New Sequence Stratigraphic Model for the Burgan, Mauddud and Wara Formations of Greater Burgan Field, Kuwait*

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Abstract

The late Albian to early Cenomanian Burgan and Wara formations from Southeast Kuwait constitutes the largest siliciclastic oil reservoir on earth. The sedimentology and stratigraphy of Greater Burgan Field is reviewed here in terms of depositional environment and relation to global eustatic changes. An updated reservoir model has been built on a sequence stratigraphic framework from 980 wells, backed by sedimentological analyses, chemostratigraphy and biostratigraphy.

The Burgan, Mauddud and Wara formations are represented by four 3rd order cycles in a coastal regime, with the lowermost cycle and the overlying rising hemicycle representing the Burgan Formation. The lowermost cycle, comprised of stacked braided channels, passes upward to tidal channel sandstones and heteroliths. Eventually a wave ravinement surface leading to a maximum flooding surface is recorded in tidal/bay to offshore environment. The regressive part of the cycle is composed of tidal channels and bars.

The top of the second cycle, manifest as a grainstone-dominated carbonate platform, represents the Mauddud Formation, with the top karstified owing to late Albian/Cenomanian sea level drop. The third cycle is represented by homogenous compact offshore shales of Wara Formation overlain by the coarse fluvio-tidal siliciclastic deposition representing the regressive stage of this 3rd order cycle.

The fourth transgressive hemicycle leading to the global Cenomanian/Turonian climatic optimum is marked by transgressive sandstones in the upper part of Wara sands, culminating in deposition of Ahmadi shales. 4th order cyclicity is denoted by marine transgressions, especially in the northeastern part of the field.

Mapping of these sequences was aided by local sea level curve and paleogeographic maps which helped decipher the Albian-Cenomanian coastal setting, contiguous to neighboring Oman, Qatar and Saudi Arabia. The new sequence stratigraphic framework has a huge impact on the reservoir management of this giant field.

New Sequence Stratigraphic Model for Burgan, Mauddud and Wara Formations,Greater Burgan Field, Kuwait

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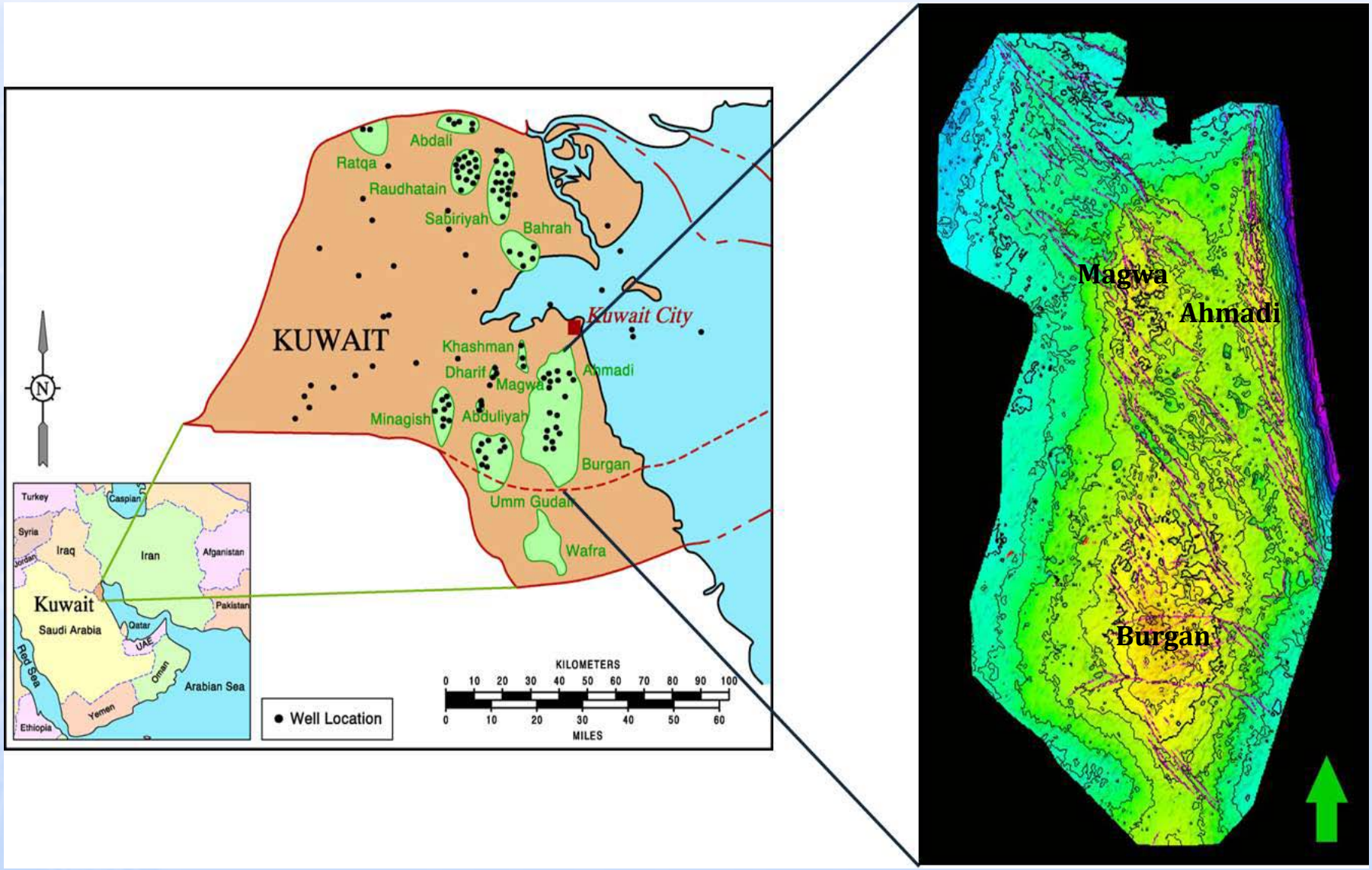
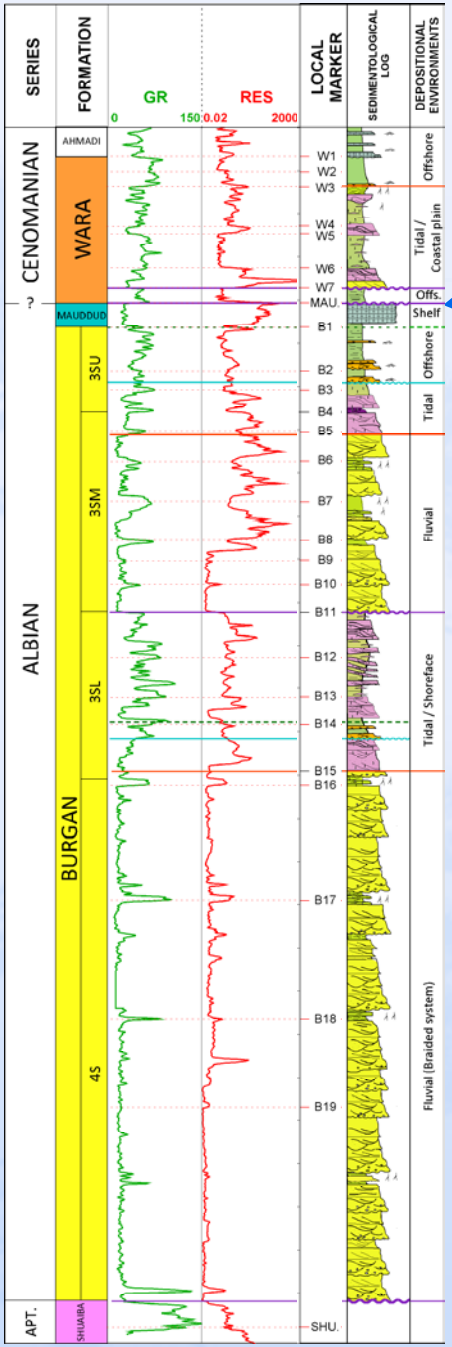
Kuwait Oil Company, Kuwait **Beicip-Franlab, France**

Location Map of Greater Burgan Field



Composite log of the studied section in Greater Burgan Field



Ahmadi

Wara : W1-W7

Mauddud

Third Sand Upper(3SU) : B1-B3

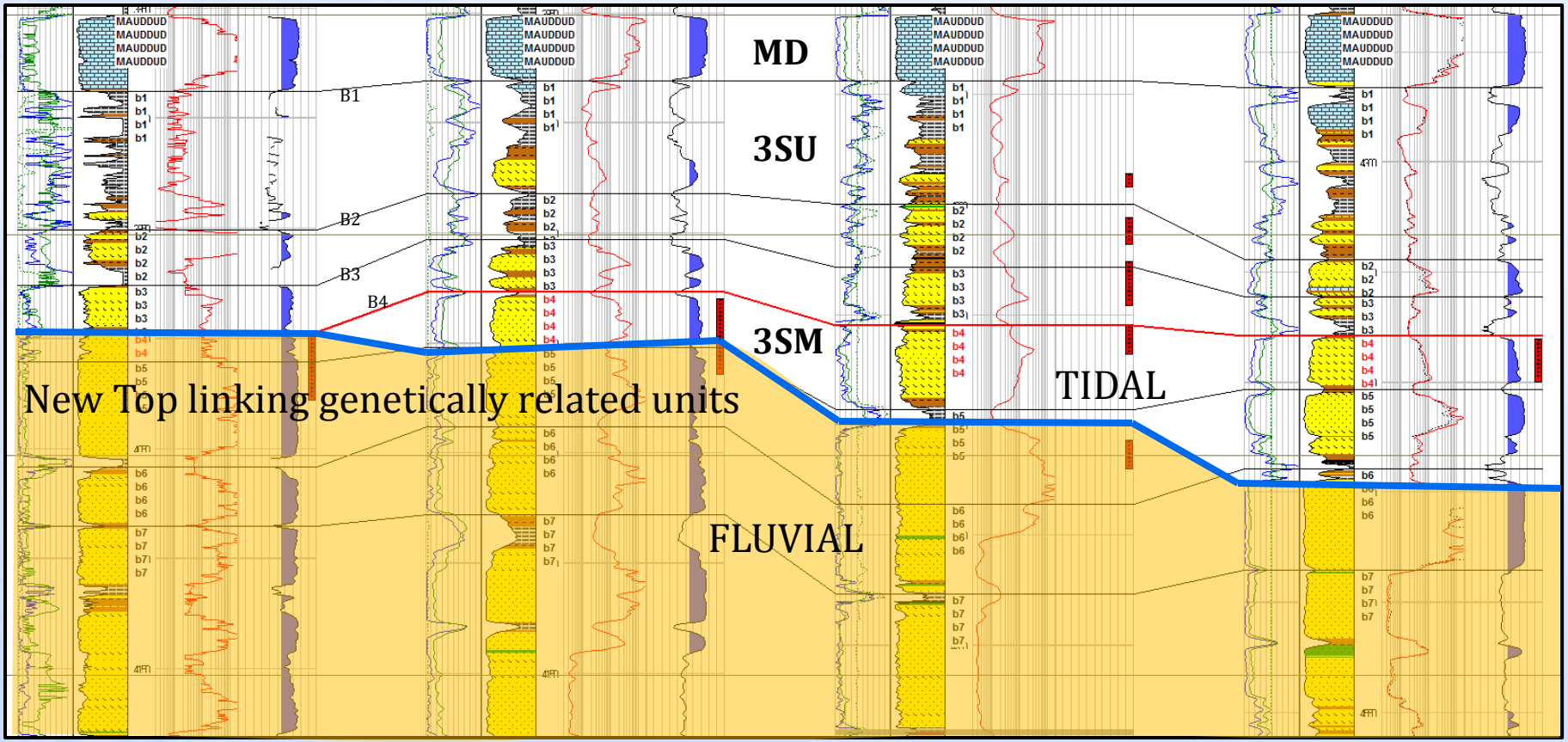
Third Sand Middle(3SM) : B4-B10

Third Sand Lower(3SL) : B11-B14

Fourth Sand (4S) : B15-B19

Shuaiba

Rationale for New Stratigraphy

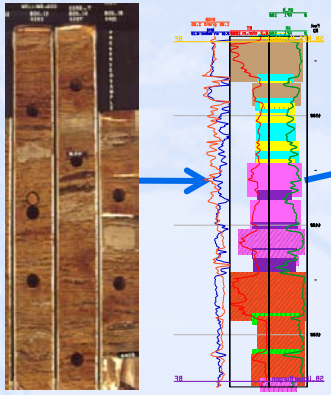


Objectives

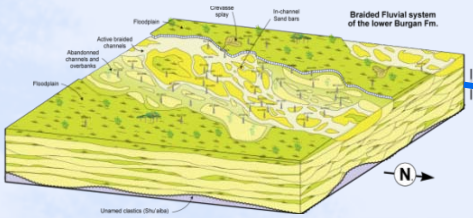
- Stratigraphic framework for a new full field geological model of Greater Burgan Field.
- To optimize the success of drilling campaign for this mature basin.
- To provide geological support for future horizontal and multilateral wells by better understanding of sand geometry and continuity.
- To establish reference frame work to be utilized as the base for future detailed geo-modeling and dynamic studies.

