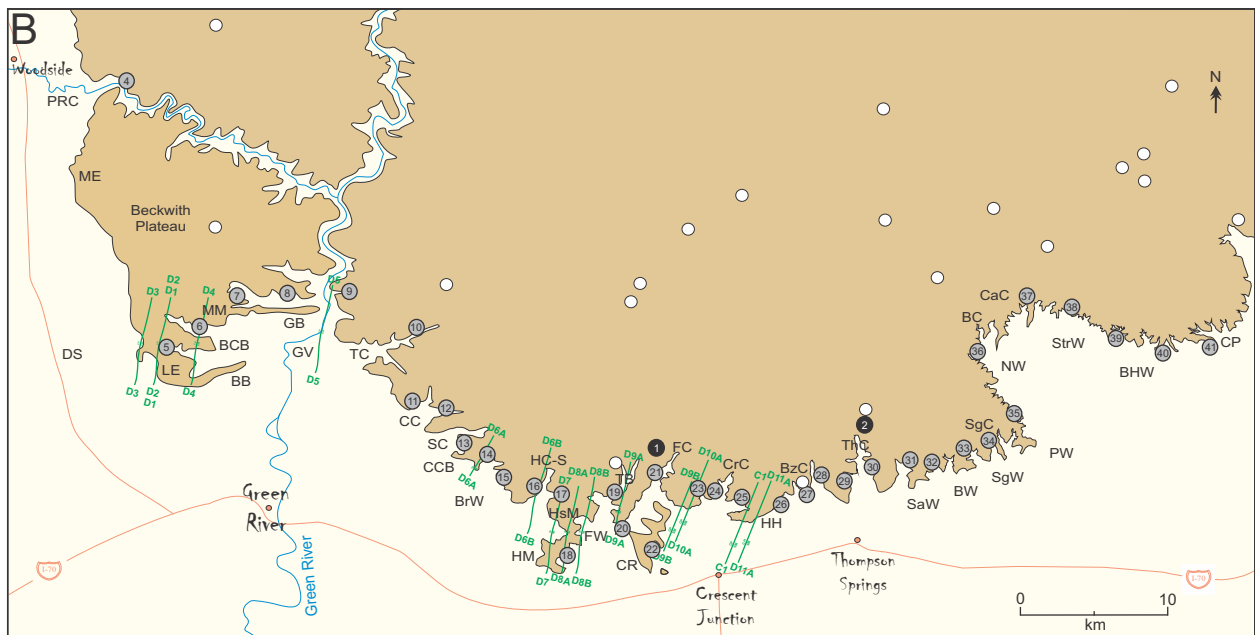
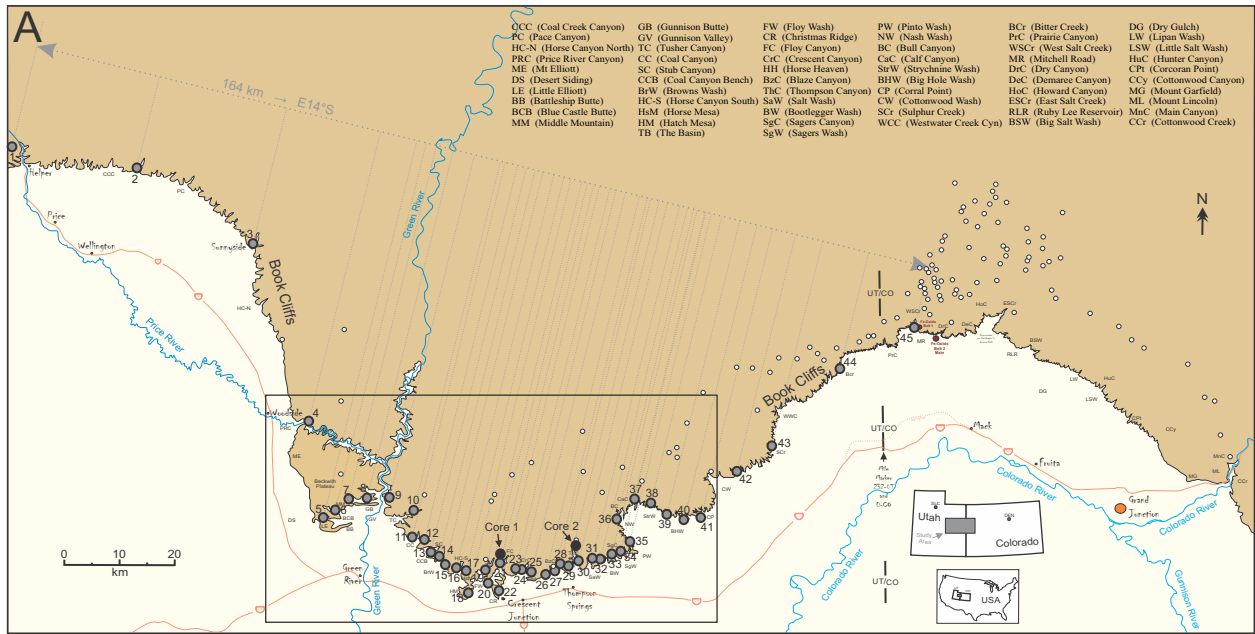


Measured Outcrop Sections

Desert Member & Lower Castlegate Sandstone

Campanian Book Cliffs
Utah-Colorado
USA

Simon A.J. Pattison
Department of Geology
Brandon University


























Measured section localities. (A) Map showing the entire Book Cliffs regions, from Helper Utah to Grand Junction Colorado. Rectangle inset map in Part B. Measured sections (grey circles, numbered 1 to 45), well logs (white circles), and Shell cores (black circles) are shown. Distances between adjacent measured sections are projected orthogonal to the N14°E paleoshoreline trend, with these distances used for spacing on all high resolution correlation panels. Down-depositional-dip distance between “end-member” sections 1 (Castle Gate, UT) and 45 (West Salt Creek, CO) is 164 km. Key canyons, creeks, mesas, washes, buttes, and other landmarks are abbreviated. See legend at top for full names. (B) Inset map of the southern Book Cliffs, showing a detailed view into the “central-core-locality” of this study. Shoreline “evolution” localities (i.e. first basinward appearance) for parasequences D1-D11 and C1, are highlighted with green lines and numbers. Measured section numbers are inset within each grey circle. Shell core 1 (Floy Canyon) and Shell core 2 (Thompson Canyon) are highlighted by black circles with inset white numbers.

Measured Sections

- 1 Castle Gate
- 2 Soldier Creek Canyon
- 3 Sunnyside
- 4 Woodside-Price River Canyon
- 5 The Cove
- 6 Middle Mountain - Central
- 7 Middle Mountain - East
- 8 Long Canyon
- 9 NE of Swaseys Beach
- 10 Tusher Canyon - N-Side Cyn-East
- 11 Coal Canyon - NW Bowl
- 12 Coal Canyon - North Wall East
- 13 Stub Canyon - SE Bowl
- 14 Browns Wash Canyon - NW Bowl
- 15 Browns Wash Canyon - SE Bowl
- 16 Horse Canyon - West Side Cyn
- 17 Horse Mesa - NW Cyn
- 18 Hatch Mesa - SE Bowl
- 19 Trough Spring Ridge-The Basin
- 20 Trough Spring Ridge - East Face
- 21 Floy Wash - East Wall
- 22 Christmas Ridge - SE Bowl
- 23 Thompson Pass - East Bowl
- 24 Crescent Canyon - SW Wall
- 25 Horse Heaven - NW-SW Bowls
- 26 Horse Heaven - South Face-East
- 27 West of Blaze Canyon - East Wall
- 28 Blaze Canyon - East Side Cyn
- 29 Thompson Canyon - West Side Cyn
- 30 Thompson Canyon - East Side Cyn
- 31 Salt Wash Canyon - NE Side Cyn
- 32 Bootlegger Wash Canyons - West Cyn
- 33 Sagers Canyon - NW Wall
- 34 East of Sagers Canyon - East Wall
- 35 Pinto Wash - East Fork
- 36 Nash Wash
- 37 Calf Canyon
- 38 Strychnine Wash
- 39 Big Hole Wash - West
- 40 Big Hole Wash - East
- 41 Corral Point - East
- 42 Long Canyon
- 43 Sulphur Creek
- 44 Bitter Creek
- 45 West Salt Creek

Legend

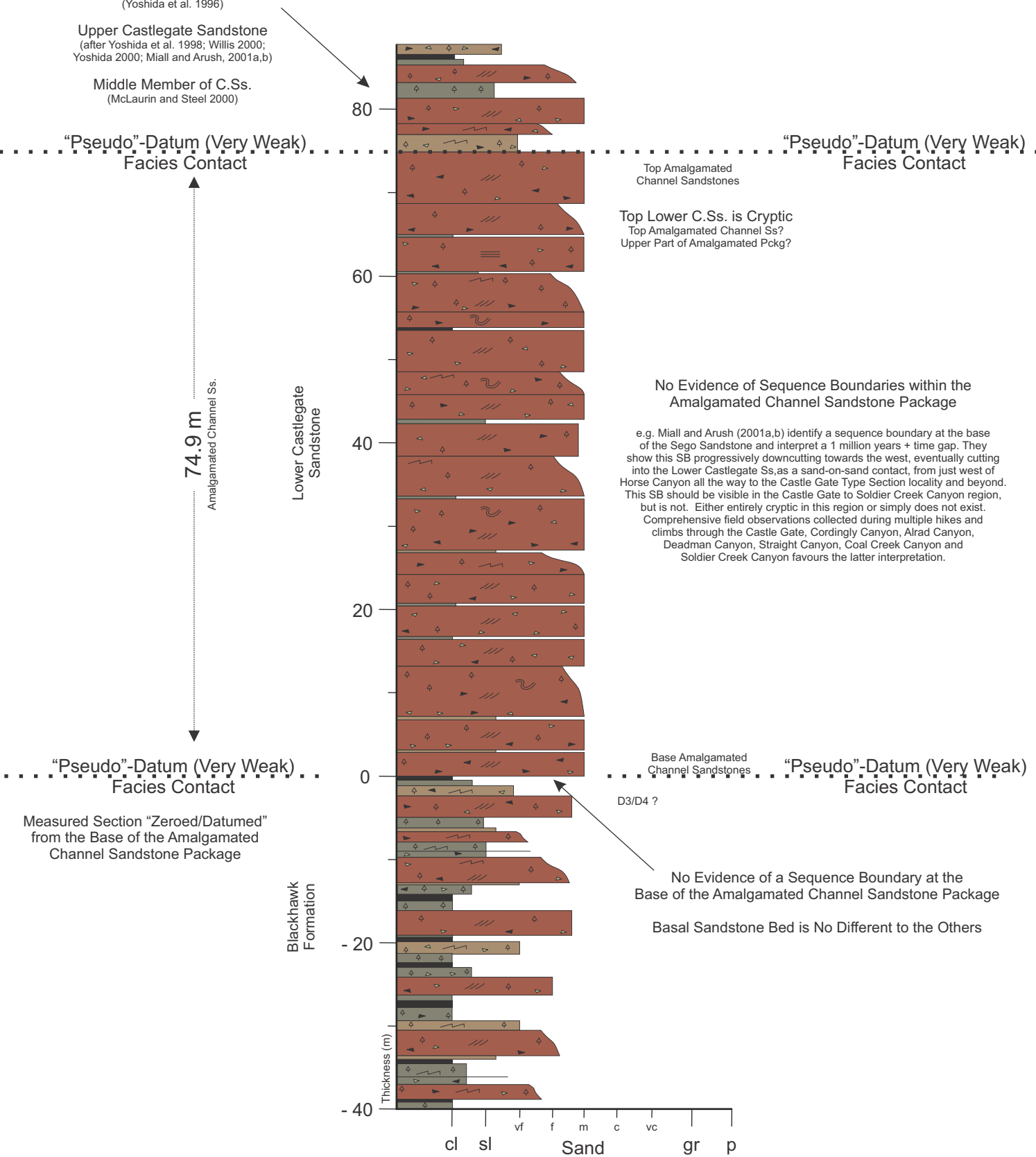
| | | | |
|---|--------------------------------------|---|--------------------------|
|  | Horizontal/Planar Laminated |  | Bioturbation |
|  | Cross Bedded | BI:0-6 | Bioturbation Index (0-6) |
|  | Swaley Cross Stratified | N:G 30% | Net to Gross Ratio |
|  | Hummocky Cross Stratified | C | <i>Chondrites</i> |
|  | Current Rippled | D | <i>Diplocraterion</i> |
|  | Wave Rippled | O | <i>Ophiomorpha</i> |
| T _{bc} | Turbidite Bed-Bouma BC | Pa | <i>Paleophycus</i> |
|  | Convolute Bedding | PI | <i>Planolites</i> |
|  | Flame Structure | Sk | <i>Skolithos</i> |
|  | Scour | Te | <i>Teichichnus</i> |
|  | Concretion | Ter | <i>Teredolites</i> |
|  | Pebbles | Th | <i>Thalassinoides</i> |
|  | Mudstone Clasts |  | Plant Material |
| x x x x x | Bentonite Layer |  | Wood Fragments |
| Fe | Iron-Bearing Cement |  | Coal Fragments |
|  | Spherulites |  | Roots |
| CU | Coarsening Upward | BF | Bone Fragments |
| FU | Fining Upward | SF | Shell Fragments |
| LAS | Lateral Accretion Surface | ST | Shark's Teeth |
| IHS | Inclined Heterolithic Strata |  | Sandstone |
| WC | White-Capped Sandstone |  | Siltstone |
| FAF | Flat and Foreshore |  | Mudstone |
| FS | Flooding Surface |  | Coal |
| SB | Sequence Boundary |  | Scree Cover |
| RSME | Regressive Surface of Marine Erosion | | |

Variety of Lithostratigraphic Names:

- Price River Formation
(Spieker and Reeside 1925)
- Neslen Facies of the P.R.Fm.
(Young 1955)
- Bluecastle Tongue of C.Ss.
(Fouch et al. 1983)
- Neslen Formation
(Lawton 1986)
- Mudstone Member of C.Ss.
(Yoshida et al. 1996)
- Upper Castlegate Sandstone
(after Yoshida et al. 1998; Willis 2000;
Yoshida 2000; Miall and Arush, 2001a,b)
- Middle Member of C.Ss.
(McLaurin and Steel 2000)

1. Castle Gate

Key Photos: DSCN0182, DSCN01101

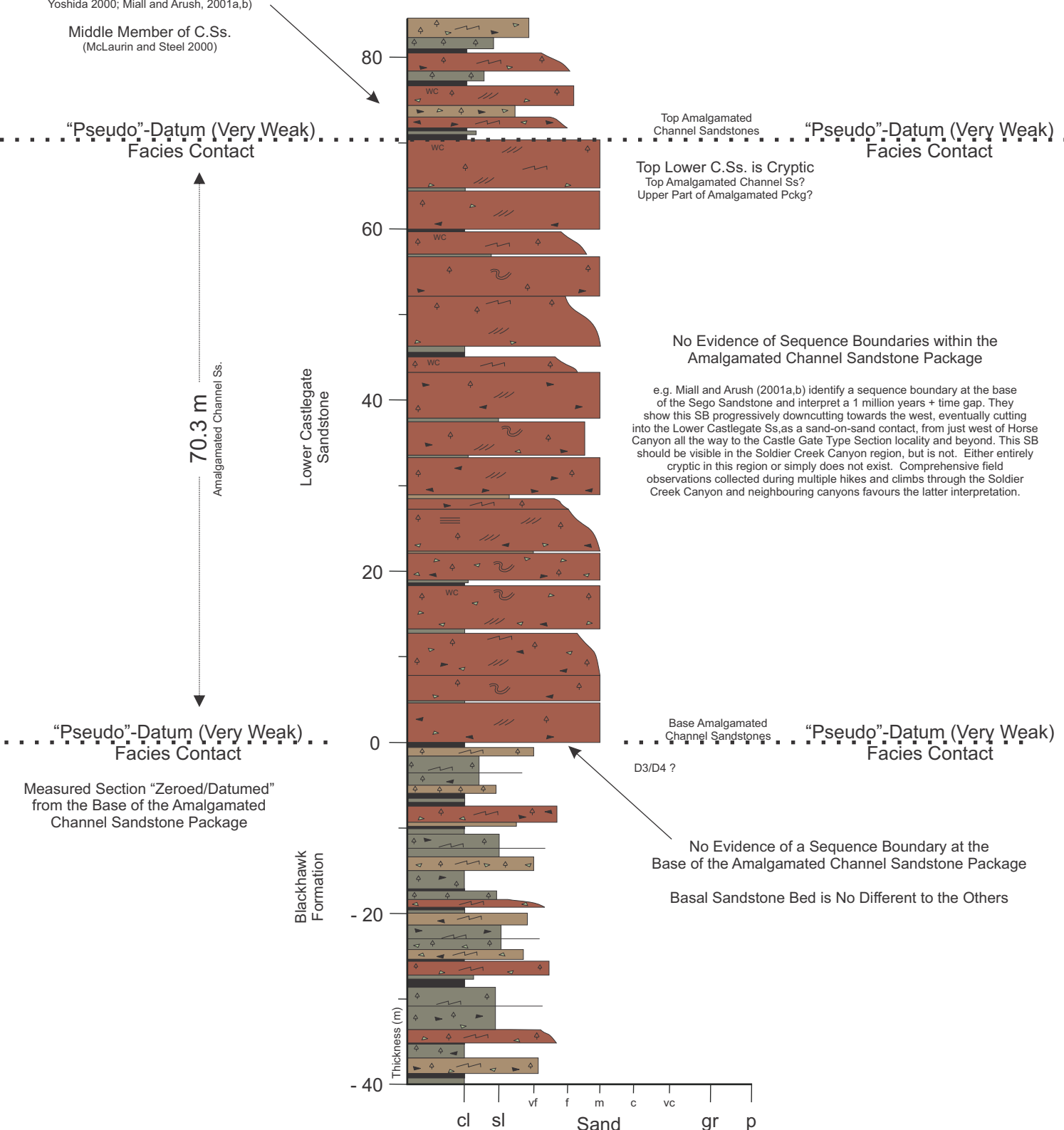


Variety of Lithostratigraphic Names:

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- Middle Member of C.Ss.
(McLaurin and Steel 2000)

2. Soldier Creek Canyon

Key Photos: DSCN0008, DSCN0119



3. Sunnyside

Key Photos: DSCN0141, DSCNa0020, DSCNa0025, DSCN0169, DSCNa0008.

Variety of Lithostratigraphic Names:

Price River Formation
(Spieker and Reeside 1925)

Neslen Facies of the P.R.Fm.
(Young 1955)

Bluecastle Tongue of C.Ss.
(Fouch et al. 1983)

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Upper Castlegate Sandstone
(after Yoshida et al. 1998; Willis 2000; Yoshida 2000; Miall and Arush, 2001a,b)

Middle Member of C.Ss.
(McLaurin and Steel 2000)

"Pseudo"-Datum (Weak)
Facies Contact

Top CSs ? "Pseudo"-Datum (Weak)
Facies Contact

Top Lower C.Ss. ?

Top Amalgamated Channel Sandstones

55.5 m
Amalgamated Channel Ss.
of the Lower C.Ss.

83.9 m

Lower Castlegate
Sandstone

"Pseudo"-Datum (Weak)
Facies Contact

Base Amalgamated Channel Sandstones
"Pseudo"-Datum (Weak) Facies Contact

Blackhawk
Formation

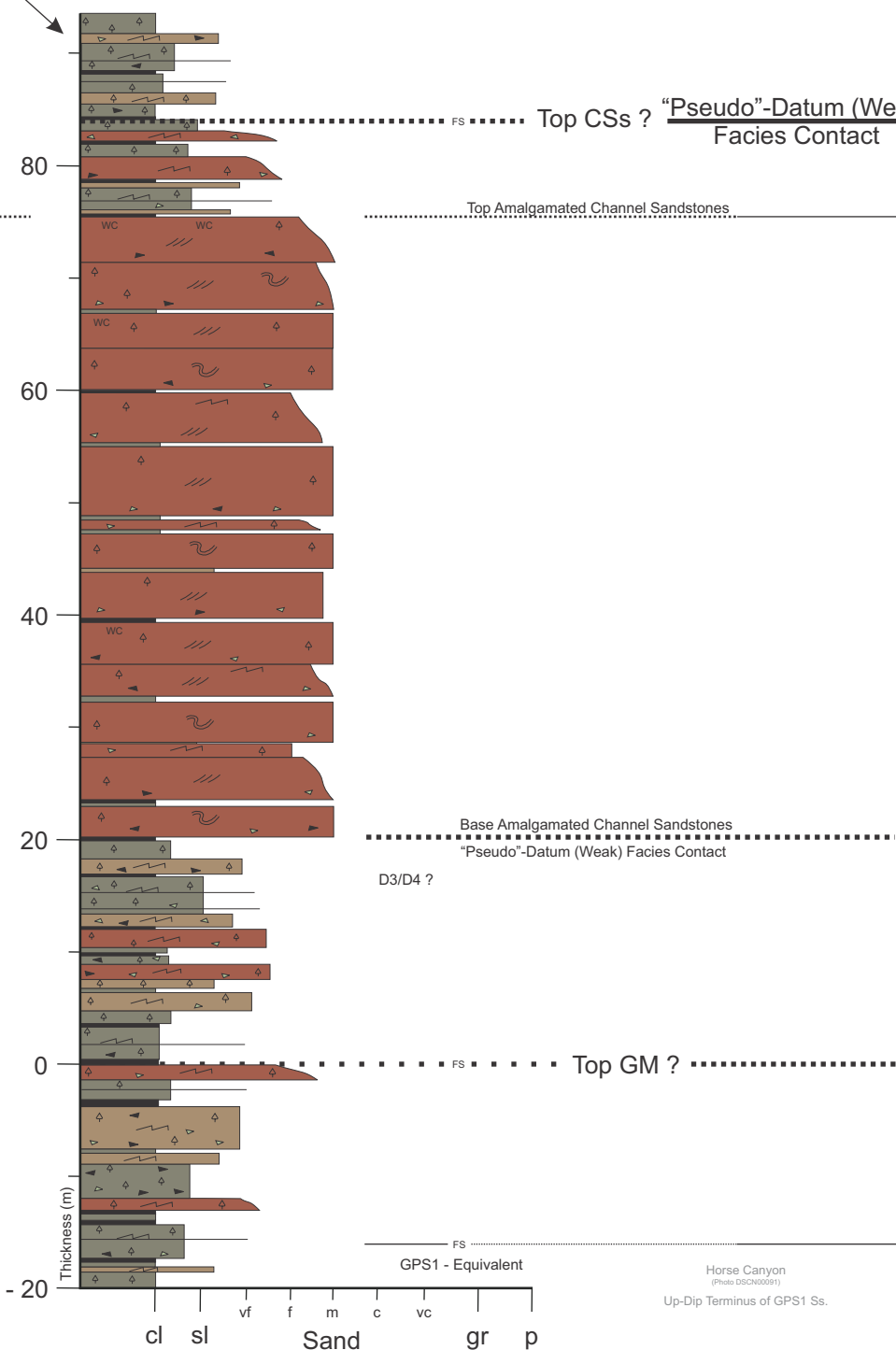
D3/D4 ?

