Characterisation of the Mid-Cretaceous Mishrif Reservoir of the Southern Mesopotamian Basin, Iraq*

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Abstract

The Cenomanian-early Turonian Mishrif Formation reservoir of the Mesopotamian Basin accommodates more than one third of the proven Iraqi oil reserves within rudist-bearing stratigraphic units. Difficulty in predicting the presence of reservoir units is due to the complex palaeogeography. Extensive accumulation of rudist banks occurred along an exterior shelf margin of the basin along an axis that runs from Hamrin to Badra and southeast of that, with interior margins around an intrashelf basin. Buildups were stacked or sometimes shingled as thicker shallowing-up cycles of several smaller-scale accommodation cycles. As a result, each field shows different combinations of pay zones, barriers and seal geometries.

The sequence stratigraphic analysis led to three complete 3rd order sequences being distinguished. Eustatic sea level changes controlled development of the sequence stratigraphy. Tectonism primarily defined the sites of platform development that complicated the architectural heterogeneity of the depositional sequences.

A porosity-predictive model, employing sequence stratigraphic concepts, shows porosity increasing beneath sequence boundaries due to meteoric dissolution and karstification, whilst rising sealevel induces dolomitization on the platform, causing porosity enhancement at early TST. Porous rudist facies usually coincide with the crestal areas of many fields in the region, particularly in those anticlines which show evidence of synsedimentary structural growth. However, other structures have also proven to be non-productive on their crests because of the presence of tight or microporous offshore facies instead of rudist-bearing reservoir facies. Occurrences of interconnected vuggy pores of grain-dominated fabric in the grainy facies make them the best reservoir units. Dissolution of the aragonitic components of rudist shells was the most important diagenetic process that enhanced reservoir characteristics. Presence of rudist-bearing facies with their diagenetic effects within highstand systems tracts is considered the primary factor in effective porosity development and distribution.

Predicted facies relationships indicate prograding and pinch-out of rudist-bearing facies, including lowstand shelf systems, into shallow open facies that can form stratigraphic traps. However, exploring such trap types will require 3D seismic to fine-tune the positions of the external and internal shelf margins via application of high-resolution sequence.

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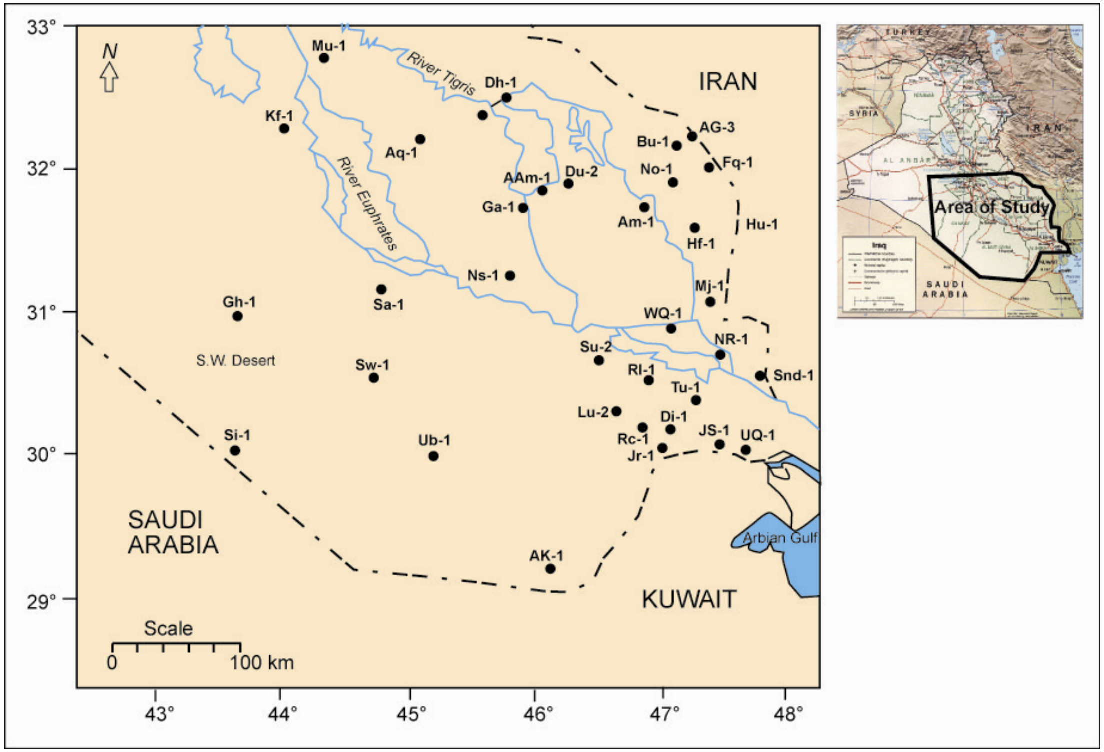
Introduction

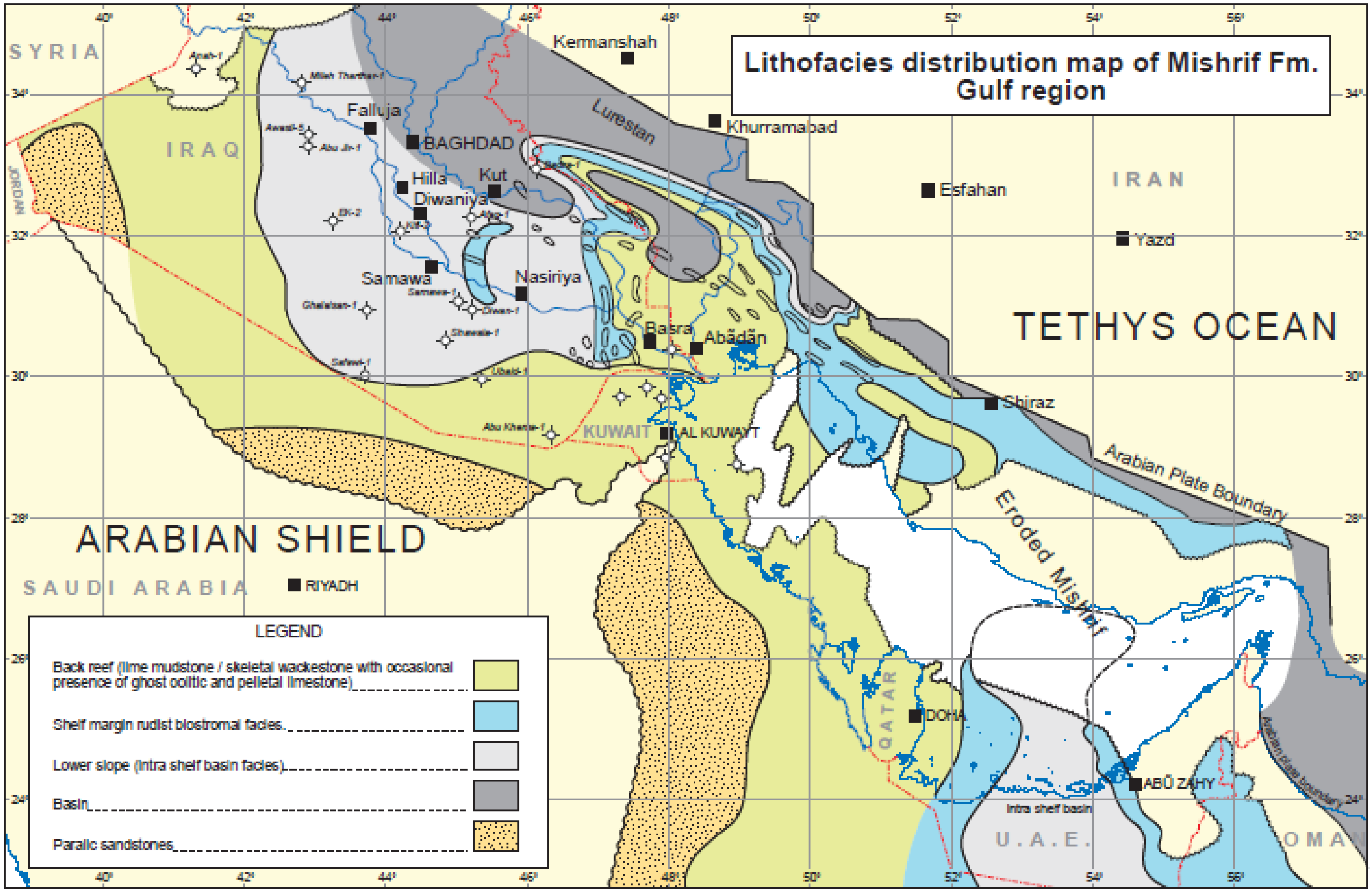
- This presentation is a continuation of Aqrawi and Horbury (Geo2008)

- **The objectives are:**
  - **To review characterization of the Mishrif Reservoir in Southern Mesopotamian Basin, and**
  - **To develop a PoroPerm-predictive procedure for E&P purposes**



(map modified from Aqrawi et al. 1998)

Distribution of the Mishrif main depositional facies associations across the Middle East region (after Dhihny, 1998 based on data from various sources)



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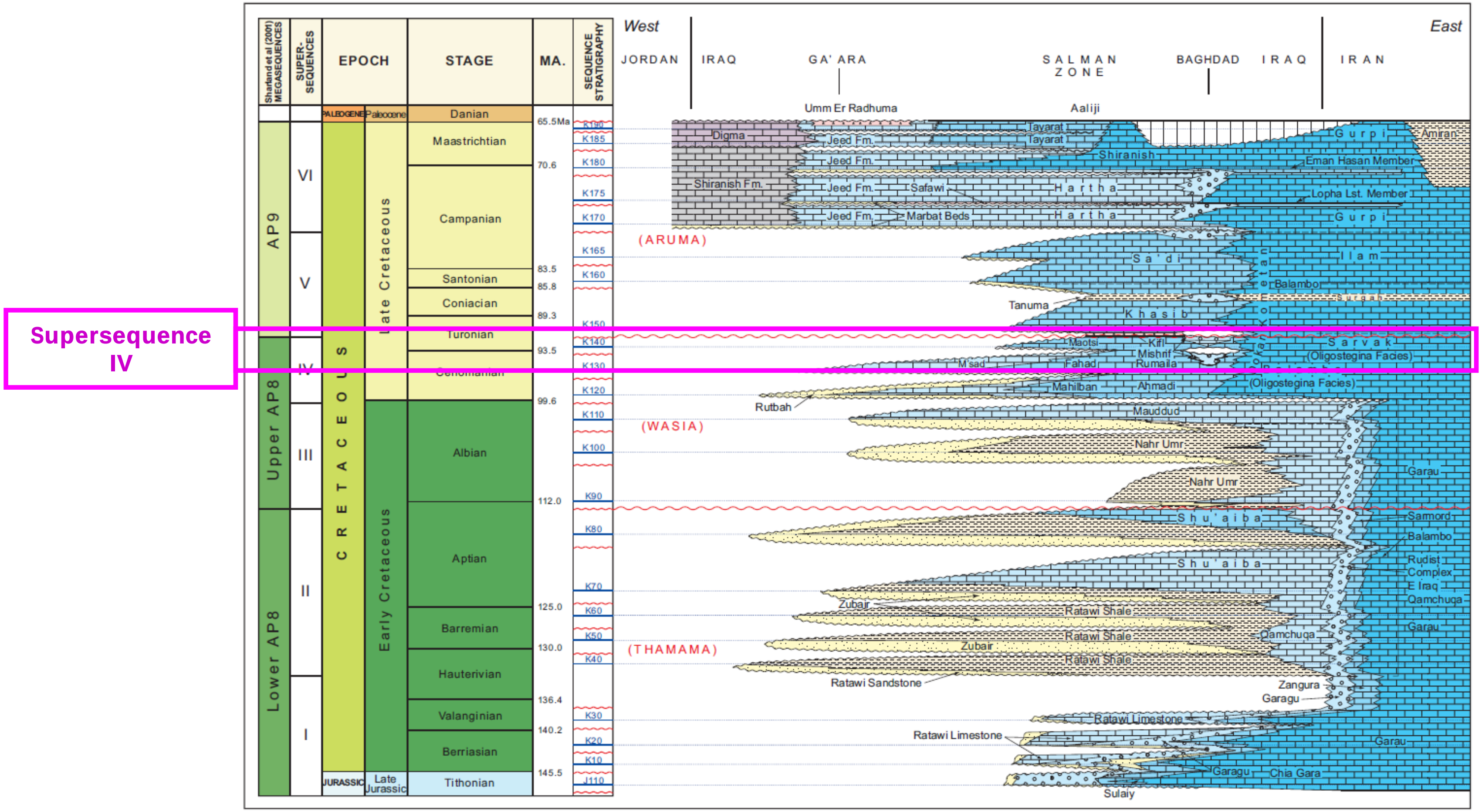
Cretaceous chronostratigraphy of Iraq (Aqrawi et al. 2010)