Workflow for the sequence stratigraphy study of Greater Burgan Field

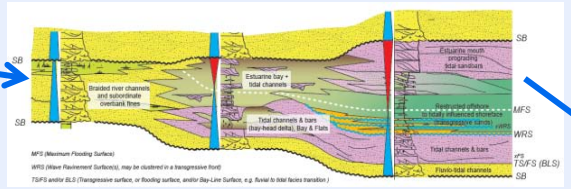
Core description
43 wells



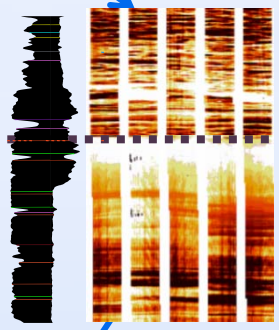
Conceptuel sedimentological model

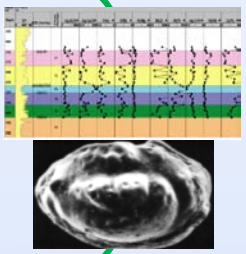


Conceptual stratigraphic Model,
Facies partition and lateral extension

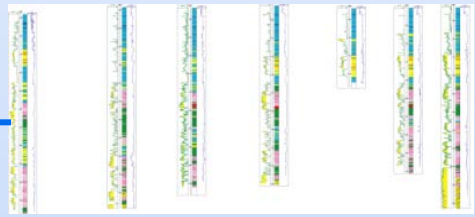


Facies Extension
Integration of image logs
(50 wells)

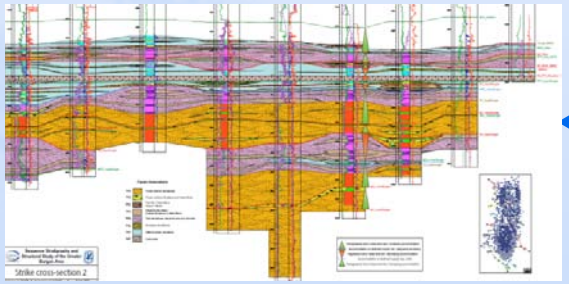




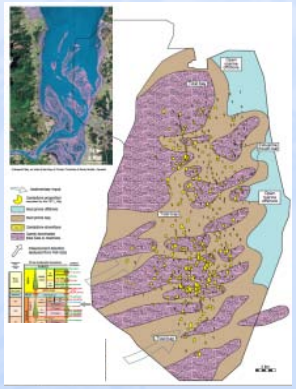
Bio/Chemo stratigraphy



Full Field Extension
(900 wells)

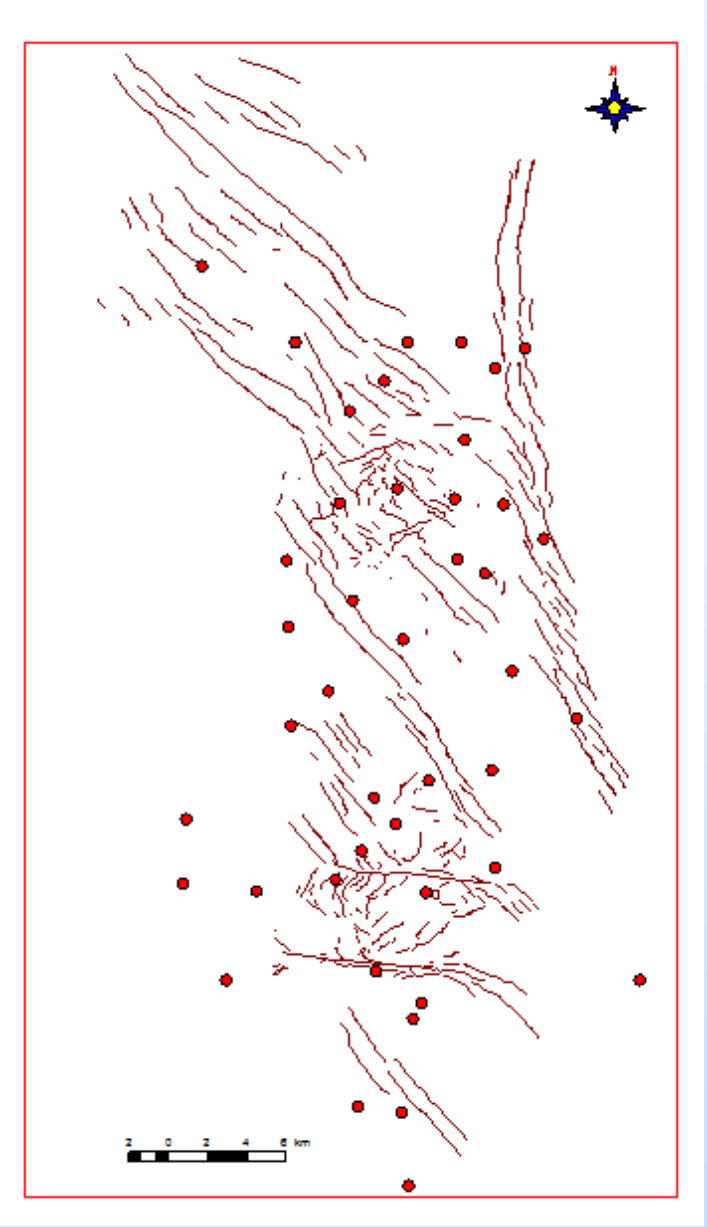


Correlations, stratigraphic architecture



Mapping of each stratigraphic intervals

Core Description Data base



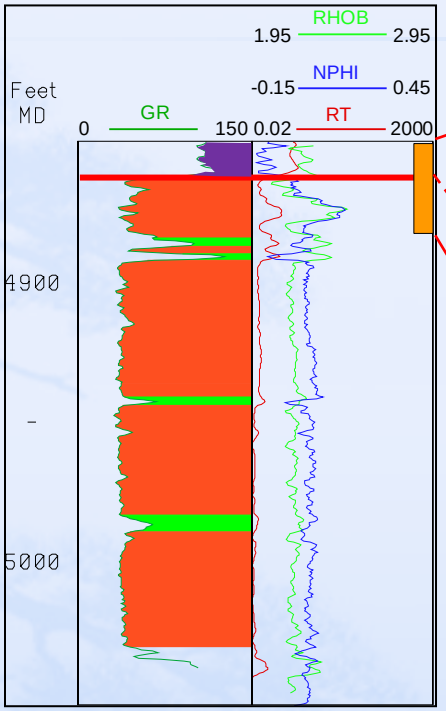
➔43 wells for calibration

Facies association: Fluvial environment

FA1: Fluvial Channel dominated:
Clean S.ST, X-bedded,
Braided channel fill.
Dominant in 3SM, 4S
and base of Wara.
Thickness- 50-80'

FA2 : Fluvial over bank and levees: higher values of GR within sandstones, correspond to flood plain fines
Thickness-1-2'

FA3 : Marsh, lagoonal, swamp.
Horizontal laminated shales with organic rich material.
High GR values, low density if carbonaceous. Thickness-1-2'



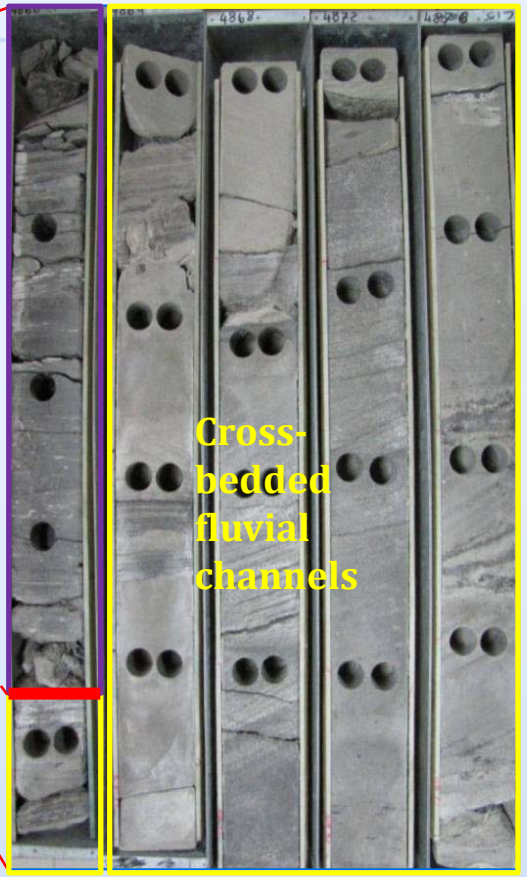
FA1: Fluvial, channel dominated

FA2: Fluvial, overbanks and levees

FA3: Marsh, lagoonal, swamp

X-SZF

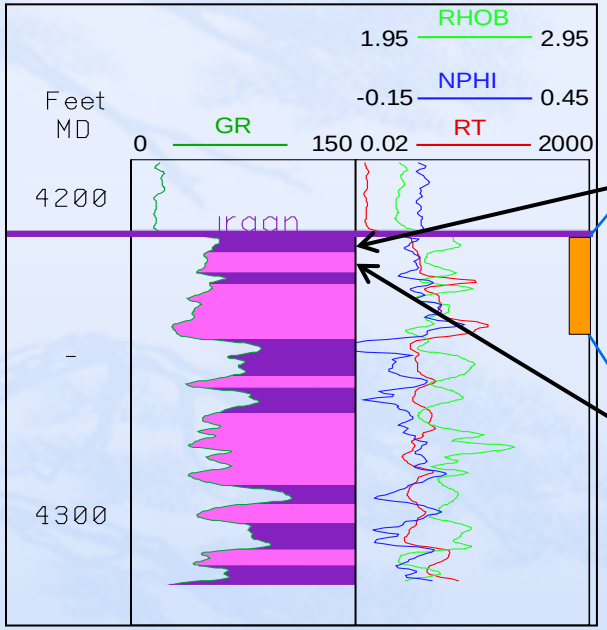
Bay shales



Facies association : Tidal environment

FA4 : Bay, mudstone dominated
Intercalated layers of shale/siltstone.
Horizontal laminated. Locally with lenticular beds.
Abundant burrows.With higher GR values
Deposited in bays, estuaries . Common in 3SL, 3SU and Wara.
Thickness 5-15'.