No Longer a Datum
Cryptic at Best

Top GM ?

Top GM ?

Grassy Member

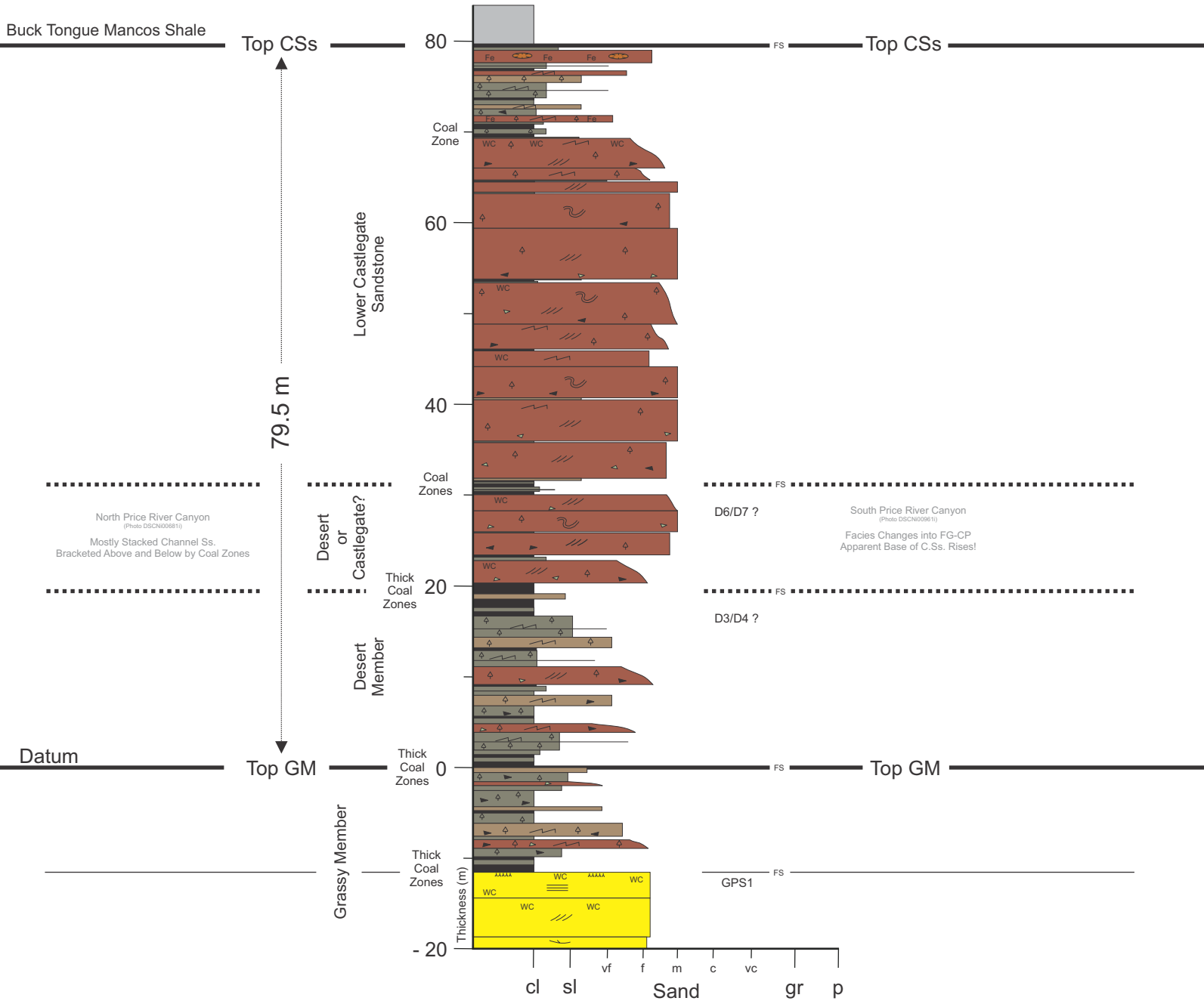


GPS1 - Equivalent

Horse Canyon
(Photo DSCN0091)
Up-Dip Terminus of GPS1 Ss.

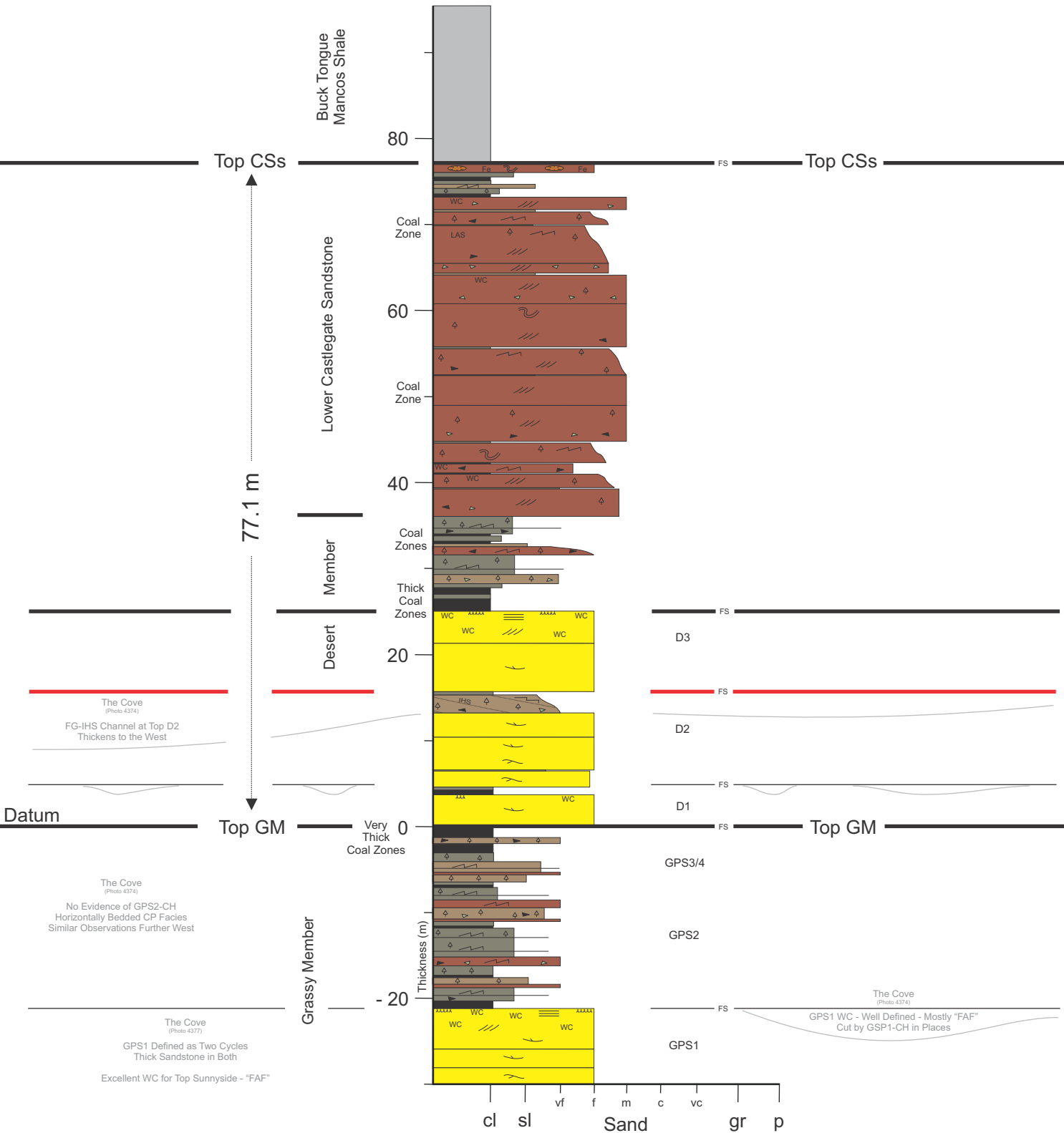
4. Woodside-Price River Canyon

Key Photos: DSCNi00961i, DSCNi00971i.



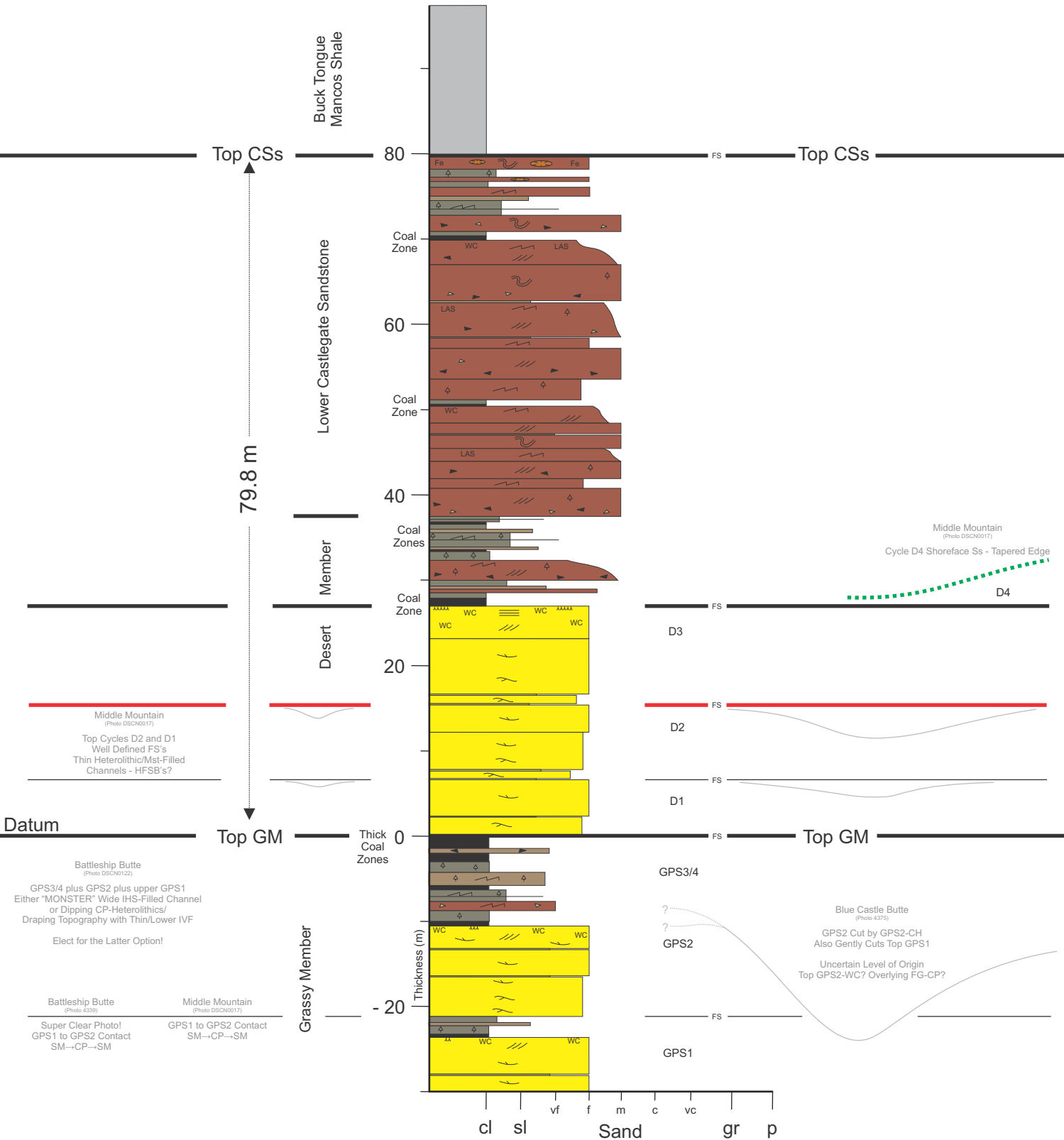
5. The Cove

Key Photos: 4374, DSCN0119, DSCN0122, 4339.



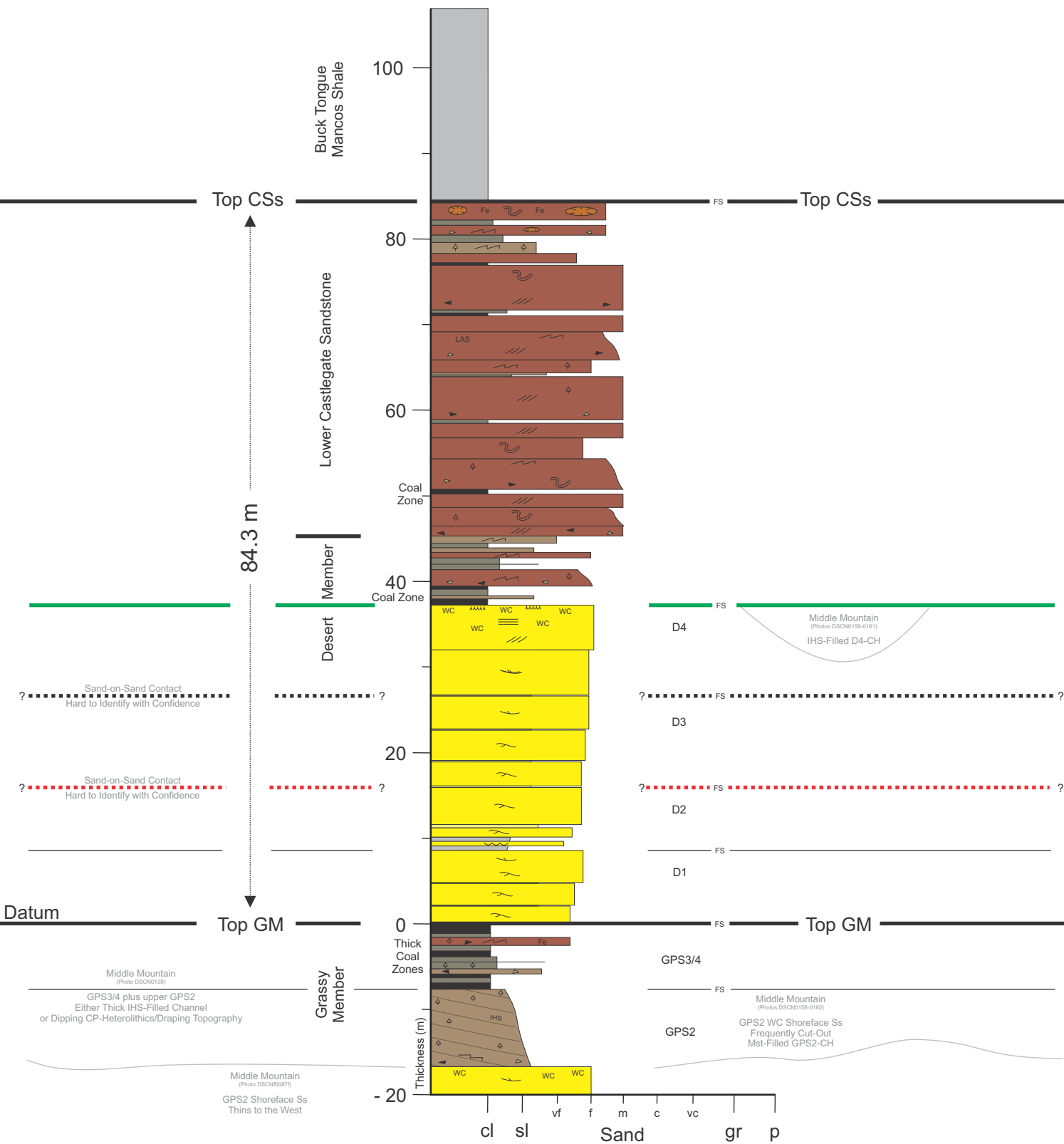
6. Middle Mountain - Central

Key Photos: DSCN0017, DSCN0016, 4352, 4375, 4377, DSCN0122.



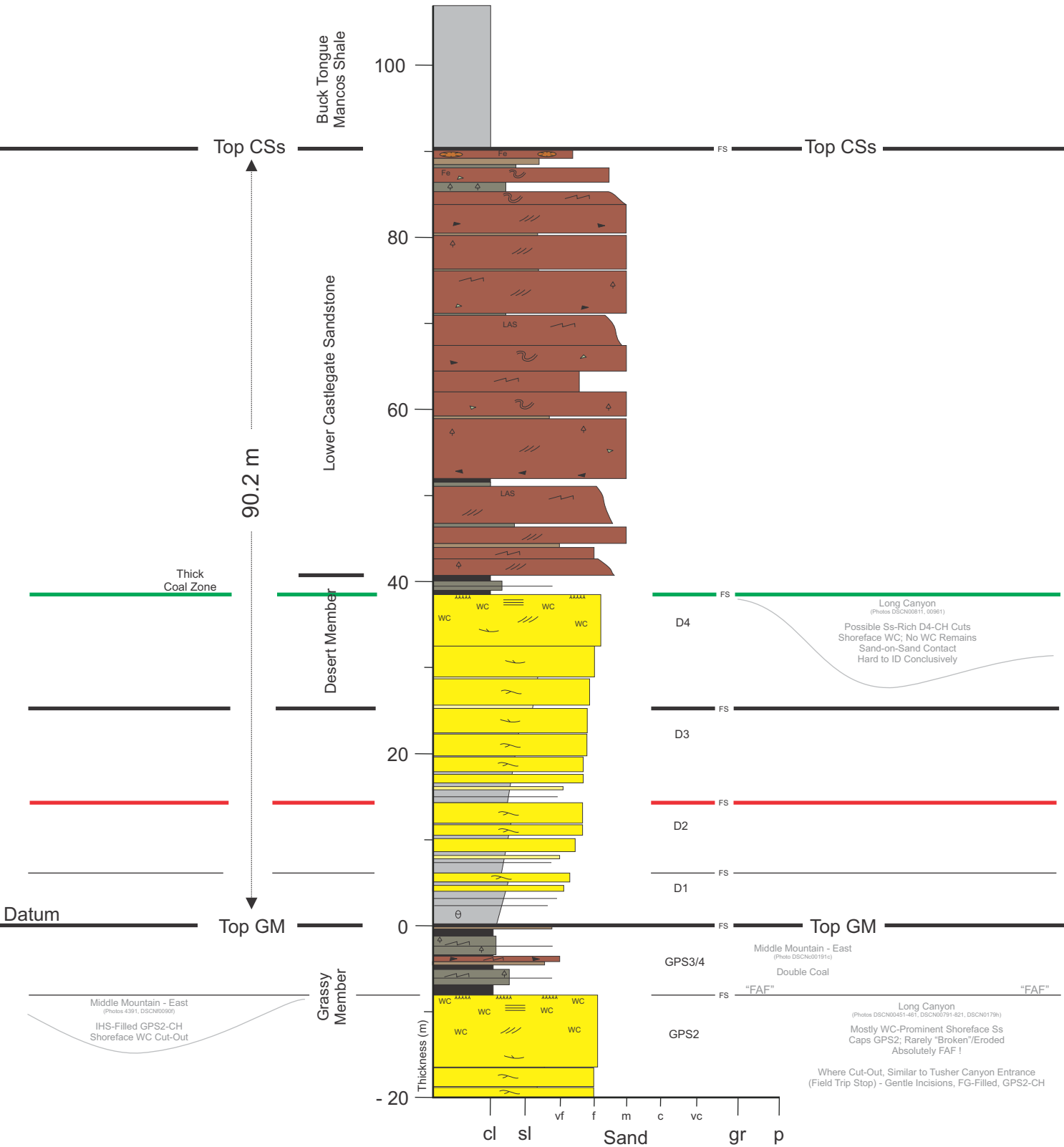
7. Middle Mountain - East

Key Photos: DSCNf0087f, DSCN0161, DSCN0158.



