

Reviving a Classic Exploration Play in Kuwait: The Lower Cretaceous Ratawi Formation*

Sara Bader Al-Tendail¹, Aavo Taal¹, Talal Al-Adwani¹, Ali Abu Ghneej¹, Raju Arasu¹, Duncan Barr², and Patrick Clews²

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¹Kuwait Oil Company, Ahmadi, Kuwait (sabader@kockw.com)

²Halliburton Overseas Limited Company, Dubai, United Arab Emirates

Abstract

The Ratawi Formation is a significant hydrocarbon reservoir in many parts of the Middle East. North of Kuwait, the Ratawi is productive in several fields. It is also productive in northern Saudi Arabia and the Neutral Zone. In Kuwait, the Ratawi Formation has tested oil and gas in many wells, but is classed a minor reservoir. So why is the Ratawi not a significant producing horizon in Kuwait?

To answer this question, in 2007 Kuwait Oil Company (KOC) undertook a geological study of approximately 1310 feet of Ratawi core from 18 wells across Kuwait. Detailed core descriptions were supported by thin section, SEM, XRD, and conventional core data. The Ratawi Formation has traditionally been divided into an upper Ratawi Shale Member and a lower Ratawi Limestone Member, with the latter being the main exploration target. Major discoveries were made in the lower part of the Limestone Member (then termed the Ratawi Oolite) at Wafra Field in 1953 and Umm Gudair Field in 1964. In Kuwait, the Ratawi Oolite interval was renamed the Minagish Oolite, or more formally, the Middle Minagish Member (Oolite) of the Minagish Formation.

The 2007 study identified several factors which negatively affected the hydrocarbon potential of the Ratawi Limestone Member. Its diagenetic history records up to 11 periods of porosity reduction by calcite and other cements. Where oil is present in cores, it appears to have migrated into the reservoir during late diagenesis, following precipitation of these cements. The study also identified several positive factors. There are packstone and grainstone facies present in the Limestone Member with porosities up to 25% in southern and offshore Kuwait. Oil quality is good (28-46° API). Reservoir potential may also be enhanced by late fracturing.

KOC has now shifted its exploration efforts to the Ratawi Shale Member. In northern Kuwait, this shallow marine interval of limestones (30-50%), sandstones (10-15%) and shales (35-60%) has already tested oil in Abdali, Raudhatain and Sabriya fields. Both structural and stratigraphic plays are being pursued. Seismic mapping has identified several structural traps at the Ratawi Shale level. Additional cores acquired in the Ratawi Shale in 2010-11 are now being evaluated. A review of existing exploration wells identified a number of intervals

with possible bypassed oil pay in the Ratawi Shale Member; these zones will be tested in 2012-13. Outside the established fields, Kuwait still has areas of low well density with “plenty of room” for new discoveries to be made.

References

Haq, B.U., and A.M. Al-Qahtani, 2005, Phanerozoic cycles of sea-level change on the Arabian Platform: *GeoArabia*, v. 10/2, p. 127-160.

Sharland, P.R., R. Archer, D.M. Casey, R.b. Davies, S.H. Hall, A.P. Heward, A.D. Horbury, and M.D. Simmons, (eds.), 2001, *Arabian Plate sequence stratigraphy*: *GeoArabia Special Publication 2*, 371 p., 3 sheets. et al., 2001—slide 7 of 34

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Sara Bader Al-Tendail*, Aavo Taal, Talal Al-Adwani, Ali Abu Ghneej and Raju Arasu
Kuwait Oil Company

Duncan Barr and Patrick Clews
Halliburton Overseas Limited Company

Prospect Evaluation Team, Exploration Group
Kuwait Oil Company

www.kockw.com

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- **The Manager of Exploration group.**

Agenda

- ☐ Introduction.
- ☐ Background.
- ☐ Stratigraphy of Ratawi Formation.
- ☐ Prospectivity of Ratawi Limestone Member.
- ☐ Prospectivity of Ratawi Shale Member.
- ☐ Conclusion.
- ☐ Way forward.