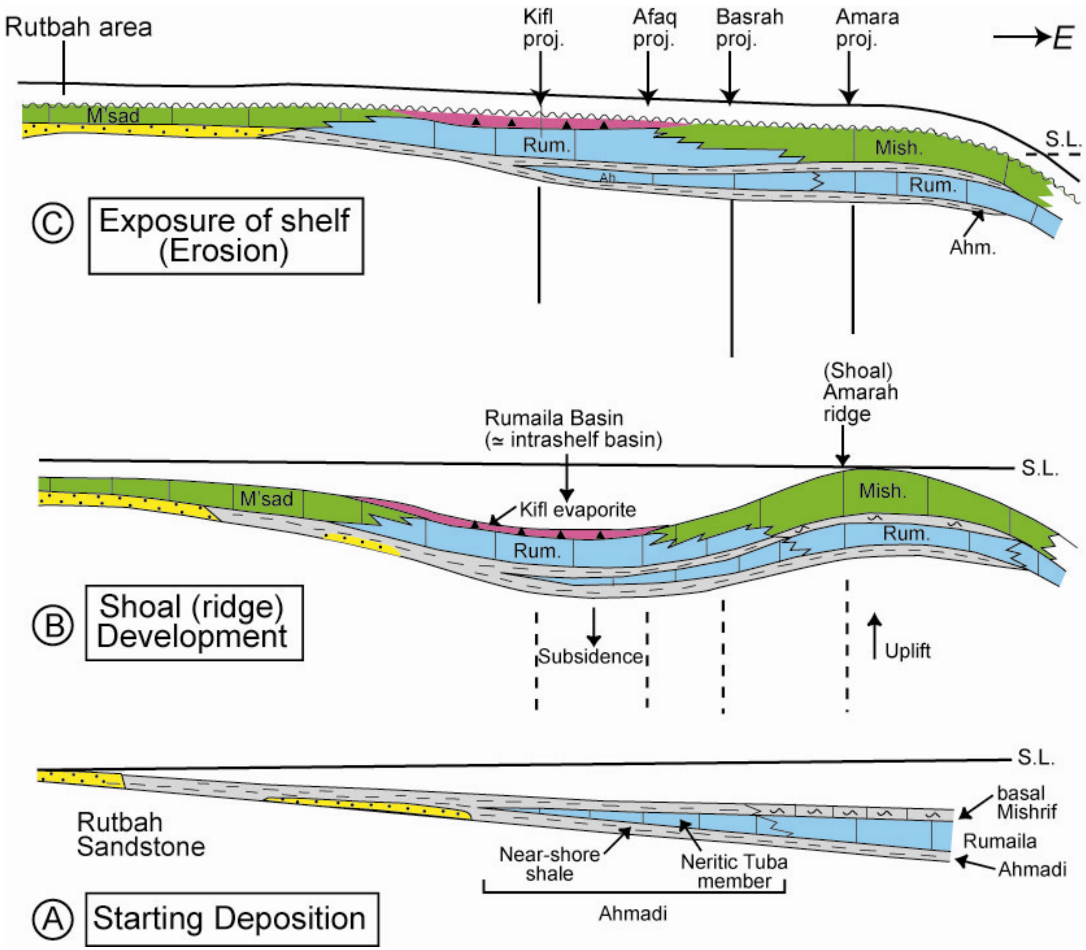
(Ahmadi, Rumaila and Mishrif and their equivalents represent a Type 2 sequence bounded by Type 1 SB above Mishrif and Type 2 SB beneath the Ahmadi)



(3) Then into an attached shelf

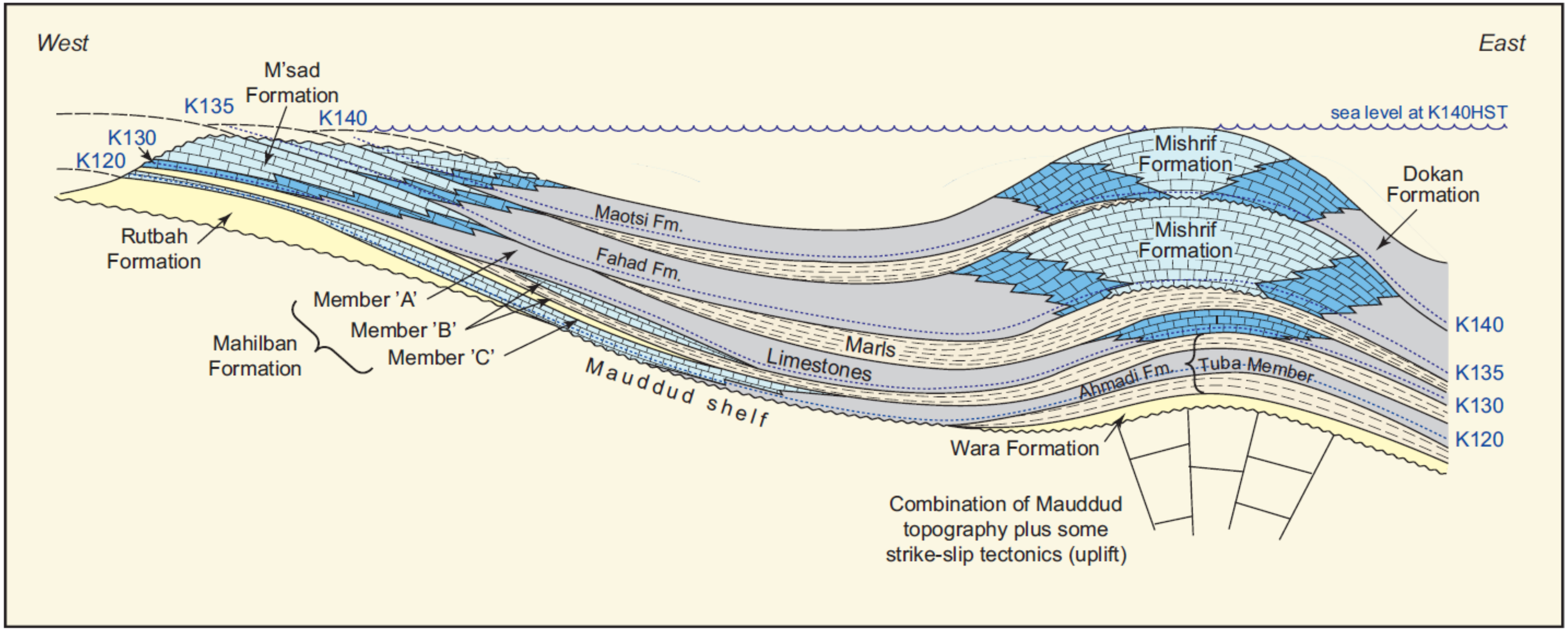
(2) Followed by a detached rimmed-shelf

(1) The platform initiated as a ramp



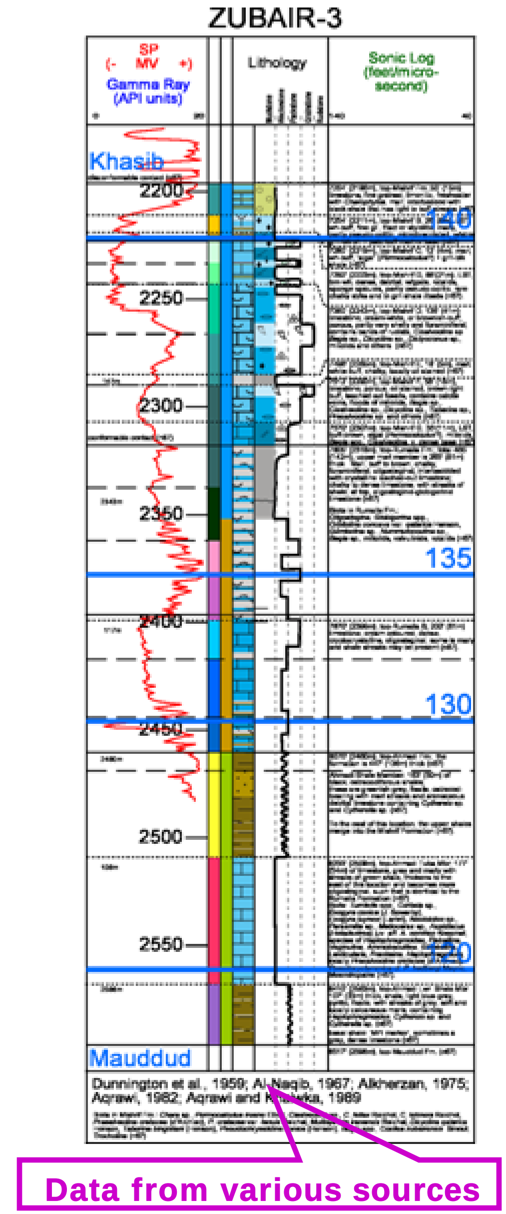
Palaeogeographic evolution of Cenomanian-early Turonian in Southern Iraq (modified from Chatton and Hart, 1962)

The final organization and relative thicknesses of the stratigraphic units in the Cretaceous Supersequence IV (Aqrawi et al. 2010)



General Geology

- After being introduced by Rabanit (1952), Mishrif Fm together with Rumaila and Ahmadi formations were formally described by Owen and Nasr (1958) in well Zubair-3, which is regarded as a type section.
- The majority of previous studies assigned the age of these formations and their equivalents to Cenomanian, with extension up into early Turonian with respect to Mishrif Formation.
- The Cenomanian-early Turonian time interval is also regarded as an early subcycle within a larger cycle (major sequence) of Cenomanian-early Campanian by Buday (1980) and Jassim & Buday (2006).
- The so-called paleohighs, or ridges, had strongly affected the distribution of Mishrif facies, such as the Samarra-Dujaila-Amarah ridge (e.g. Aqrawi et al. 1998, 2010).



