CORE SEDIMENTOLOGY LOG

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PROJECT: i0127

badley ashton
Reservoir Geoscience

WOLFCAMP
24-15, Sterling County, Texas

ENCLOSURE	1
SCALE 1:24	
Interpretation by: Adian Neal & Jack Beuthin	PRELIMINARY
Date:	March 2018
Well deviation:	Vertical
Core width/cut:	4"
Core Curation:	Excellent
Client/s:	

geo>graphics<

Lithology

Mudstone | Clasts
Siltstone | Muddy
Sandstone | Clast-charged mudrock (siltstone + mudstone)

Lithological qualifiers

g - glauconite
ph - phosphate
m - mica
f - feldspar
c - comminuted carbonaceous detritus (in lithology column)
in grain size column is smectitic clay

Clasts

Quartz | Plant detritus/ carbonaceous matter (speckles) | Coal fragment | Extraformational clasts | Intraform- ational mudclasts — in lithology column / in sedimentary column
Wood fragment | Armoured mudballs | Limestone clast | Heterolithic clasts | Detritic clasts

Extraformational clasts are assumed to be sandstone unless qualified in the remarks column, or by suffixes: Gr - granitic Gb - gabbroic B - basaltic Sc - schistose Gs - greissic Ch - chalk

Bioclasts

Bivalves (articulated) | Bivalves (disarticulated) | Belemnites | Ammonites | Bryozoa

Sedimentary structures

Trough cross-bedding | Subcritical climbing ripple cross-laminated sandstones | Multidirectional ripple lamination | Load cast/flamed contact
Planar cross-bedding | Supercritical climbing ripple cross-laminated sandstones | Wave-ripple lamination | Soft sediment deformation
Flat-lying lamination | Planar ripple lamination | Hummocky cross-bedding | Banded fabric
Spaced lamination | Trough ripple lamination | Injection structures

Consolidation fabrics

Consolidation lamination | Sheet and pipe/pillar structures (dashed where faint) | Irregular fluidisation pipes and patches | Disrupted fabric with mixed mudstone and sheared sand fabric
Dish structures | Thick sheet and pillar structures | Irregular/contorted, partially mobilised dewatering pipes, sheets and patches | Pseudonodular/loaded fabric

Biogenic structures

Pellet lined burrows eg. *Ophiomorpha* | Horizontal spreiten/meniscate burrows eg. *Rhizocorallium* | Sand-lined and/or clustered burrows eg. *Terebellina* | Root traces
cm-scale horizontal sand-filled burrows eg. *Thalassinoides* | 'U' burrows eg. *Arenicolites, Diplocraterion* (with spreiten) | Mud-lined burrows eg. *Palaeophycus* | Worm tubes
Simple vertical burrows eg. *Skolithos* | Horizontal spreiten-filled burrows eg. *Teichichnus* | Meniscate/spreiten burrows eg. *Zoophycos, Taenidium* | Undifferentiated burrows: sand-filled/mud-filled
Vertical spreiten/backfilled burrows eg. *Diplocraterion, Rhizocorallium, Cylindrichnus* | Concentric burrow-fills *Cylindrichnus, Phoebichnus, Cylindrichnus* | *Chondrites*/Phycosiphon style burrows | Glossifungites
Collapse/escape burrows eg. *Monocraterion* | Conical vertical burrows eg. *Rosselia, Cylindrichnus* | *Scolicia* | General bioturbation

Cements (calcite, unless qualified)

Nodule | Irregular/patchy | Diffuse boundaries
Displacive nodule | Weakly cemented | Disseminated cement
Cemented stringer | Pervasively cemented | Bitumen

Qualifiers - applies to fracture fills as well

q - quartz | ph - phosphate | d - dolomite
ca - calcite | ga - galena | cl - clay lined
p - pyrite | sp - sphalerite | ha - halite
h - haematite | ba - barite | ce - cemented
b - bitumen | an - anhydrite
ka - kaolinite

Fractures

Open fractures | Stylolite - incipient
Closed fractures | Stylolite - pronounced
Cemented fractures | Grain shear
Deformation band | Septarian fracture system
Zone of intense fracturing | Coring-induced
Sealed fracture (stylolitised) | Microfault (normal/reverse)