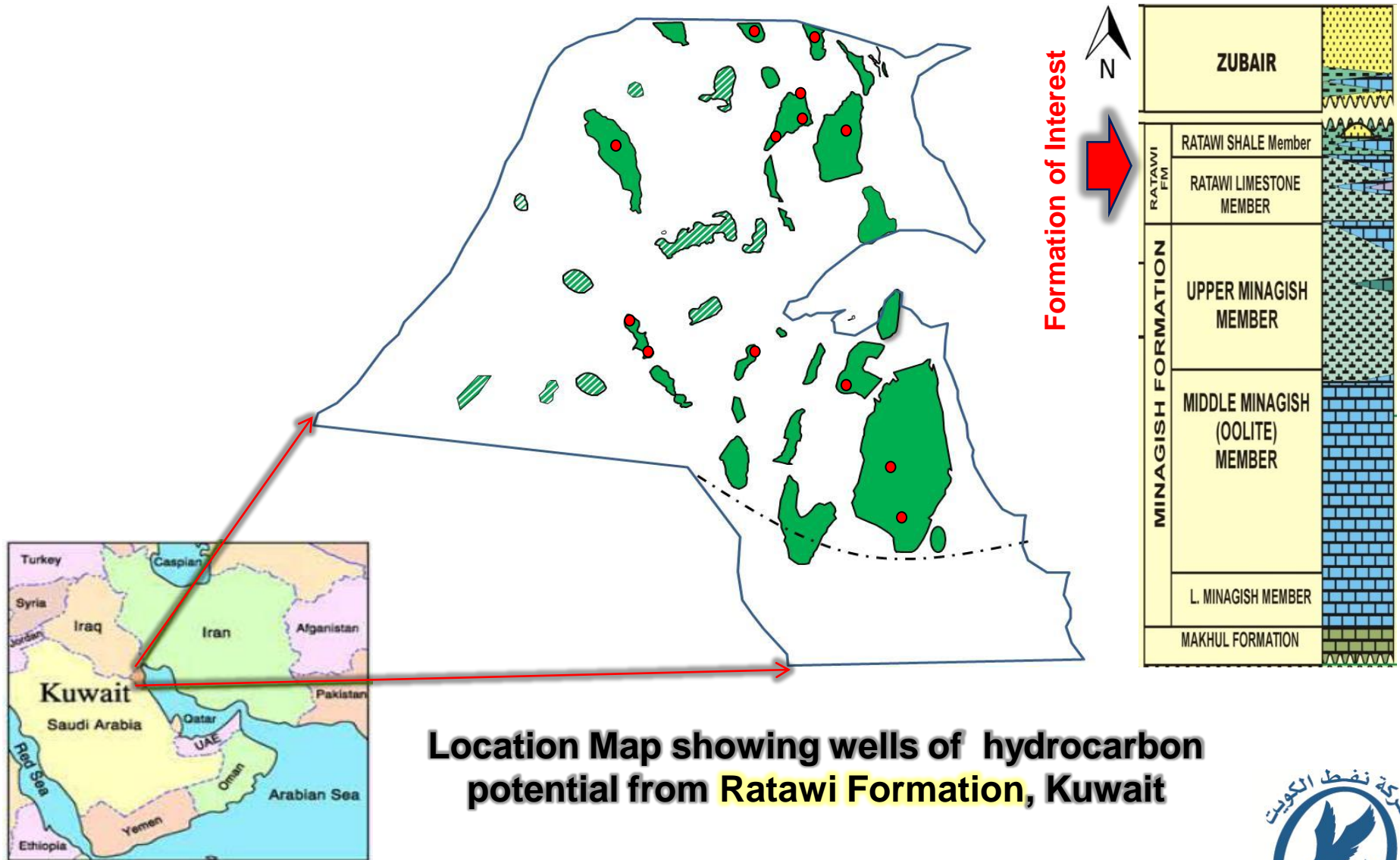


Location Map Of Kuwait

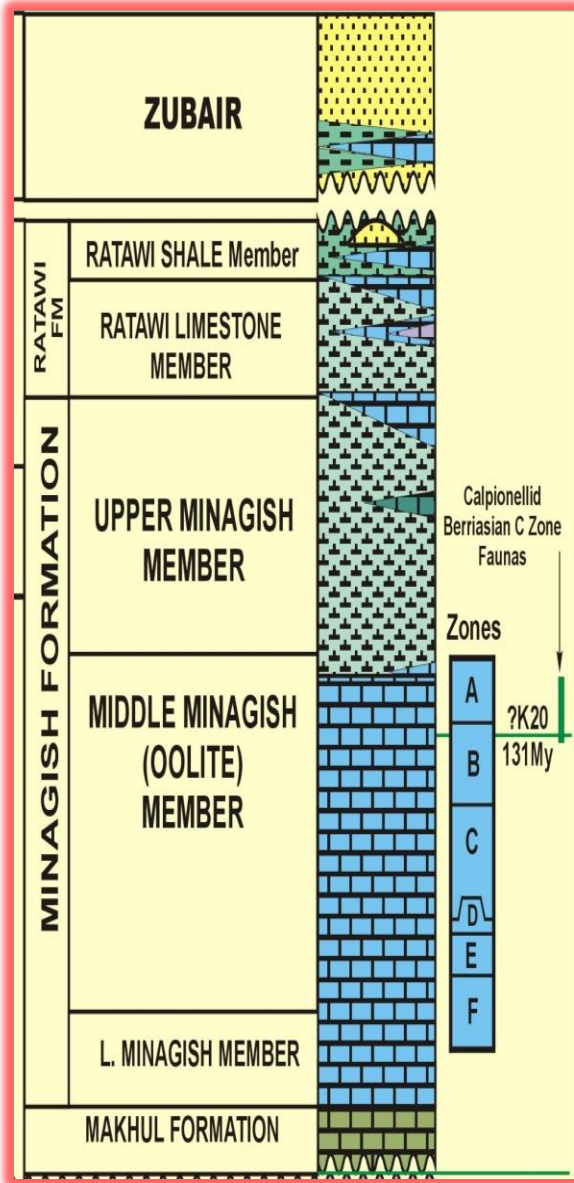


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Location Map Of Kuwait

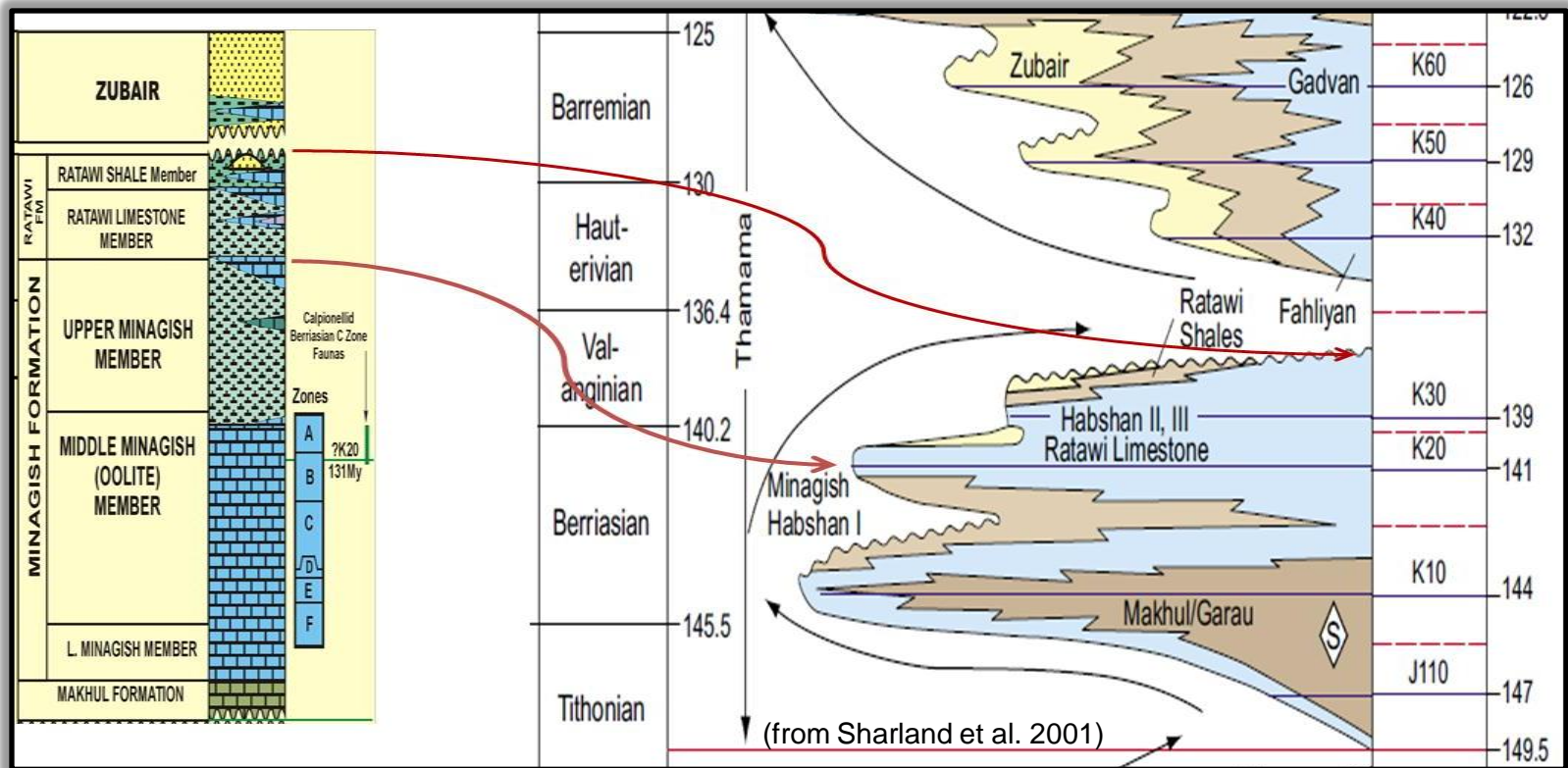


Stratigraphy of Ratawi Formation



- The Ratawi Formation overlies the Minagish Formation and underlies the Zubair Formation, is informally divided into a lower Ratawi Limestone Member and an upper Ratawi Shale Member having a sharp contact in between.
- The thickness of Ratawi Formation is nearly **uniform** and varies from **600** to **700** feet.
- ❖ **Ratawi Shale member:** Dominantly shale with limestone interbeds, middle unit consisting of interbedded shale and sandstone, and the upper part consisting dominantly of shale with siltstone and limestone beds.
- ❖ **Ratawi Limestone member:** Deposited on a low-gradient carbonate ramp and consists mostly of limestone with minor, localized calcareous claystone and thin, argillaceous dolostone layers.

Stratigraphy of Ratawi Formation



- ❖ During the Early Cretaceous an intra-platform basin developed in central Arabia in which sediments forming the dark mudstone of the lower part of the Sulaiy Formation (equivalent of Makhul Formation) were deposited.