FA5 : Tidal dominated bars and channels.
Shaly sandstones , GR values higher than fluvial and more variable fining upward or coarsening upward units, generally sharp base, upper part is more heterolithic.
Common in 3SU, 3SL and Wara. Thickness 20-50'



FA4: Bay, mudstone dominated

FA5: Tidal dominated (bars, channels, heterolithics)

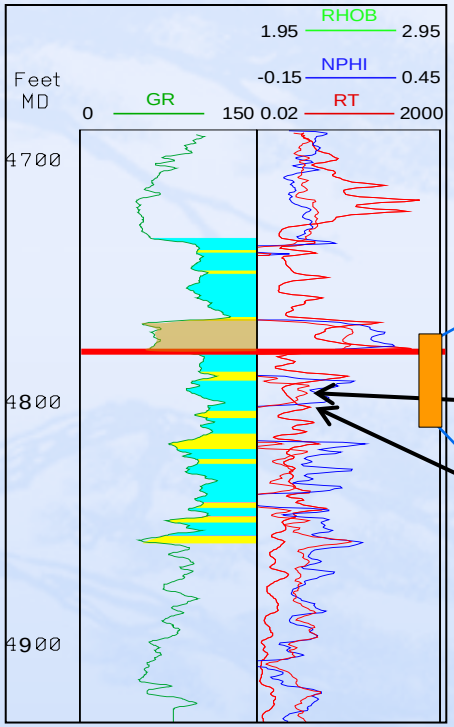
X-FON

Facies association: Shoreface and Offshore environment

FA7 : Offshore shales; Poorly bioturbated with frequent Siderite nodules. High GR.
Deposited in shoreface and offshore environment. 10-20'

FA6 : Transgressive shoreface/Glauconitic Sandstone.
Closely associated with offshore shales. Formed due to reworking of shelf deposits during transgression. High density and high GR. 1-5' in thickness.

FA8 : Shallow marine carbonate : Bioclastic packstone/grainstone. Abundant foraminifera -Orbitolinids, echinoid fragments and occasional rudist fragments. Clean GR response



FA6: Glauconitic Sandstones

FA7: Offshore, marine shelf

FA8: Carbonate

Carbonates

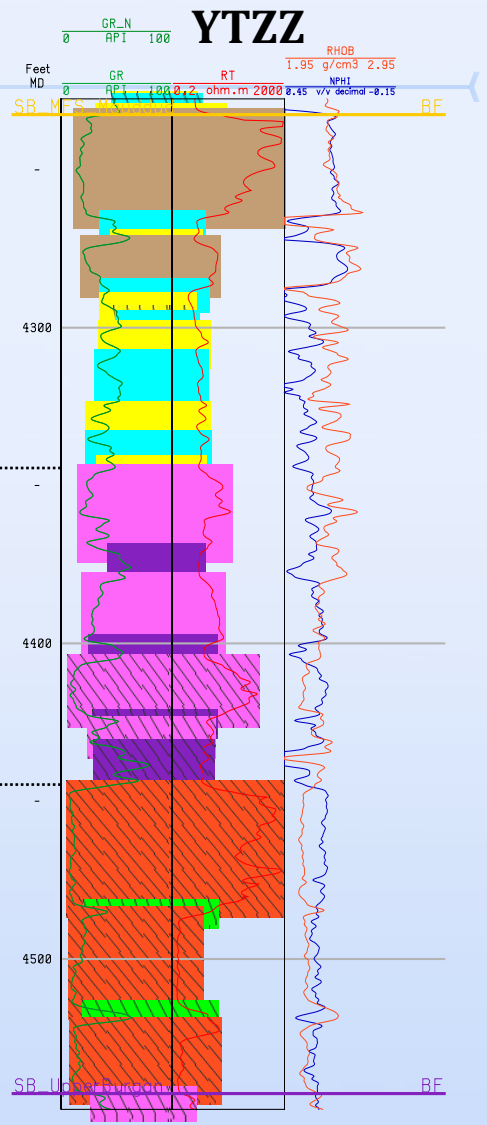
Shales

Glauconitic sands

Well-X-SOT

Vertical Distribution of Facies associations (example from well Y- ZZ)

FA1: Fluvial, channel dominated
FA2: Fluvial, overbanks and levees
FA3: Marsh, lagoonal, swamp
FA4: Bay, mudstone dominated
FA5: Tidal dominated (bars, channels, heterolithics)
FA6: Glauconitic Sandstones
FA7: Offshore, marine shelf
FA8: Carbonate



Open marine:

FA6: Transgressive sandstones (1 to 5 ft): medium GR values, high density due to glauconite content

FA7: Offshore shales (10 to 20 ft): highest GR values observed, generally corresponding to maximum flooding zones

FA8: Shallow marine carbonates: clean GR response but with typical response on NPHI/RHOB.

Tidal:

FA4: Bay: Intercalated layers (5 to 15 ft) with higher GR values (bays, estuary).

FA5: Tidal bars and channels: shaly sandstones (20 to 50 ft) with GR with values higher than fluvial and more variable (fining upward, coarsening upward units), prograding and retrograding.

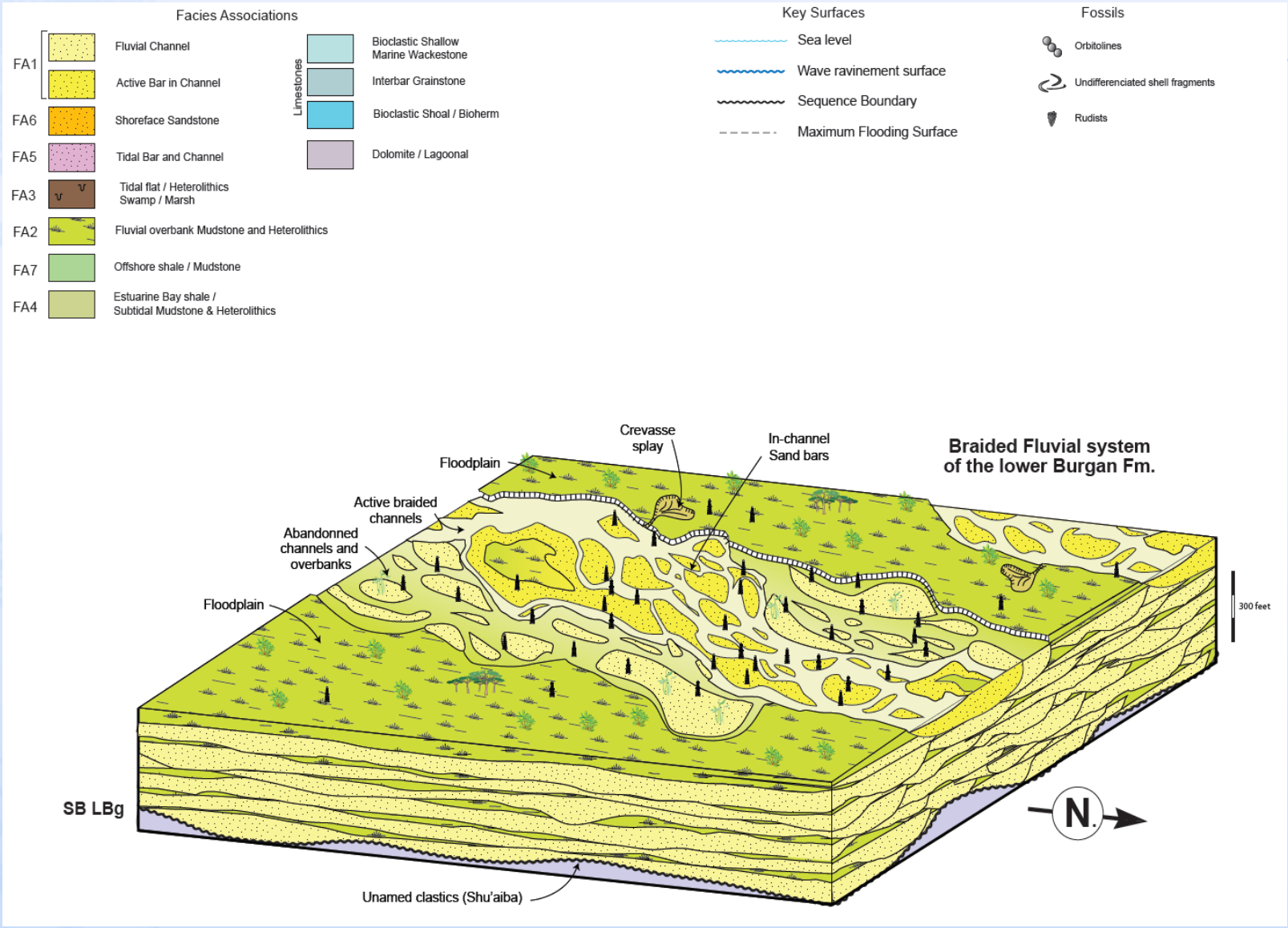
Fluvial

FA1: Fluvial sandstone lowest GR values, thick and massive (50 to 80 ft), aggrading, good separation between RHOB-NPHI.

FA2: Overbanks levees: higher values of GR within sandstones

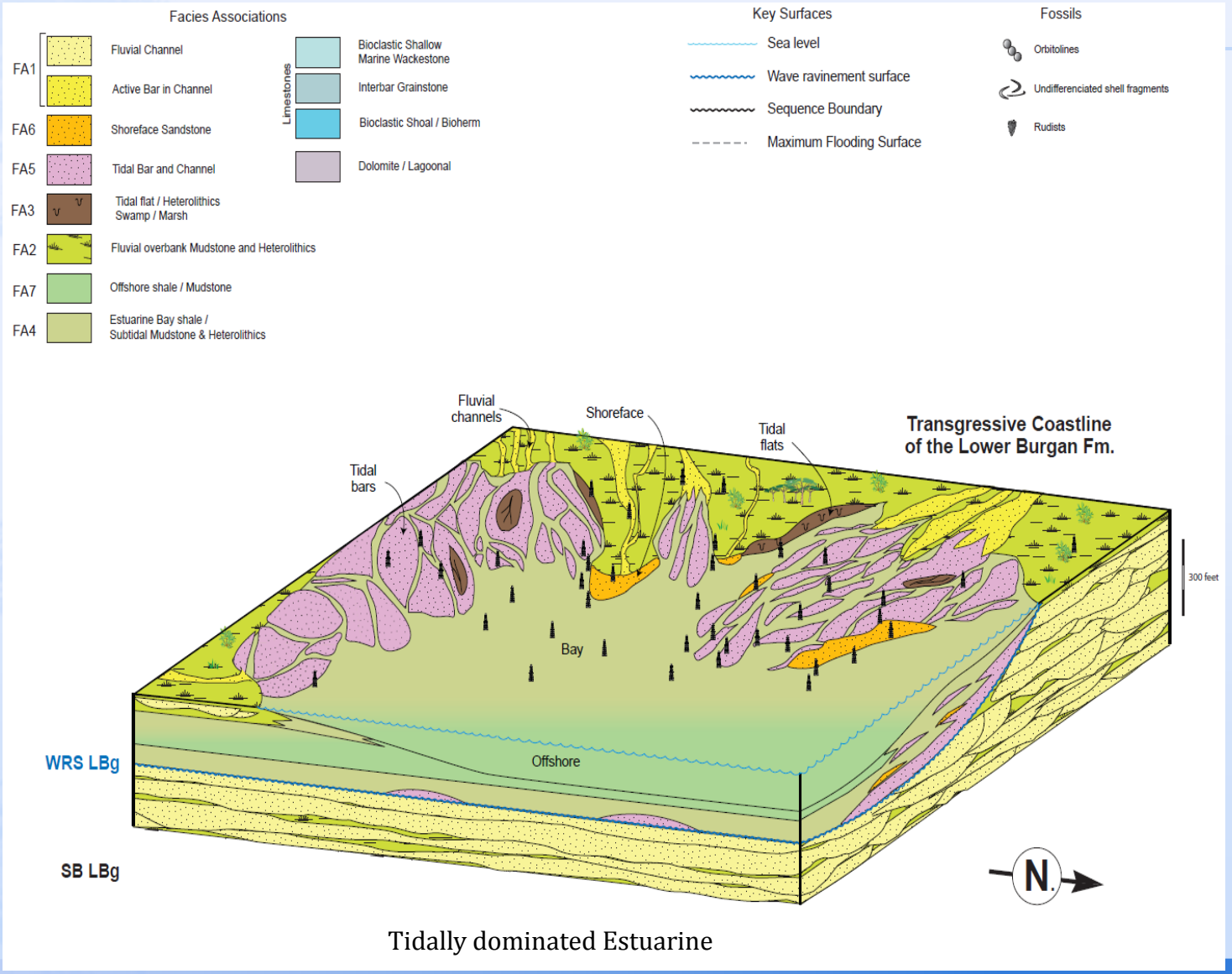
FA3: Marsh, swamp: high GR values, low density if carbonaceous