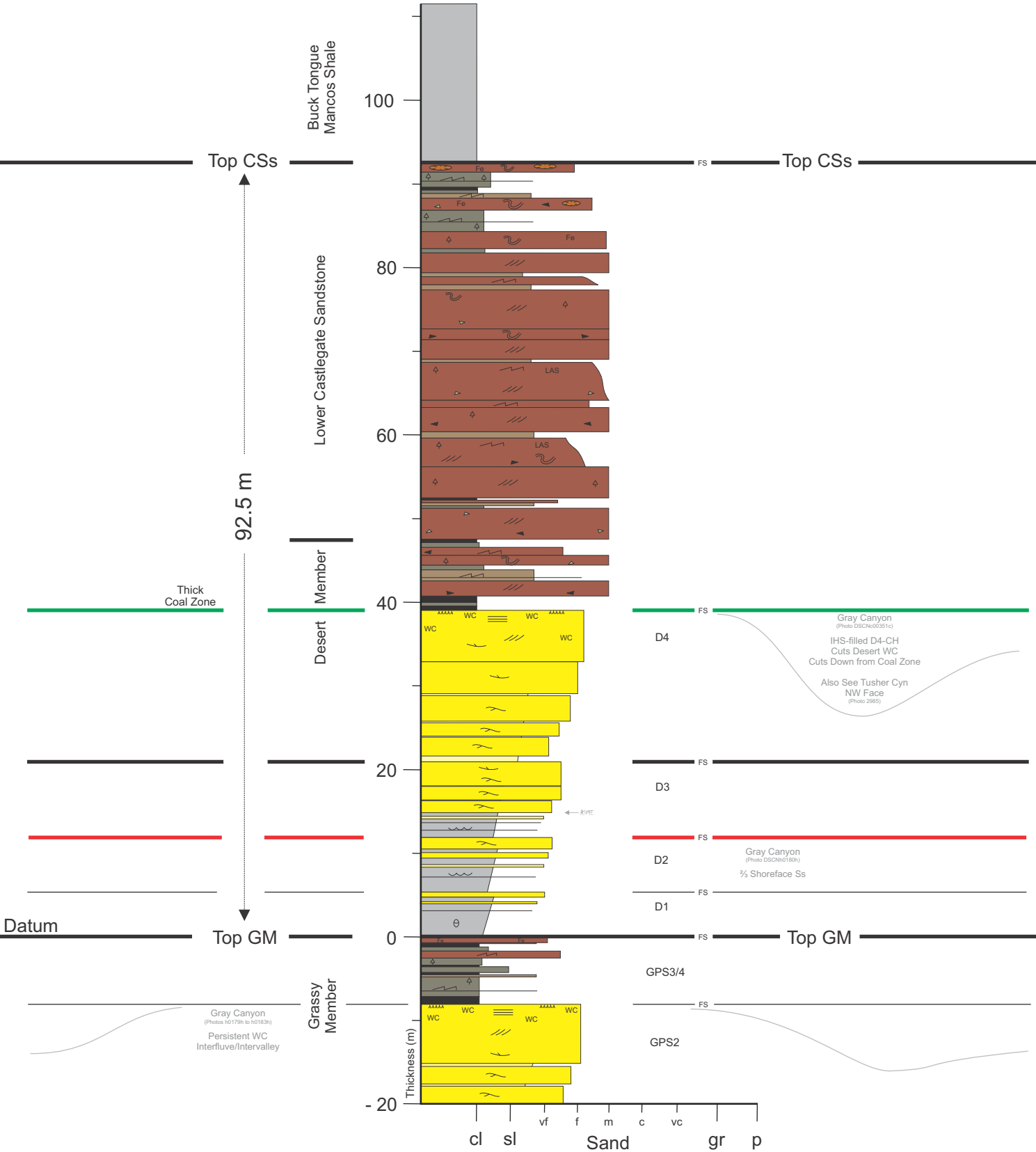
8. Long Canyon

Key Photos: DSCN01011, DSCN00761, DSCN00801, DSCN00821.



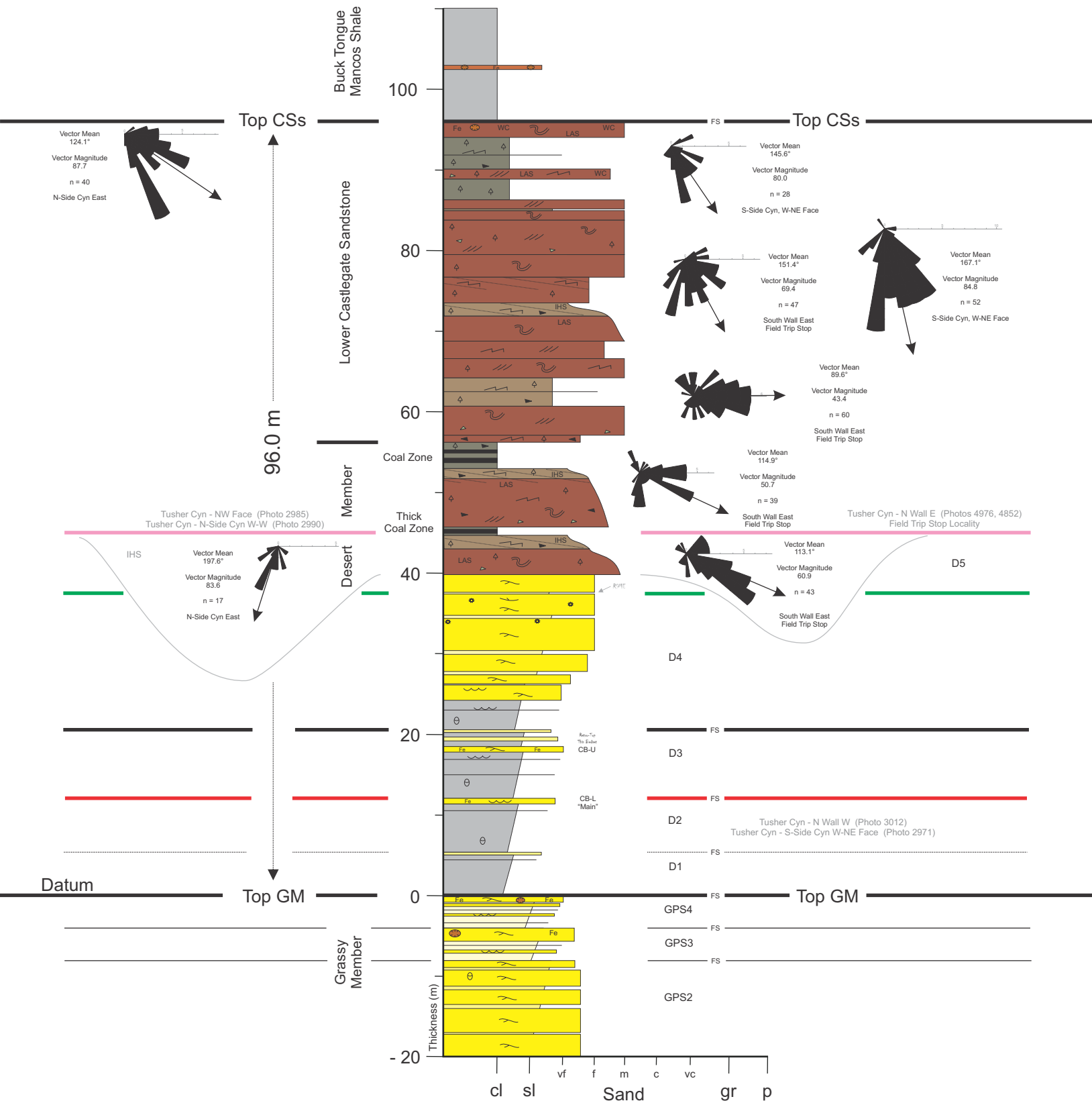
9. NE of Swaseys Beach

Key Photos: DSCNh0180h, DSCNc00351c, 4562



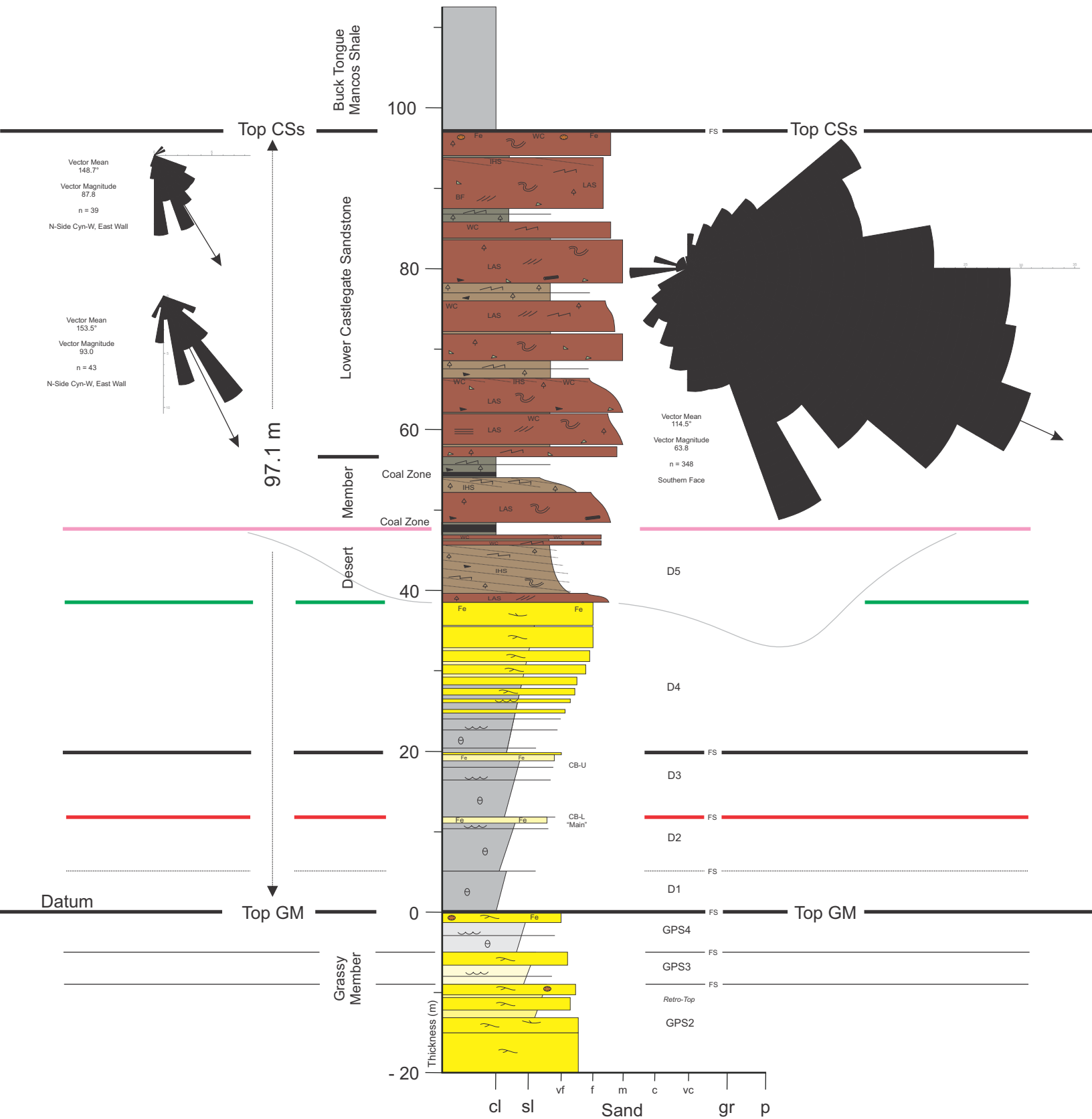
10. Tusher Canyon - N-Side Cyn-E

Key Photos: 3487, 4329/4484, 4518, 4535, 4304, 4251



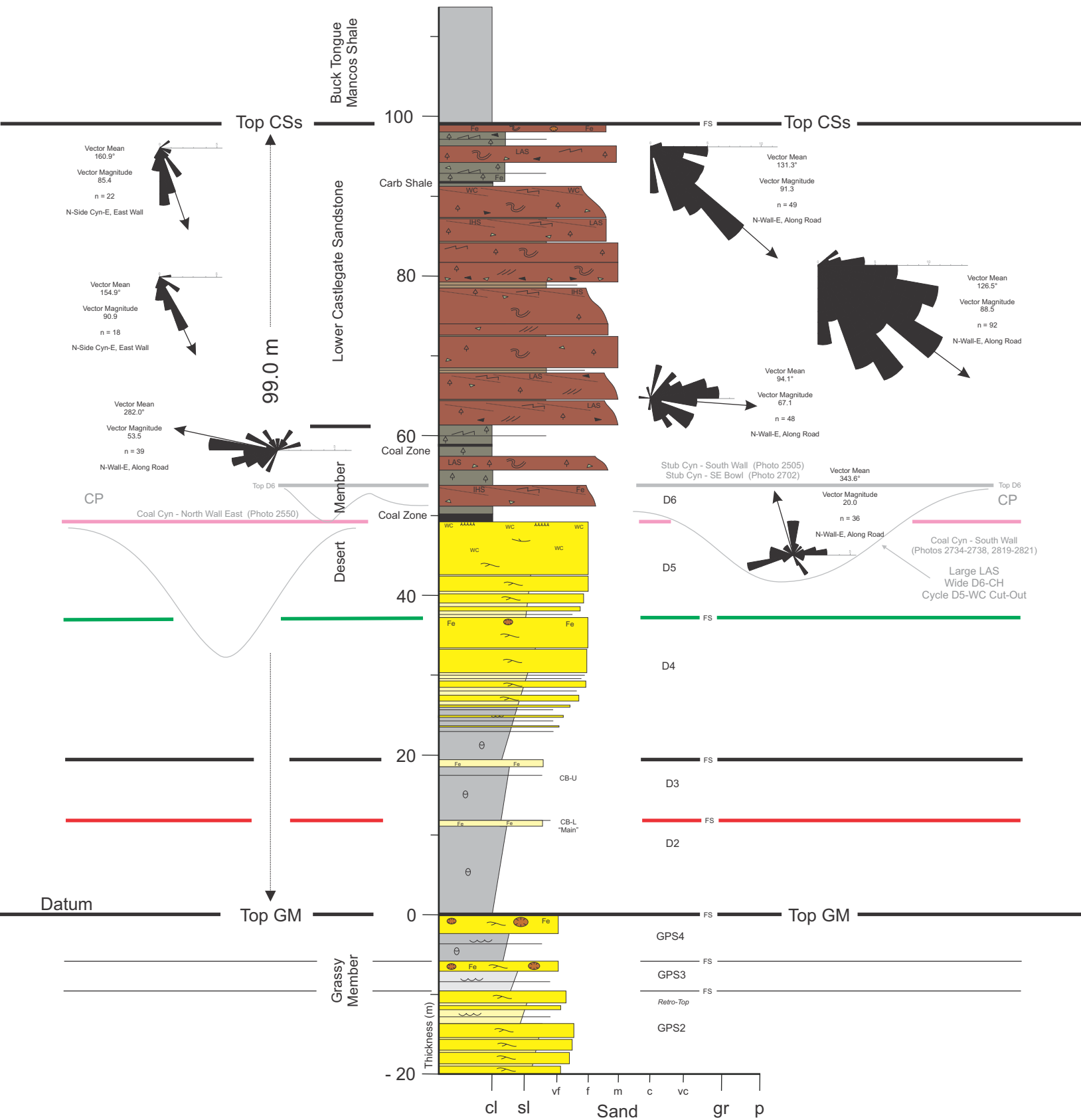
11. Coal Canyon - NW Bowl to N-Side Cyn W