- ❖ The overlying Minagish and Ratawi formations in Kuwait represent the transition from intra-platform basin conditions to shelf sedimentation and the existence of a **wide carbonate rock platform**.
- ❖ Ratawi Limestone deposited in shelf environment.
- ❖ Ratawi shale (mixed to continental) with impregnated sand indicates HST in ramp setting with influx of fluvial channel.

Stratigraphy of Ratawi Formation

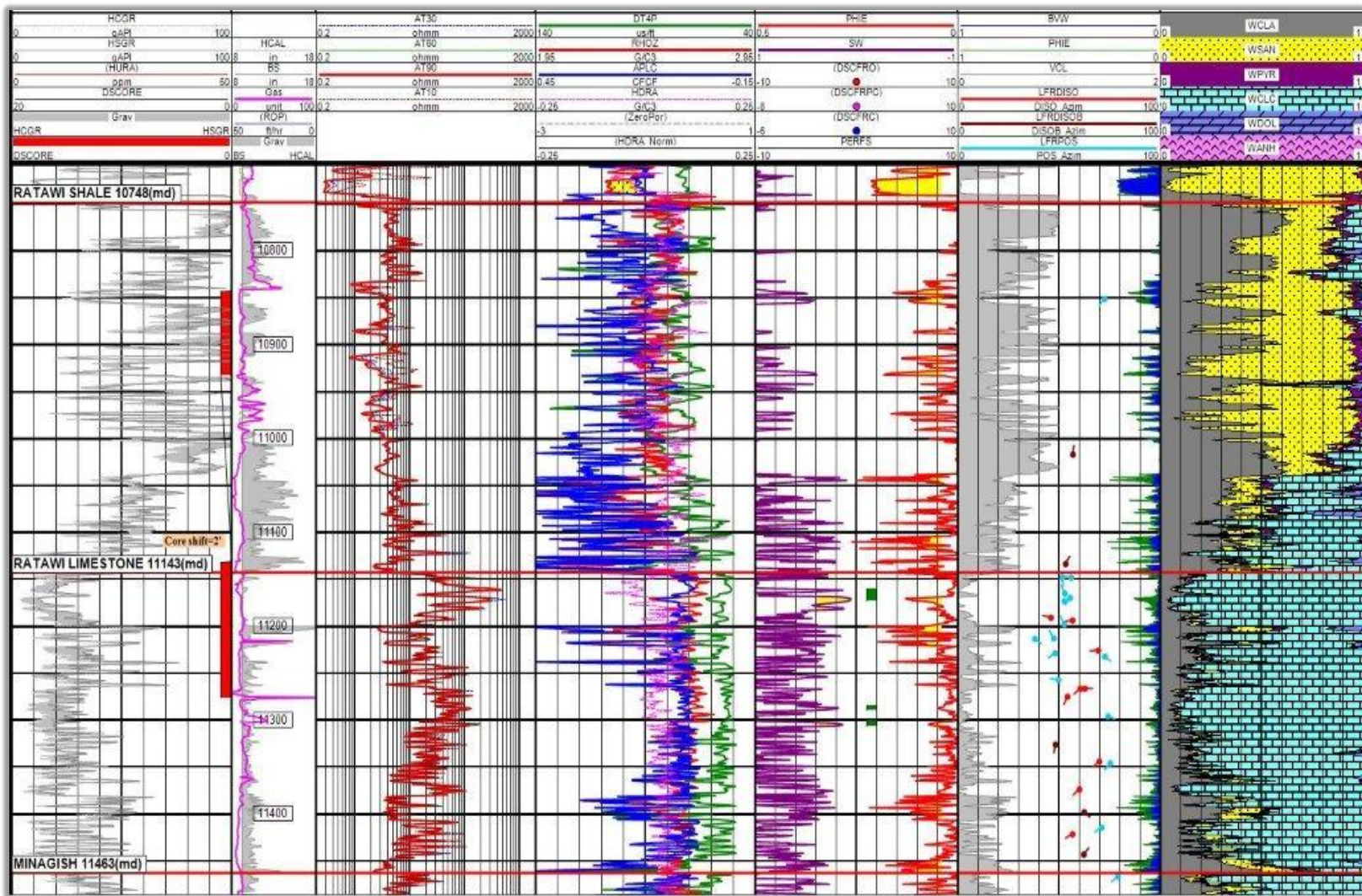
ERA	PERIOD	EPOCH	STAGE	Ma Haq*		Southwest Proximal	KUWAIT carbonate ramp	Northeast Distal	Lithology	Candidate Sequence Cycles		Biozone
MESOZOIC	CRETACEOUS	EARLY	Hauterivian	137	THAMAMA GROUP	ZUBAIR FORMATION			Sandstones and minor shales	3rd	2nd	
			Early Valanginian			RATAWI FORMATION	RATAWI SHALE MEMBER		Shales with minor sandstones. Limestones at base	KSB40 cand mfs SB		
				RATAWI LIMESTONE MEMBER			Limestones, some grainstone shoals	mfsK30				
			Berriasian - Valanginian	MINAGISH FORMATION		UPPER MINAGISH MEMBER	MINAGISH FORMATION (distal facies)	Limestones. Middle member grainstones and oolite shoals	KSB30	?	LK2	
						MIDDLE MINAGISH MEMBER (OOLITE)			mfsK20			
						LOWER MINAGISH MEMBER						
			Berriasian	MAKHUL FORMATION					Lime mudstones, anoxic claystone at base	KSB20	?	LK1
						Tithon.	144	mfsK10		KSB10		
			147									
			149							JSB149		