Conceptual diagram of the Lower Burgan (4S) paleoenvironment



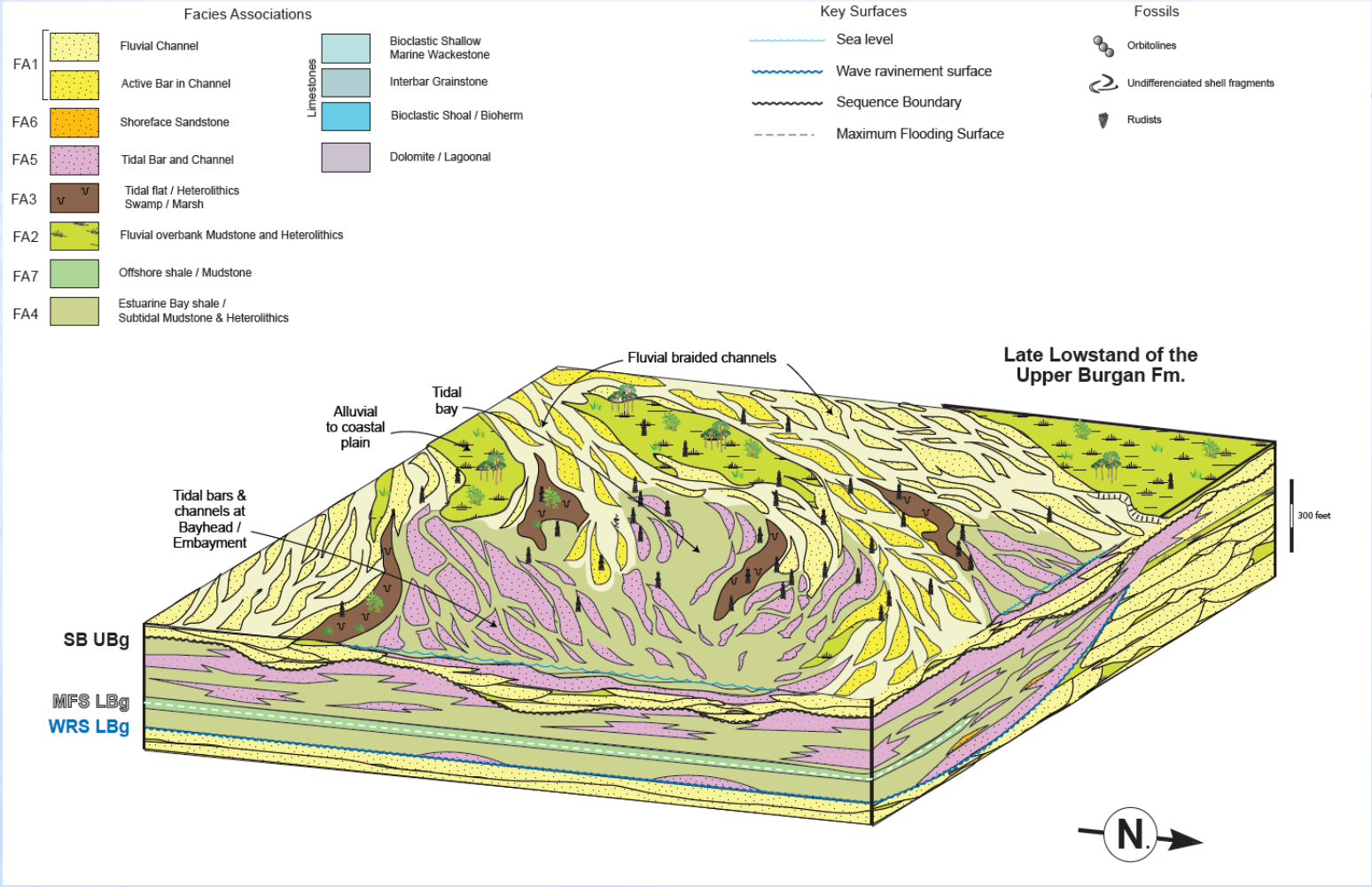
Overbank (levee) mottled sandstone.

Conceptual diagram of the Lower Burgan (3SL) paleoenvironment

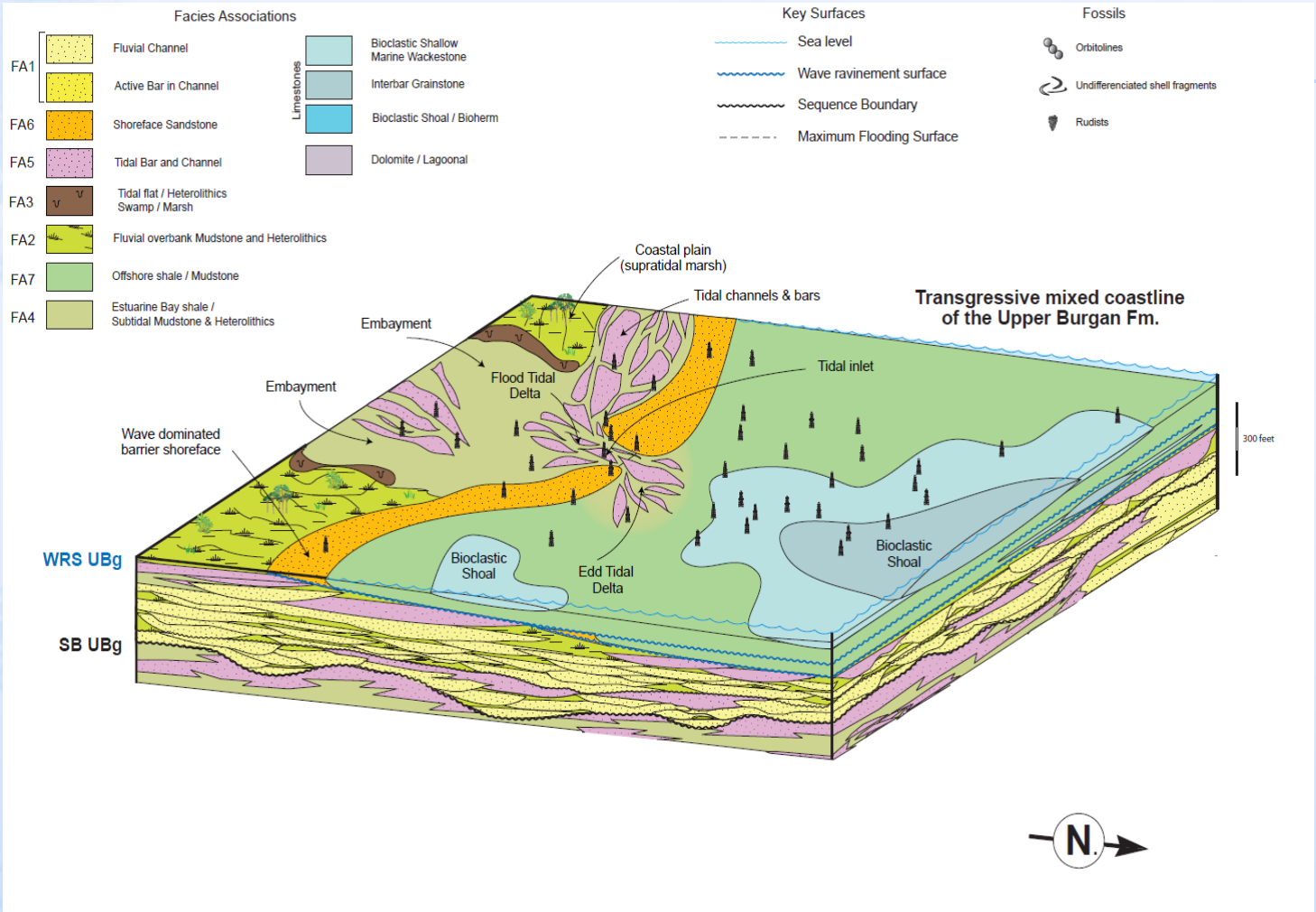


Tidally dominated Estuarine

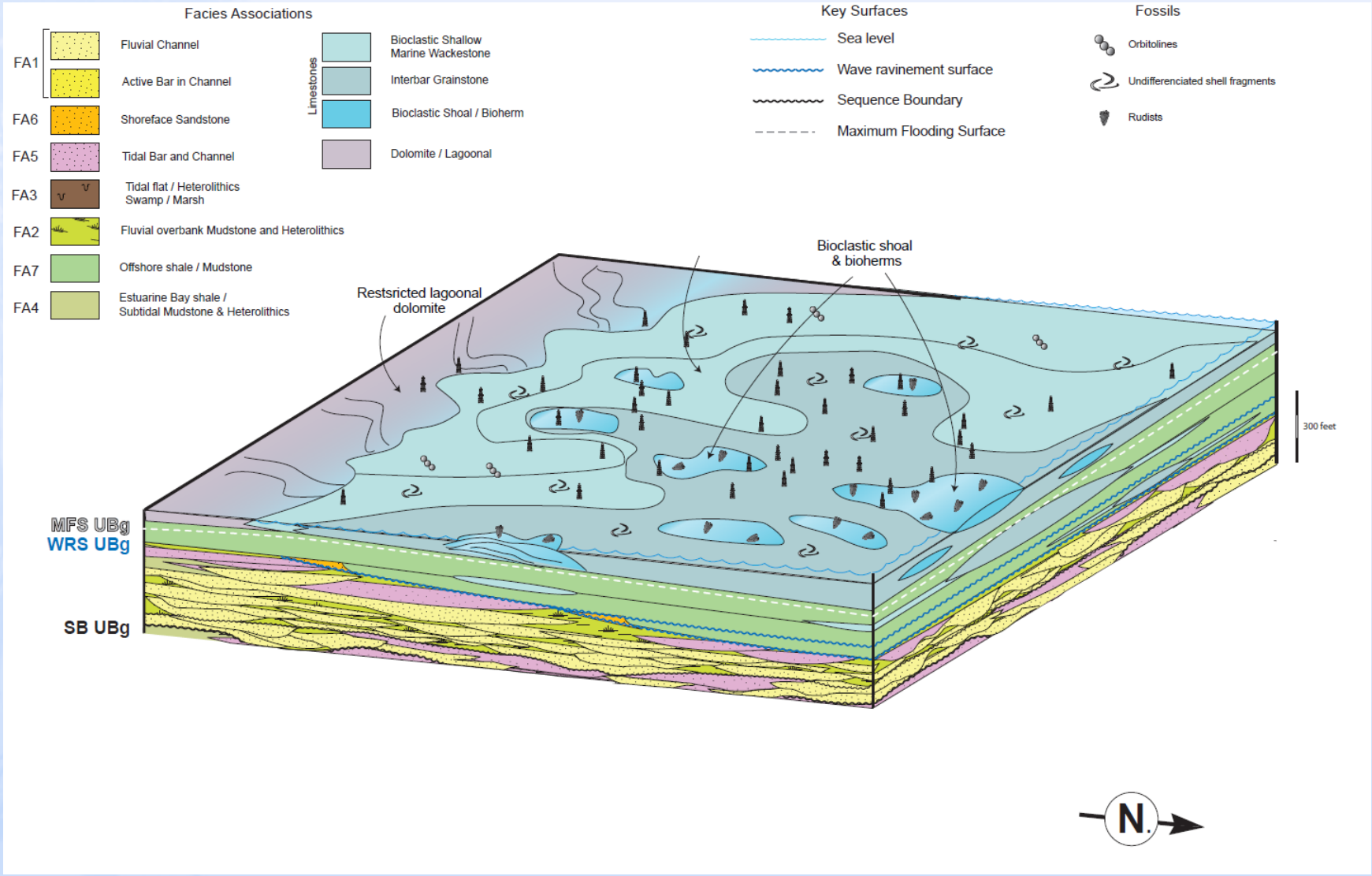
Conceptual diagram of the lower Upper Burgan Formation (3SM) Paleoenvironment