Key Photos: 8679 to 2860/2866



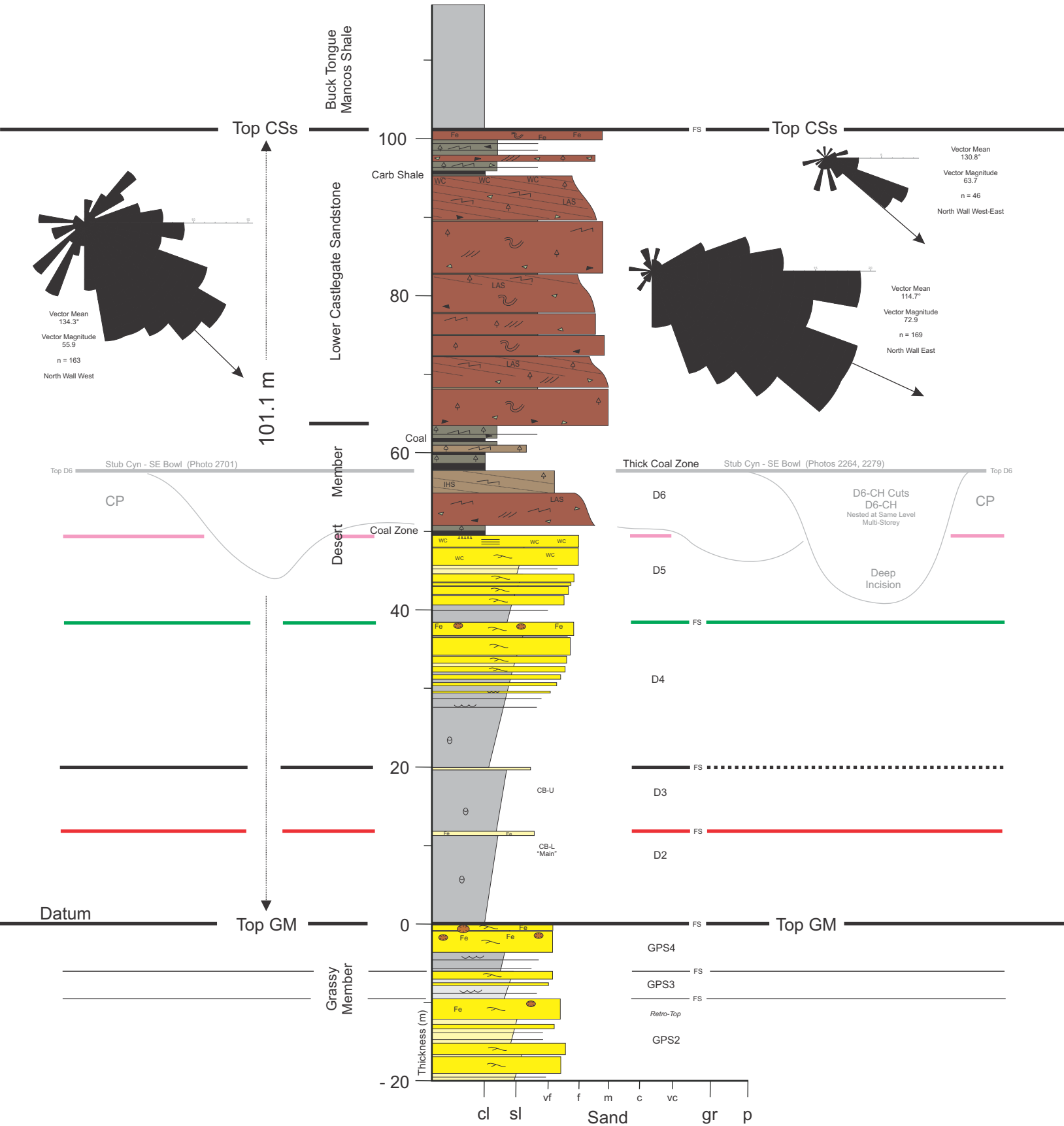
12. Coal Canyon - North Wall East

Key Photos: 2575/2597, 2550, 8326/2775, 4822/4815



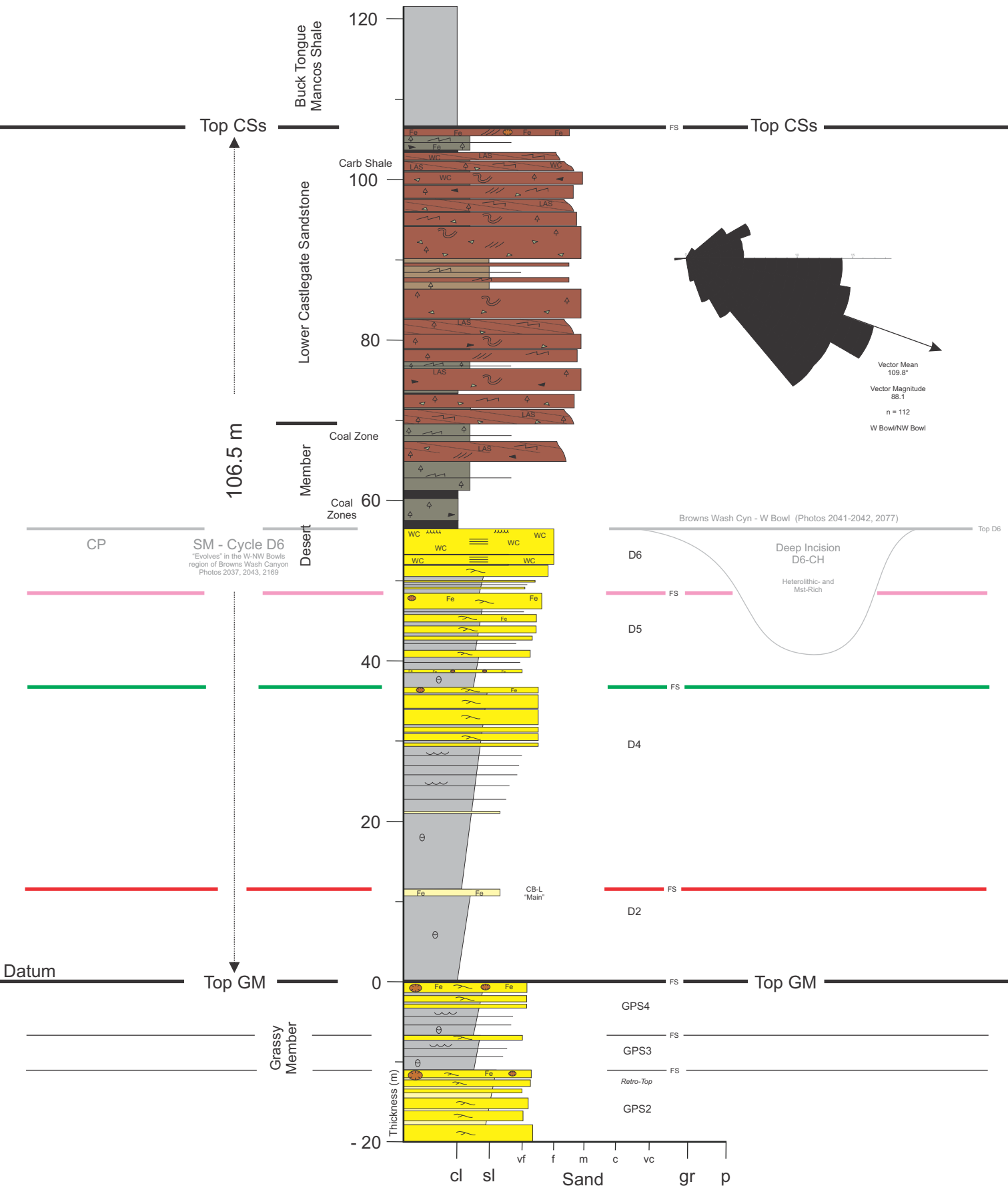
13. Stub Canyon - SE Bowl

Key Photos: 2505/2702/2279, 2282, 8253, 2253



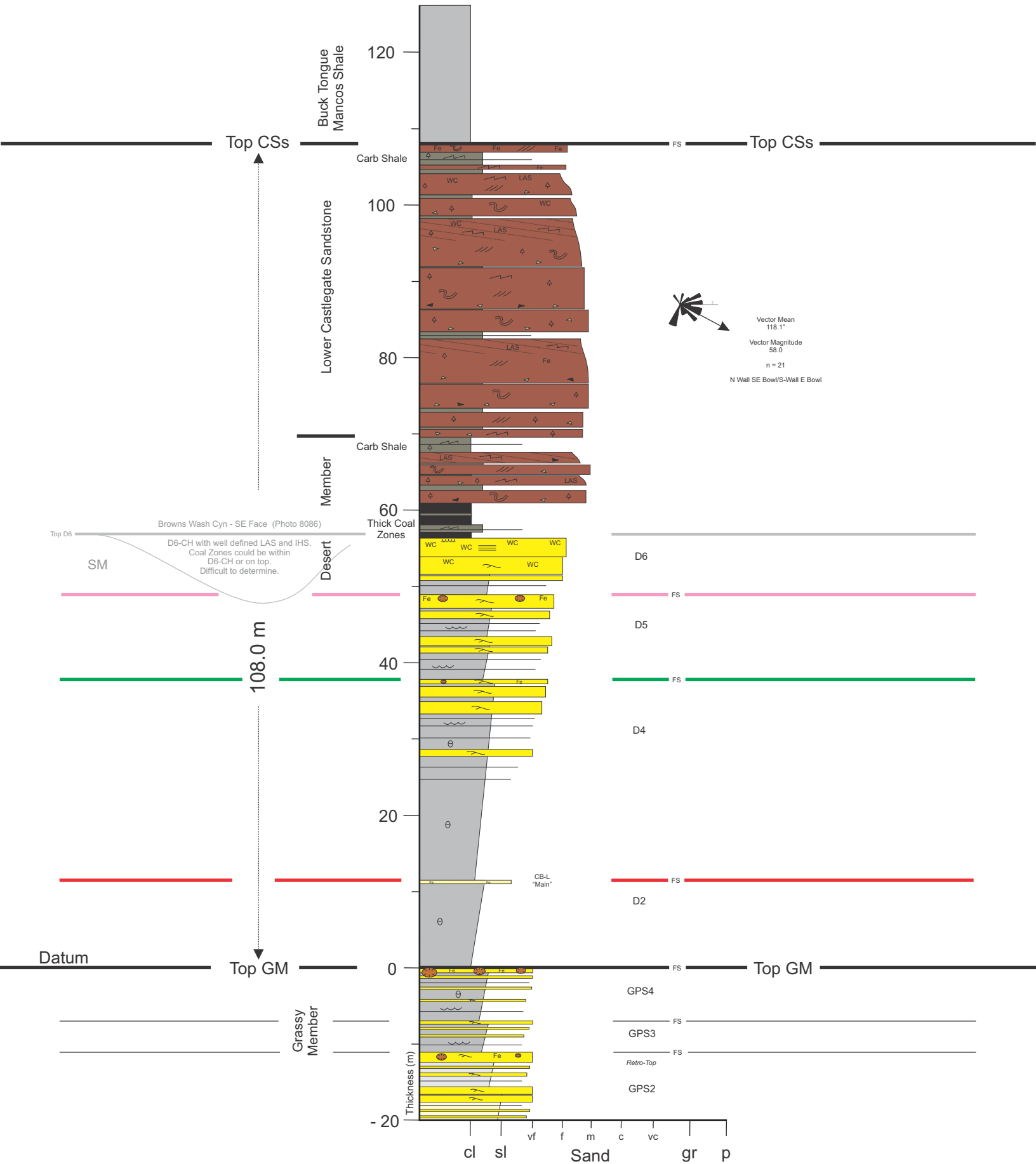
14. Browns Wash Canyon - NW Bowl

Key Photos: 2037, 2169, 2175, 2040-2041



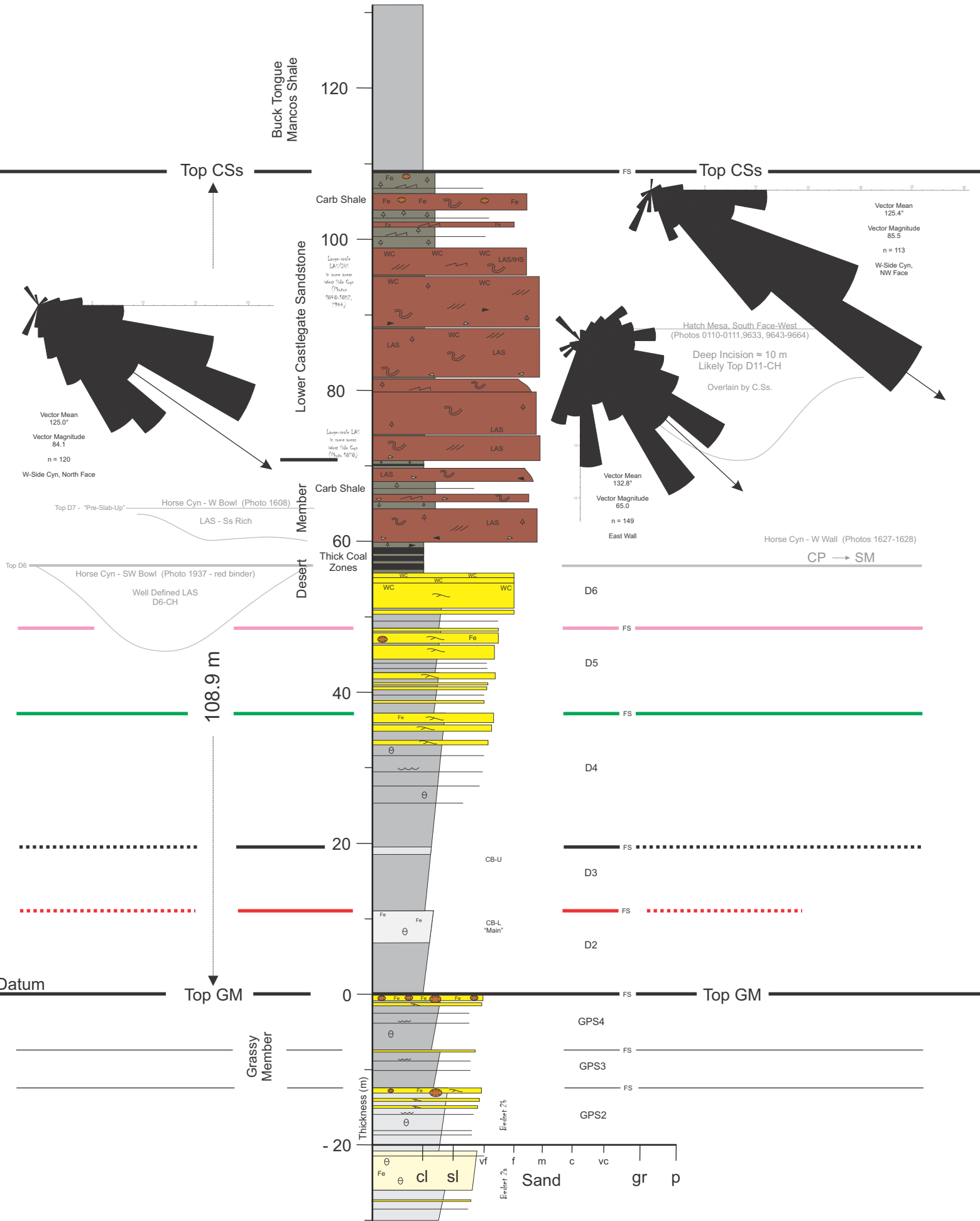
15. Browns Wash Canyon - SE Bowl

Key Photos: 2066/8104 (Css), 2069/2072 (DM), 2059/2213 (GM)



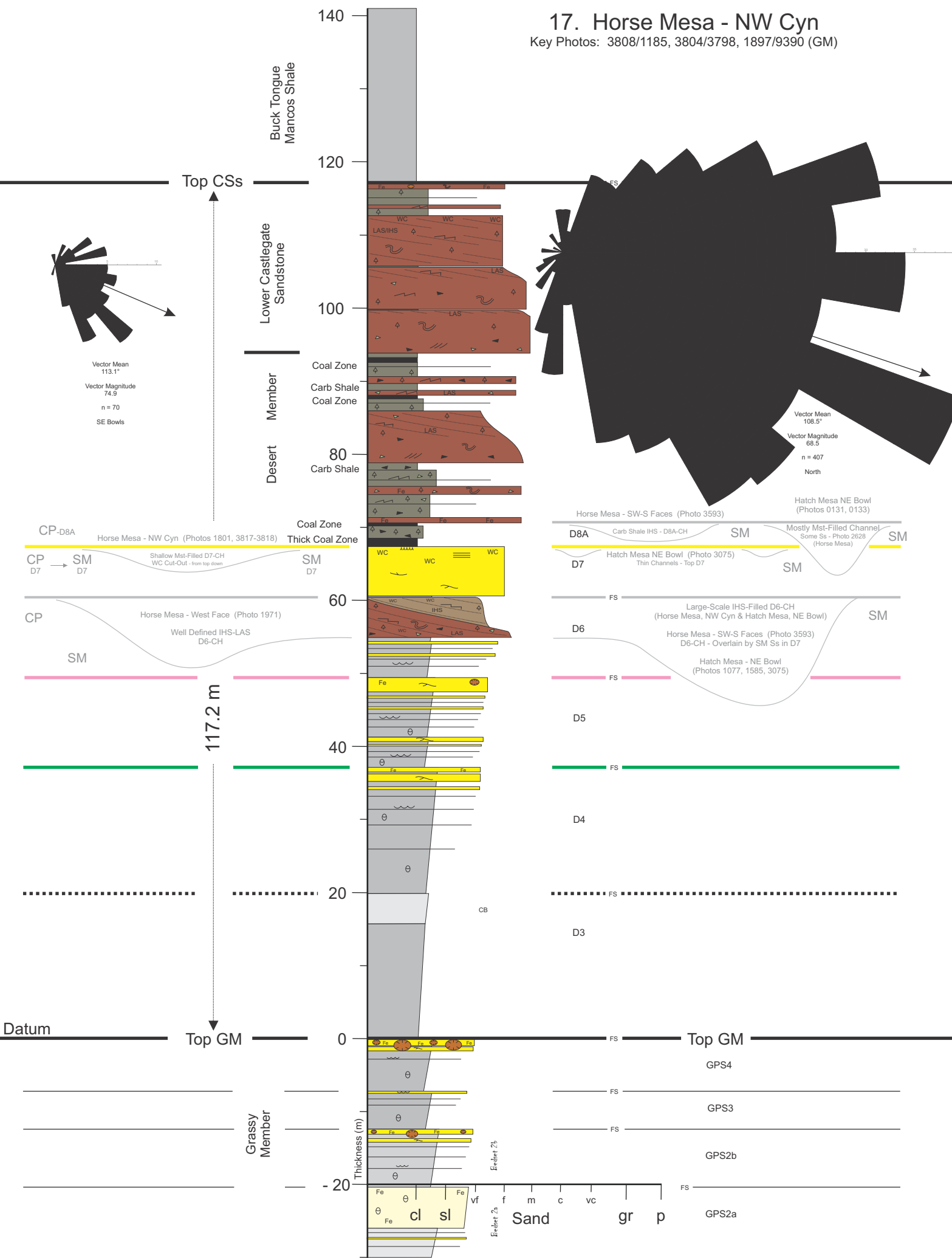
16. Horse Canyon - West Side Cyn

Key Photos: 1765/7846/8017 (CSs), 3319/8050/1869/1875 (DM), 9371/9375/9399 (GM)



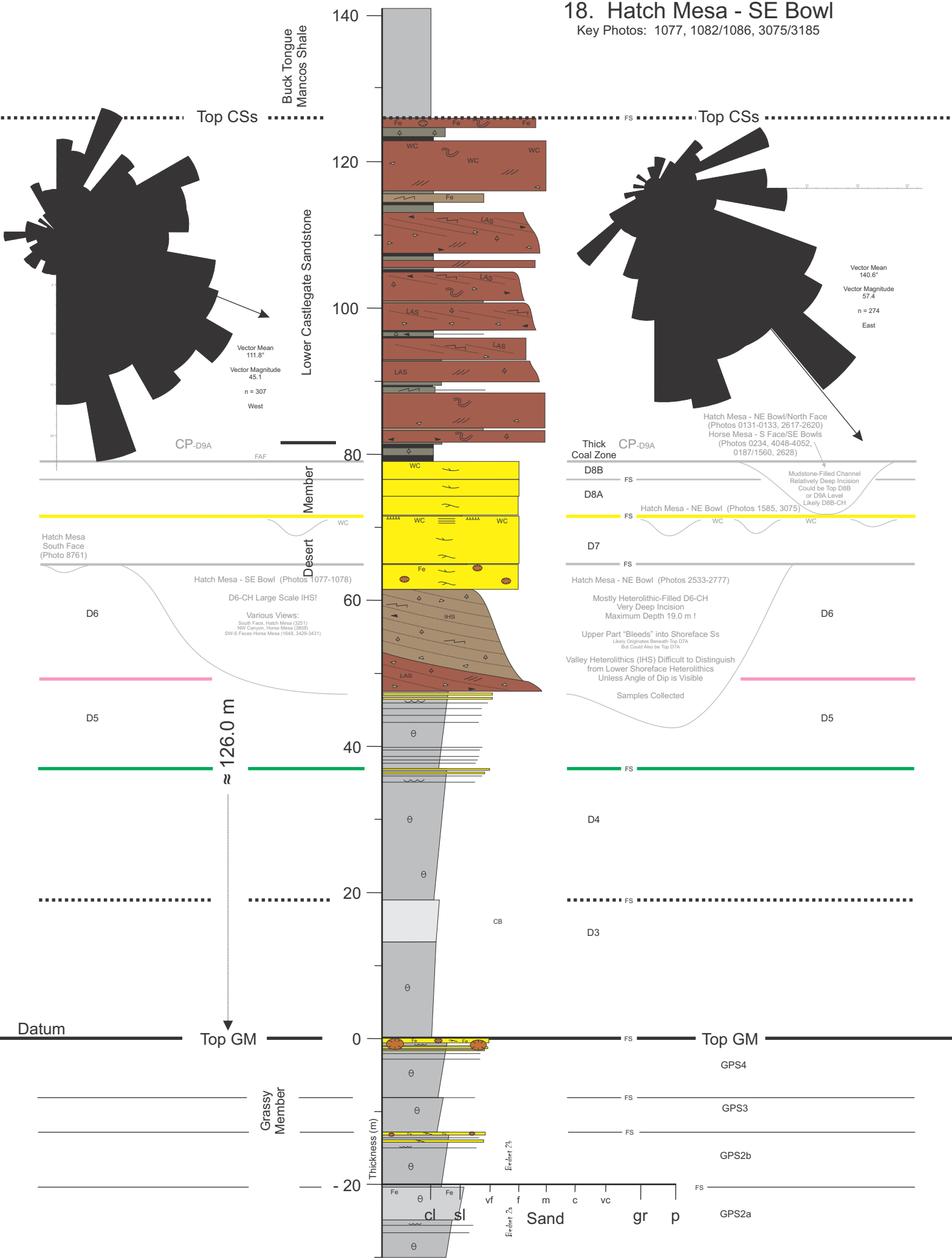
17. Horse Mesa - NW Cyn

Key Photos: 3808/1185, 3804/3798, 1897/9390 (GM)



18. Hatch Mesa - SE Bowl

Key Photos: 1077, 1082/1086, 3075/3185



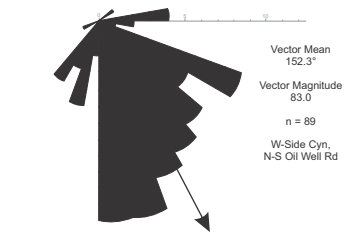
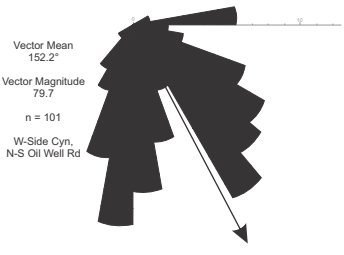
19. Trough Spring Ridge - The Basin

Key Photos: 3887/2711 (TSR), 7216/8914 (TB), 1142 (East Cyn, TB)

Buck Tongue Mancos Shale

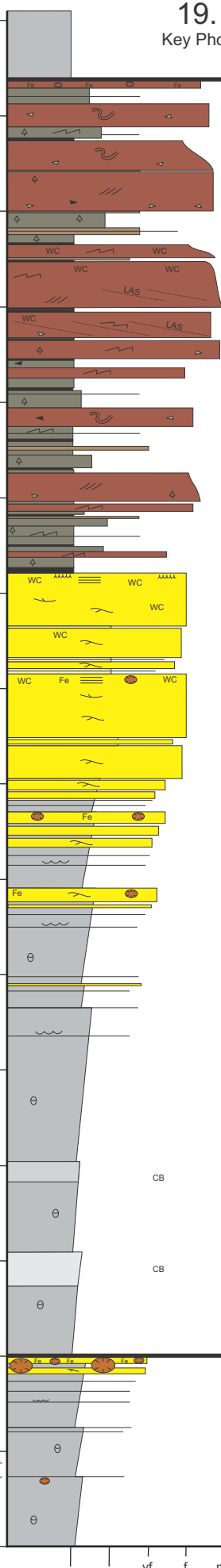
Top CSs

Top CSs



Lower Castlegate Sandstone

Desert Member



MS-3

MS-2

SM-D9A

D8B

D8A

D7

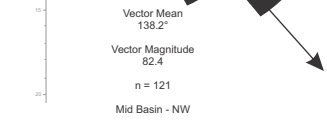
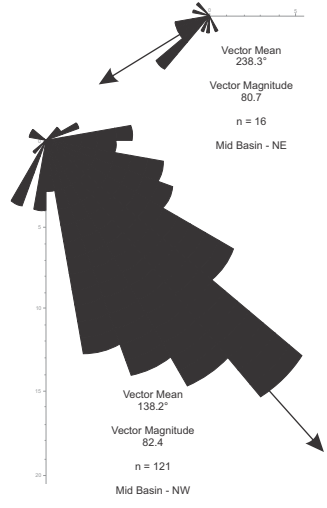
D6B

D6A

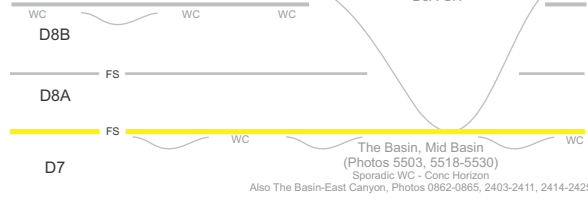
D5

D4

D3



The Basin - East Canyon (Photo 1142)
Christmas Ridge - West Bowl (Photo 2815)



CP-D9A

FAF

WC

WC

WC

WC

WC

WC

WC

WC

WC

WC

WC

WC

WC

WC

WC

WC

WC

WC

WC

WC

WC

WC

WC

WC

WC

WC

WC

WC

WC

WC

WC

TSR - West/South Faces (Photos 3886, 2208)

Probable D8B-CH

Discontinuous D7-CH Cuts Along WC Horizon

Trough Spring Ridge - South Face (Photos 0314, 2208, 3886)

Possible Thin Channel-Fills Upper Cycle D6B (i.e. not at top of cycle)

Trough Spring Ridge - South Face (Photo 0314)

133.8 m

Upper Cycle D6B

Upper Cycle D6B

Upper Cycle D6B

Upper Cycle D6B

Upper Cycle D6B

Upper Cycle D6B

Upper Cycle D6B

Upper Cycle D6B

Upper Cycle D6B

Upper Cycle D6B

Upper Cycle D6B

Upper Cycle D6B

Upper Cycle D6B

Upper Cycle D6B

Upper Cycle D6B

Upper Cycle D6B

Upper Cycle D6B

Upper Cycle D6B

Upper Cycle D6B

Upper Cycle D6B

Upper Cycle D6B

Upper Cycle D6B

Upper Cycle D6B

Upper Cycle D6B

Upper Cycle D6B

Upper Cycle D6B

Datum

Top GM

Top GM

Grassy Member

cl sl Sand gr p

Key Photos: 2761/1469-1470/1466 (East Face), 2717 (South Face)