* Haq & Al-Qahtani, 2005, GeoArabia 10 / 2.

- ❖ Ratawi Formation consists of **two cycles** – represented by Ratawi Shale and Ratawi Limestone members.
- ❖ Ratawi Limestone consists of **TST** and **HST** marked by **mfsK30**.
- ❖ Ratawi Shale consists of **TST** and **HST** -- TST dominantly shale; HST sand and shale alteration.



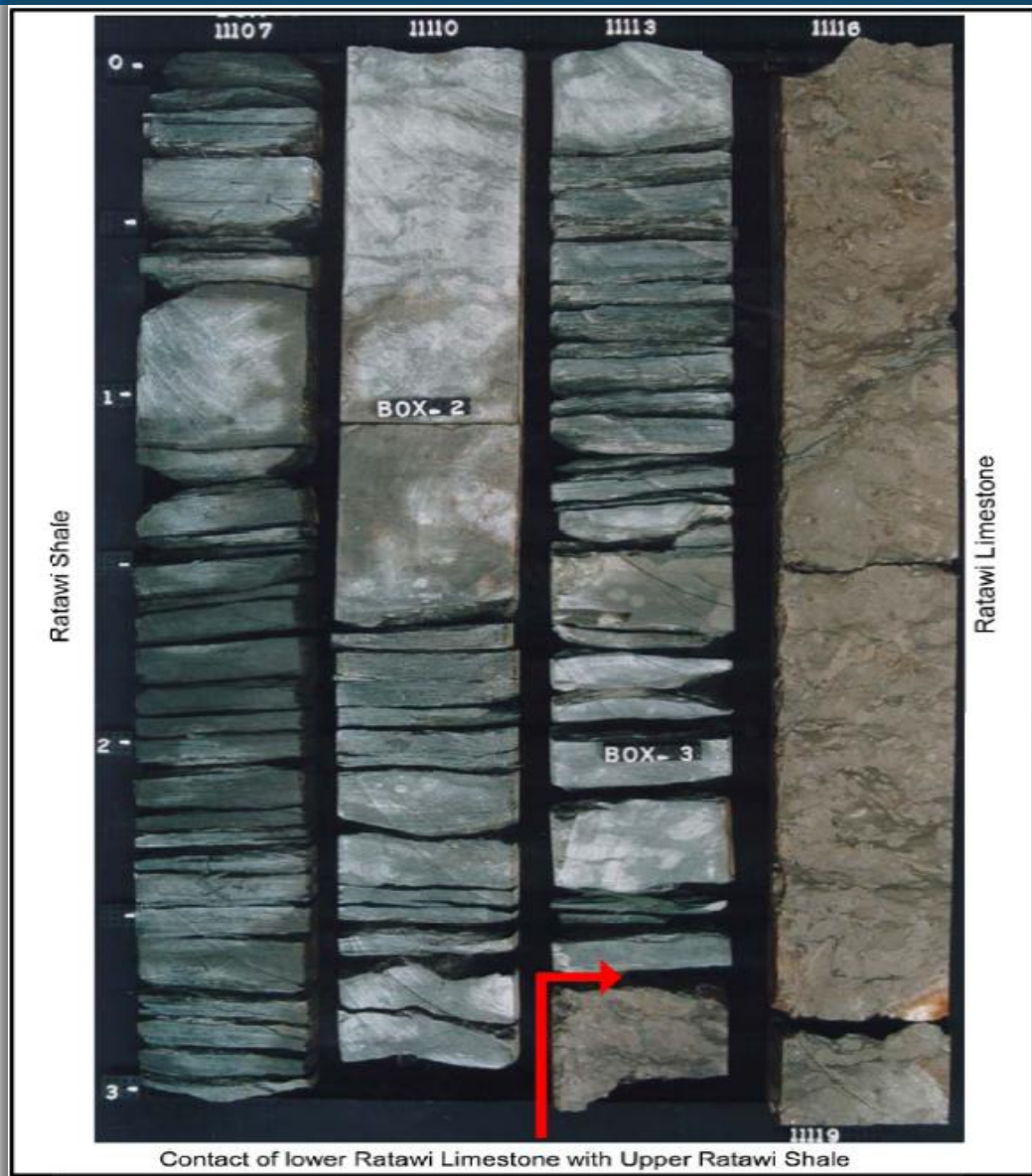
Type Log of Ratawi Formation



- ❖ Top of Ratawi Limestone Member marked by **low GR**, **high Resistivity**, **high Sonic** and **limestone-shale alteration**.