Depositional Packages

PMz Mudstone
PSz Siltstone
PSs Sandstone
CGBd Basal (fractional) conglomerate
PHMz Mudstone-prone heterolithics (10-50% interbeds)
PHZ Siltstone-prone heterolithics (10-50% interbeds)
PHZ Sandstone-prone heterolithics (10-50% interbeds)
LVEB Large-volume hybrid event beds
MDBd Muddy debrite dominated bedrock
MH Heterolithic debrite, mixed sandy and muddy debrite bedstack
SDmz Sandy debrite dominated bedstack
PIC Injection complex
Sds Injected sandstone

Interbed/matrix suffixes
s = Sandstone
z = Siltstone
m = Mudstone
u = Unlinked debrite
l = Linked debrite

Large-volume event bed components
HS Mudrock bed cap
H3s Sandy debrite
Alternative depositional packages
In situ and remobilised depositional packages for the same interval
Mixed packages

Lithotypes

M Massive mudstone
Mba Banded mudstone
Mbt Bioturbated mudstone with filled burrows
Mb3 Bioturbated mudstone with abundant grazing traces
Ml Parallel laminated mudstone
Mxl Parallel laminated mudstone with rare (<10%) siltstone laminae
Z Massive siltsone
Zl Laminated siltstone
Zwl Parallel laminated siltstone with rare (<10%) mudstone laminae
Zb3 Bioturbated siltstone with abundant grazing traces
Zr Ripple laminated siltstone
Zwr Ripple laminated siltstone with rare (<10%) mudstone laminae
HMz Mudstone heterolithic with subordinate (10-50%) siltstone interbeds
HZm Siltstone heterolithic with subordinate (10-50%) mudstone interbeds
Swl Parallel laminated sandstone with rare (<10%) mudstone laminae
MZm.d Sandy mudrock with deformed/contorted matrix
MZ.d Gravelly mudrock with deformed/contorted matrix or clasts
Zs.d Sandy siltstone with deformed/contorted matrix
Zsg.d Gravelly sandy siltstone with deformed/contorted matrix or clasts
CZs.d Conglomerate with a silty sandstone matrix and deformed/contorted matrix or clasts
Smz.d Muddy sandstone with deformed/contorted matrix
Smg.d Gravelly muddy sandstone with deformed/ contorted matrix or clasts
CSmz.d Conglomerate with a muddy sandstone matrix and deformed/contorted matrix or clasts

Dominant/certain (various colours) | Subordinate/uncertain (all lithotypes)