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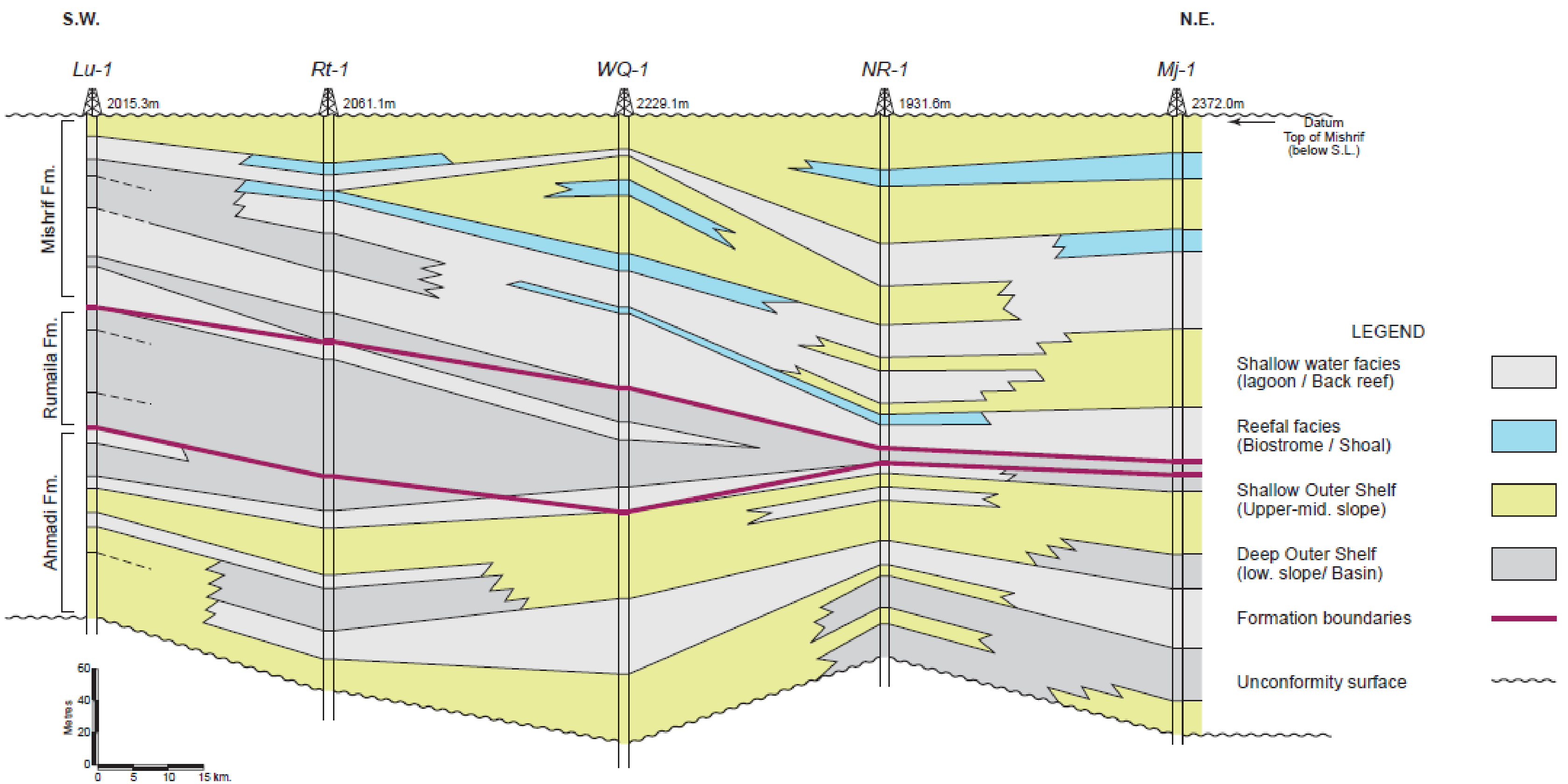
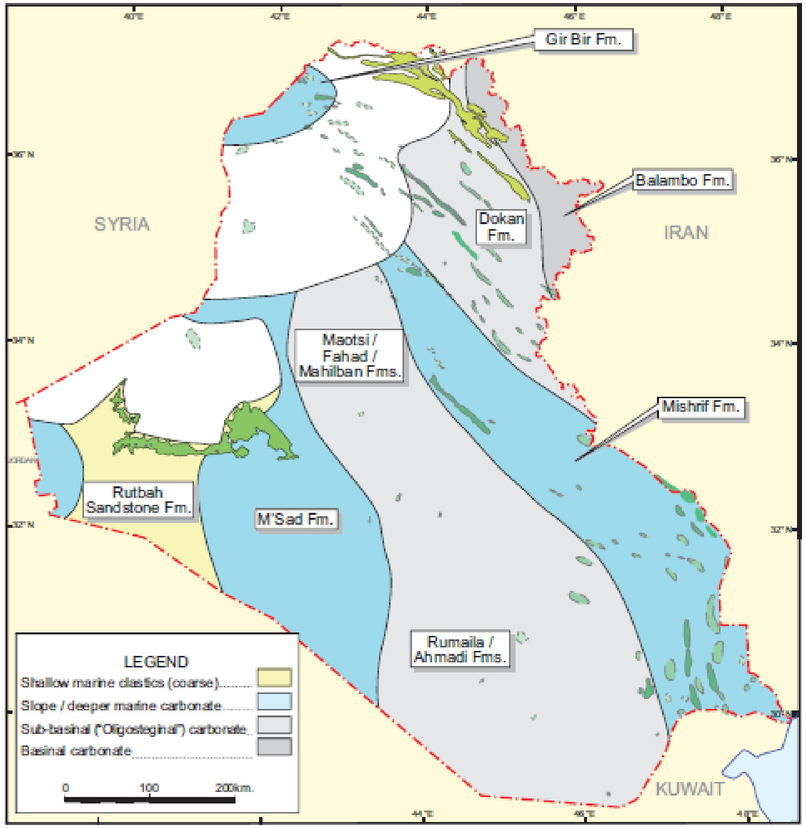
Distribution of the main depositional facies associations of the Ahmadi, Rumaila and Mishrif Formations across southern Mesopotamian Basin (after Sherwani, 1998)



Mishrif depositional system in Iraq

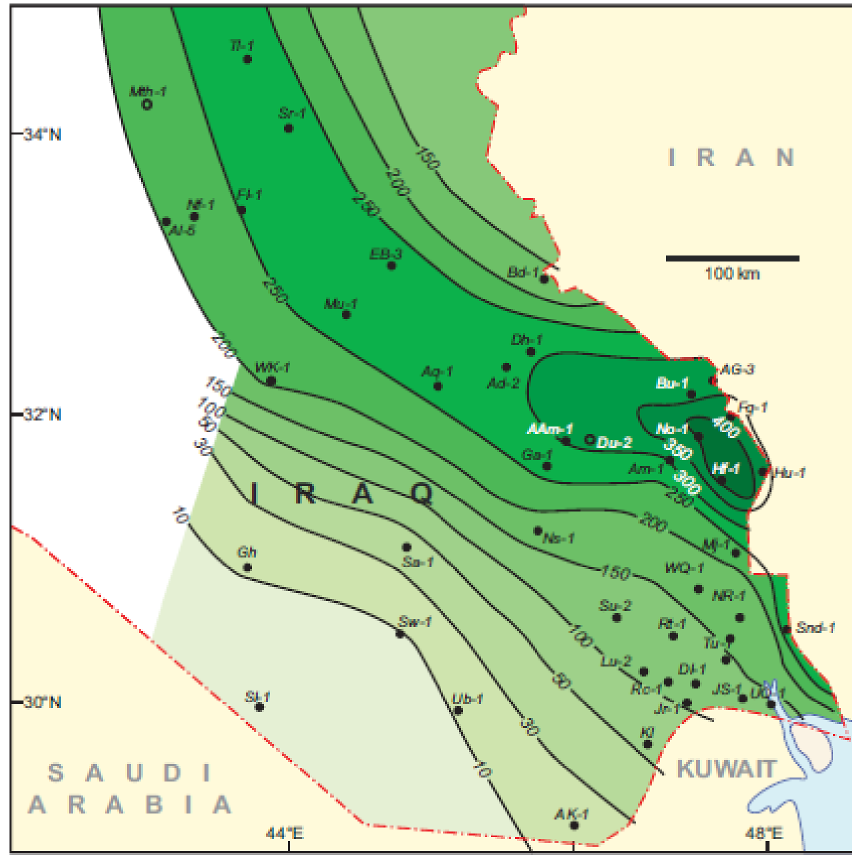


Cenomanian-early Turonian Palaeogeography (modified from Cambridge Carbonates maps, 2008)

- The Mishrif platform dominated central and southern Iraq along a NW-SE oriented ridge.
- To the W an intra-shelf basin (dominated by Oligosteginal facies) formed in the early Cenomanian and persisted until later Cenomanian/Turonian.
- The intra-shelf basin sequences in the centre were dominated by deep muddy facies.
- While to N.E. of the intra-shelf basin 'Thicker Basinal' sequences were deposited.

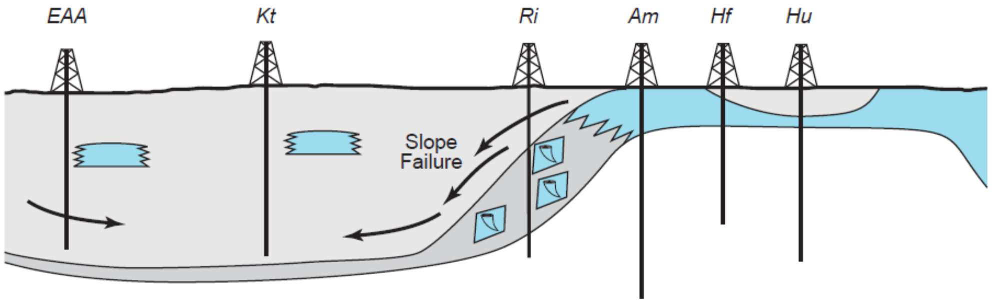
The Mishrif Play in Central and Southern Iraq

- Is localized to central and southern Iraq where thick rudist platform facies are developed
- Includes rudist-bearing shoals and biostromal carbonate reservoirs
- Thickness may reach 400m
- Porosity upto 30% and permeability locally in excess of 1000mD
- Accommodates about 30% of total Iraq oil reserves, characterized by 26-28 API°
- The hydrocarbons were probably sourced by Upper Jurassic and Lower Cretaceous basinal carbonates
- Tight muddy layers within Mishrif provide local seals for the reservoir units
- The overlying sub-basinal Khasib carbonates (or Kifl evaporites when present) provide a regional seal



(map from Aqrawi et al. 1998)

Mishrif Rudists

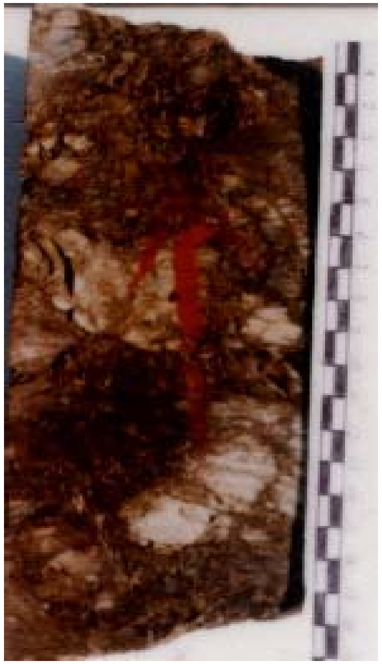


- Within subsurface sections of southern Iraq, Radiolitid rudists were widely reported.
- Rudist framework is of low maturity level ranging from Coppice to Biostrome types.
- Rudist associated fauna are usually the bivalve *Chondrodonta* which formed substrates upon which rudists grew.
- In thin sections, *Chondrodonta* may be confused for rudists.
- Large arenaceous forams, such as *Orbitolina* and *Coskinolina*, are also common in the vicinity of rudist biostromes.

