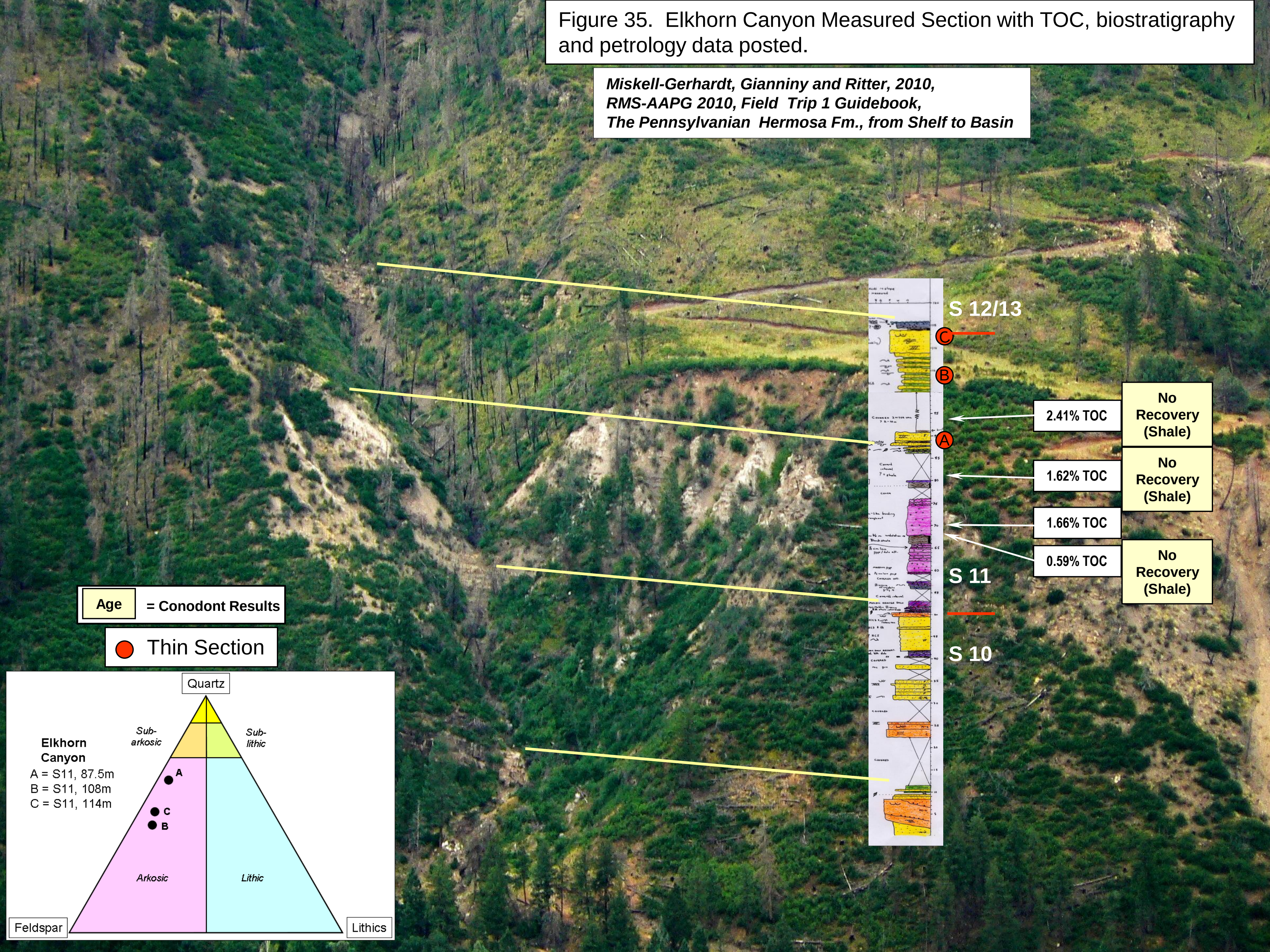