Bed boundaries

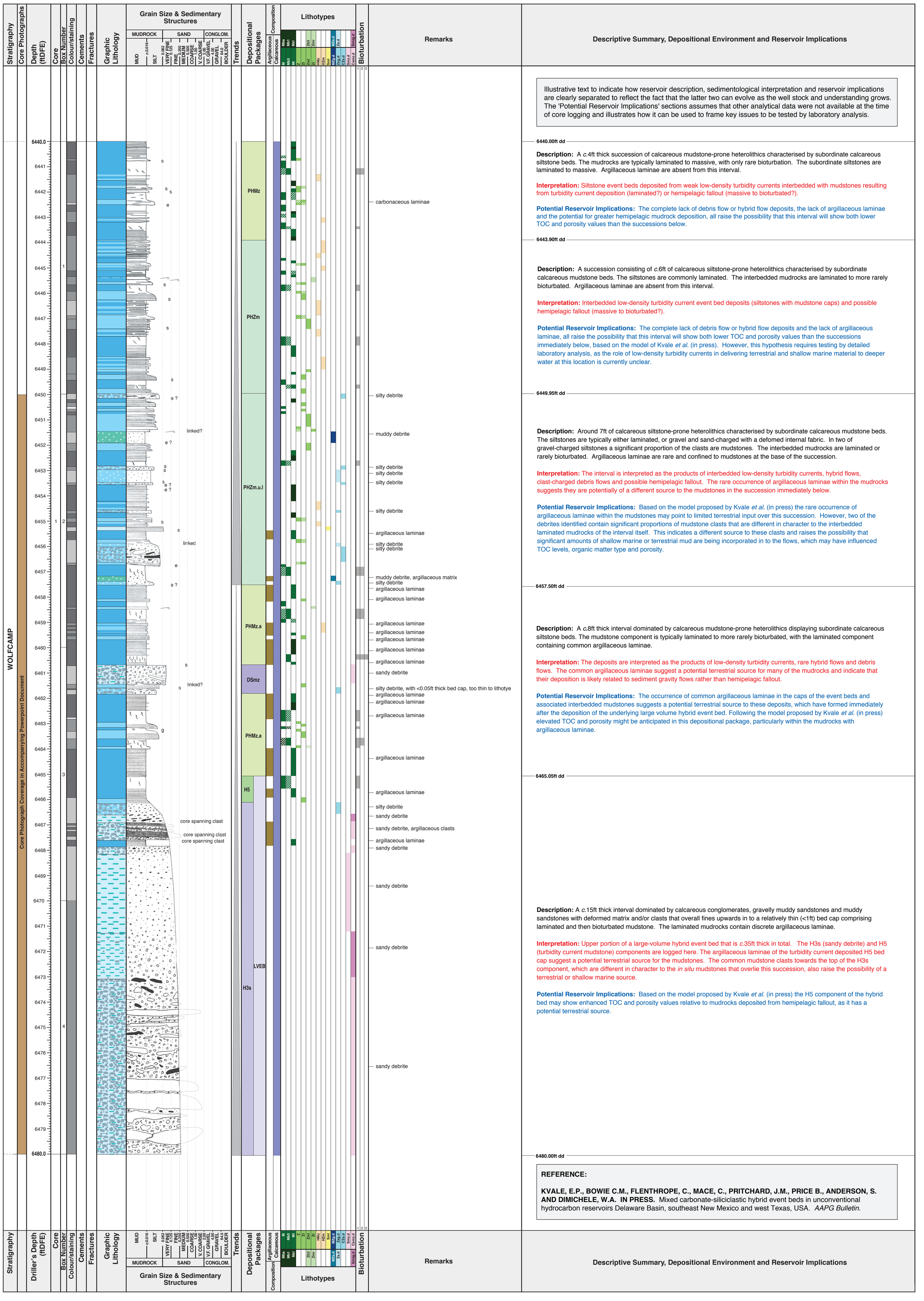
gradational (g)
sharp (s)
erosive (e)
dislocation surface (ds)
deformed (d)
injected (i)
conglomerate clast size
matrix (solid)
clasts (dashed)
rubble (r)

Samples

T - Thin-section analysis
S - Scanning electron microscope analysis
Xb - XRD (bulk)
Xbc - XRD (bulk and clay fractures)
M - Mercury injection

Trends

Major fining-up/muddying-up/bed thinning-up packages (certain/uncertain)
Major coarsening-up/sanding-up/bed thickening-up packages (certain/uncertain)
Minor fining-up/muddying-up/bed thinning-up packages (certain/uncertain)
Minor coarsening/sanding-up/bed thickening-up packages (certain/uncertain)



Illustrative text to indicate how reservoir description, sedimentological interpretation and reservoir implications are clearly separated to reflect the fact that the latter two can evolve as the well stock and understanding grows. The 'Potential Reservoir Implications' sections assumes that other analytical data were not available at the time of core logging and illustrates how it can be used to frame key issues to be tested by laboratory analysis.

6440.00ft dd

Description: A *c.*4ft thick succession of calcareous mudstone-prone heterolithics characterised by subordinate calcareous siltstone beds. The mudrocks are typically laminated to massive, with only rare bioturbation. The subordinate siltstones are laminated to massive. Argillaceous laminae are absent from this interval.

Interpretation: Siltstone event beds deposited from weak low-density turbidity currents interbedded with mudstones resulting from turbidity current deposition (laminated?) or hemipelagic fallout (massive to bioturbated?).

Potential Reservoir Implications: The complete lack of debris flow or hybrid flow deposits, the lack of argillaceous laminae and the potential for greater hemipelagic mudrock deposition, all raise the possibility that this interval will show both lower TOC and porosity values than the successions below.

6443.90ft dd

Description: A succession consisting of *c.*6ft of calcareous siltstone-prone heterolithics characterised by subordinate calcareous mudstone beds. The siltstones are commonly laminated. The interbedded mudrocks are laminated to more rarely bioturbated. Argillaceous laminae are absent from this interval.