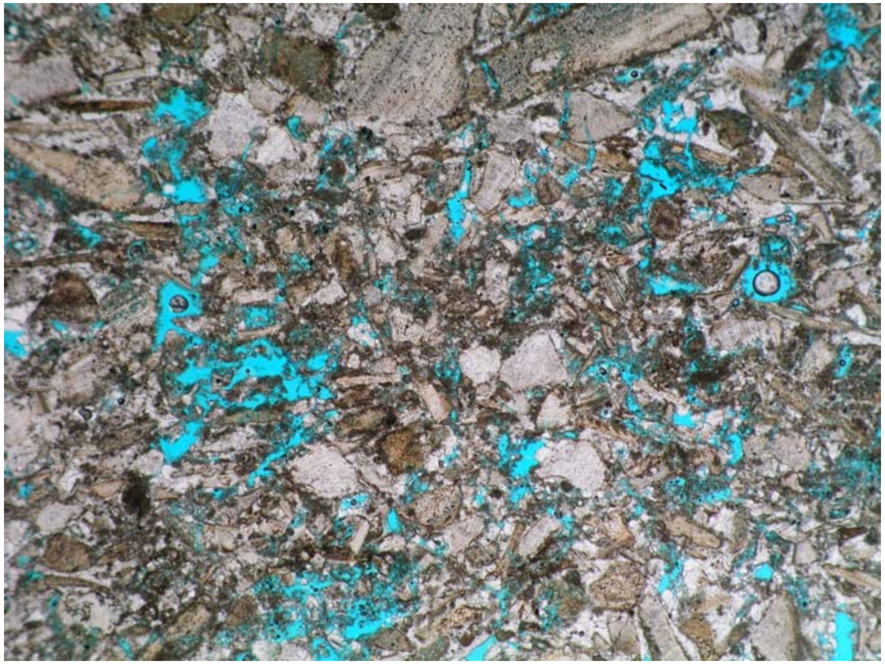
Facies rich in rudist debris form the best reservoirs as shown by cores saturated with oil residue (Sherwani, 1998)

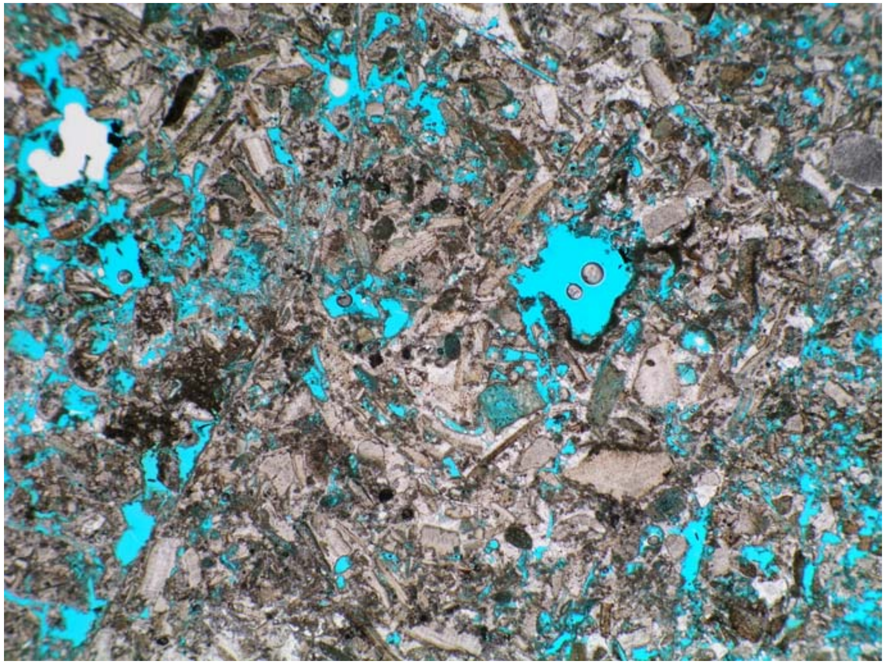
Mj-3 (2688.9m)

Mj-3 (2580.5m)



Skeletal debris accumulated at shelf-edges and as shoals represent the best reservoirs (Grainstone and Packstone facies as Rudstones) because late dissolution enhances their reservoir quality (Mahdi, 2010)





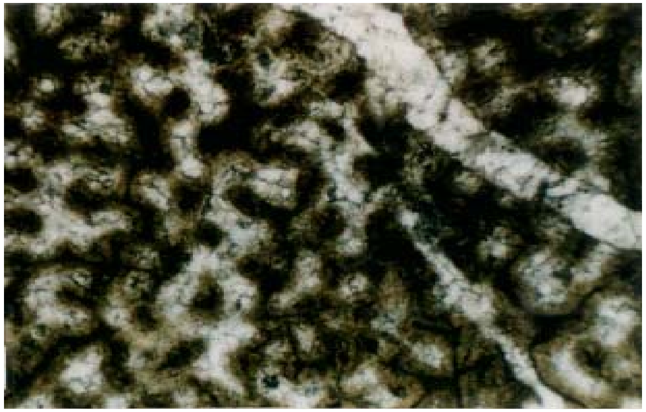
(Am-1 at 2877m depth)

Most true reefal facies (such as Framestone and Boundstone) are usually highly cemented (Sherwani, 1998)

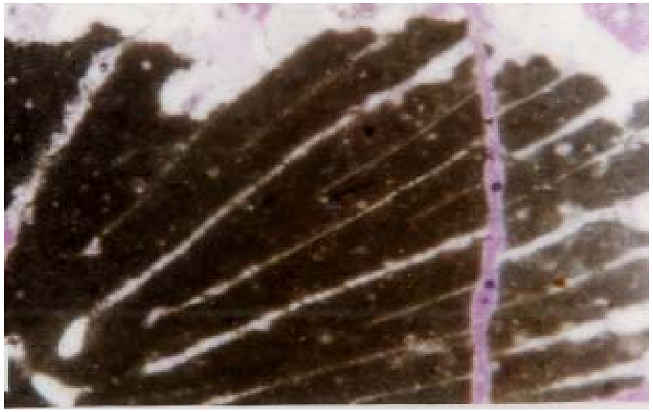
NR-1

WQ-1

NR-3



Zb-13



Some other various facies of Mishrif Fm can be recognized on Core slabs (all from the Majnoon Field and scale is in cm) (Sherwani, 1998)

Mj-3 (2547.2m)

Biostrome/Shoal

Mj-3 (2684.5m)

Lagoonal

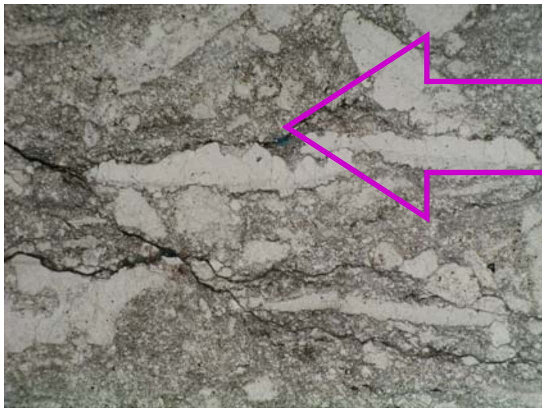
Mj-1 (2618m)

Mj-3 (2612.2m)

Back-Shoal/Lagoonal

Various diagenetic processes (in addition to depositional texture) control the quality of the Mishrif rock types (Mahdi, 2010)

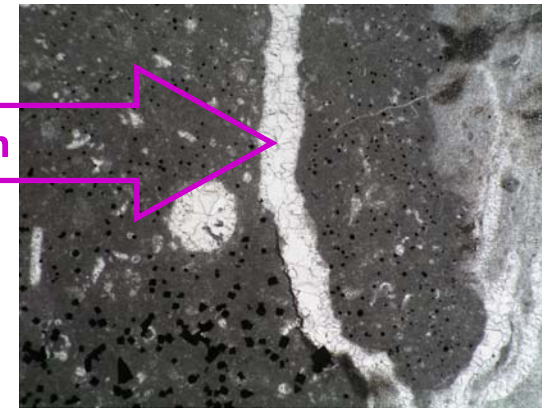
Mj-1 (2356m)



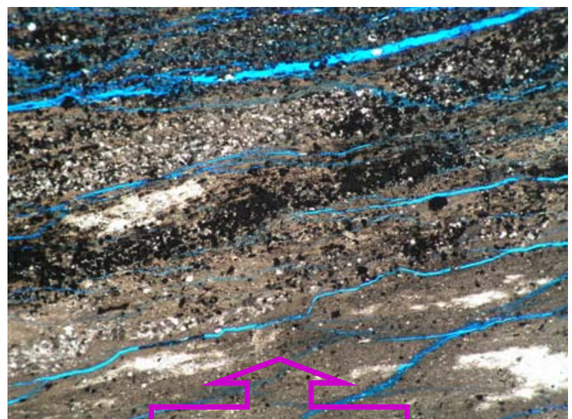
Compaction

Cementation

WQ-1 (2237.5m)

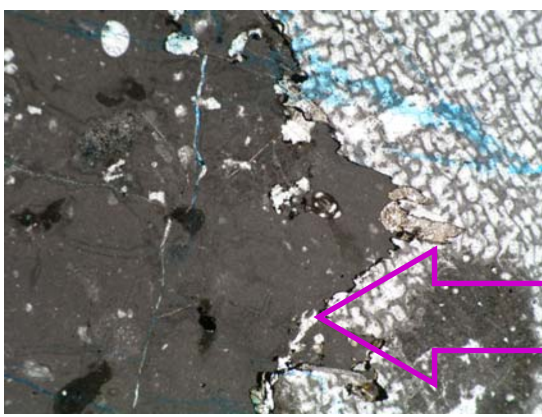


Mj-1 (2381m)



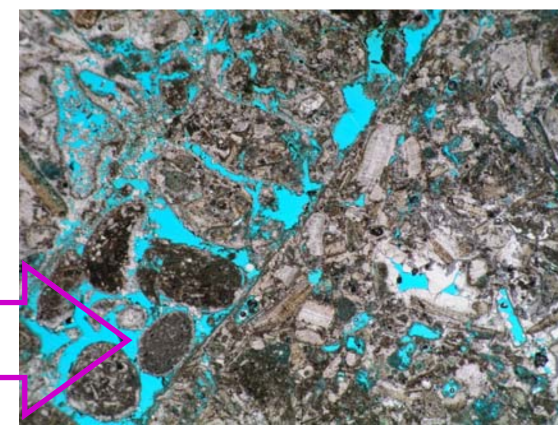
Fracturing

Mj-1 (2384m)



Stylolites

Am-1 (2877m)