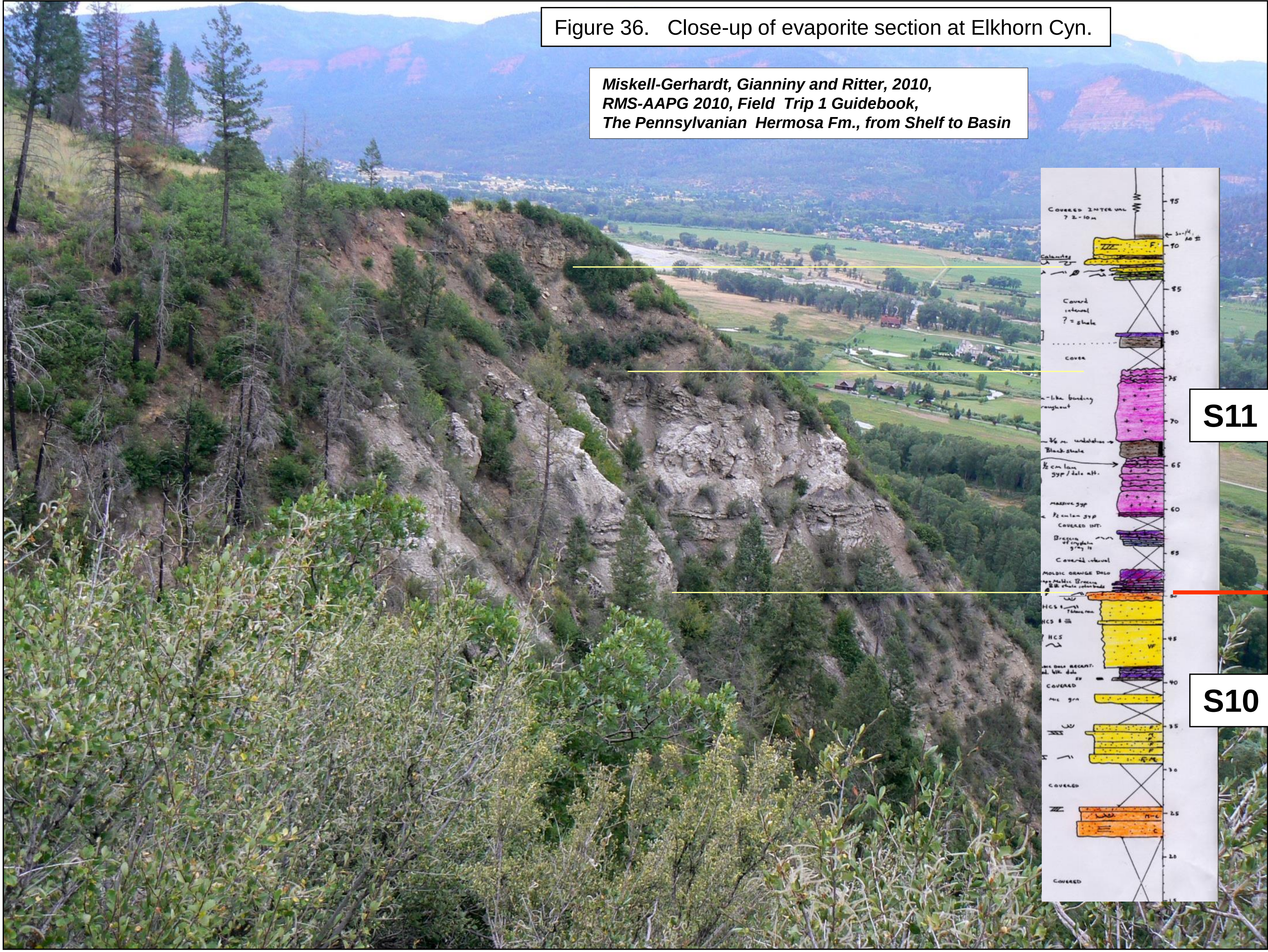