Top CSs

140

Lower Castlegate Sandstone

120

Member

100

Thick Coal Zones

80

Desert

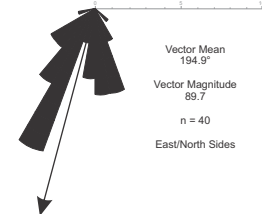
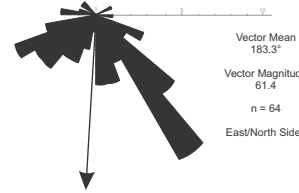
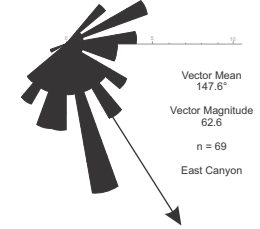
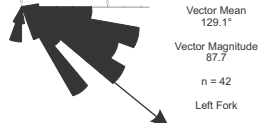
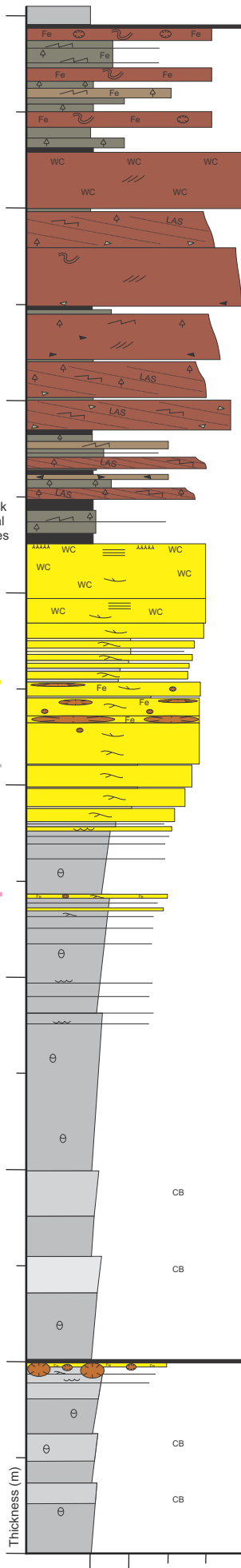
60

40

20

0

-20



138.9 m

TSR - East Face (Photo 1473)

D9A-CH
Heterolithic- and Sandstone-Filled

Relatively Deep Incision
Cuts into Upper D7

TSR - South Face (Photo 2731)

Discontinuous WC
Top Cycle D7



D9A



D8



D7



D6



D5



D4



D3

Datum

Top GM

Top GM

Grassy Member

cl sl Sand gr p

Buck Tongue - Mancos Shale

21. Floy Wash - East Wall

Key Photos: 0753, 1937, 7427, 0530-0531 (ThP-SWFace)

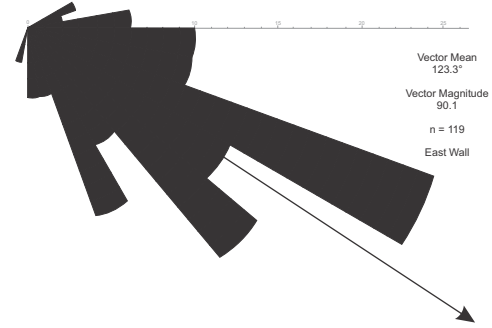
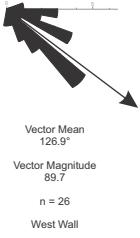
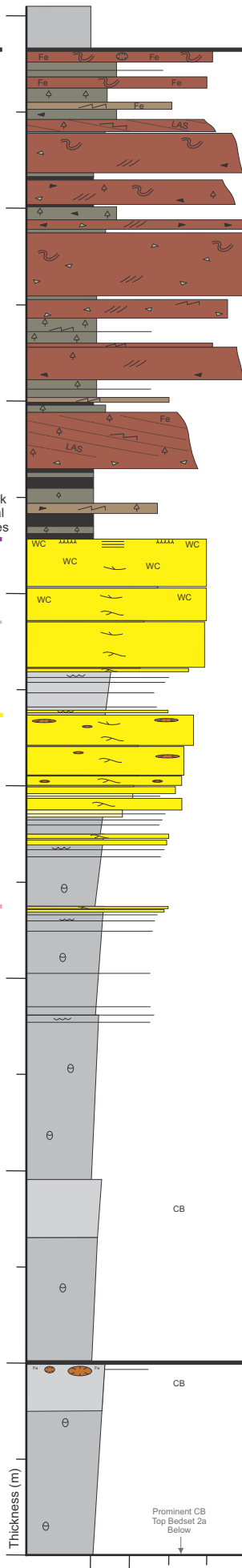
Top CSs

Lower Castlegate Sandstone

Member
Desert

Grassy Member

140
120
100
80
60
40
20
0
-20



Floy Wash - West Wall (Photos 0416, 0723-0729, 1802, 1956)

Mainly Broad-Shallow Incisions - None on East Wall
Heterolithic- and Mudstone-Filled D9A-CH
Deepest Cut Through All WC Ss's
Mostly Upper D9A Only

D8A - Thick SM Sandstone
see Photos 0748-0753
Clinoform. Top D8A drops and loses sandstone.

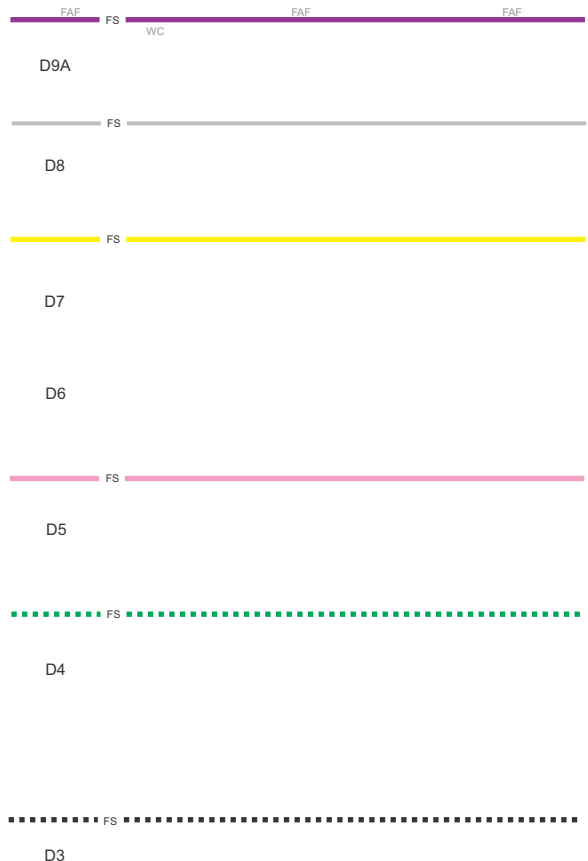
136.6 m

Datum

Top GM

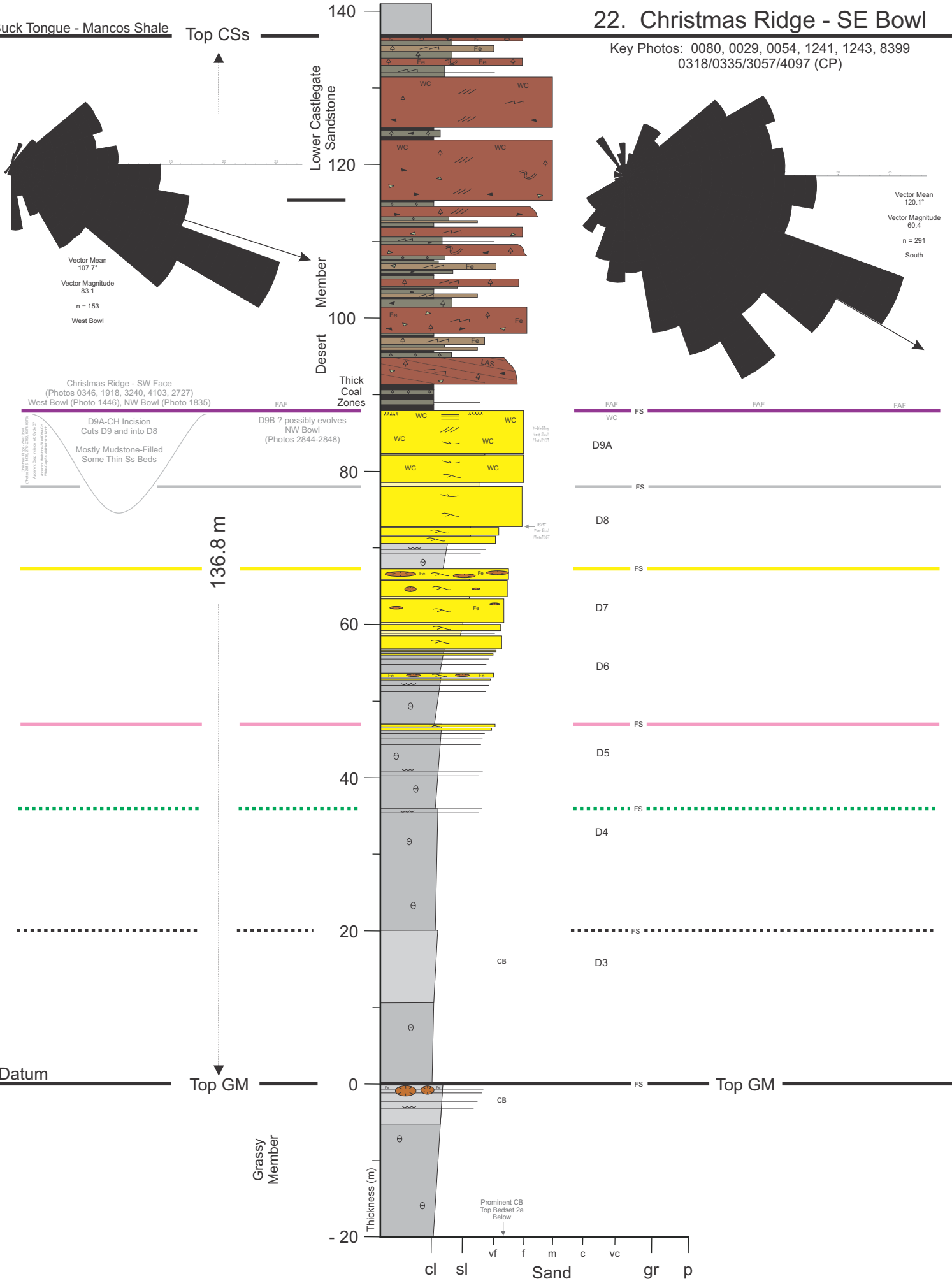
Top GM

cl sl Sand gr p



Prominent CB
Top Bedset 2a
Below

Key Photos: 0080, 0029, 0054, 1241, 1243, 8399
0318/0335/3057/4097 (CP)



Vector Mean
107.7°
Vector Magnitude
53.1
n = 153
West Bowl

Vector Mean
120.1°
Vector Magnitude
60.4
n = 291
South

Christmas Ridge - SW Face
(Photos 0346, 1918, 3240, 4103, 2727)
West Bowl (Photo 1446), NW Bowl (Photo 1835)

D9A-CH Incision
Cuts D9 and into D8
Mostly Mudstone-Filled
Some Thin Ss Beds

D9B ? possibly evolves
NW Bowl
(Photos 2844-2848)

136.8 m

Datum

Top GM

Top GM

Grassy
Member

Thickness (m)

cl sl vf f m c vc gr p
Sand

Prominent CB
Top Bedset 2a
Below

Buck Tongue - Mancos Shale

23. Thompson Pass - East Bowl

Key Photos: 2134, 2137/2141, 2144

Top CSs

Lower Castlegate Sandstone

Thompson Pass, East Bowl-May 2014 (Photos 2472-2474)
Heterolithic-Filled - C3/C4-CH?

Thompson Pass, East Bowl
(Photos 2134, 2141, 2144, 2166, 5479)

> 8 m Incision

Cuts Down to the Top of the
Very Thick Coal Zone

Vector Mean
192.7°
Vector Magnitude
21.5
n = 13
East Bowl

Member

Desert

Thick
Coal
Zones

CP-D9B → SM-D9B → "Evolves"
TP-S.Face

Thompson Pass - S. Face (Photo 1713)
IHS/Mudstone-Filled
D9A-CH

137.4 m

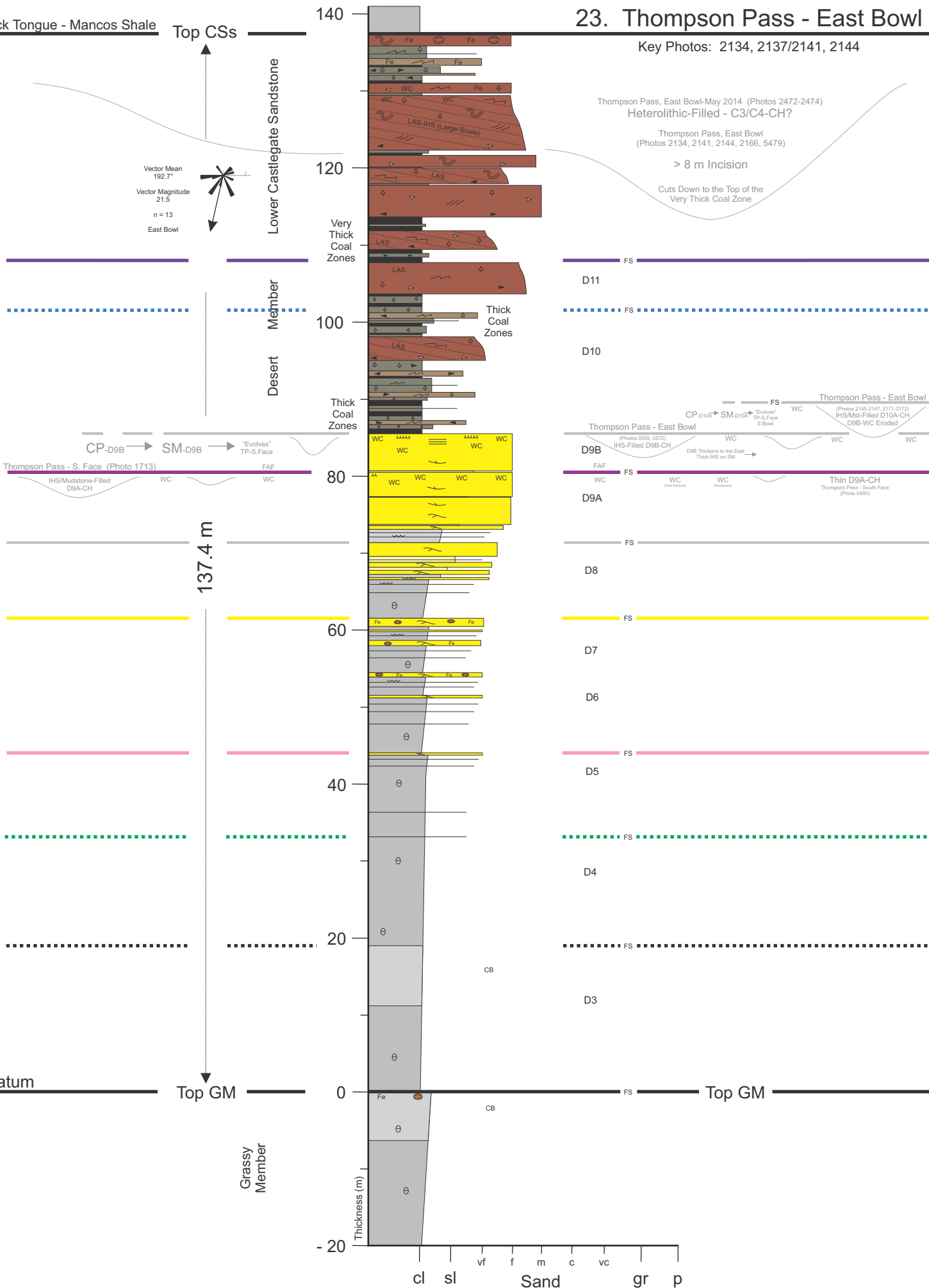
Datum

Top GM

Grassy
Member

Thickness (m)

cl sl Sand vf f m c vc gr p

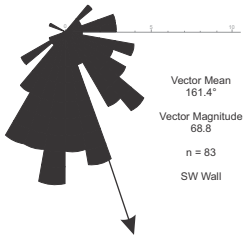


24. Crescent Cyn - SW Wall/W-Side Cyn

Key Photos: 6961/6999, 2353/4983 (W Side Cyn), 0037/0038 (Husky May 2012)

Buck Tongue - Mancos Shale

Top CSs



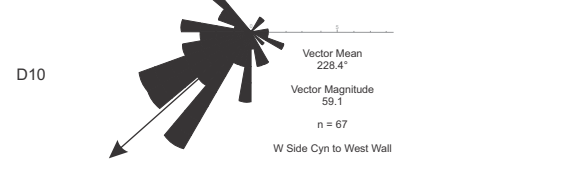
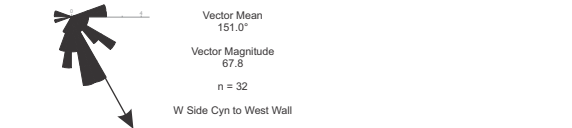
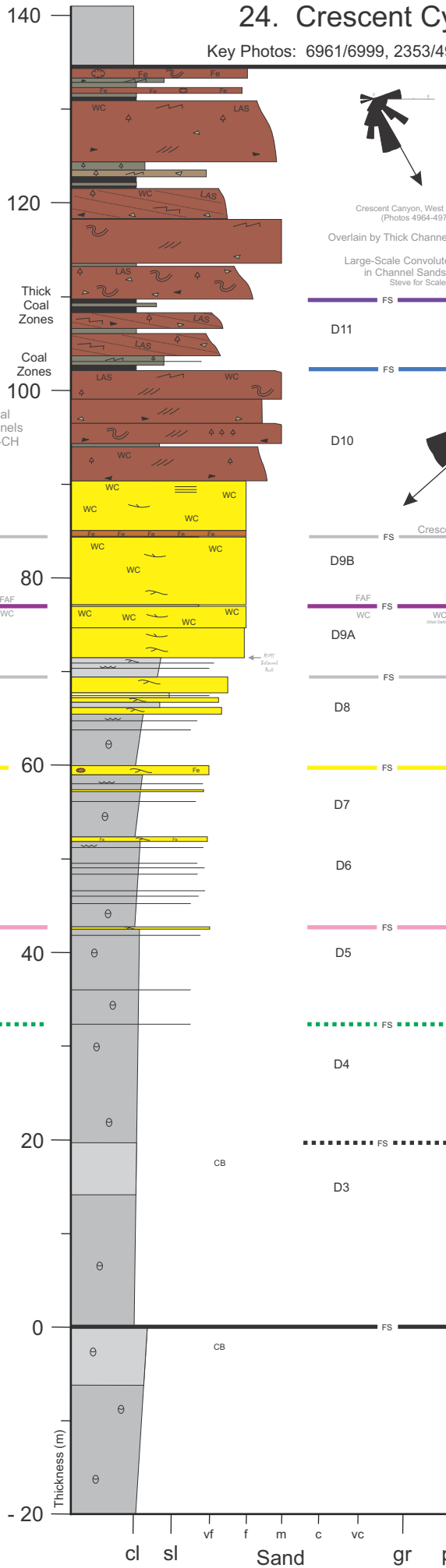
Road Level Coal (Upper Coal)

Cattleguard Coal (Lower Coal)

Lower Castlegate Sandstone

Desert Member

Tidal Channels D10-CH



134.5 m

Datum

Top GM

Grassy Member

Top GM

Crescent Canyon - SW Wall (Photo 6959)

Marginal Example
Thin IHS/Mudstone-Filled D9B-CH

Crescent Canyon - W-Side Cyn (Photo 5007)

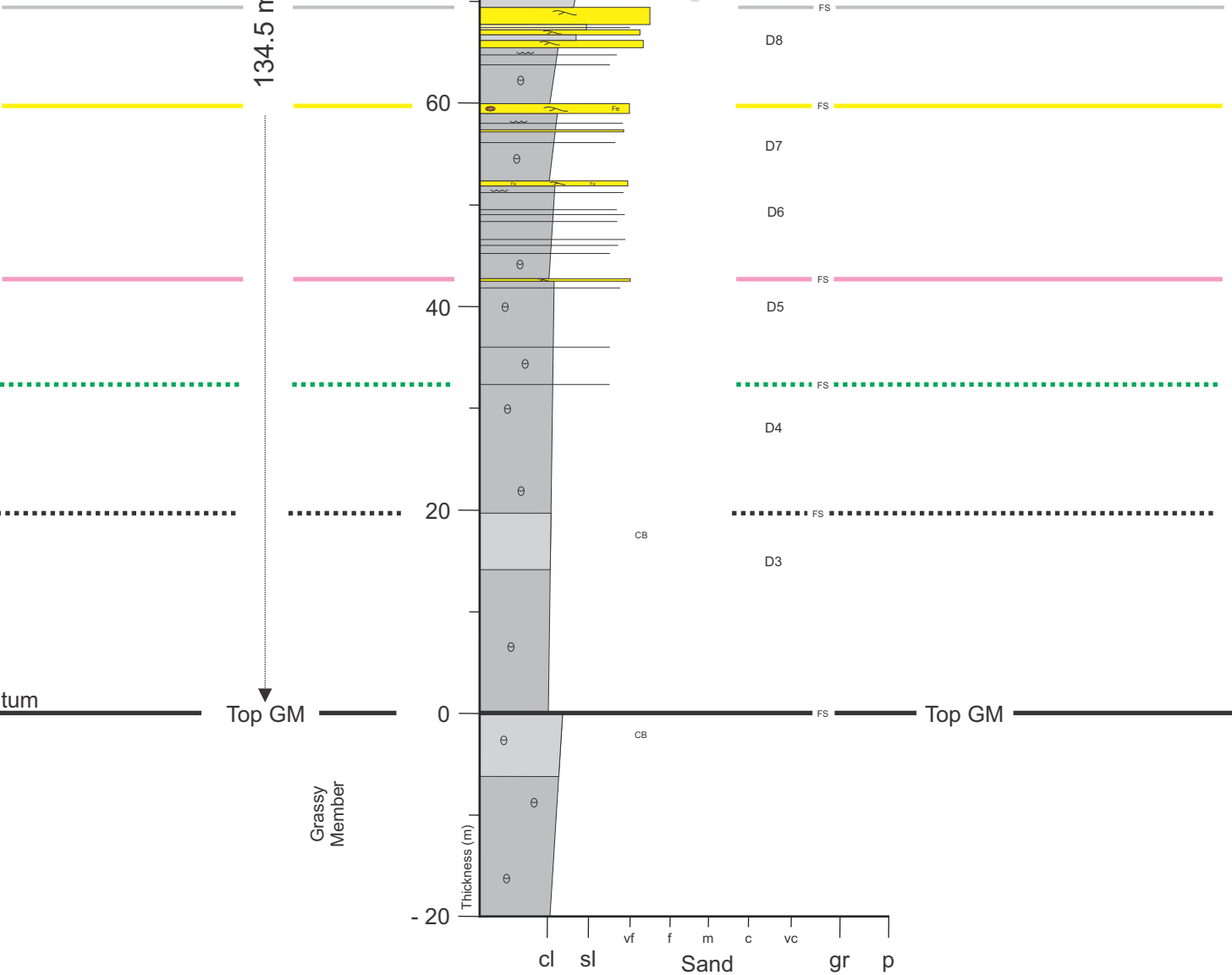
Thin IHS/Mudstone-Filled D9A-CH

Crescent Canyon - West Wall (Field Trip Stop)