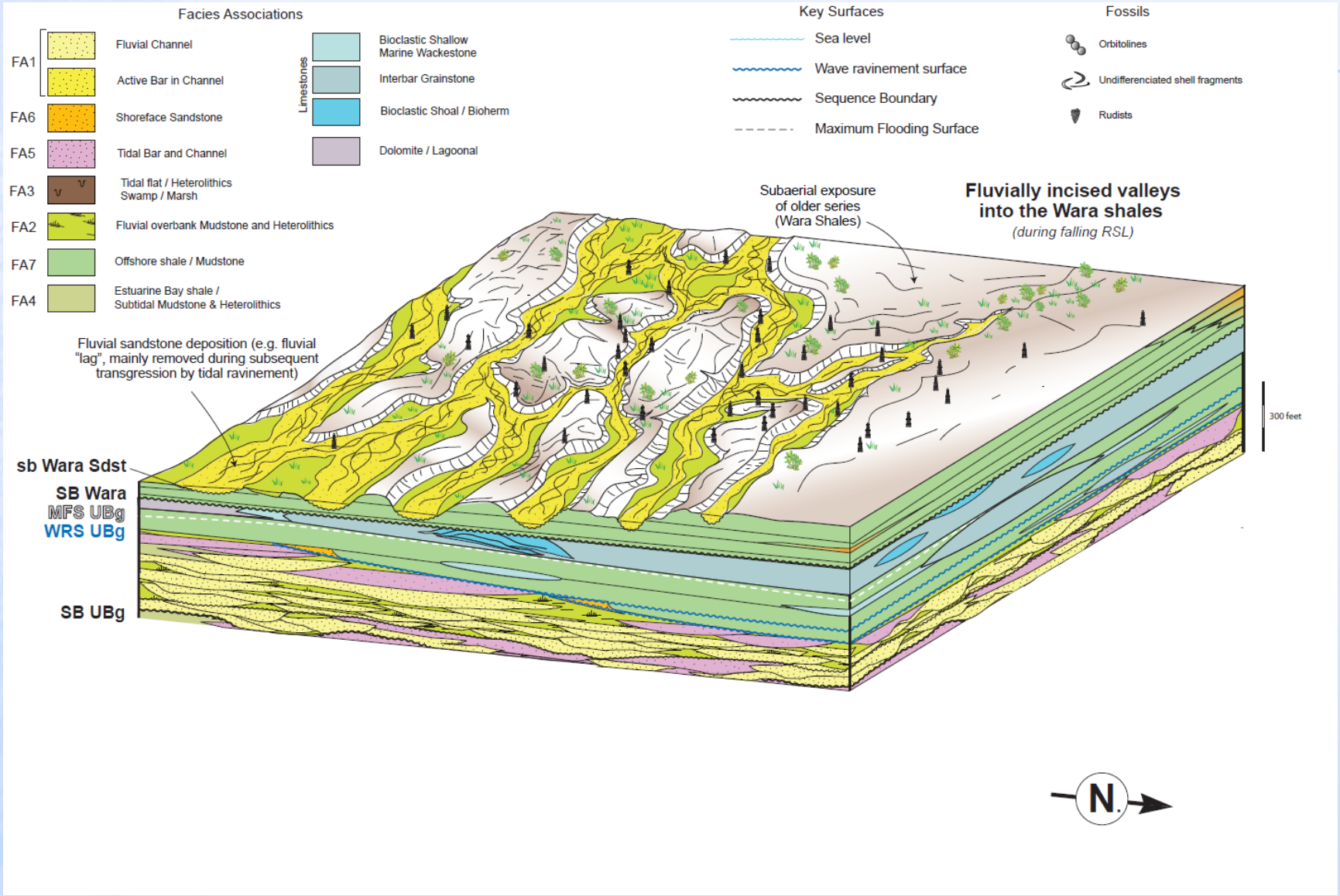
Conceptual diagram of the Upper Burgan (3SU) paleoenvironment



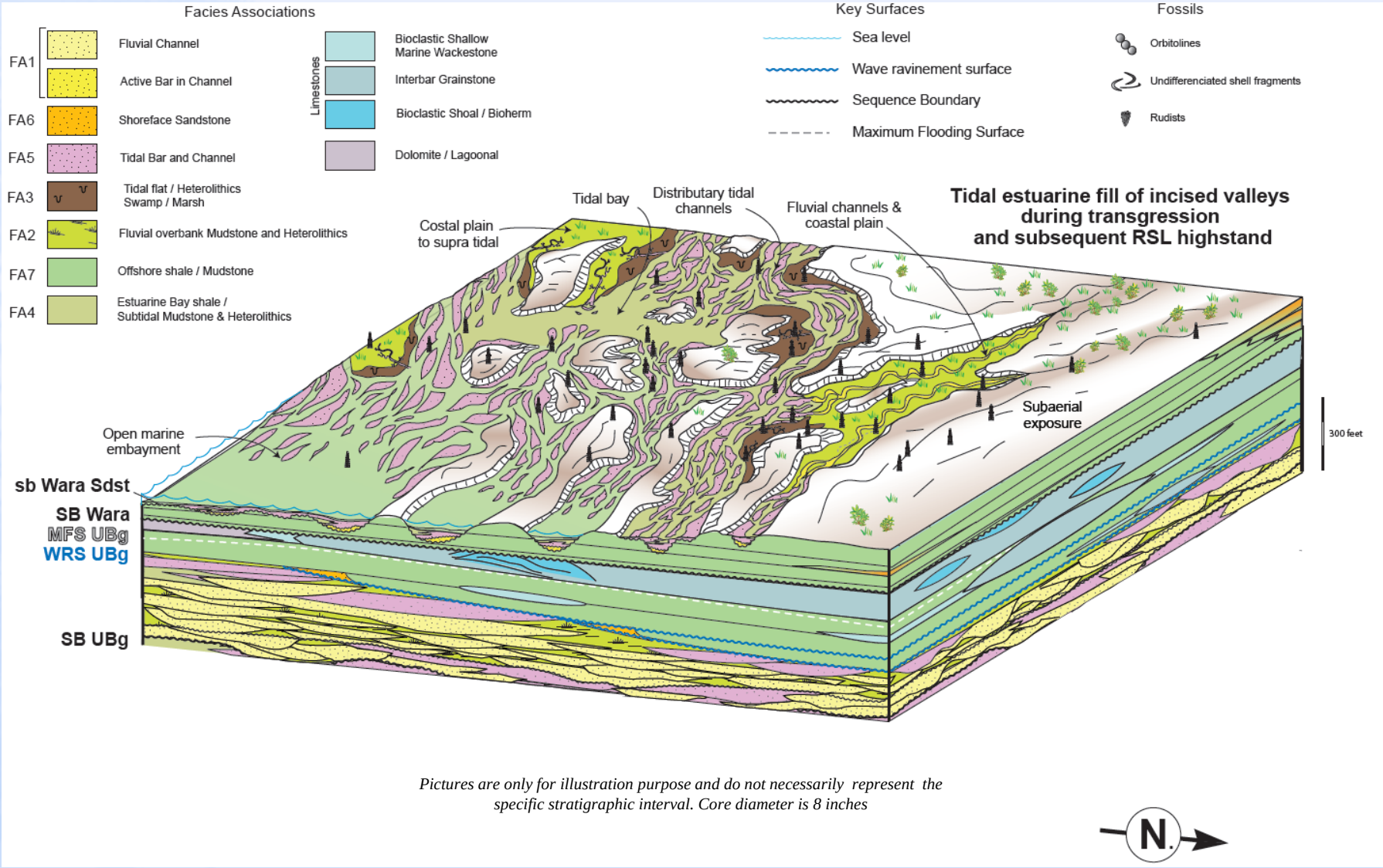
Conceptual diagram of the Mauddud Formation paleoenvironment



Conceptual diagram of the Lower Wara Formation paleoenvironment

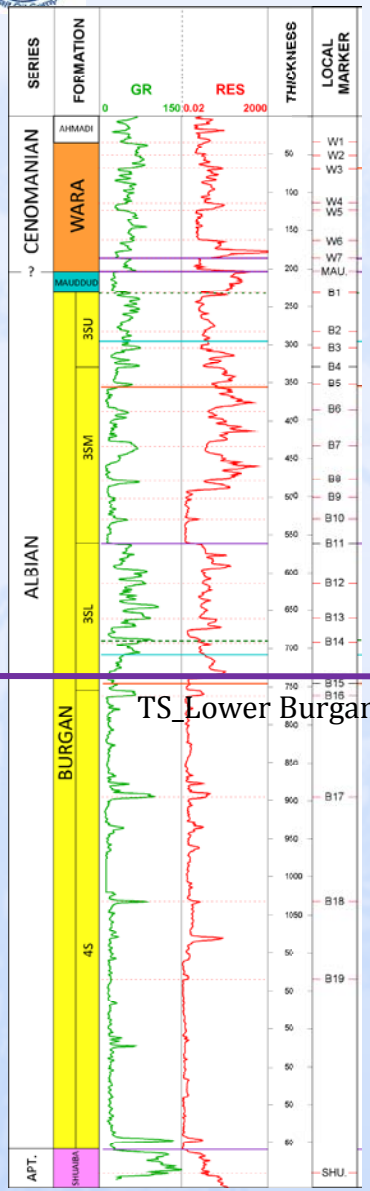


Conceptual diagram of the Wara Formation paleoenvironment



Pictures are only for illustration purpose and do not necessarily represent the specific stratigraphic interval. Core diameter is 8 inches

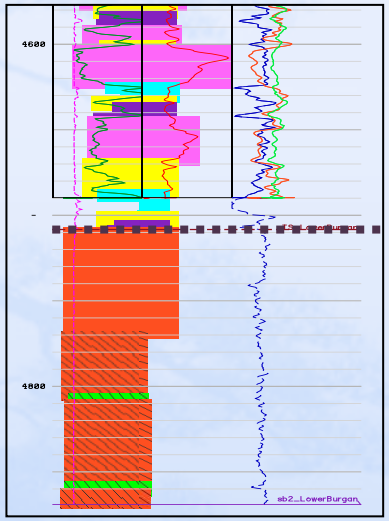
Signature of key surfaces: Transgessive surface