Figure 35. Elkhorn Canyon Measured Section with TOC, biostratigraphy and petrology data posted.

Miskell-Gerhardt, Gianniny and Ritter, 2010,
RMS-AAPG 2010, Field Trip 1 Guidebook,
The Pennsylvanian Hermosa Fm., from Shelf to Basin

Figure 36. Close-up of evaporite section at Elkhorn Cyn.

Miskell-Gerhardt, Gianniny and Ritter, 2010,
RMS-AAPG 2010, Field Trip 1 Guidebook,
The Pennsylvanian Hermosa Fm., from Shelf to Basin



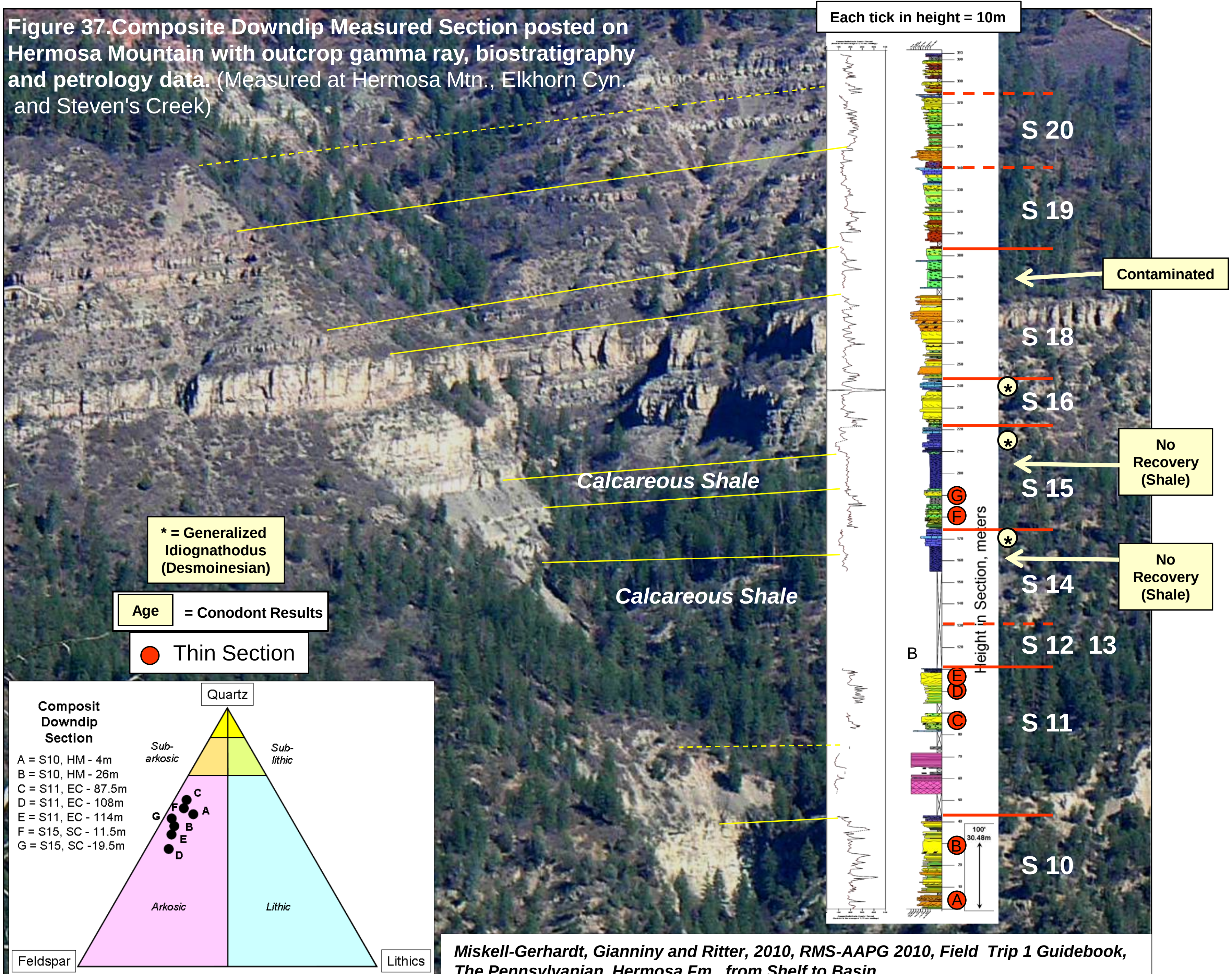


Figure 37.Composite Downdip Measured Section posted on Hermosa Mountain with outcrop gamma ray, biostratigraphy and petrology data. (Measured at Hermosa Mtn., Elkhorn Cyn. and Steven's Creek)

Miskell-Gerhardt, Gianniny and Ritter, 2010, RMS-AAPG 2010, Field Trip 1 Guidebook, The Pennsylvanian Hermosa Fm., from Shelf to Basin