Thin Layer - FG-MG Ss with Plant Material
Similar to Thin Layer in Shell Core #2

Crescent Canyon - West Wall

Thin Layer - FG-MG Ss with Plant Material
Similar to Thin Layer in Shell Core #2



25. Horse Heaven - NW/SW Bowls

Key Photos: 5125, 5149, 5151, 5157 (NW Bowl)
1723, 5279, 5353, 5109, 5276, 7009 (SW Bowl)

Buck Tongue
Mancos Shale

Top CSs

Top CSs

Lower Castlegate
Sandstone

Thick Coal
Zones

Thick Coal
Zones

80

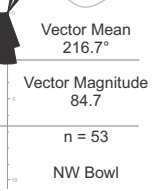
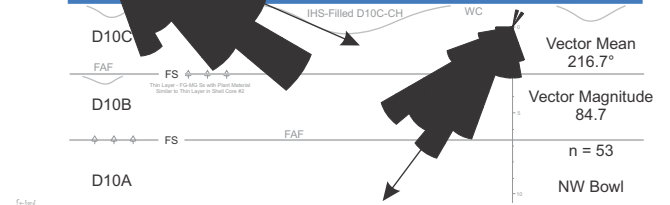
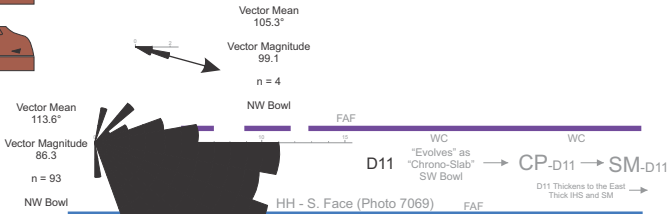
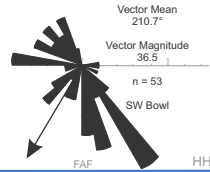
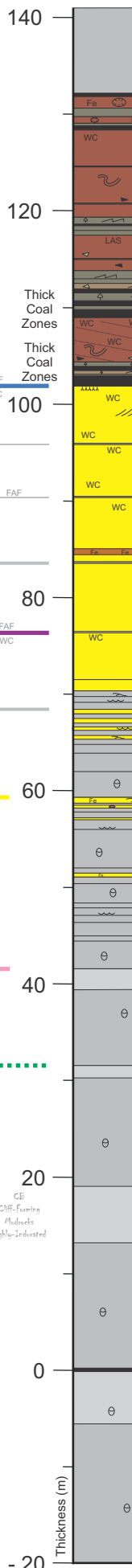
60

40

20

0

Grassy
Member



Datum

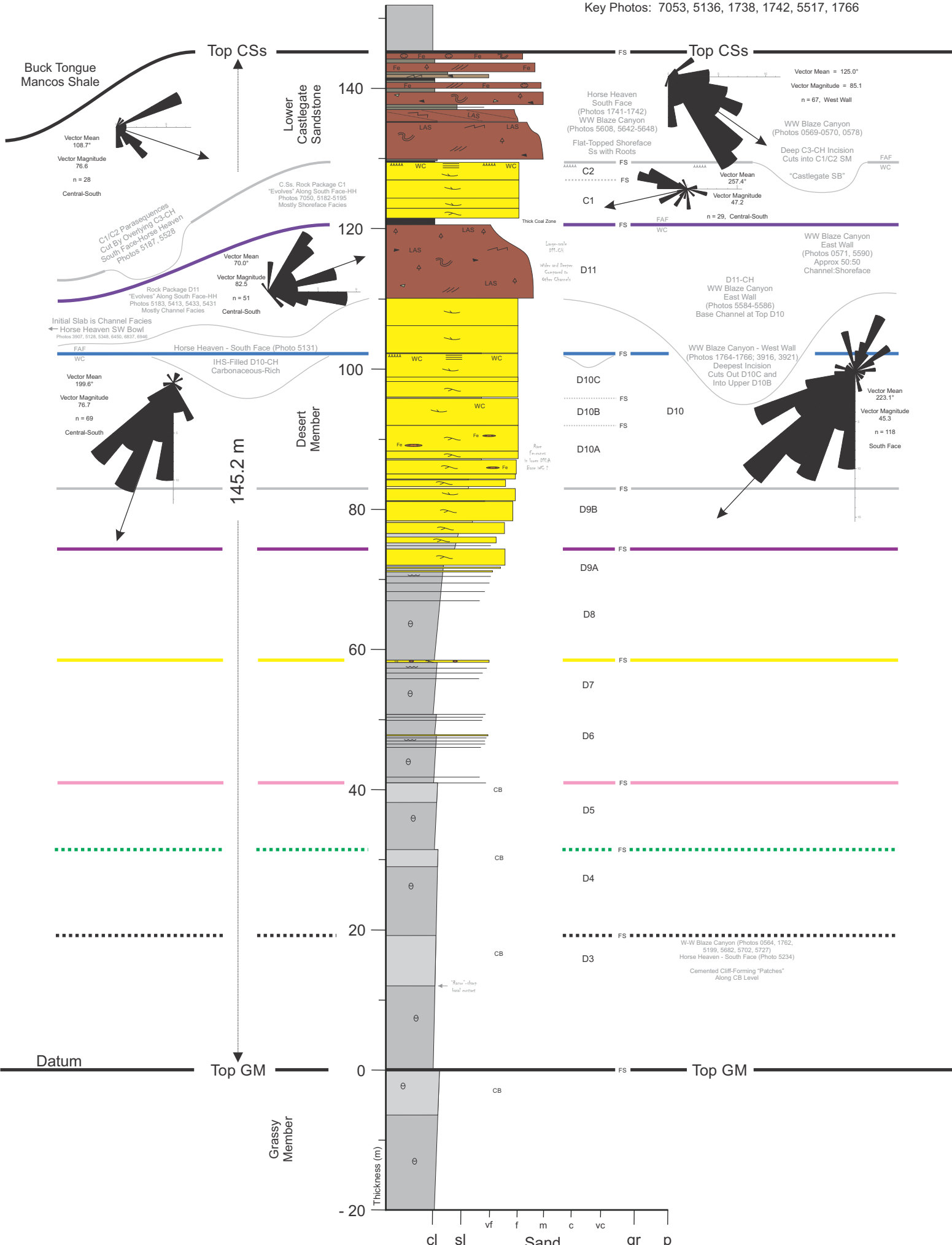
Top GM

Top GM

Thickness (m)
cl sl vf f m c vc gr p
Sand

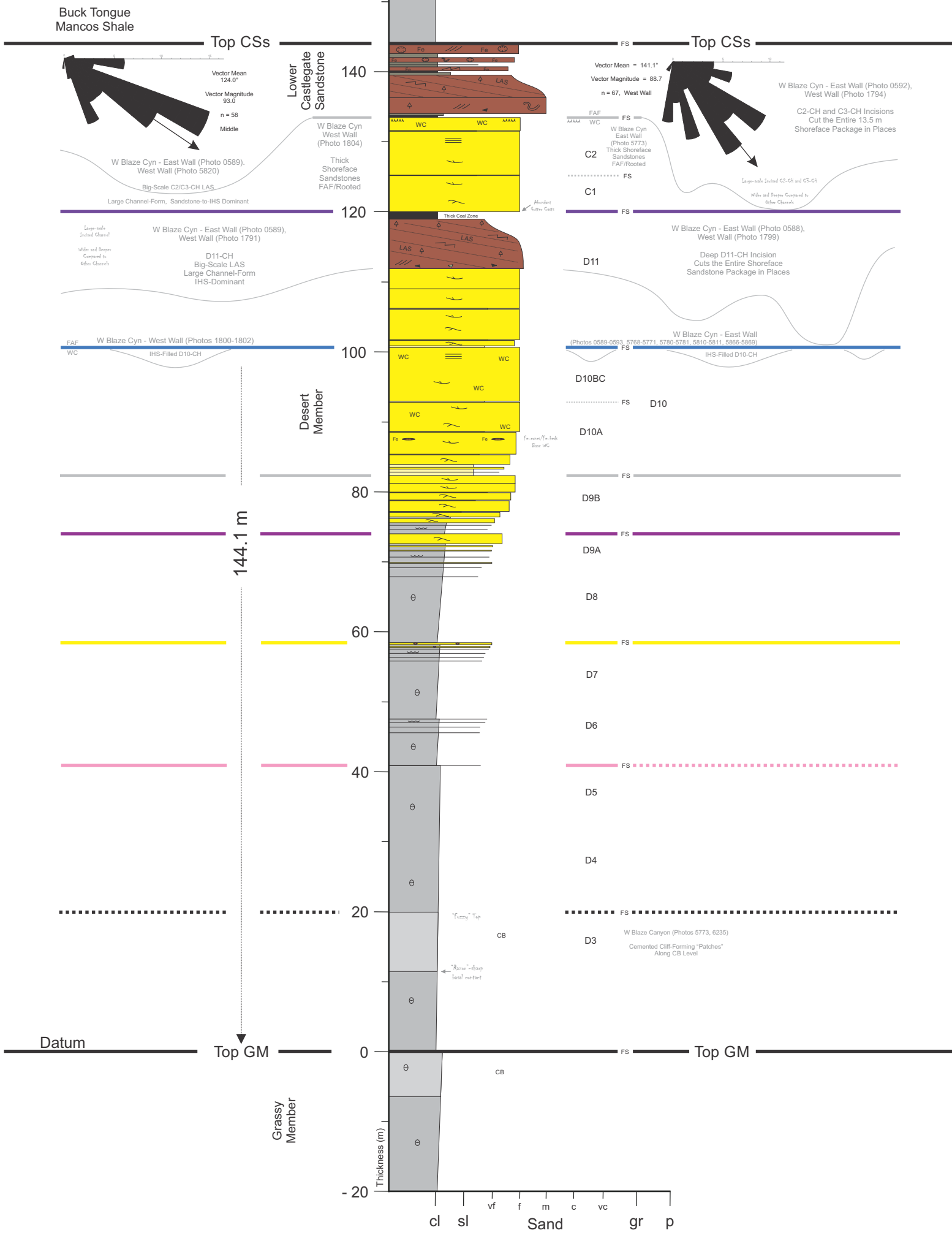
26. Horse Heaven - South Face East

Key Photos: 7053, 5136, 1738, 1742, 5517, 1766



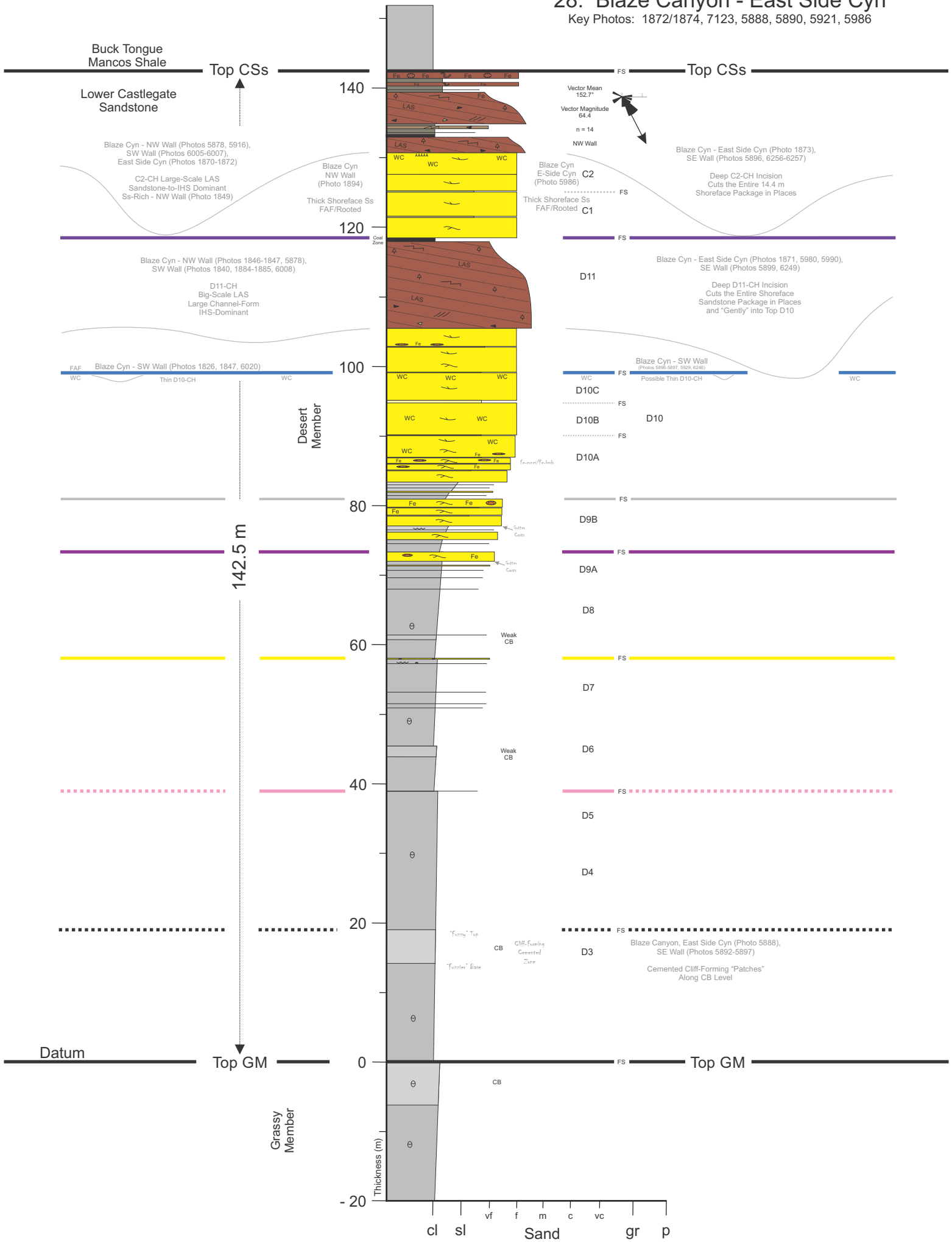
27. West of Blaze Canyon - East Wall

Key Photos: 5865, 5773, 6235-6236; 1802/1804 (West Wall)