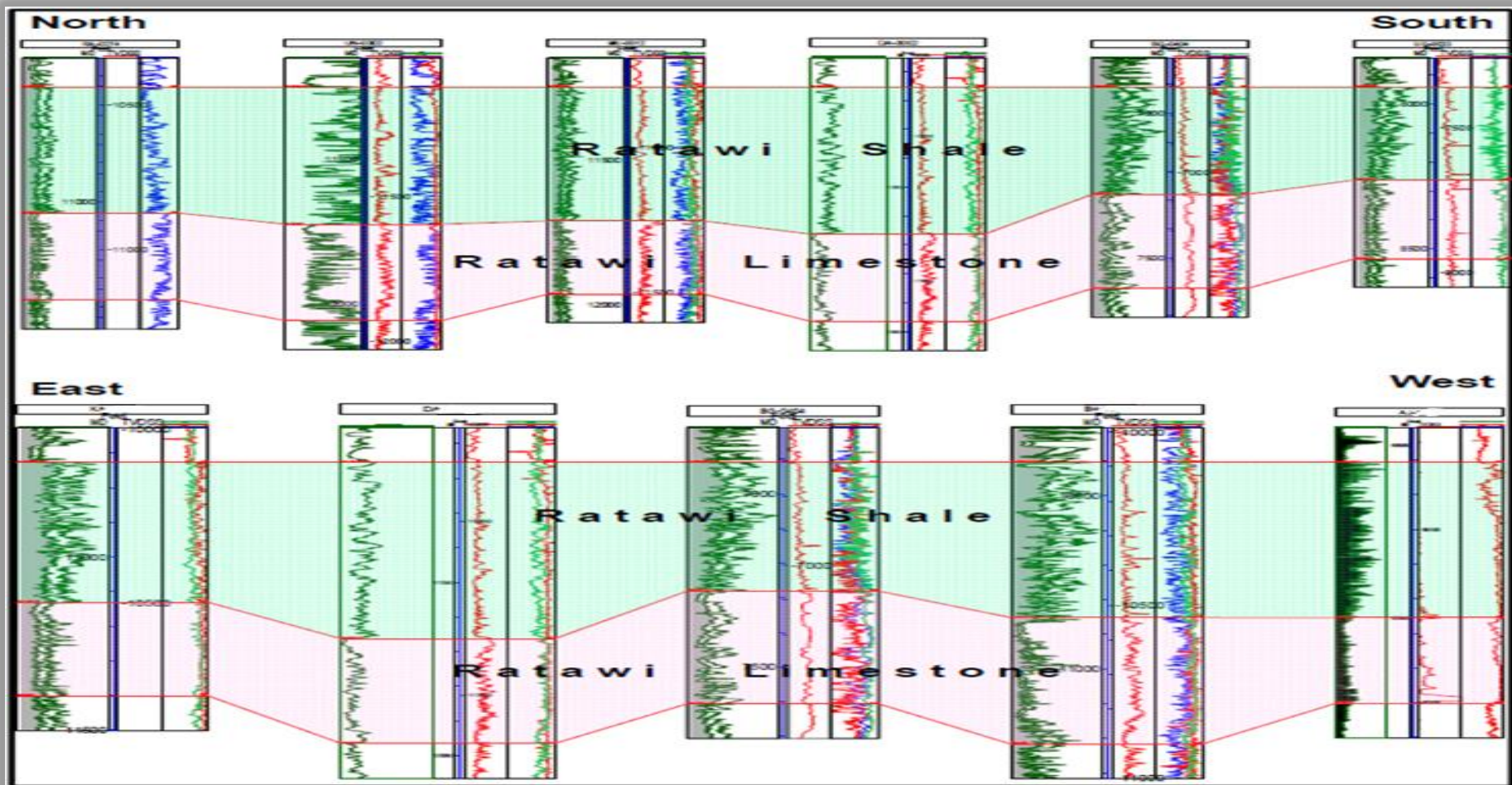
Core Photo of Ratawi Formation



- ❖ **1310 ft** of core were described from wells of different fields in Kuwait.
- ❖ Core photograph showing **contact** with **underlying Ratawi Limestone Member** and **overlying Ratawi Shale Member**



Log Correlation of Ratawi Formation in Kuwait



- ❖ Ratawi Formation nearly uniform in thickness in all of Kuwait, ranging from **600 to 700 feet**.
- ❖ Ratawi Shale Member is **400 to 450 feet** of thickness.
- ❖ Ratawi Limestone Member is **250 to 300 feet** of thickness.

Prospectivity of Ratawi Limestone Member

Prospectivity Analysis of Ratawi Limestone Member

➤ Facies Association of Ratawi Limestone

- Ratawi Limestone deposited in **Ramp setting**.

1) Inner Ramp: Skeletal to peloidal packstone/wackestones.