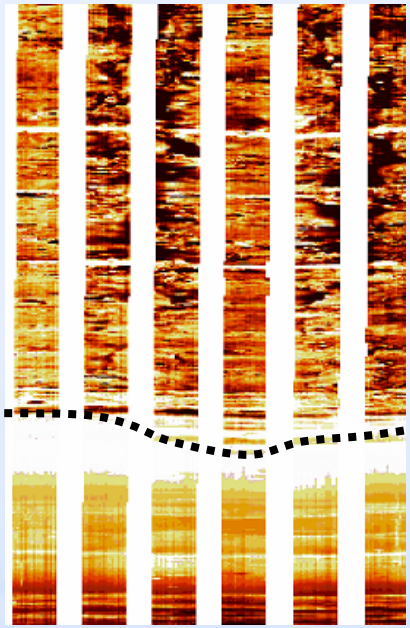
TS_Lower Burgan

Logs

Z-OZF



FMI



Cores

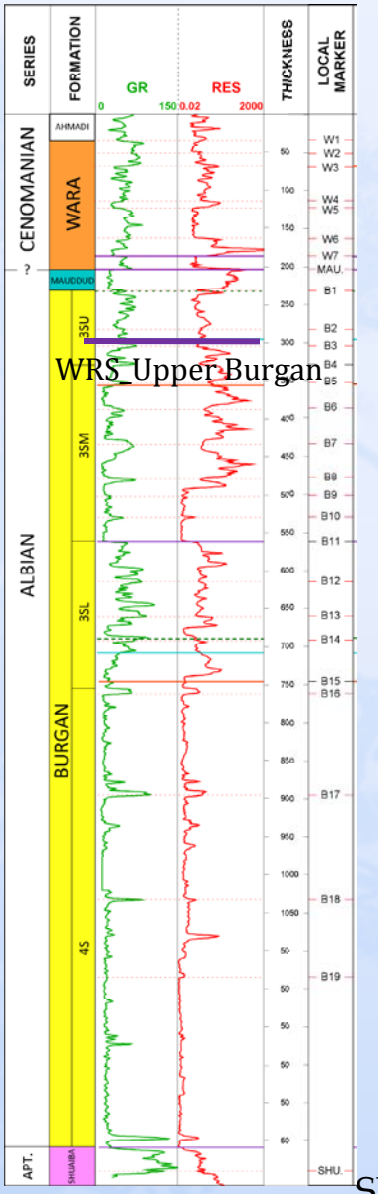
Glauconitic sands

Z-OZF

Lower Burgan: Massive sands

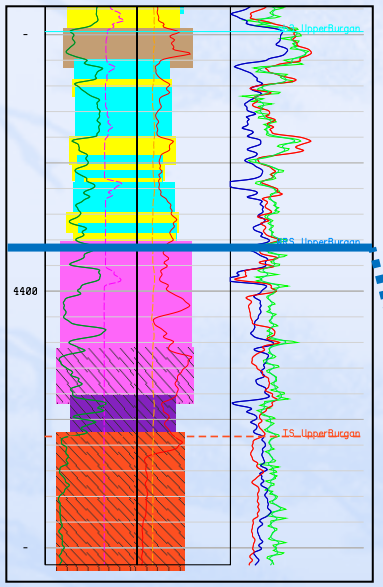
Sharp contact between massive cross bedded fluvial sands and tidal sands and heterolithics.

Signature of key surfaces : Wave Ravinement Surface



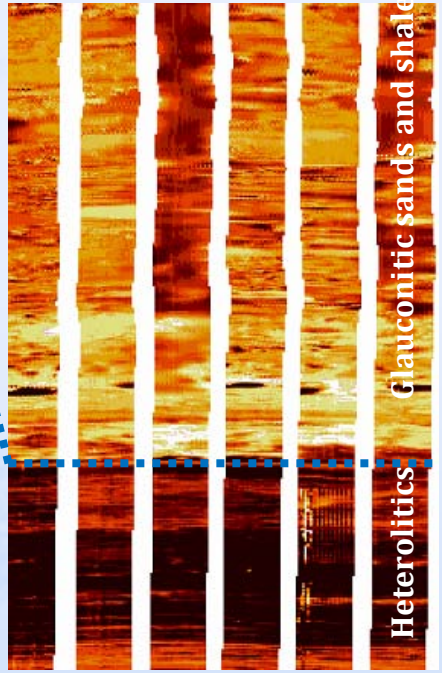
Logs

Y-ONS



FMI

Y-TTZ

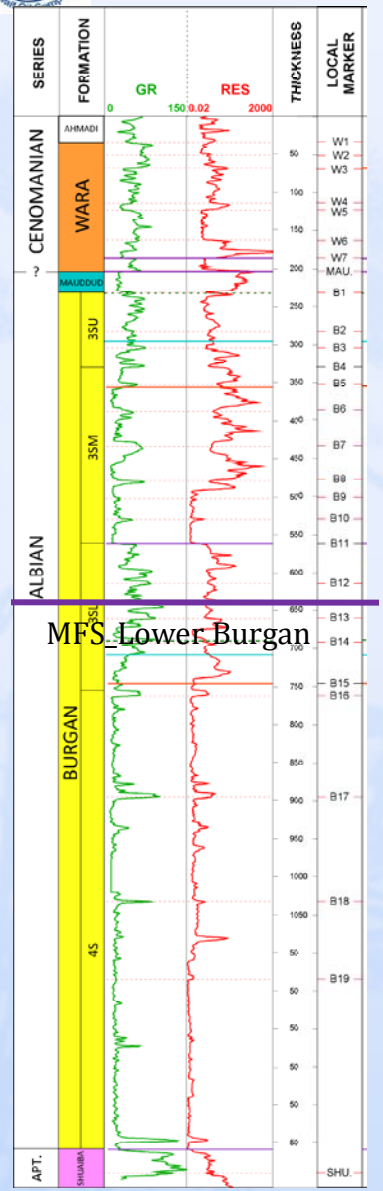


Cores

X-SZF

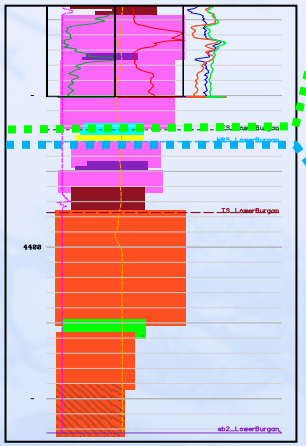
Sharp erosive contact between fine sand, heterolitics and laminated shale rich in siderite nodules or glauconitic sands.