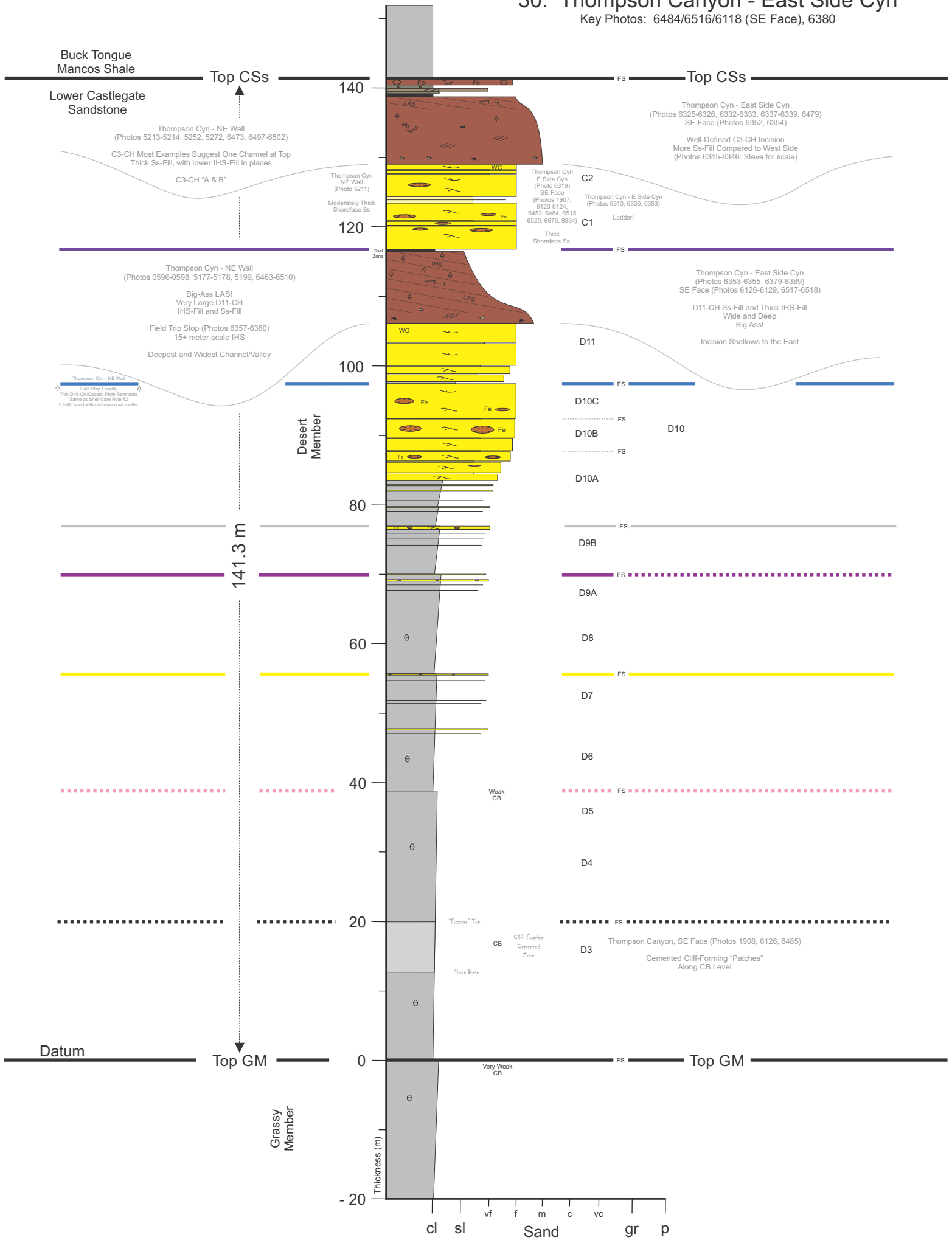
28. Blaze Canyon - East Side Cyn

Key Photos: 1872/1874, 7123, 5888, 5890, 5921, 5986



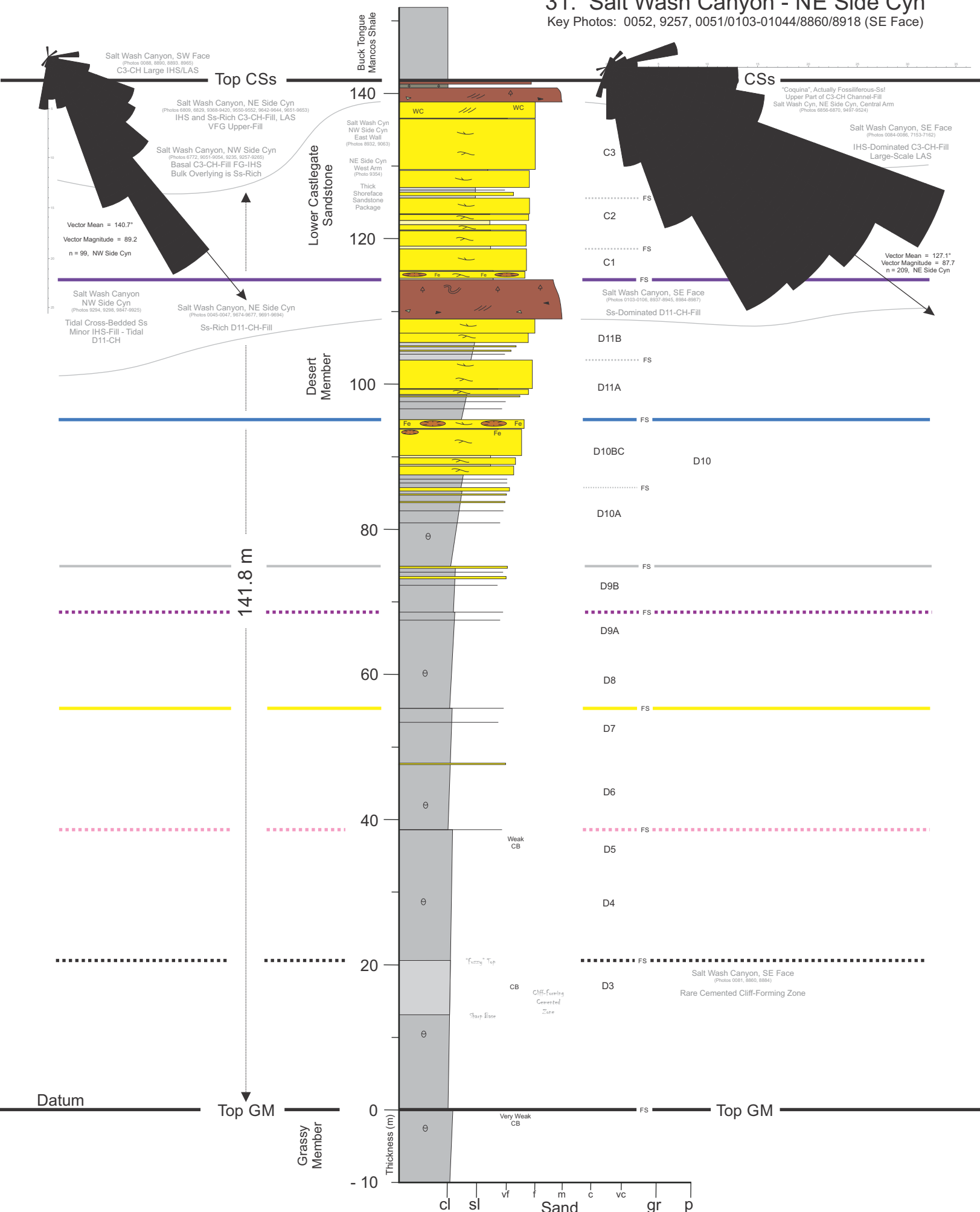
30. Thompson Canyon - East Side Cyn

Key Photos: 6484/6516/6118 (SE Face), 6380



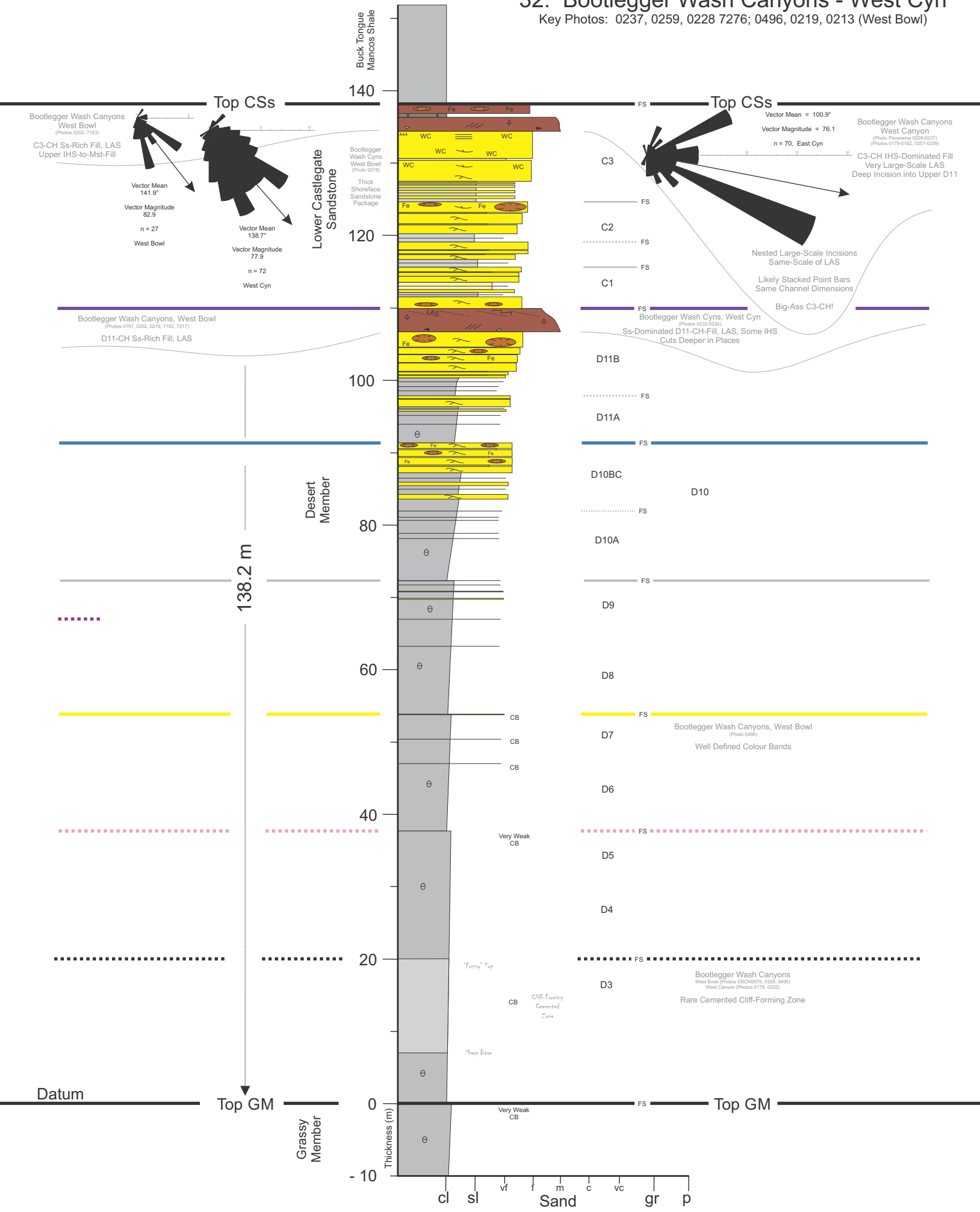
31. Salt Wash Canyon - NE Side Cyn

Key Photos: 0052, 9257, 0051/0103-01044/8860/8918 (SE Face)



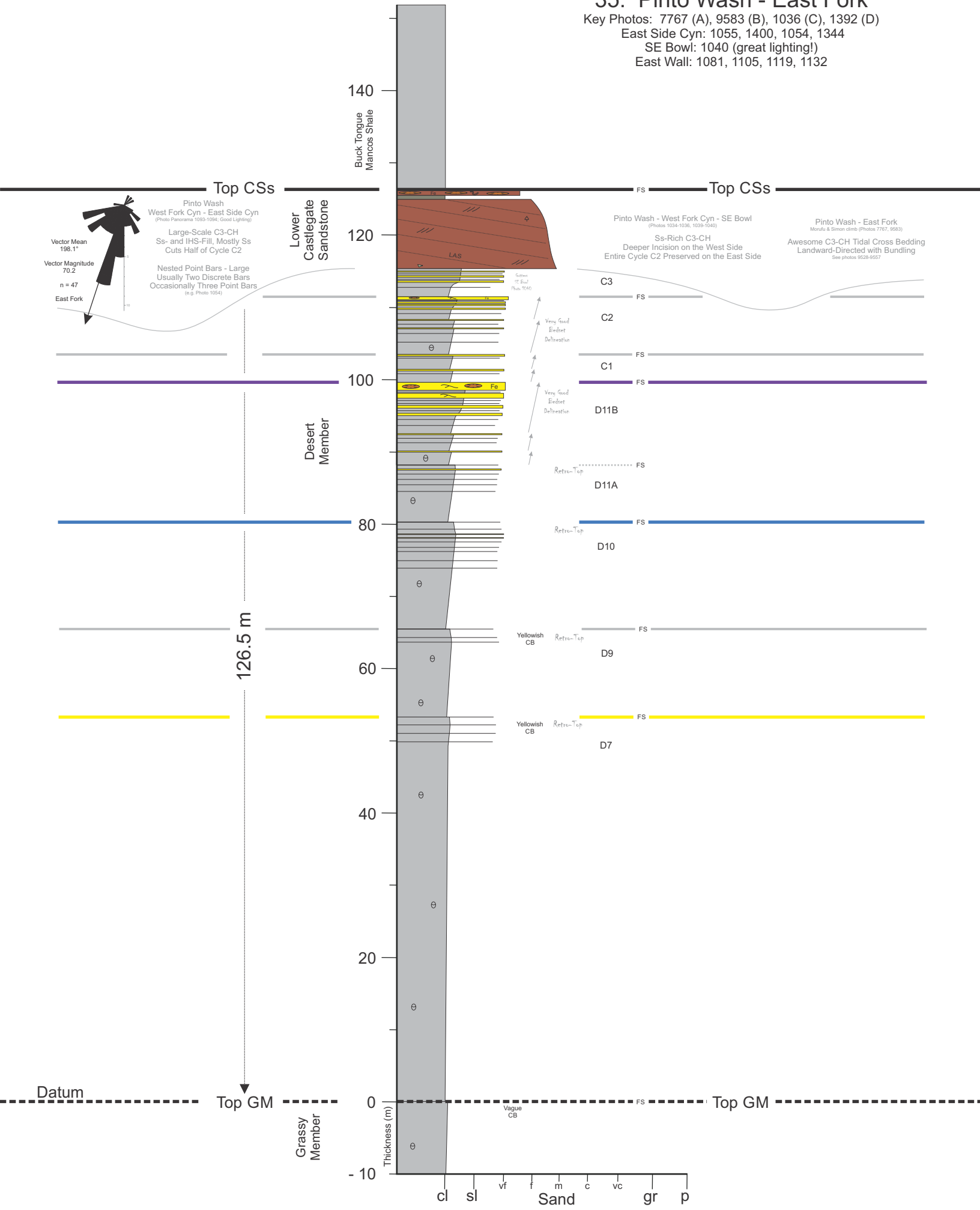
32. Bootlegger Wash Canyons - West Cyn

Key Photos: 0237, 0259, 0228 7276; 0496, 0219, 0213 (West Bowl)



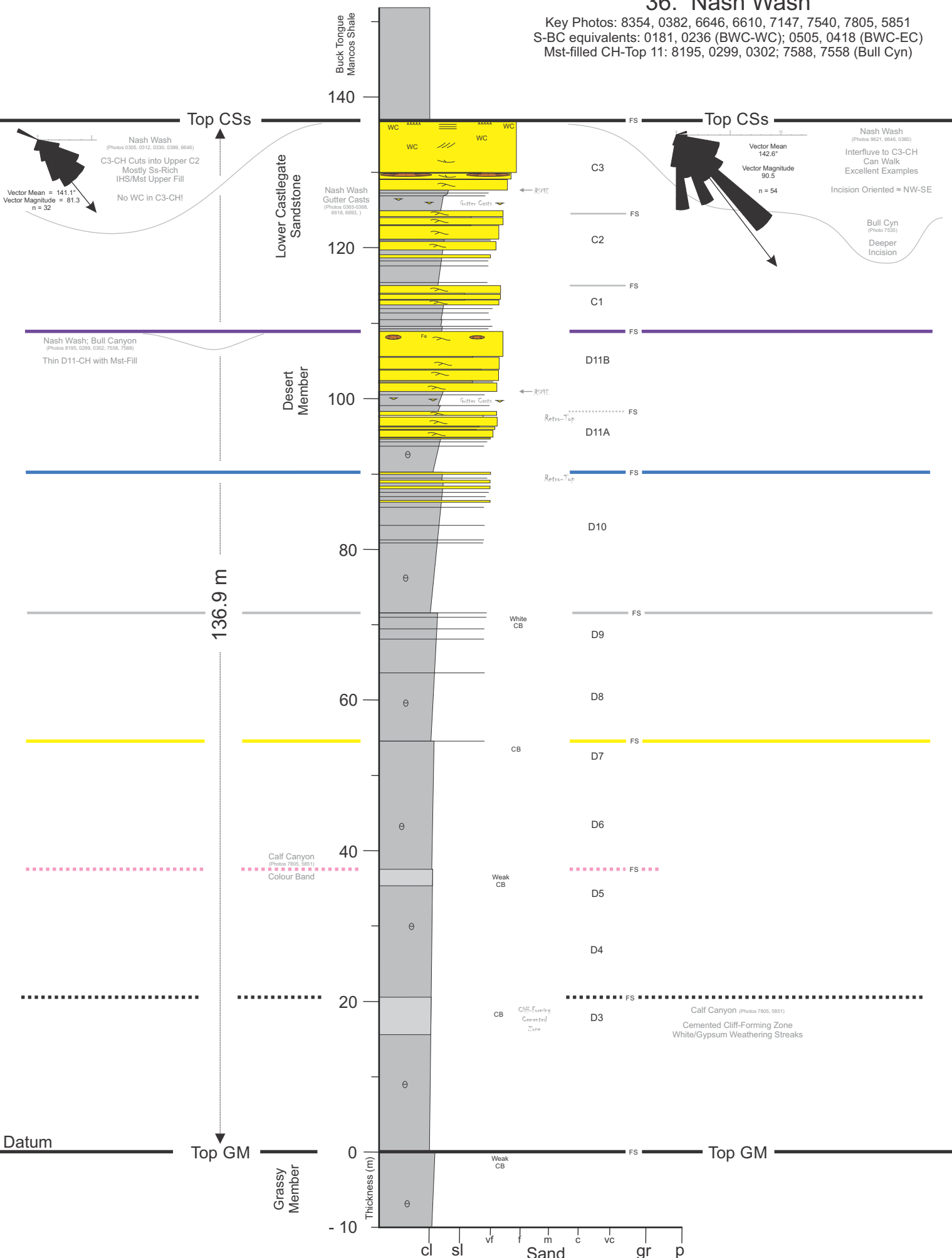
35. Pinto Wash - East Fork

Key Photos: 7767 (A), 9583 (B), 1036 (C), 1392 (D)
 East Side Cyn: 1055, 1400, 1054, 1344
 SE Bowl: 1040 (great lighting!)
 East Wall: 1081, 1105, 1119, 1132



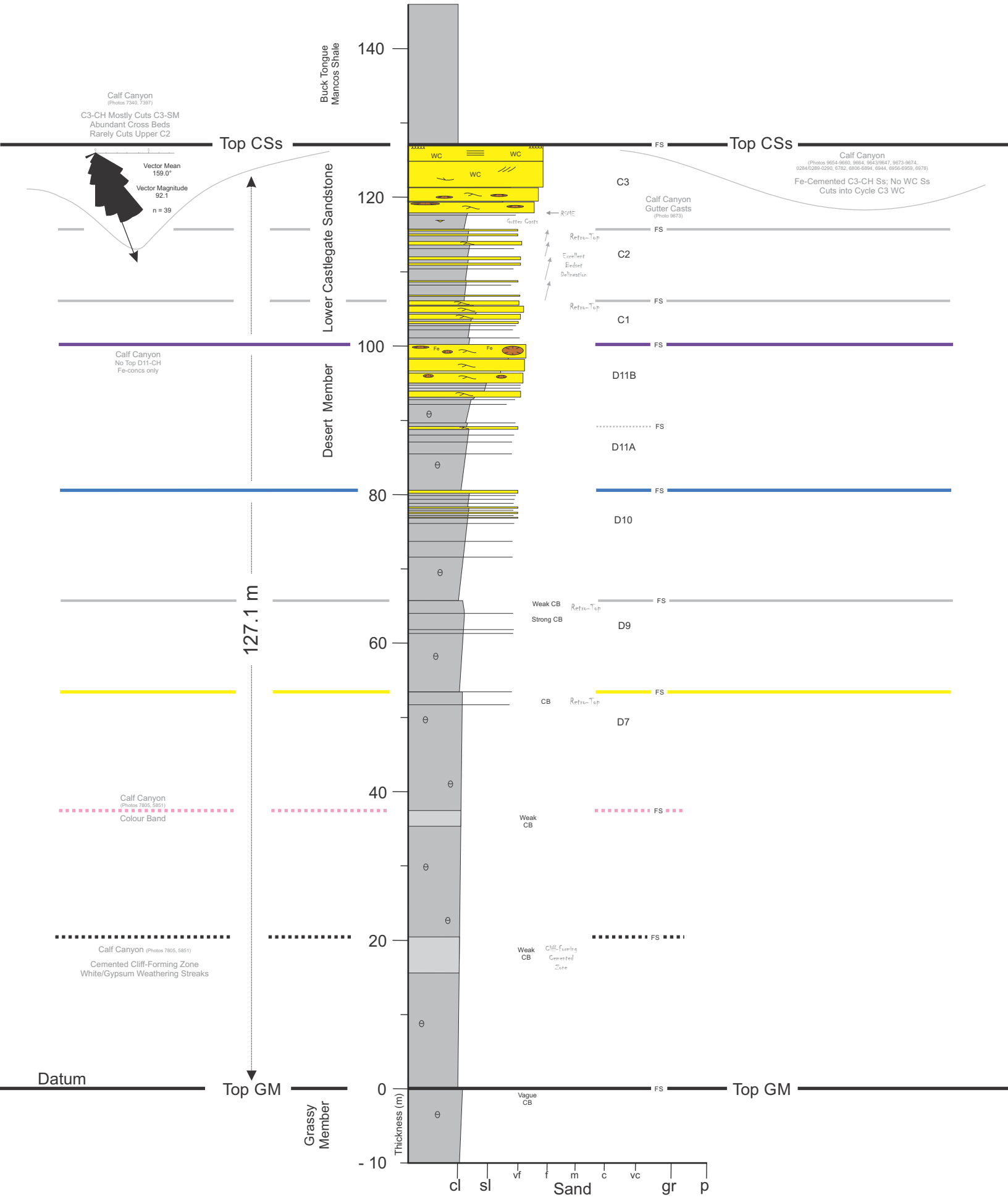
36. Nash Wash

Key Photos: 8354, 0382, 6646, 6610, 7147, 7540, 7805, 5851
 S-BC equivalents: 0181, 0236 (BWC-WC); 0505, 0418 (BWC-EC)
 Mst-filled CH-Top 11: 8195, 0299, 0302; 7588, 7558 (Bull Cyn)