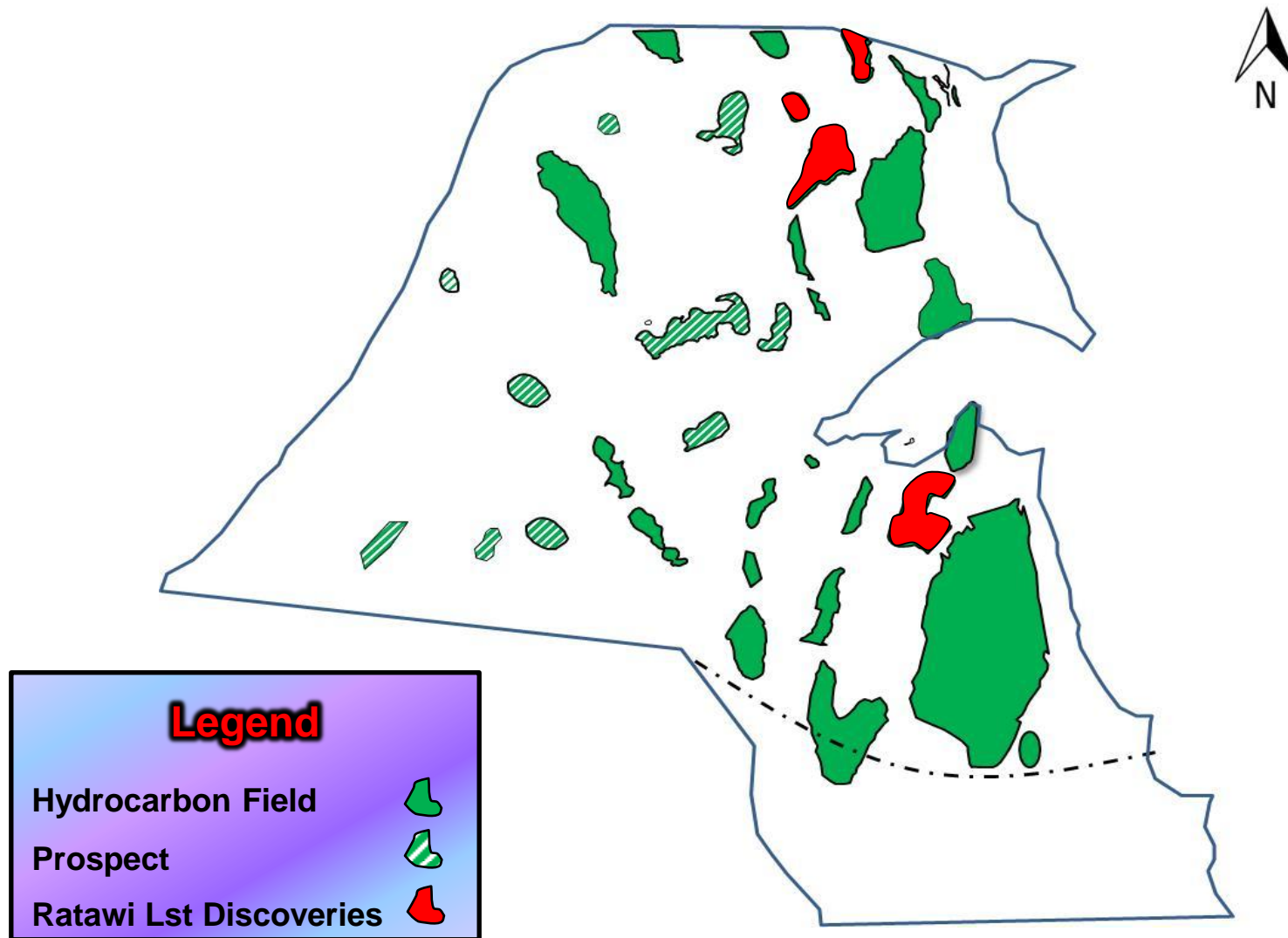
2) Middle Ramp: Skeletal wackestones to packstone/wackestones.

3) Outer Ramp: Calcareous claystone to lime mudstone and argillaceous wackestones, rare argillaceous dolostone.

- The good reservoir facies--mostly found within **the Inner Ramp and the Middle Ramp environment**.



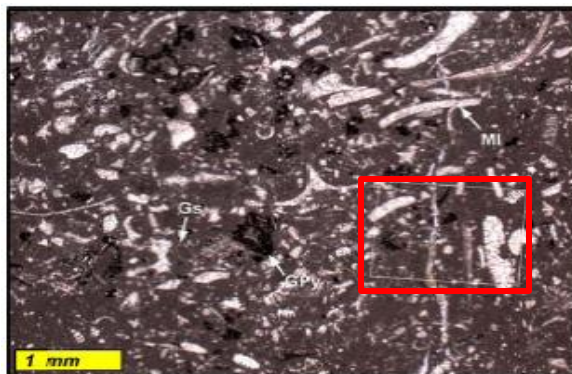
Prospectivity Analysis of Ratawi Limestone Member



The test results : Oil @ **900** to **1500** BOPD.

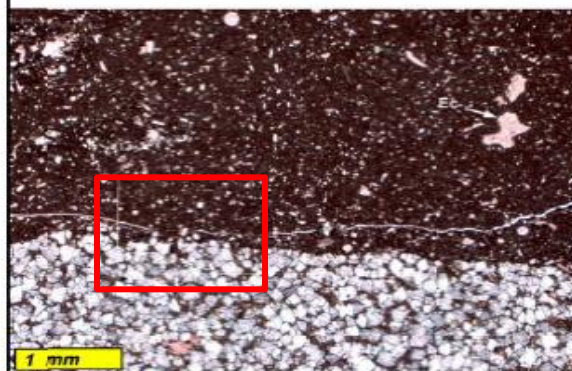
Petrography of Ratawi Limestone Member

Northern Part Of Kuwait



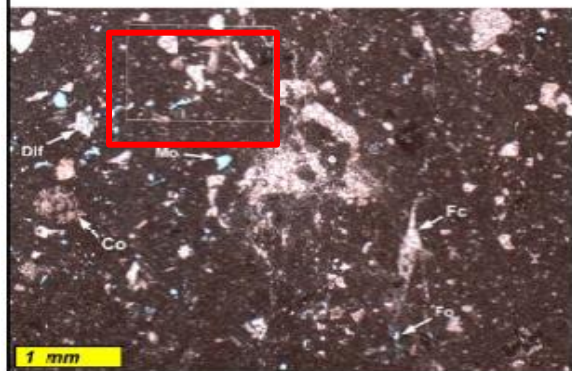
Skeletal wackestone

Porosity fair to good--
mainly molds with algal and
mollusc fragments.



Peloidal Packstone

Porosity fair--mainly moldic
and interparticle.