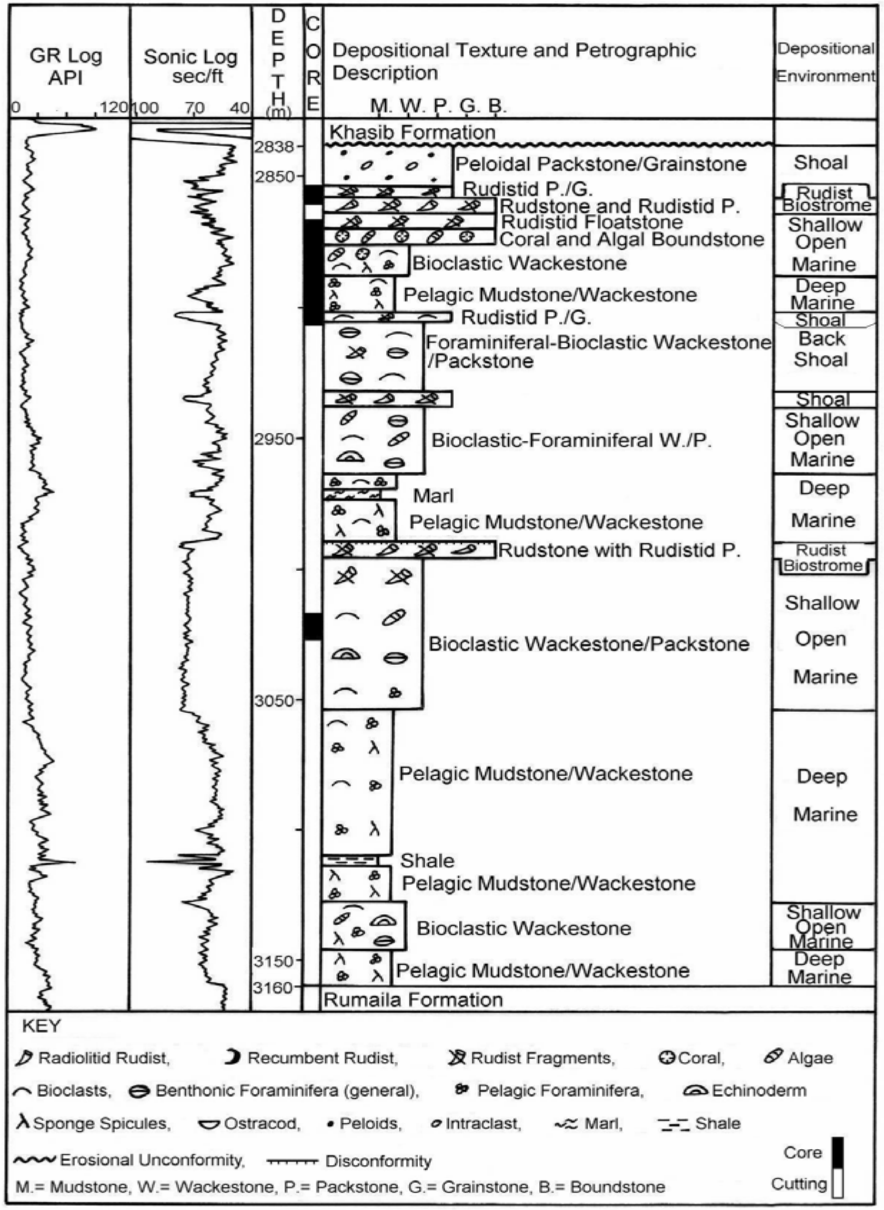


Dissolution

Mishrif Reservoir Facies May Form Potential Stratigraphic Traps

- The main Mishrif reservoir layers consist of bioclastic and peloidal facies of shoal and shelf margin facies (Aqrawi et al. 1998; Sherwani, 1998; Mahdi, 2004).
- Bioclasts are derived mainly from rudist banks/reefs along the shelf margin to the east of southern Mesopotamian Basin and also at the crestal parts of some giant structures (e.g. Rumaila, Zubair and West Qurna) to the south (Sadooni and Aqrawi, 2000).
- These rudist reefs were eroded continuously during deposition whilst the basin was shallowing-up to wave base (Sadooni, 2005).
- Data from the Dujaila Field suggests that these reefs may act as stratigraphic traps that produced oil from a relatively structurally lower well Du-1 while the higher well Du-2 was found to be dry (Sadooni, 2005).
- This extesion of rudist facies into barrier facies may lead to the existence of large updip hydrocarbon accumulations in the Mishrif in areas beyond the known anticlines (i.e. act as a stratigraphic trap).
- In future, 3D seismic surveys should help prove this hypothesis.

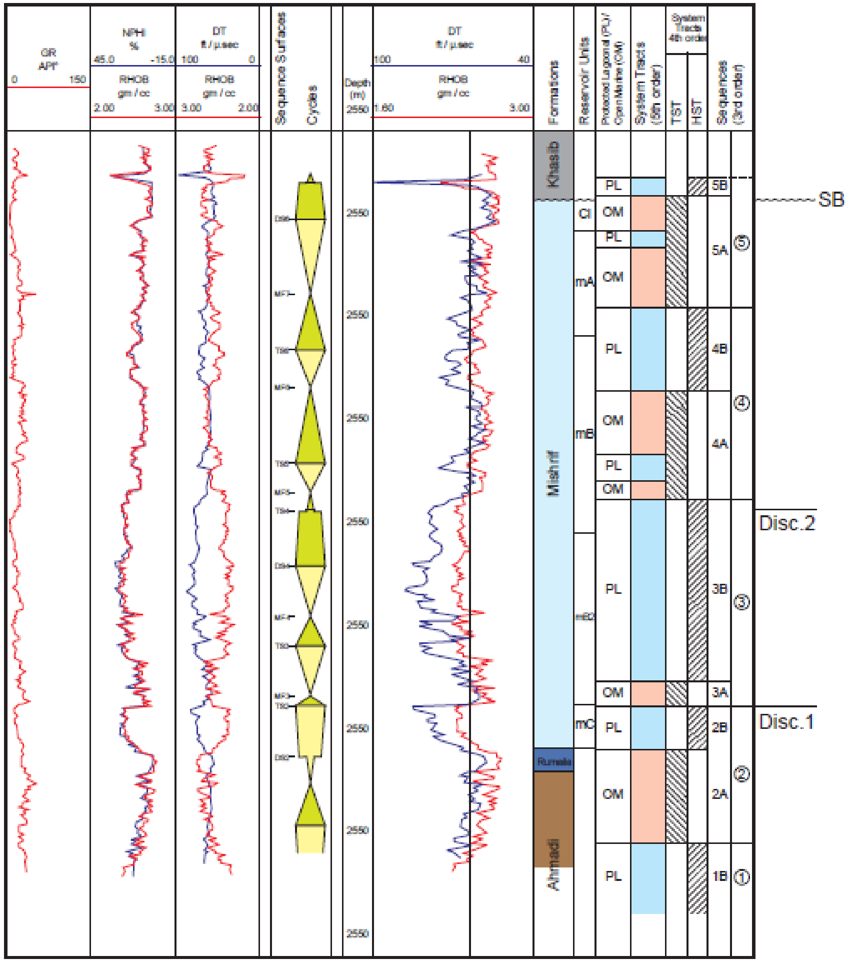
Identification of the Reservoir Units in Mishrif based on cores and wireline logs



Lithologies and biofacies generally match well to log data, and allow log-based definition of Sequence Stratigraphic units such as in Du-1 well (Mahdi, 2004)

Sequence identification based on wireline log analysis in well Mj-5 (Sherwani, 1998) employing Vahrenkamp et al (1993) methodology by modifying and re-running density (FDC) and sonic (BHC) wireline logs with narrower ranges. This differentiates protected lagoonal facies (PL) from open marine facies (OM)

(Leftward shift of sonic to high velocity indicates less porosity and higher density suggesting a lagoonal facies and vice versa may suggest an open marine facies. Shaliness using VS log may indicate open marine facies as more shaly than the lagoonal facies. After several trials the value of 62 ft/usec was found to be the best fit for differentiating lagoonal from open marine facies)



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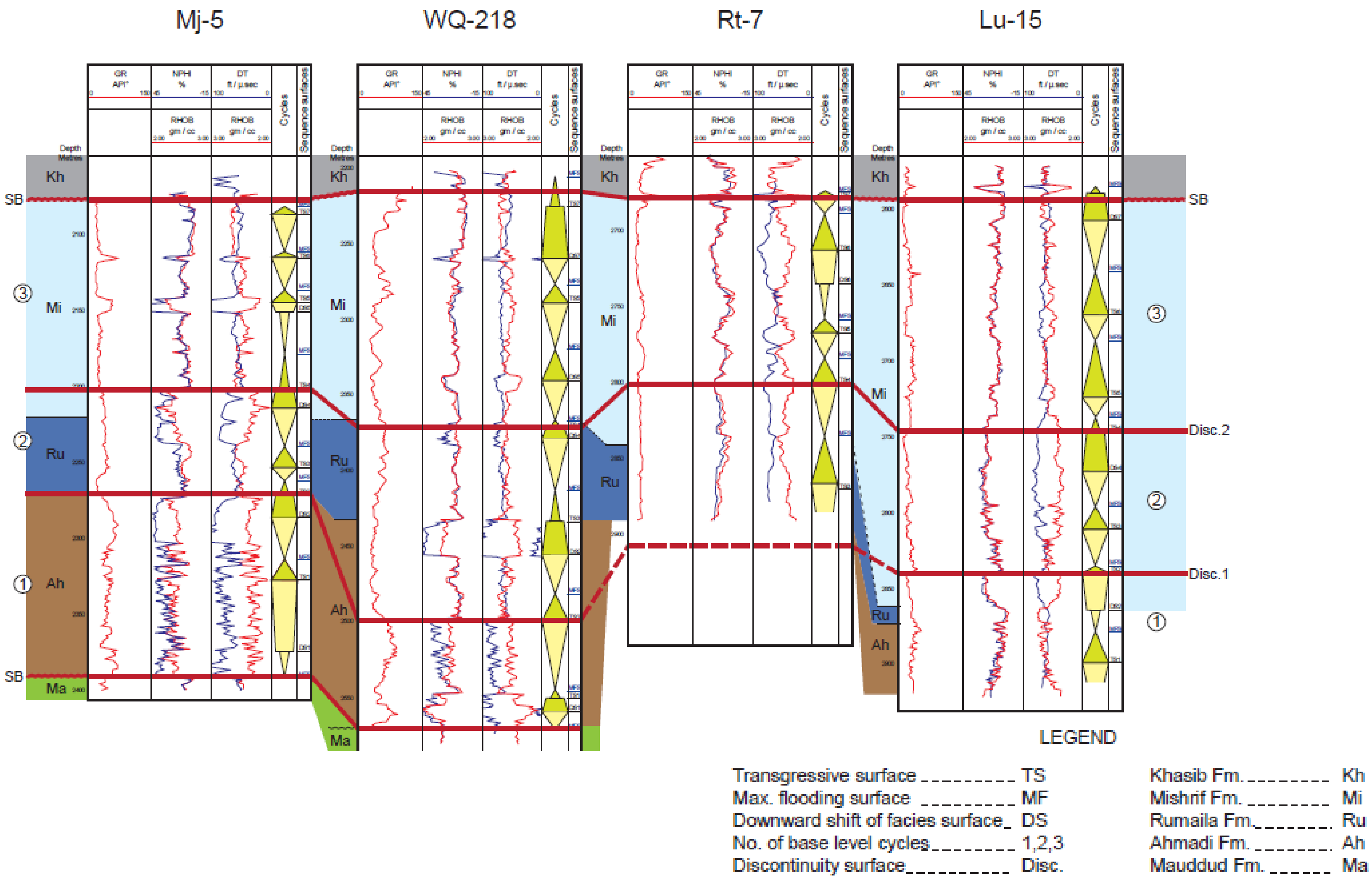
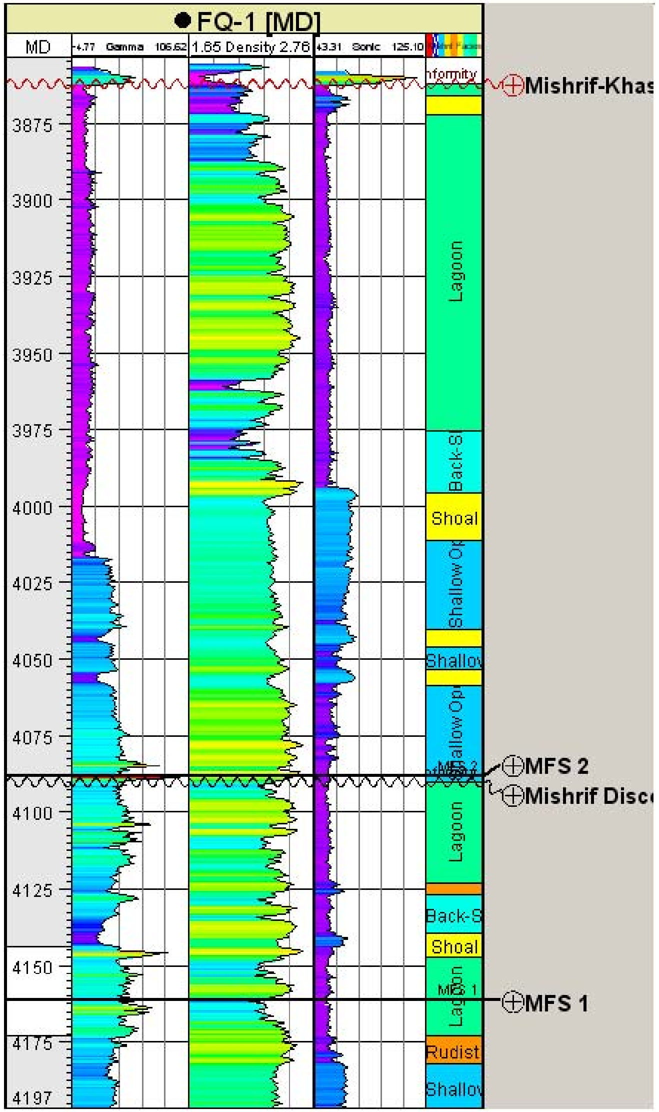
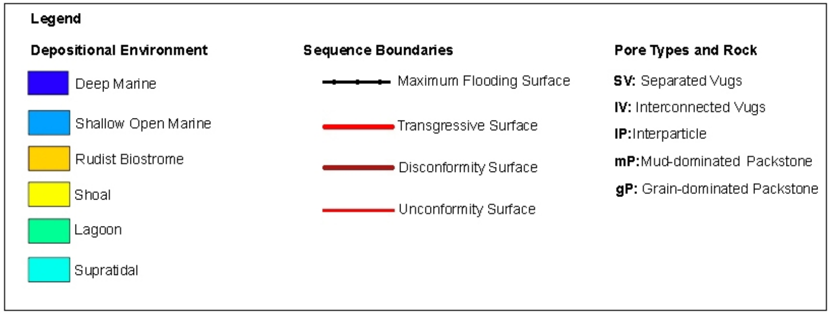
Correlation of the accommodation cycles recognized in the Ahmadi, Rumaila and Mishrif Formations across the southern Mesopotamian Basin (Sherwani, 1998)