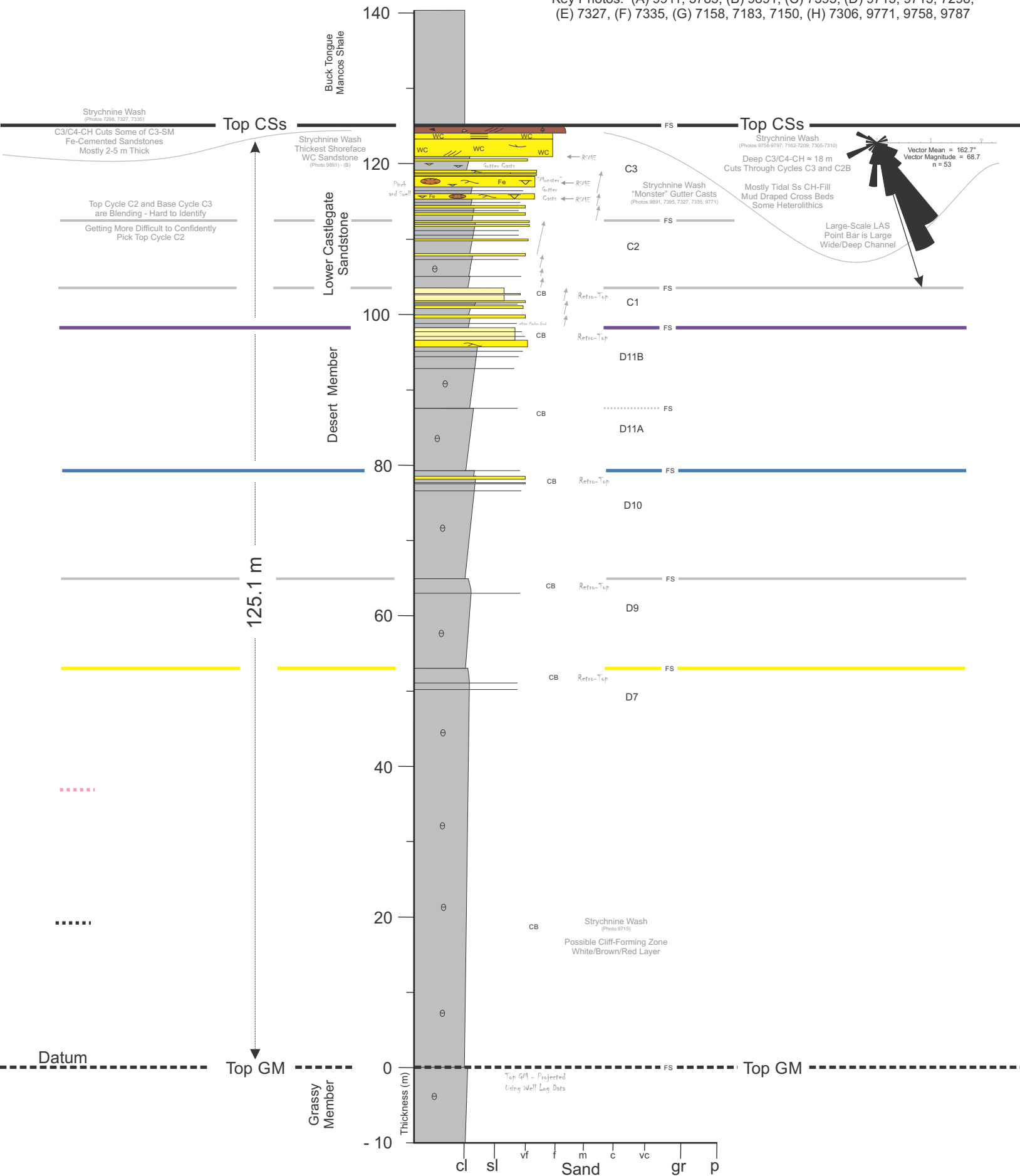
37. Calf Canyon

Key Photos: 0292, 7041/7031, 9643/6956/9673, 9697/7015, 9659/9657



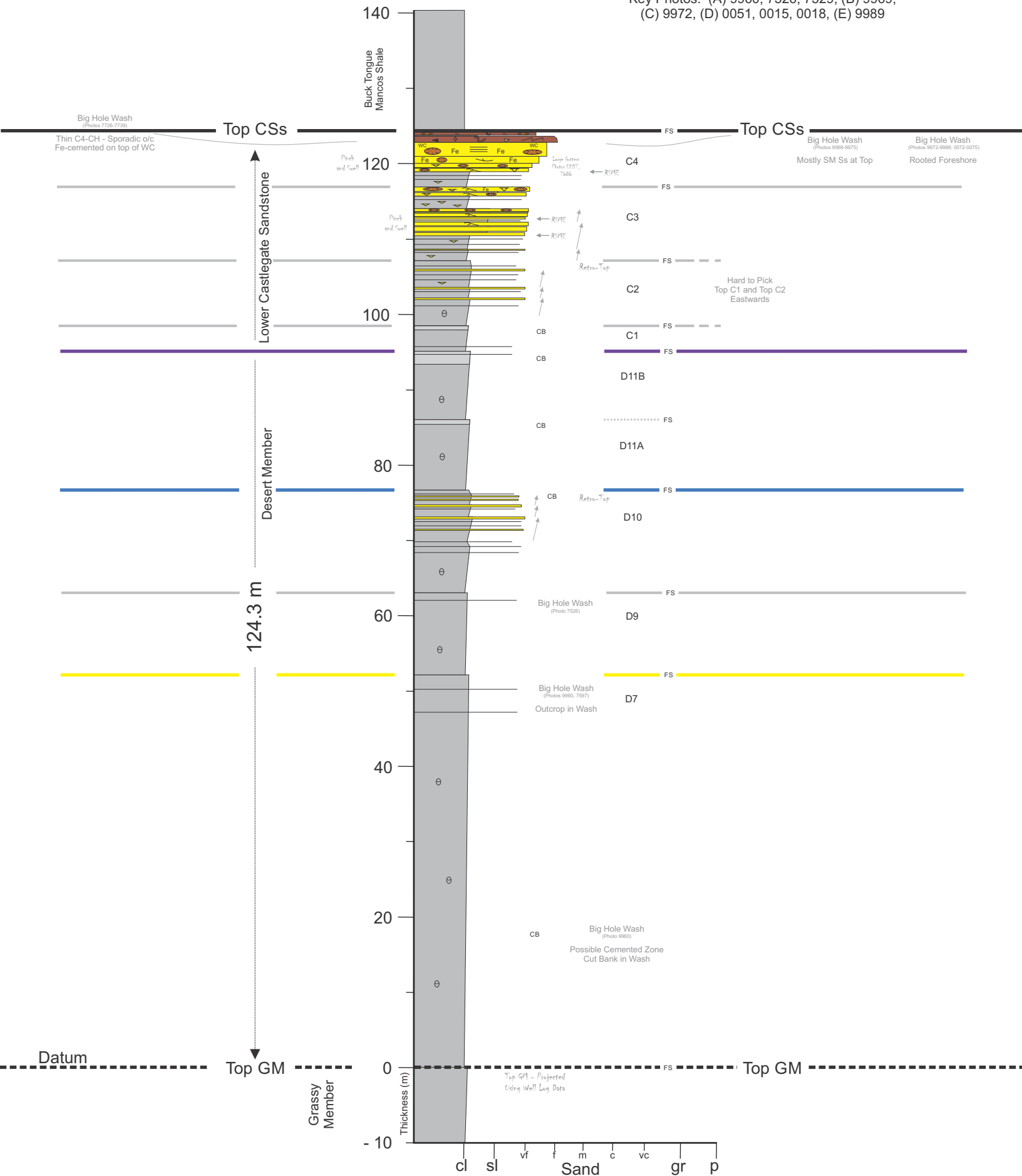
38. Strychnine Wash

Key Photos: (A) 9911, 5785, (B) 9891, (C) 7395, (D) 9713, 9715, 7298, (E) 7327, (F) 7335, (G) 7158, 7183, 7150, (H) 7306, 9771, 9758, 9787



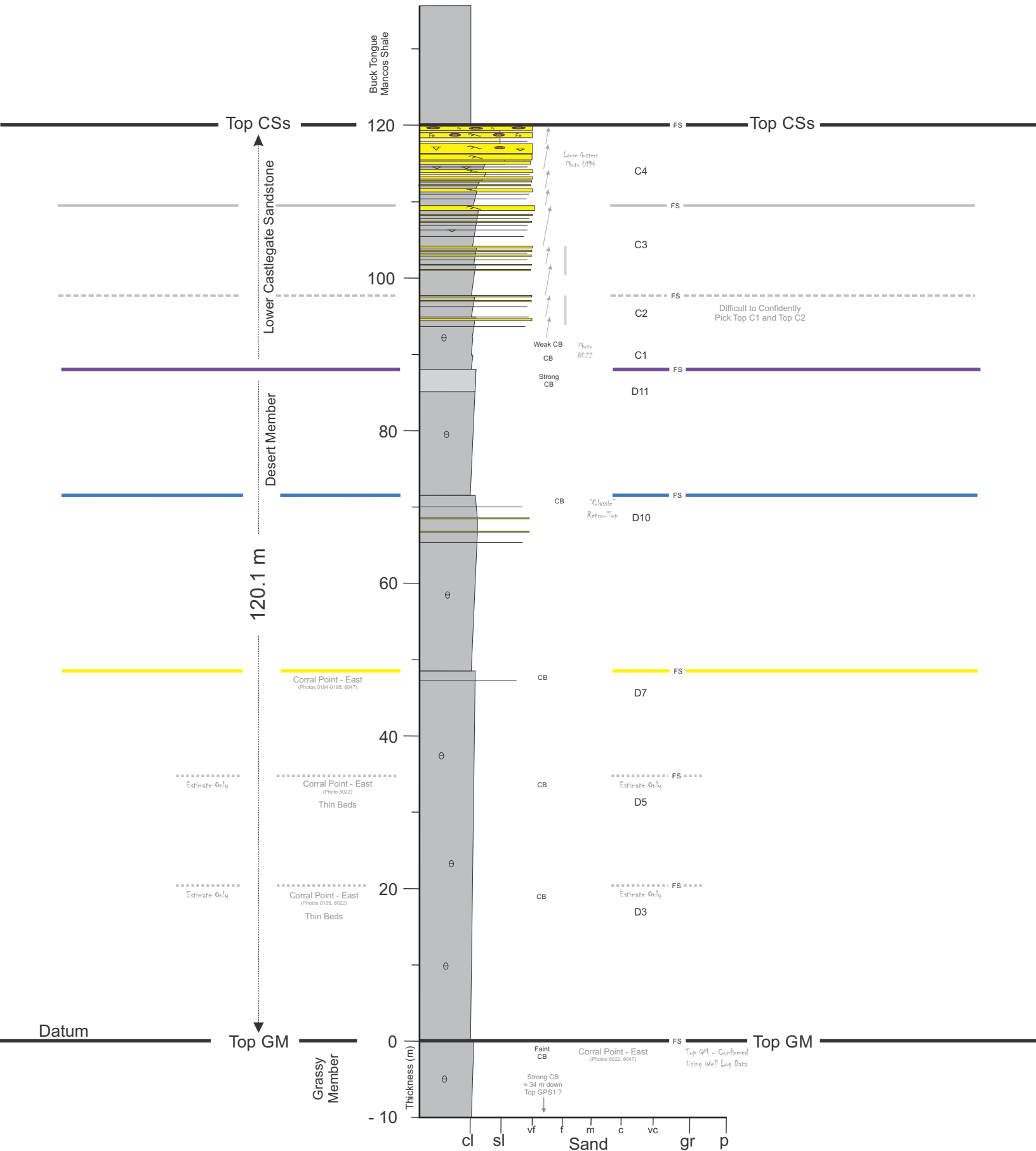
39. Big Hole Wash - West

Key Photos: (A) 9960, 7526, 7529, (B) 9969, (C) 9972, (D) 0051, 0015, 0018, (E) 9989



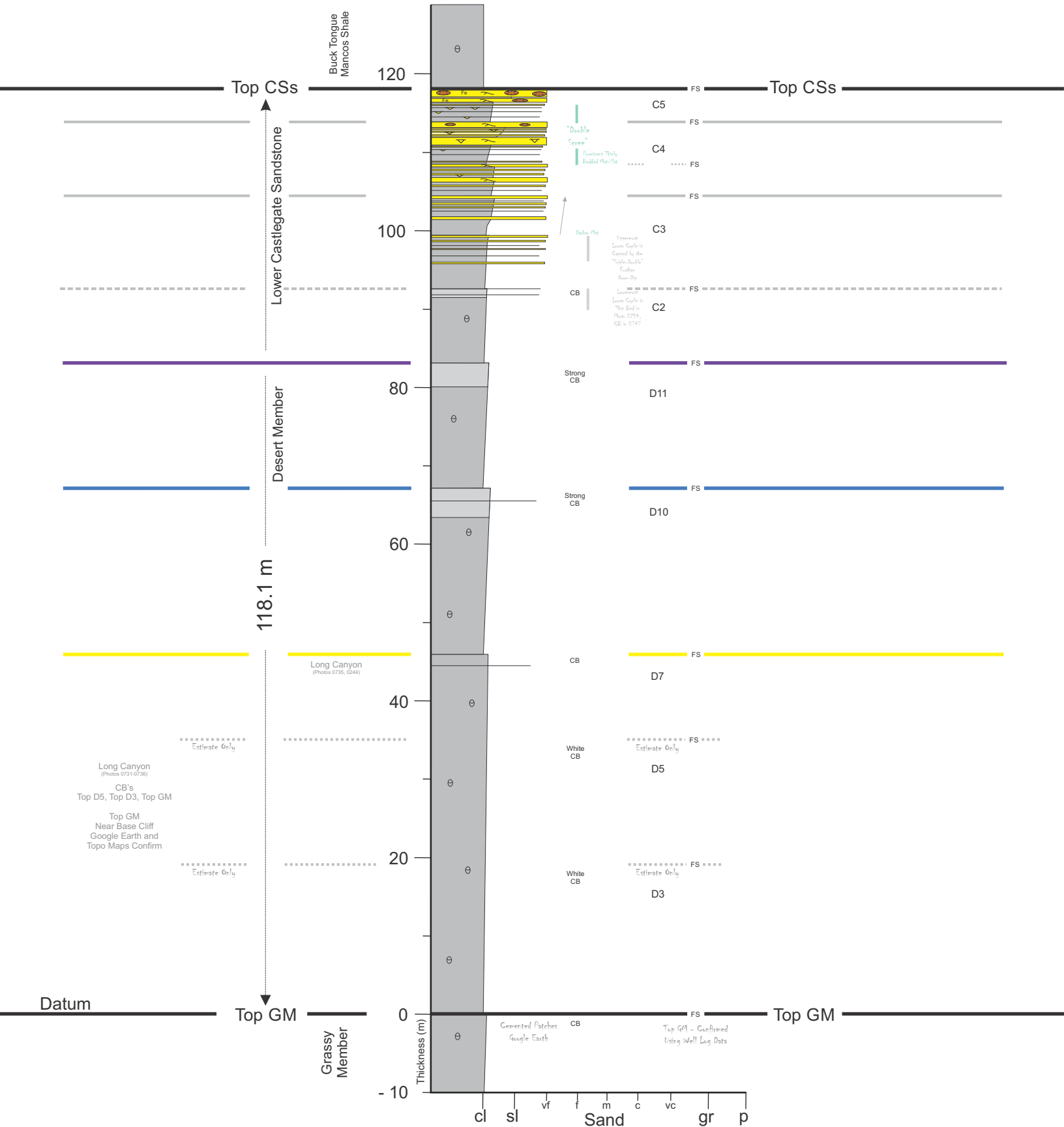
41. Corral Point - East

Key Photos: 8022/0195; West-to-East: 7859, 0179, 8515, 0191, 8513, 0194, 8015/8047/8048, 8503, 8029/8051, 8079/8053, 8498, 7947/8566/8567



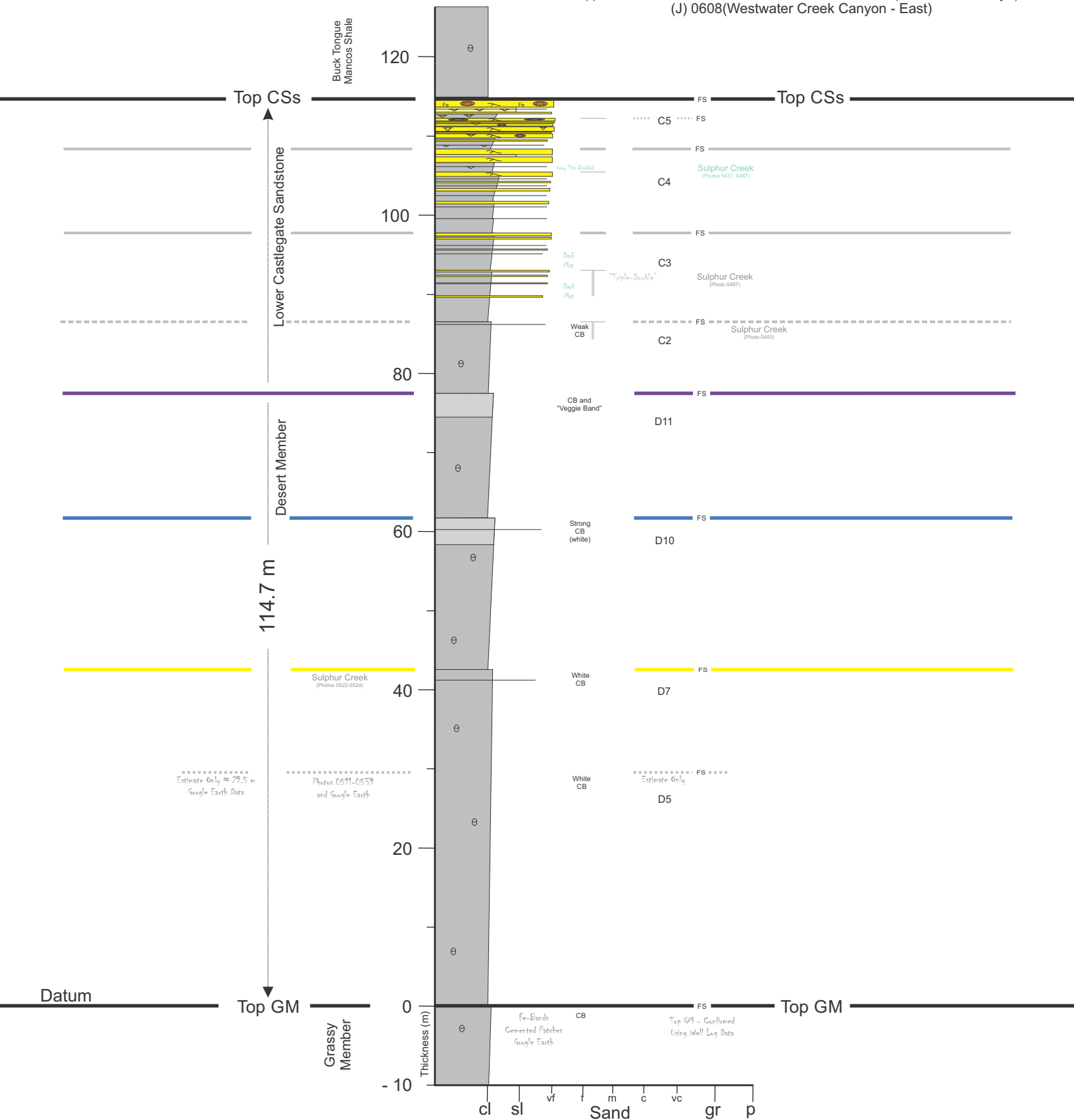
42. Long Canyon

Key Photos: 0727, 0246, 8445, 8450, 8455, 0254 (Cottonwood Wash - M1/S1)
 0735, 0419, 0423, 0427, 8489, 8495 (Long Canyon - M2/S2)
 8511, 0747, 8525 (Long Canyon East - M3/S3)



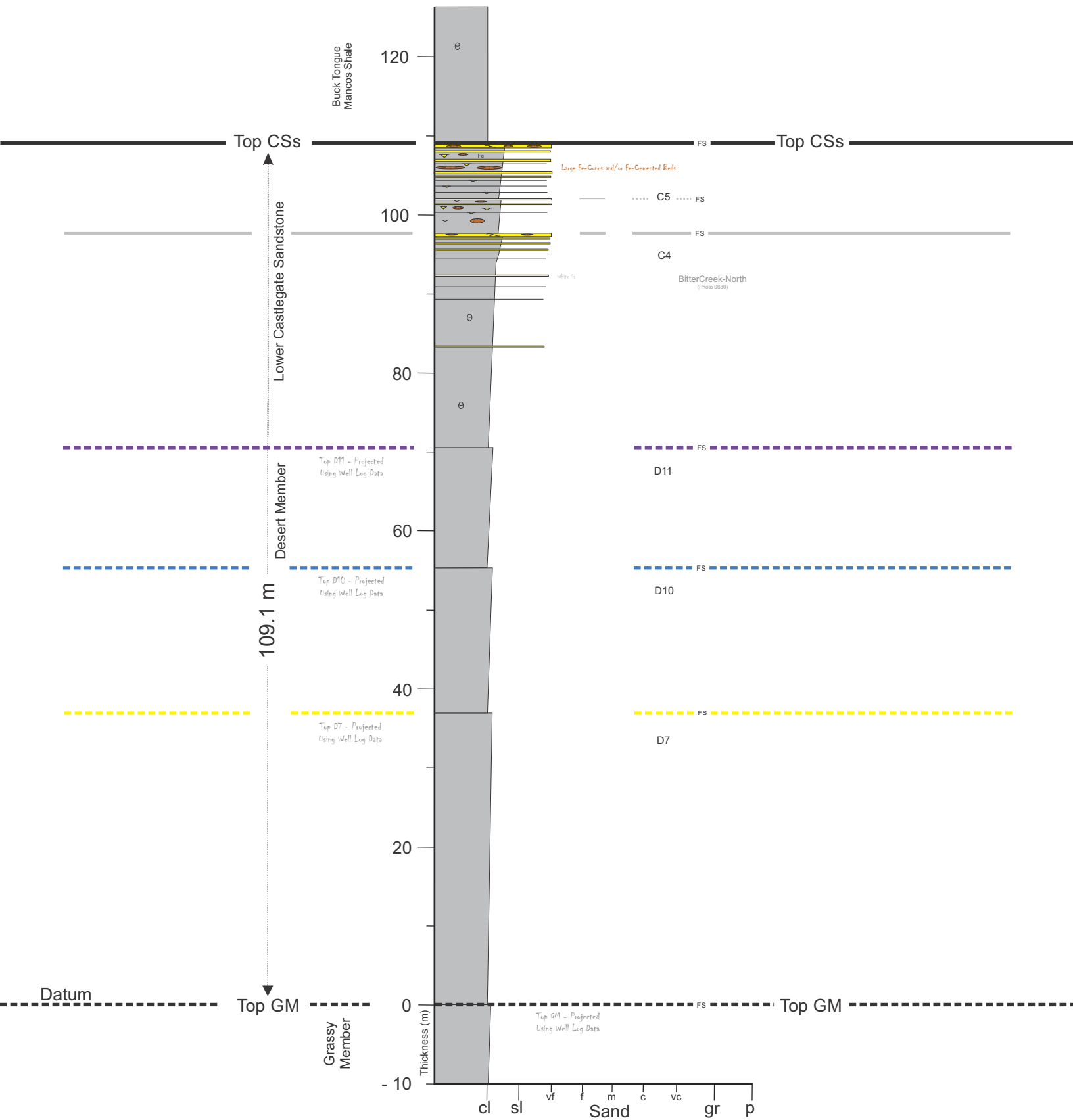
43. Sulphur Creek

- Key Photos: (A) 8516, 0749, 8547 (Long Canyon East - M3/S3)
 (B) 0752, 0753, 0448/0457, 0454, 8599 (Antone Wash - M4/S4)
 (C) 0465, 0464 (Antone Wash - Btwn S4-M5)
 (D) 8679, 8624/8669 (Sulphur Creek - M5)
 (E) 0495 (Sulphur Creek - S5); (F) 8693, 8698 (Sulphur Creek)
 (G) 0477, 0483/0487, 0472/8833 (Sulphur Creek)
 (H) 8800, 0540/0542 (Sulphur Creek - North)
 (I) 8803, 0588/0595, 0601/0605, 0552/8745/0557 (Westwater Ck Cyn)
 (J) 0608 (Westwater Creek Canyon - East)



44. Bitter Creek

Key Photos: (A) 0670 (Bitter Creek-South)
 (B) 0645, 0676, 8839, 8861 (BC-Lion Bench)
 (C) 0630 (BC-North), (D) 0690 (BC-North)
 (E) 0694 (BC-North); (F) 0707 (Prairie Canyon-West)
 (G) 0713 (PC-West)
 (H) 0721, 0731, 8932, 0746, 0774, 0748 (PC)



45. West Salt Creek

Key Photos: (A) 0735, 8946, 8932, 0761, 0764, 0757, 8956 (Prairie Canyon), (B) 9037, 9066 (West Salt Creek) (C) 9058, 9072 (WSC), (D) 9079, 0782, 0801, 8988, 9008, 9055 (WSC- Western Fe-Ooids) (E) 9068 (WSC-East); (F) 0828 (County Road 206-West) (G) 0858, 0809, 0835 (County Road 206-Main Fe-Ooids) (H) 0846, 0848 (County Road 206-East) (I) 0849, 0850 (Camp Gulch-West)