Signature of key surfaces : Maximum Flooding Surface



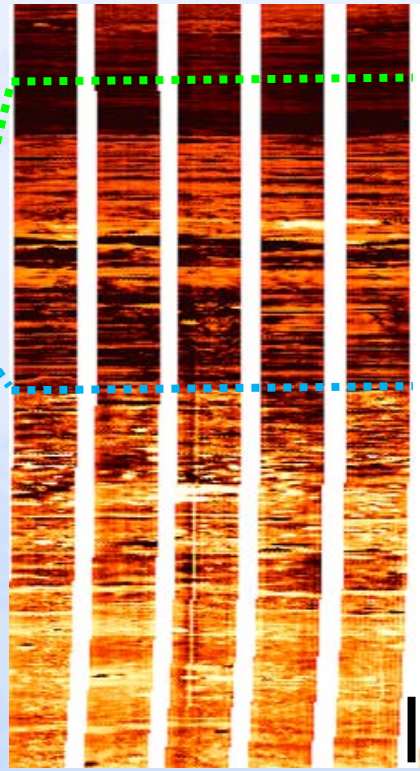
Logs

X-FOT



FMI

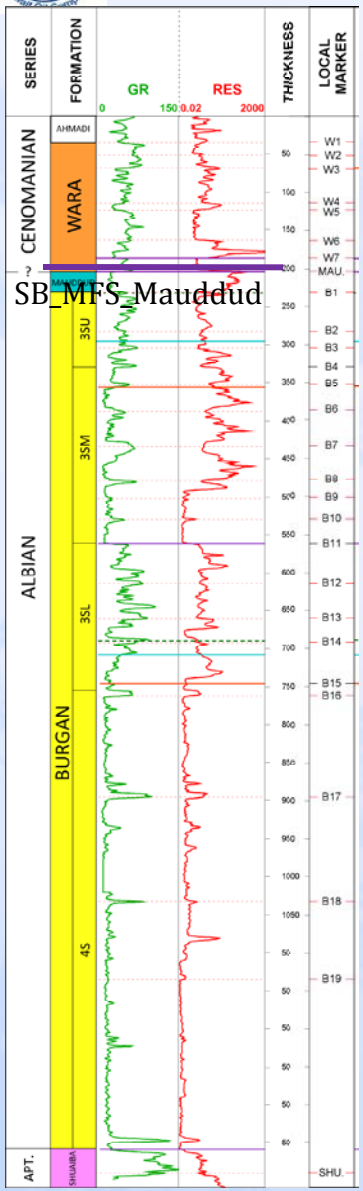
X-FNN

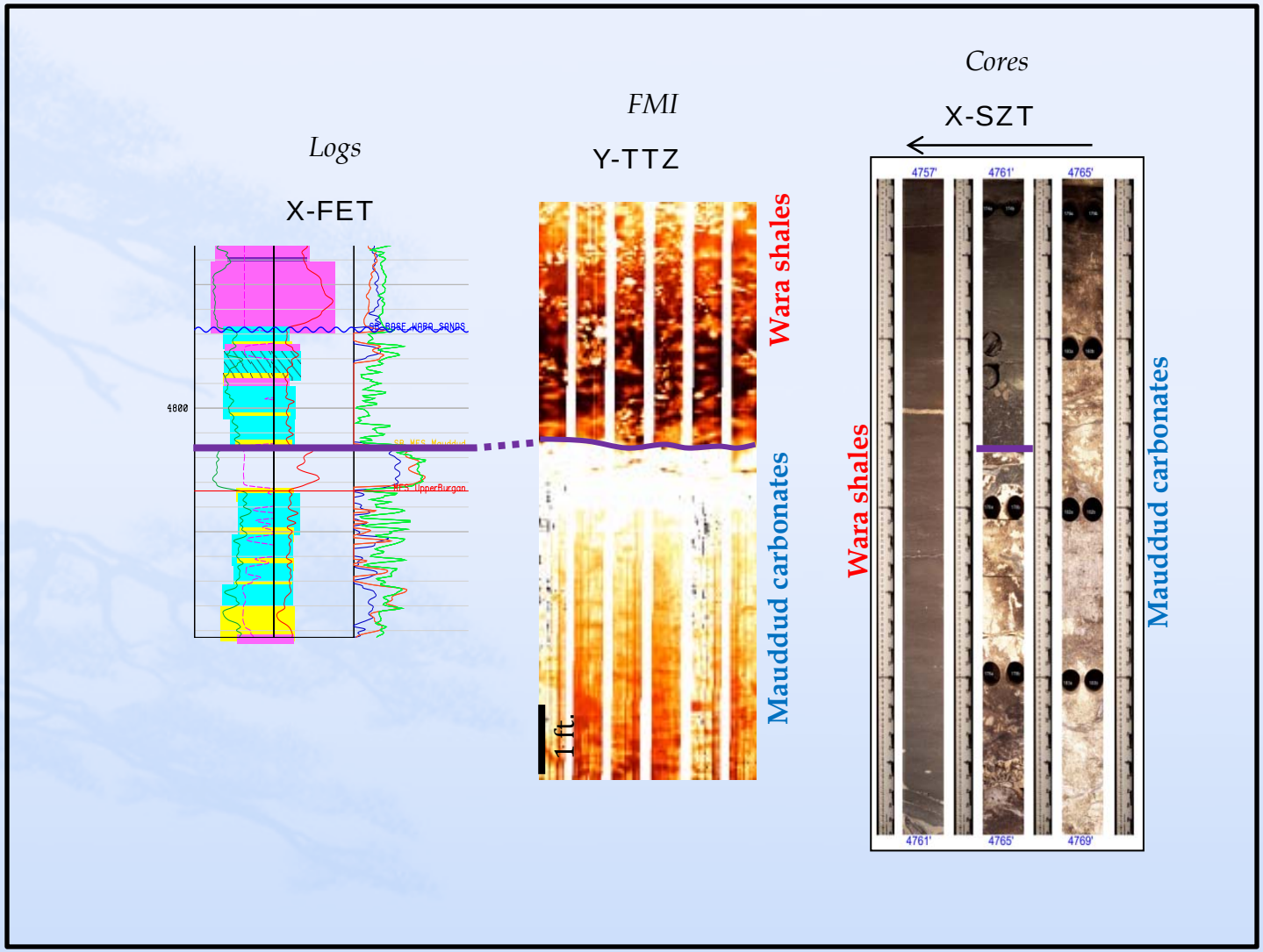


Cores

X-FOT

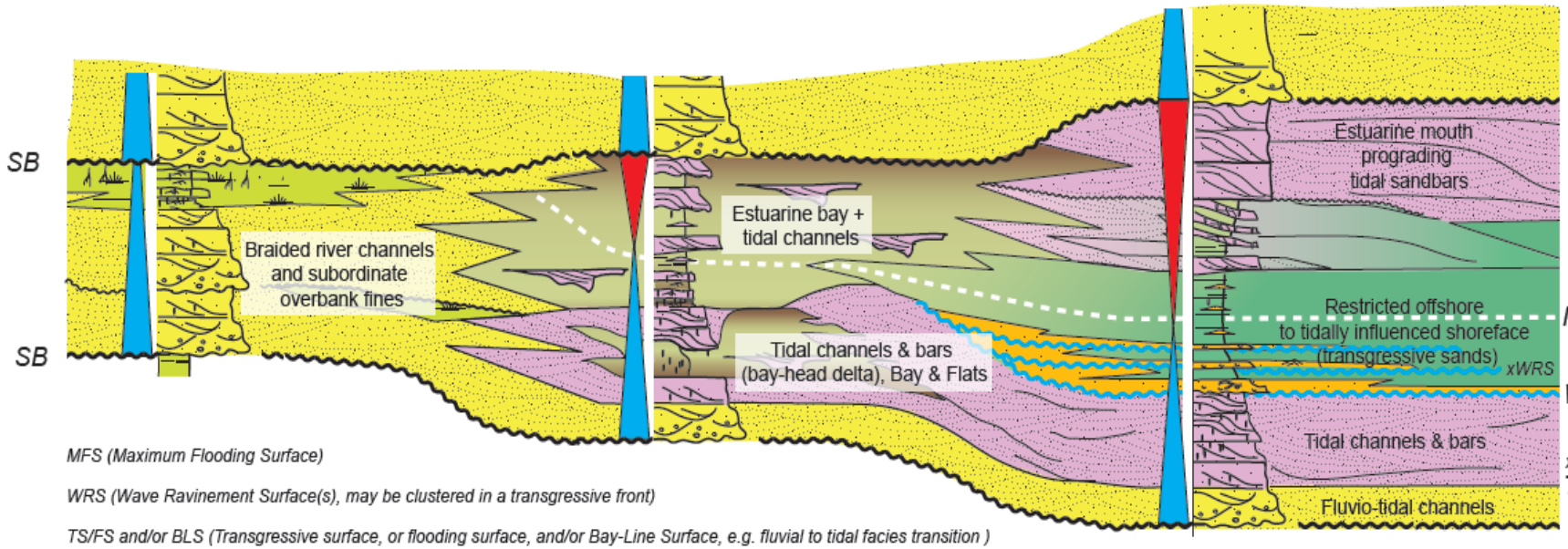
Signature of the key surfaces: Sequence boundary





Sharp contact between Maudddud carbonates and Wara shales
With dissolution features and associated vugs.

Type sequence of the Burgan Formation : lateral architecture



MFS (Maximum Flooding Surface)

WRS (Wave Ravinement Surface(s), may be clustered in a transgressive front)

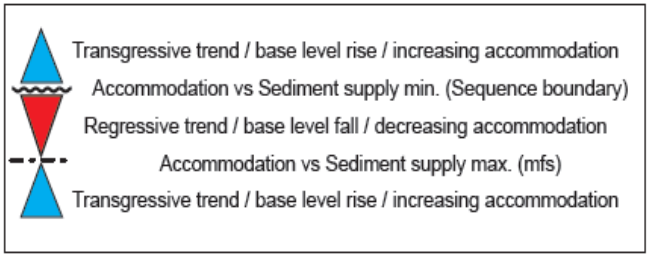
TS/FS and/or BLS (Transgressive surface, or flooding surface, and/or Bay-Line Surface, e.g. fluvial to tidal facies transition)

SB (Sequence Boundary)

Facies Associations

FA1	Fluvial channel Sandstones
FA2	Fluvial overbank Mudstone and Heterolithics
FA3	Tidal flat / Heterolithics Swamp / Marsh
FA4	Estuarine Bay shale / Subtidal Mudstone & Heterolithics
FA5	Tidal sandstones, estuarine bars and channels
FA6	Shoreface Sandstones
FA7	Offshore shale / Mudstone

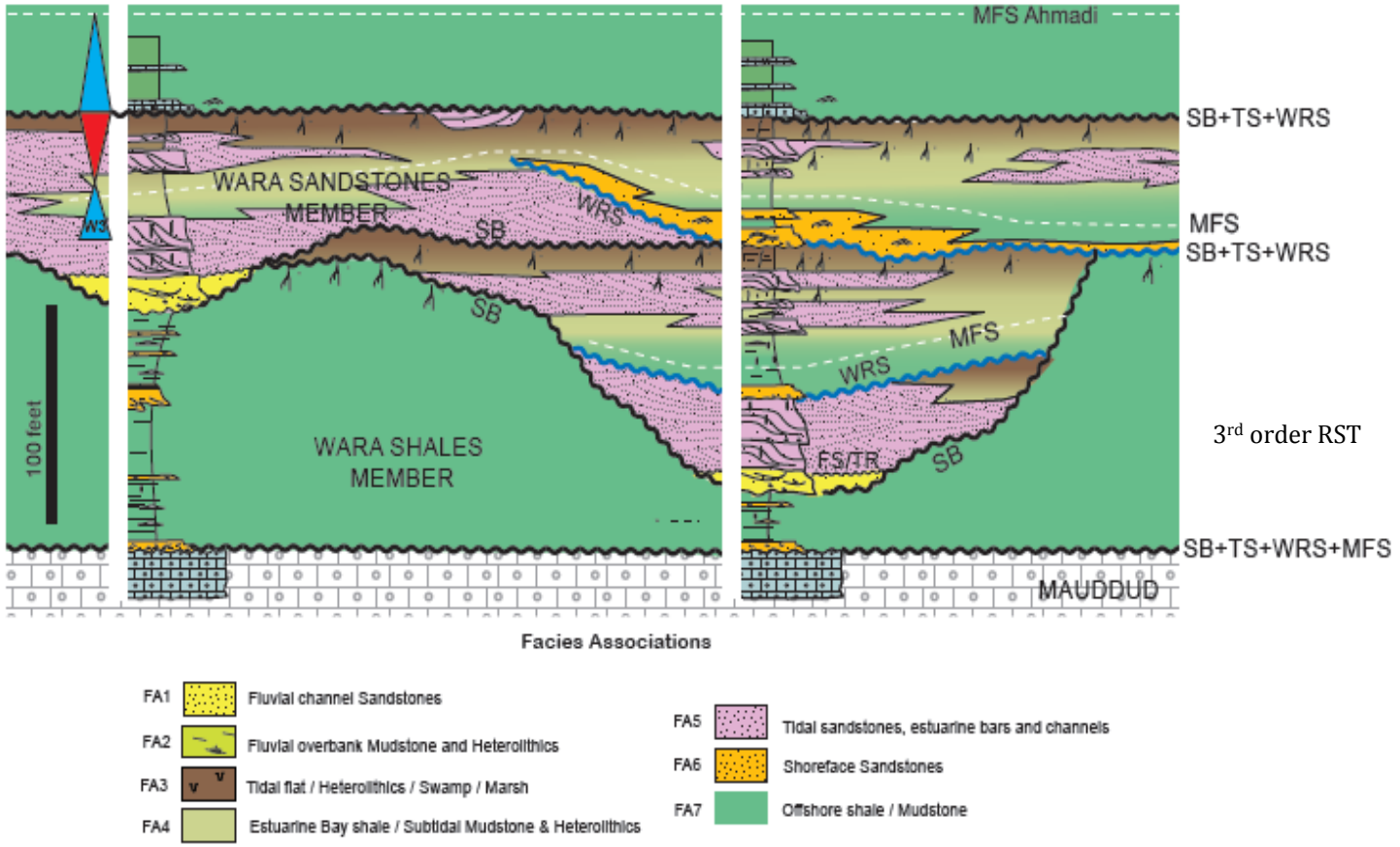
Burgan Formation (Lower & Upper Members)
sequence stratigraphic model for a tide-dominated estuarine environment,
facies partitionning within a single base level rise/fall cycle



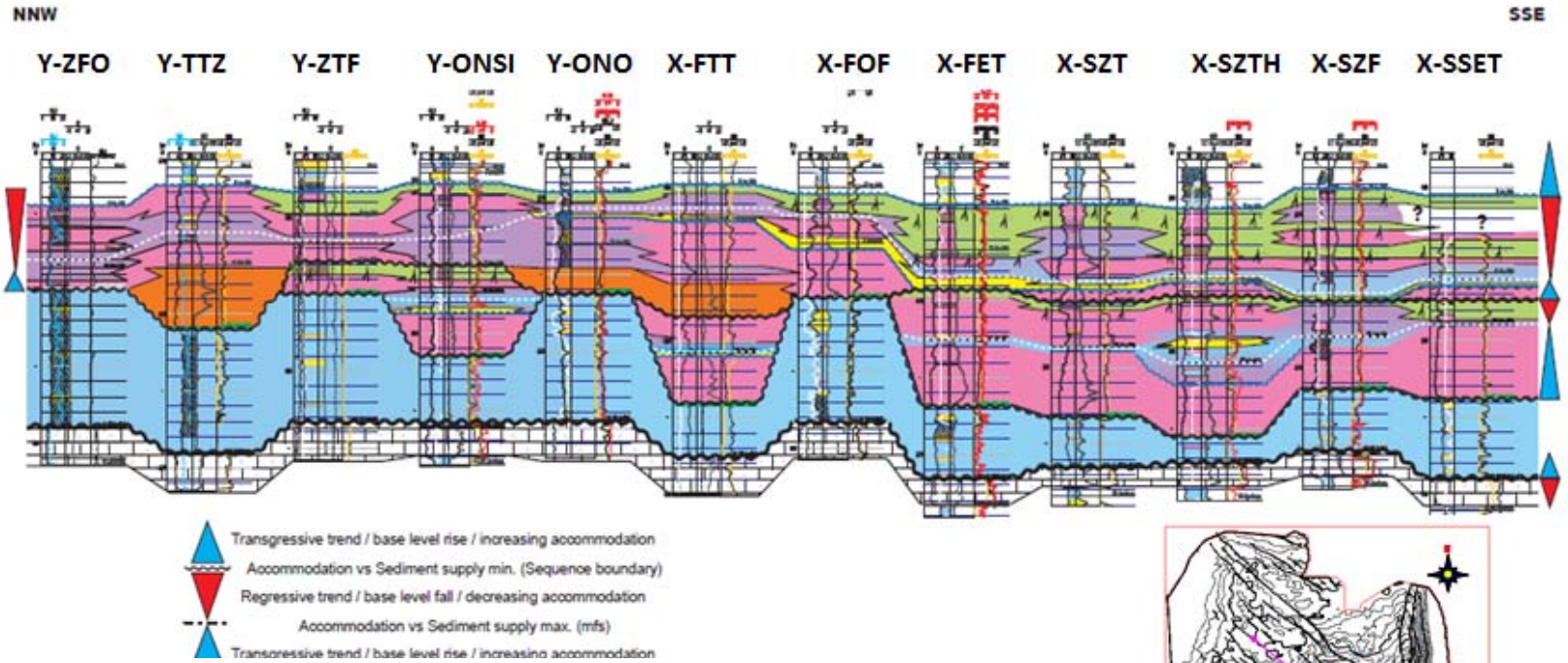
Genetic stratigraphic scheme linking depostional environments in a single depositional profile