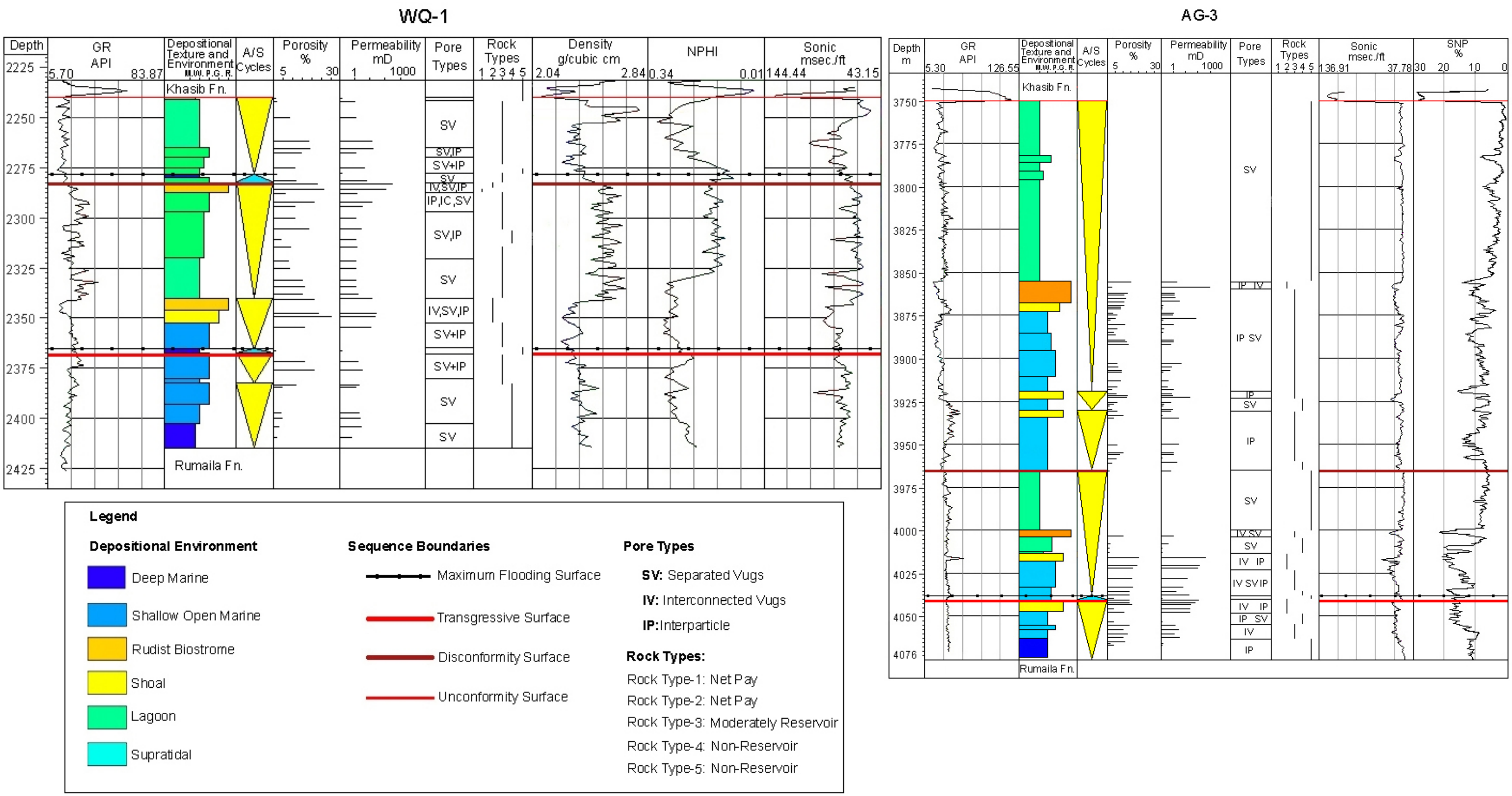




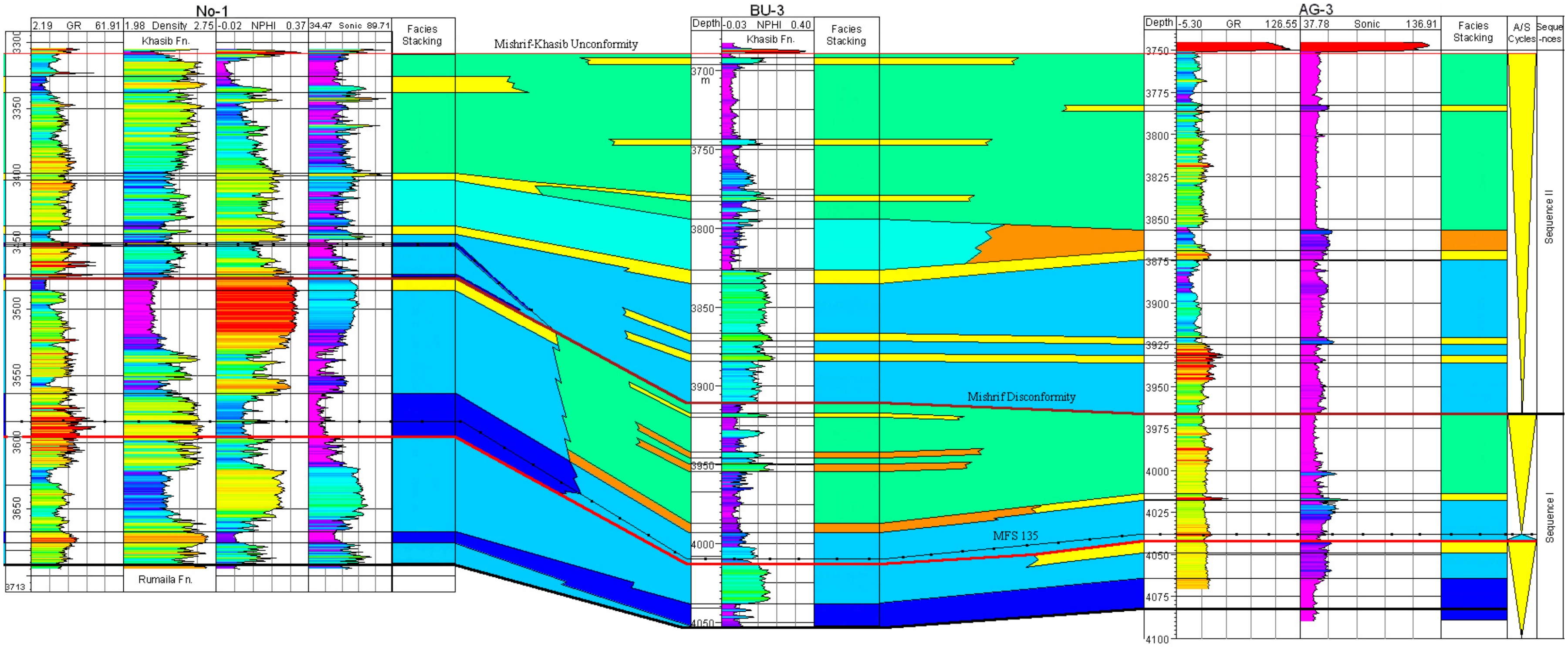
Distribution of the Mishrif facies towards east of the Mesopotamian basin and their distribution using Sonic, Density and GR logs is more meaningful such as in the Fq-1 well (Mahdi, 2010)



Mishrif main facies and their distribution using, Neutron, Sonic, Density and GR logs in the WQ-1 well (Mahdi, 2010), note better reservoir quality and thicker pay zones in lower sequences of AG-3



Sequence Stratigraphic analysis offers a good correlation of the Mishrif defined units among the adjacent wells such as in NE parts of the Southern Mesopotamian Basin (Maisan Fields), where Shoal and Biostrome facies represent the most productive reservoir zones (Mahdi, 2010)