Interpretation: Interbedded low-density turbidity current event bed deposits (siltstones with mudstone caps) and possible hemipelagic fallout (massive to bioturbated?).

Potential Reservoir Implications: The complete lack of debris flow or hybrid flow deposits and the lack of argillaceous laminae, all raise the possibility that this interval will show both lower TOC and porosity values than the successions immediately below, based on the model of Kvale *et al.* (in press). However, this hypothesis requires testing by detailed laboratory analysis, as the role of low-density turbidity currents in delivering terrestrial and shallow marine material to deeper water at this location is currently unclear.

6449.95ft dd

Description: Around 7ft of calcareous siltstone-prone heterolithics characterised by subordinate calcareous mudstone beds. The siltstones are typically either laminated, or gravel and sand-charged with a defomed internal fabric. In two of gravel-charged siltstones a significant proportion of the clasts are mudstones. The interbedded mudrocks are laminated or rarely bioturbated. Argillaceous laminae are rare and confined to mudstones at the base of the succession.

Interpretation: The interval is interpreted as the products of interbedded low-density turbidity currents, hybrid flows, clast-charged debris flows and possible hemipelagic fallout. The rare occurrence of argillaceous laminae within the mudrocks suggests they are potentially of a different source to the mudstones in the succession immediately below.

Potential Reservoir Implications: Based on the model proposed by Kvale *et al.* (in press) the rare occurrence of argillaceous laminae within the mudstones may point to limited terrestrial input over this succession. However, two of the debrites identified contain significant proportions of mudstone clasts that are different in character to the interbedded laminated mudrocks of the interval itself. This indicates a different source to these clasts and raises the possibility that significant amounts of shallow marine or terrestrial mud are being incorporated in to the flows, which may have influenced TOC levels, organic matter type and porosity.

6457.50ft dd

Description: A *c.*8ft thick interval dominated by calcareous mudstone-prone heterolithics displaying subordinate calcareous siltstone beds. The mudstone component is typically laminated to more rarely bioturbated, with the laminated component containing common argillaceous laminae.

Interpretation: The deposits are interpreted as the products of low-density turbidity currents, rare hybrid flows and debris flows. The common argillaceous laminae suggest a potential terrestrial source for many of the mudrocks and indicate that their deposition is likely related to sediment gravity flows rather than hemipelagic fallout.

Potential Reservoir Implications: The occurrence of common argillaceous laminae in the caps of the event beds and associated interbedded mudstones suggests a potential terrestrial source to these deposits, which have formed immediately after the deposition of the underlying large volume hybrid event bed. Following the model proposed by Kvale *et al.* (in press) elevated TOC and porosity might be anticipated in this depositional package, particularly within the mudrocks with argillaceous laminae.

6465.05ft dd

Description: A c.15ft thick interval dominated by calcareous conglomerates, gravelly muddy sandstones and muddy sandstones with deformed matrix and/or clasts that overall fines upwards in to a relatively thin (<1ft) bed cap comprising laminated and then bioturbated mudstone. The laminated mudrocks contain discrete argillaceous laminae.

Interpretation: Upper portion of a large-volume hybrid event bed that is *c.*35ft thick in total. The H3s (sandy debrite) and H5 (turbidity current mudstone) components are logged here. The argillaceous laminae of the turbidity current deposited H5 bed cap suggest a potential terrestrial source for the mudstones. The common mudstone clasts towards the top of the H3s component, which are different in character to the *in situ* mudstones that overlie this succession, also raise the possibility of a terrestrial or shallow marine source.

Potential Reservoir Implications: Based on the model proposed by Kvale *et al.* (in press) the H5 component of the hybrid bed may show enhanced TOC and porosity values relative to mudrocks deposited from hemipelagic fallout, as it has a potential terrestrial source.

6480.00ft dd

REFERENCE:

KVALE, E.P., BOWIE C.M., FLENTHROPE, C., MACE, C., PRITCHARD, J.M., PRICE B., ANDERSON, S. AND DIMICHELE, W.A. IN PRESS. Mixed carbonate-siliciclastic hybrid event beds in unconventional hydrocarbon reservoirs Delaware Basin, southeast New Mexico and west Texas, USA. *AAPG Bulletin.*