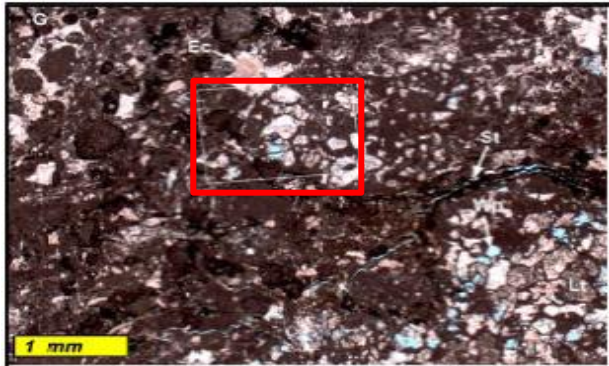
Wackestone

Porosity poor to fair;
undifferentiated cemented
molds reduces porosity.

Increasing porosity

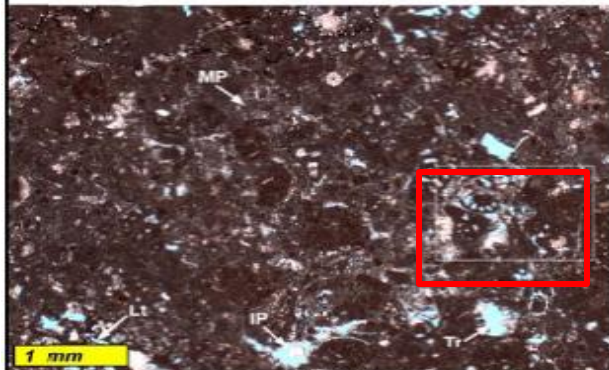
Petrography of Ratawi Limestone Member

Southern Part Of Kuwait



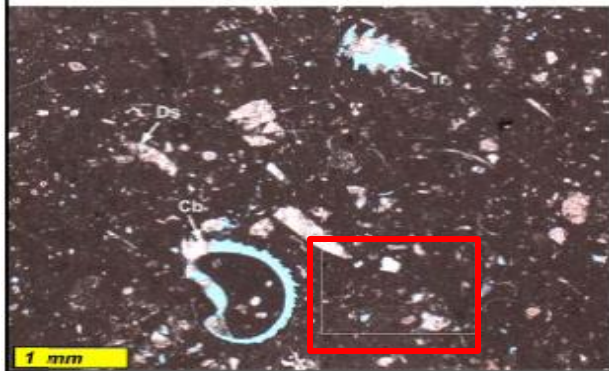
Peloidal Packstone

Porosity good, dominantly interparticle.



Peloidal Packstone

Porosity fair to good, mainly moldic, interparticle and dissolution-enhanced interparticle pores

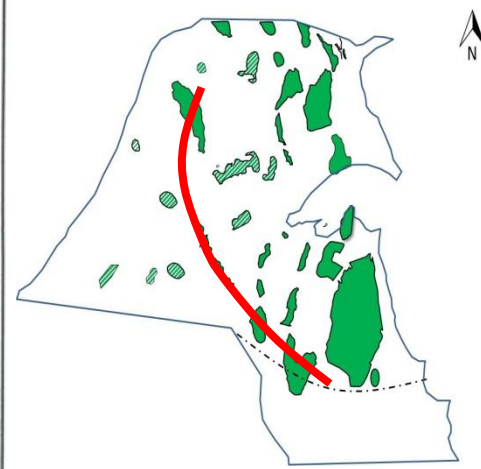


Coral Floatstone

Porosity fair, mainly molds and irregular vugs.

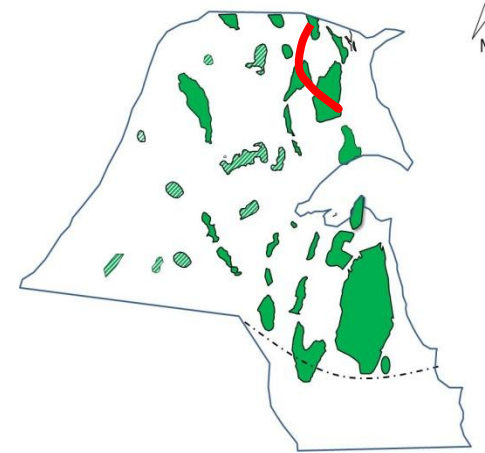
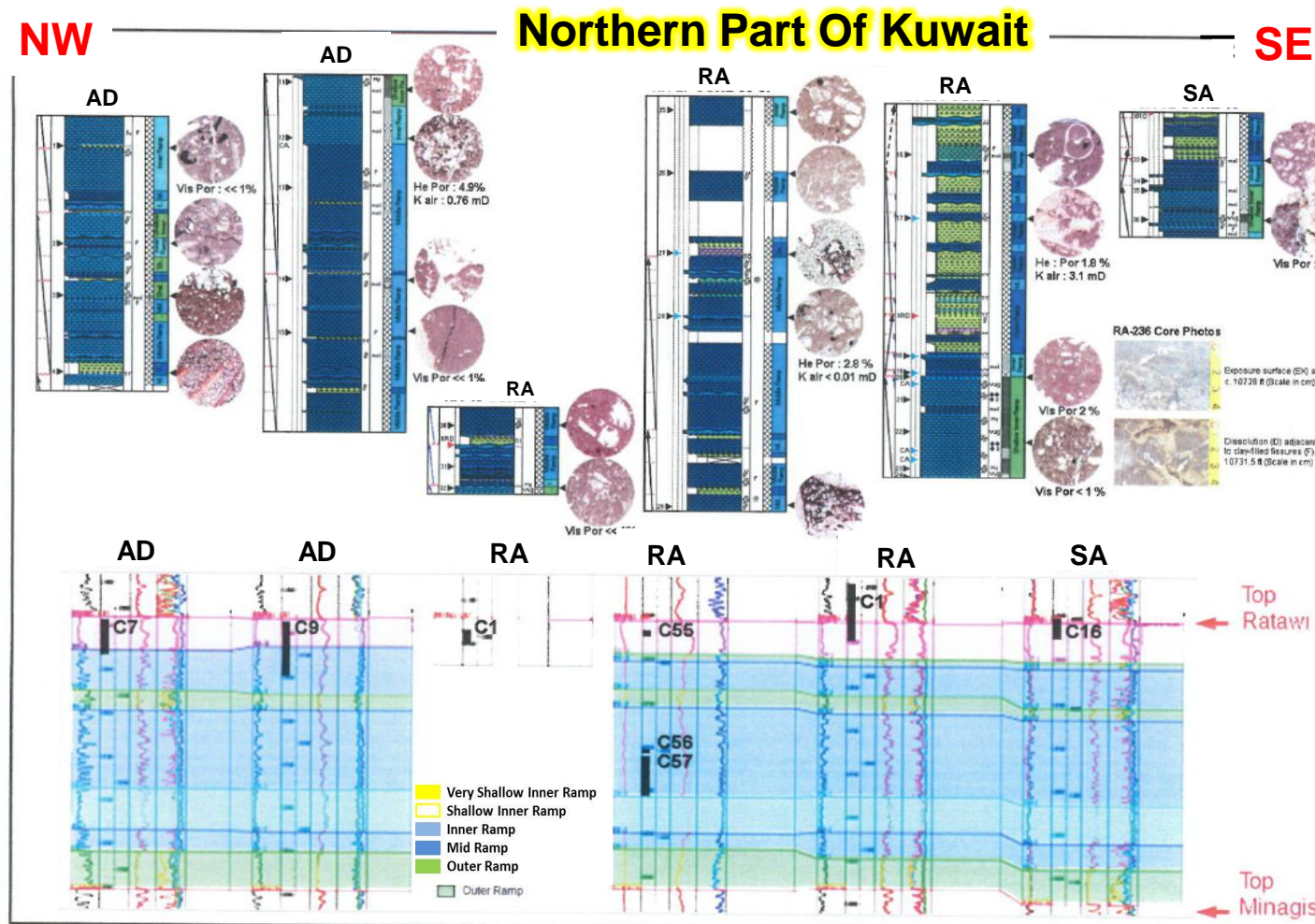
Increasing porosity