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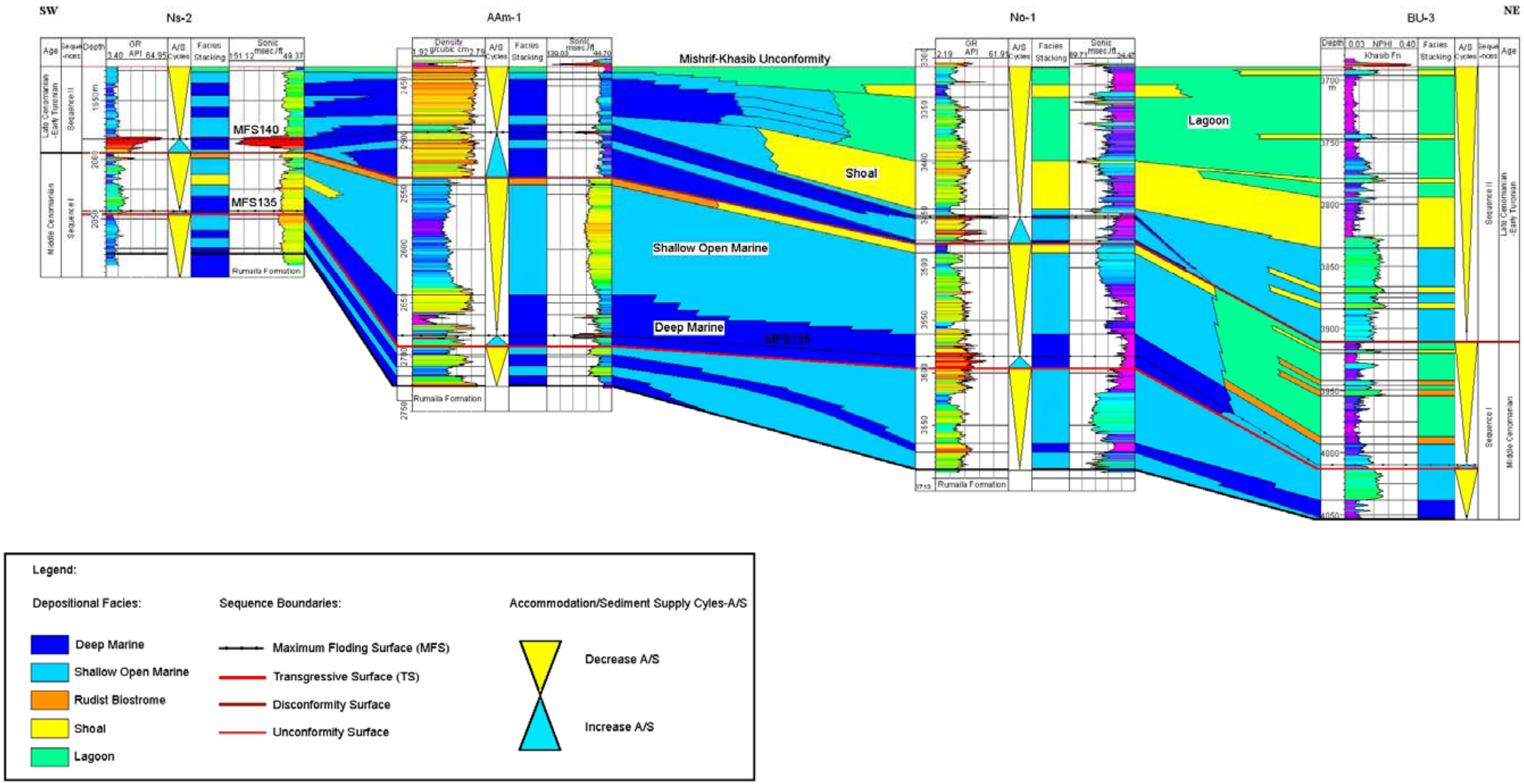
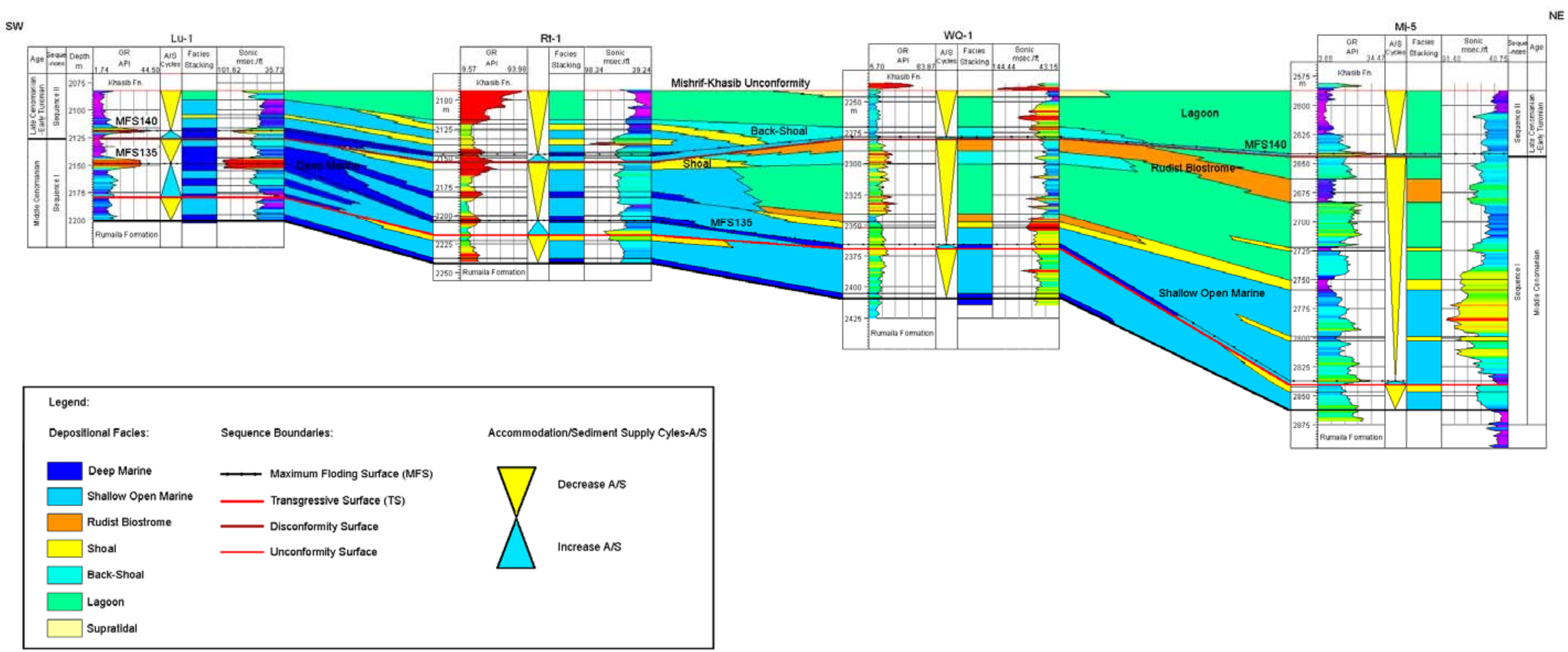
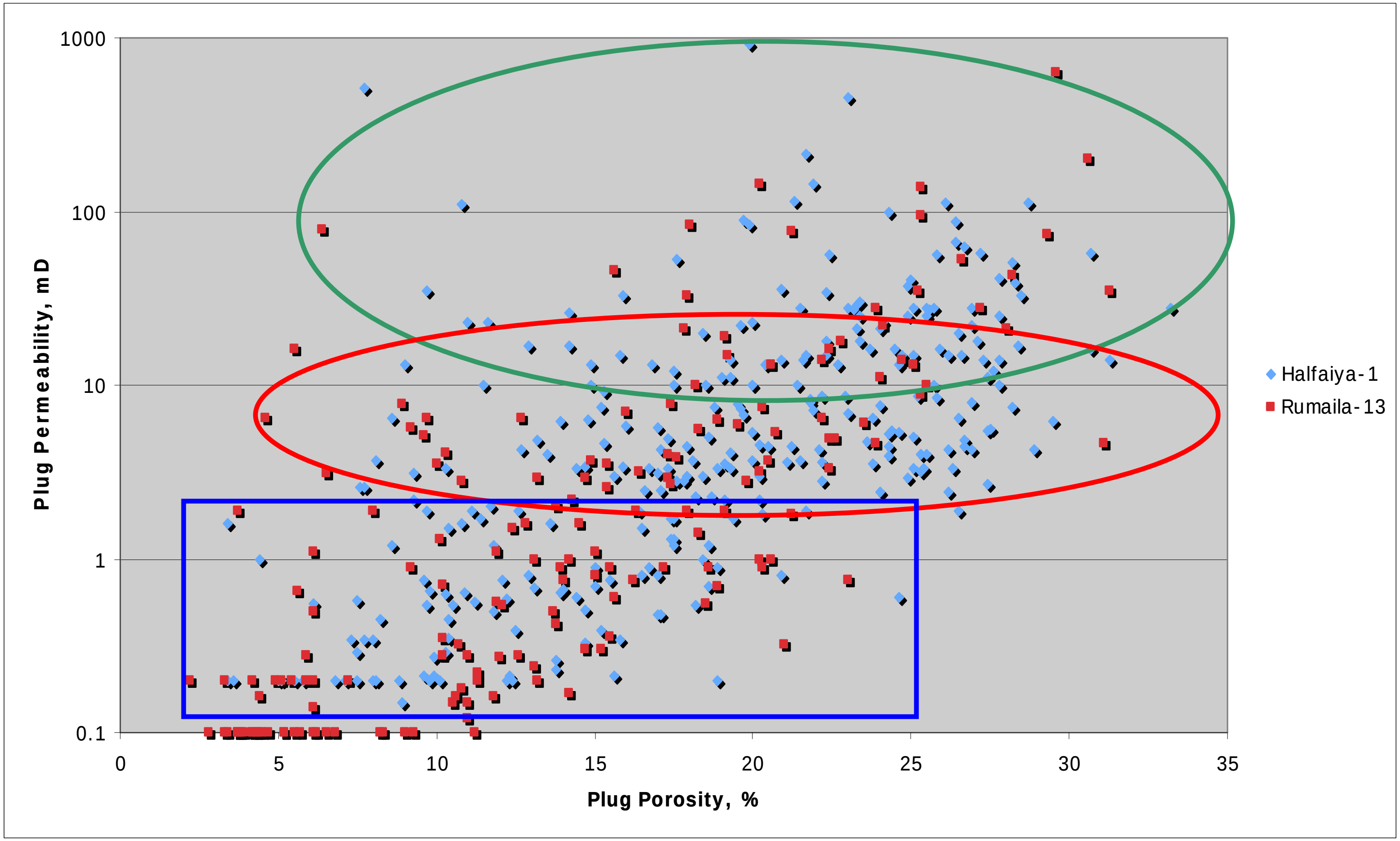
Correlation of reservoir units among widely spaced wells across the basin becomes less consistent as the Mishrif reservoir facies better developed towards the eastern side while the intra-shelf basin facies dominate the western side (Mahdi, 2010)



Although correlation of reservoir units among widely spaced wells becomes less consistent, it may show the facies distribution across the basin (Mahdi, 2010)



Position in basin does not appear to influence overall reservoir quality of Mishrif facies (after Aqrawi and Horbury, 2008 based on data from Mahdi, 2004)