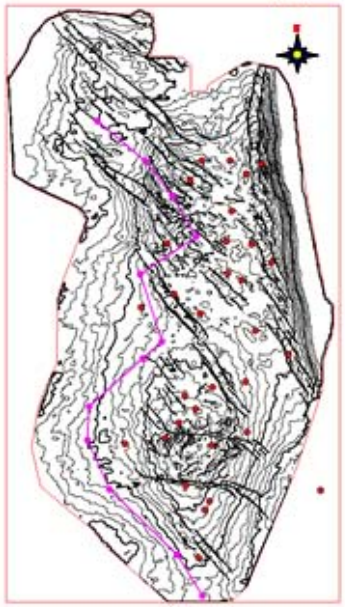
Type Sequences for Wara Formation : Theoretical Model

N Burgan (Magwa, Ahmadi) **S Burgan**

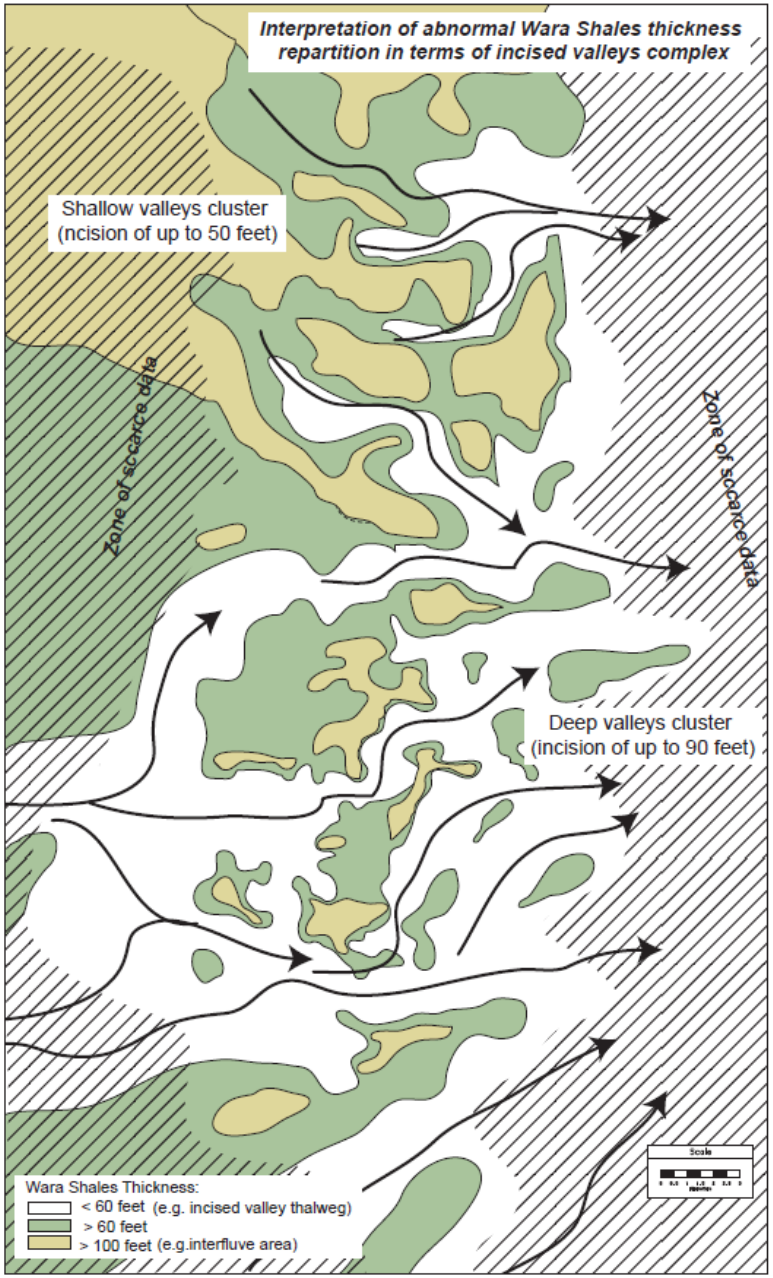


Type Sequences for the Wara Formation : Lateral architecture

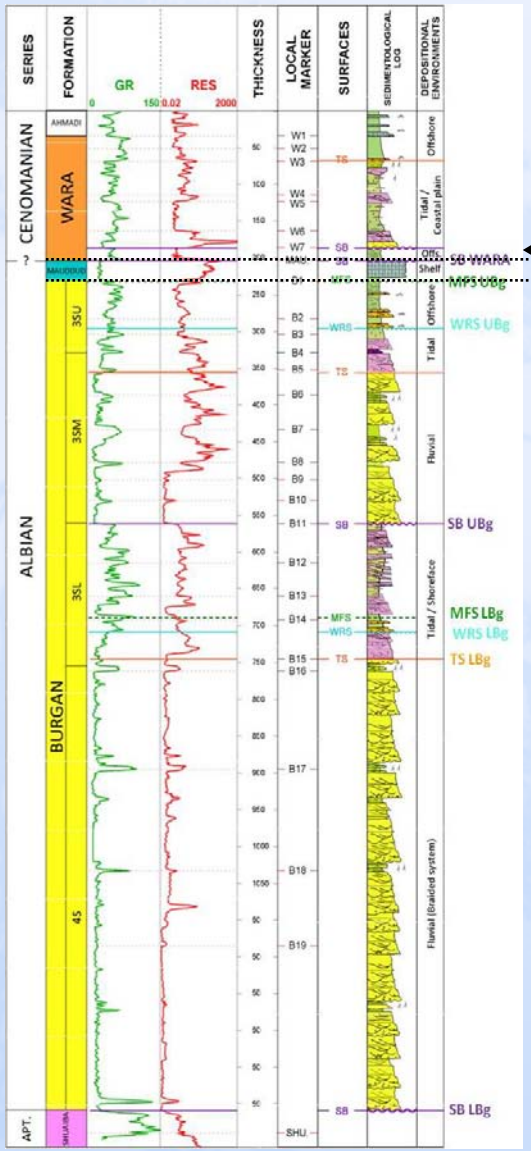





Wara Shales isochore map (in feet)
(n=879 wells)


Interpretation of abnormal Wara Shales thickness repartition in terms of incised valleys complex
Shallow valleys cluster
(ncision of up to 50 feet)
Zone of scarce data
Zone of scarce data
Deep valleys cluster
(incision of up to 90 feet)
Wara Shales Thickness:
< 60 feet (e.g. incised valley thalweg)
> 60 feet
> 100 feet (e.g.interfluve area)

Biostratigraphy: Age



Ostracodes

Glenocythere reticulata
Glenocythere triangularis
Eocytheropteron aff postilum
Cytherella gigantosulcata
Dolocytheridea atlasica
Louza amygdaloidea
Metecytheropteron pleura
Glenocythere bahreinensis
Cythereis streblolophata schista
Glenocythere bahreinensis

Foraminifers

Trocholina altispira Henson
Orbitolina concava (Lamarck)
O. discoidea Gras
Hemicyclammina sigali Maync
H. whitei Henson

Palynomorphs

Cytherella sp OMN 11
Pontocyprella IR.E.15
Eocytheropteron IR.C.13
Dordoniella ? cf bairdarensis

S. Perlucida
E.castelaini
E. Klaszi
E. jansonius

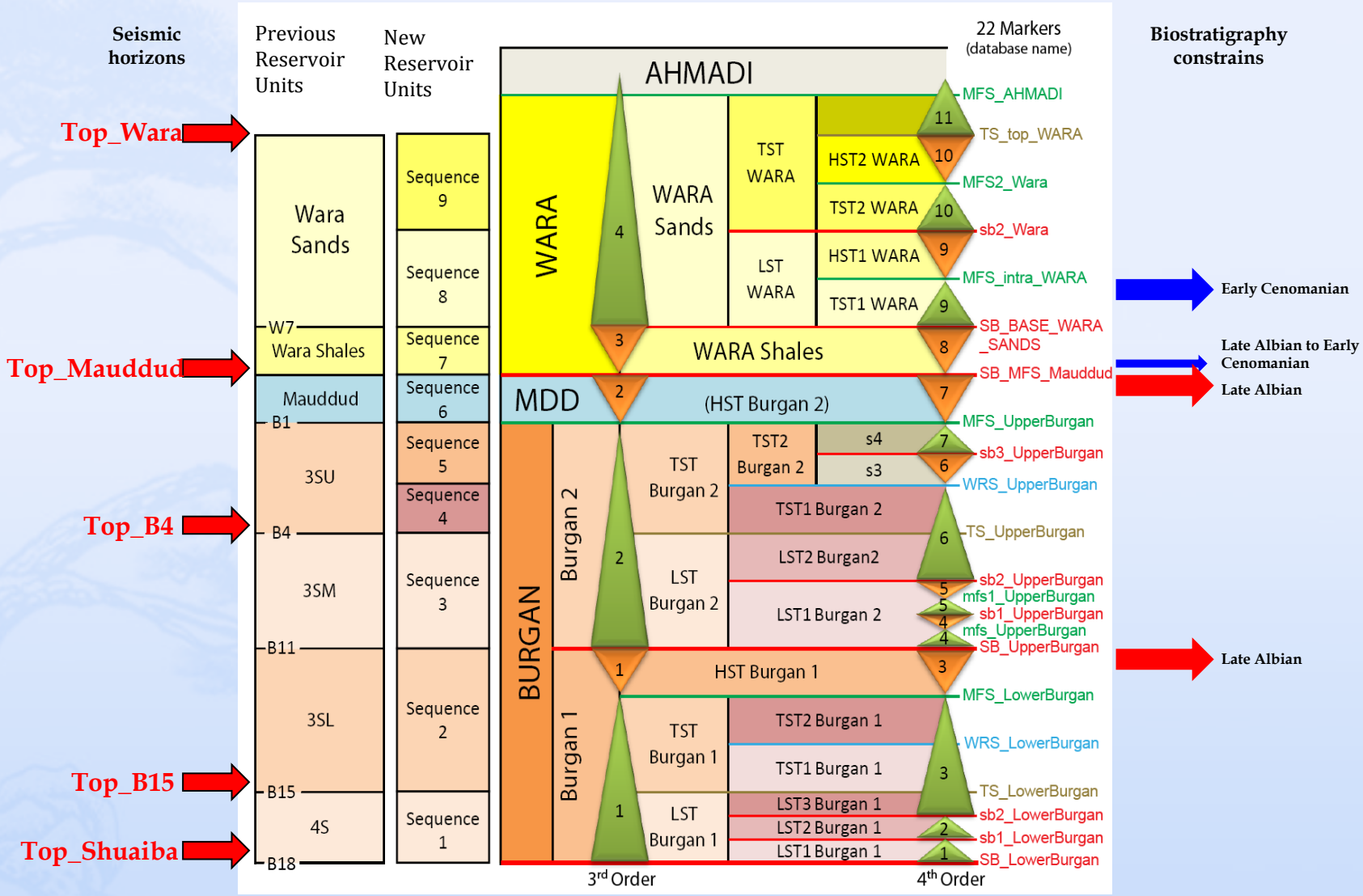
Early Cenomanian

Late Albian to Early Cenomanian

Late Albian

Late Albian

Stratigraphic schème



Conclusions

- Burgan, Mauddud and Wara formations were divided into four 3rd order and eleven 4th Order Sequences.
- Twenty genetically related units were identified and correlated in the full field.
- Seven Facies associations were established within the interval.
- Biostratigraphic and Chronostratigraphic studies helped to firm up the stratigraphic framework.
- Paleogegraphic maps prepared for major stratigraphic interval helped in understanding the distribution of the facies over the field.
- The new Stratigraphy will constrain the future Geostatistical model for realistic mapping of reservoir units .