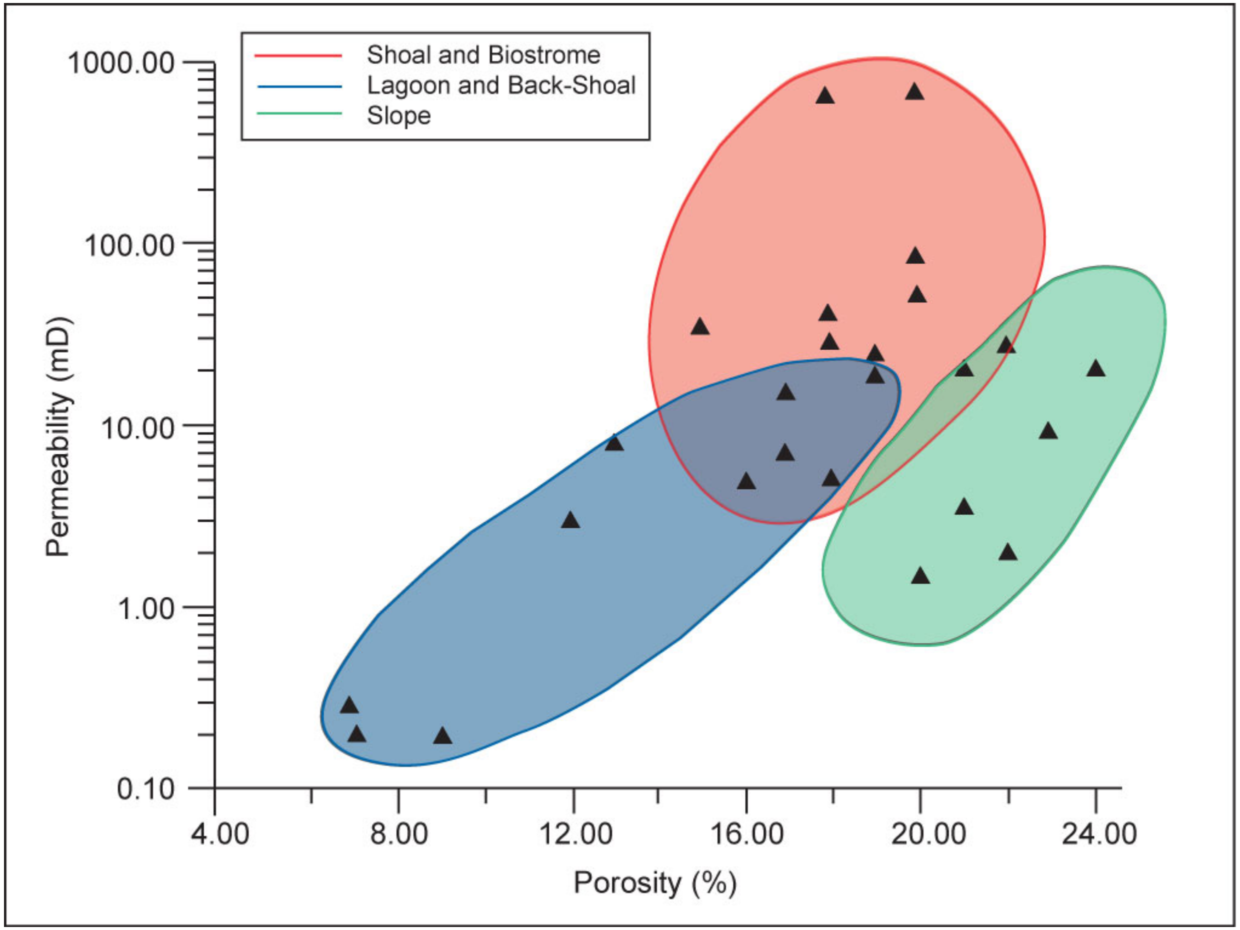
Data from different locations/facies plot on top of each other,
although some very good quality (green) and good quality (red) reservoirs could be differentiated from less quality reservoirs (blue)

Diagenetic overprinting (particularly by cementation and dissolution) affects the preservation of reservoir quality of the Mishrif depositional textures and reservoir quality (Sherwani, 1998)

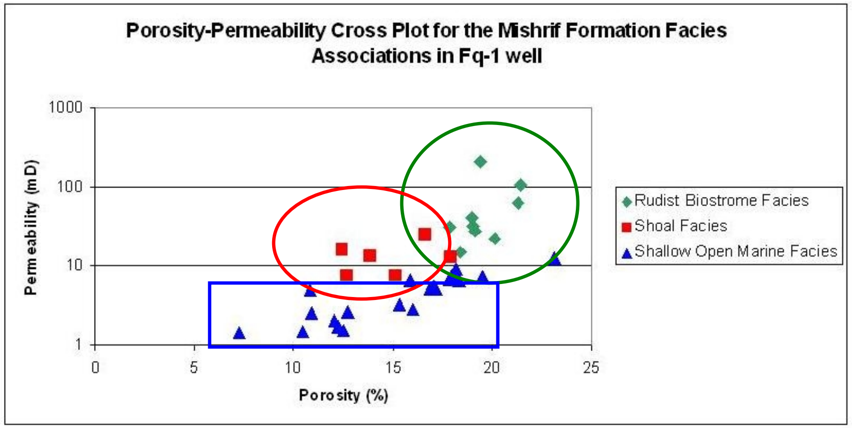
Meteoric (fresh water) vadose zone (well WQ-1)					
Precipitation Zone - Intervals rich in vadose silt low reservoir quality			Solution Zone - porous intervals with high vuggy, moldic, and intergranular porosities		
Depth (m.)	Ave. ϕ%	Ave. K md	Depth (m.)	Ave. ϕ%	Ave. K md
2288 - 2290	9	4	2284 - 2288	27	144
2304 - 2324	-	-	2294 - 2304	15	6
2346 - 2348	22	15	2342 - 2346	25	56

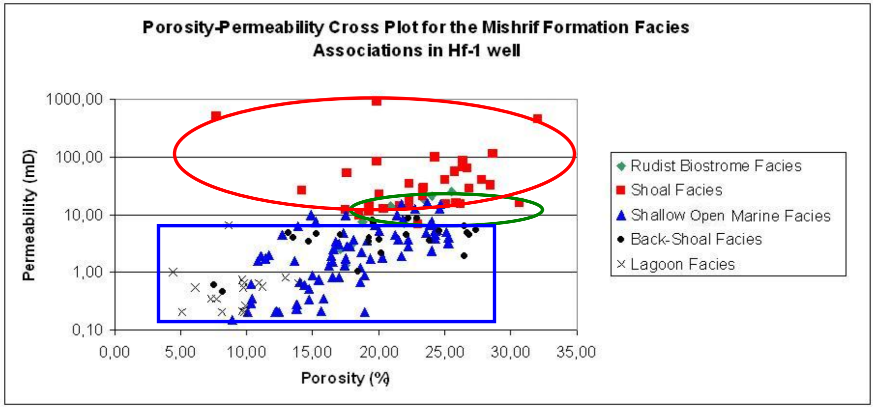
The facies/rock types in Well WQ-11 could be differentiated as the field structure was growing during deposition of the Mishrif (Sadooni and Aqrawi, 2000) and diagenesis usually enhanced the primary reservoir quality of the depositional textures (after Sherwani, 1998)

- Highest PoroPerm values are in Shoal and Biostrome facies
- Slope facies have high porosities and reasonable permeabilities
- Both back-barrier and lagoonal facies have the lowest permeabilities in the dataset although porosities may reach 20%

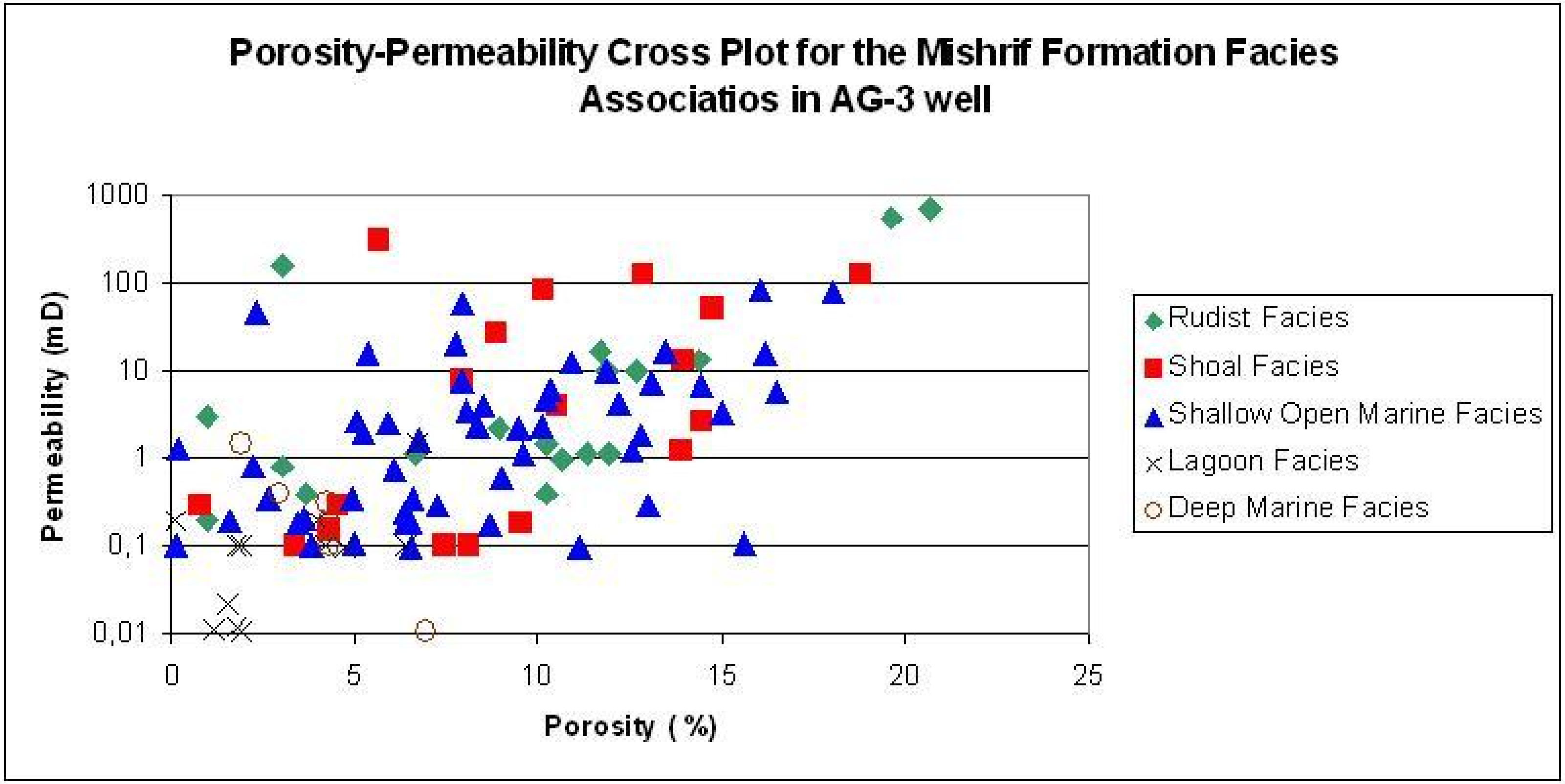


The facies/rock types in most eastern fields could be differentiated as the region formed a palaeo-high during deposition of the Mishrif (Aqrawi et al. 1998). Diagenesis enhanced the primary reservoir quality of the depositional textures (Mahdi 2010)





Such grouping of the facies/rock types may not be recognizable when diagenesis role is negative on depositional texture, and intensive cementation and compaction took place, such as in well AG-3 (Mahdi, 2010)



Conclusions:
Identification of the Reservoir Units in the Mishrif Fm requires:

- Regional understanding of geology and palaeogeography.
- Detailed Petrography and Core Description via:
  - Characterization of the reservoir units with highest primary PoroPerm (usually consist of bioclastic and peloidal facies deposited from shelf margins, and shoals during both HST and TST).
  - Investigating the role of diagenesis on the reservoir quality of these units (particularly cementation and dissolution in addition to compaction and pressure solution which are the most common diagenetic processes).
- Definition of the Rock Types :
  - First using wireline logs thorough cored intervals of analyzed PoroPerms allows definition of rock types;

  Rock Type= Depositional Texture + Diagenetic Overprint

  - Then generalize the defined rock type intervals over non-cored intervals using the available log signatures (particularly GR, Sonic, and Density)
  - Log signatures can indicate clearly most Mishrif reservoir rock types and seq startigraphic boundaries.
- Sequence Stratigraphic Analysis offers a good tool for correlation of these reservoir units (or Rock Types), specially among the adjacent wells.

Thank you

Presentation title: Characterisation of the mid-Cretaceous Mishrif Reservoir of the sothern Mesopotamian Basin

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