Region	KM (%)	KA (%)	UG (%)
North	45	35	20
Central	40	40	20
South	35	45	20



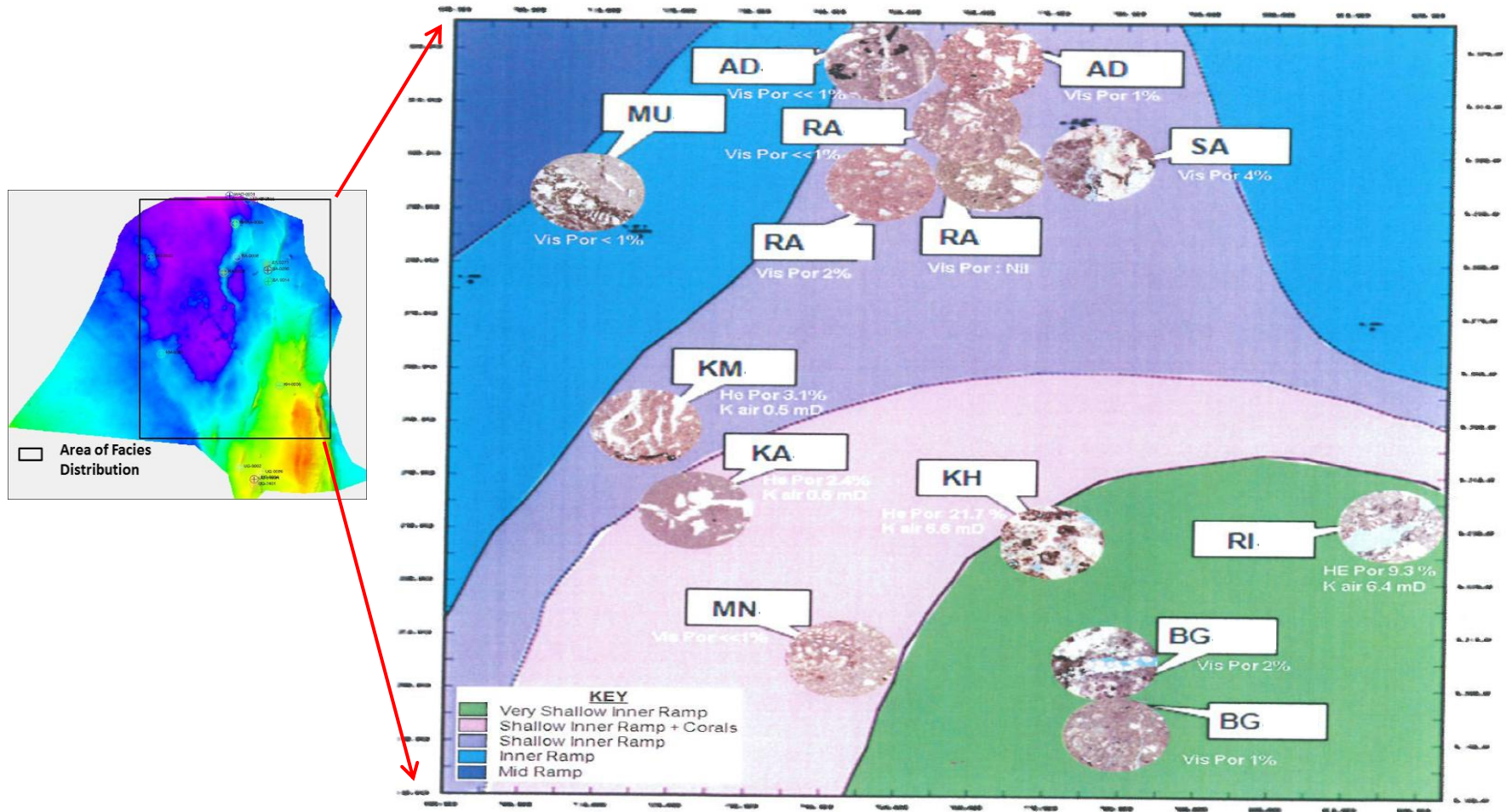
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Reservoir Facies of Ratawi Limestone Member



- ❖ In North Kuwait, a **nearly uniform thickness** of limestone extends from Abdali to Sabriyah.
- ❖ Lithofacies mainly **skeletal wackestone**, occasionally **packstone/lime mudstone**.
- ❖ **Poor to fair Porosity** development observed in this area.

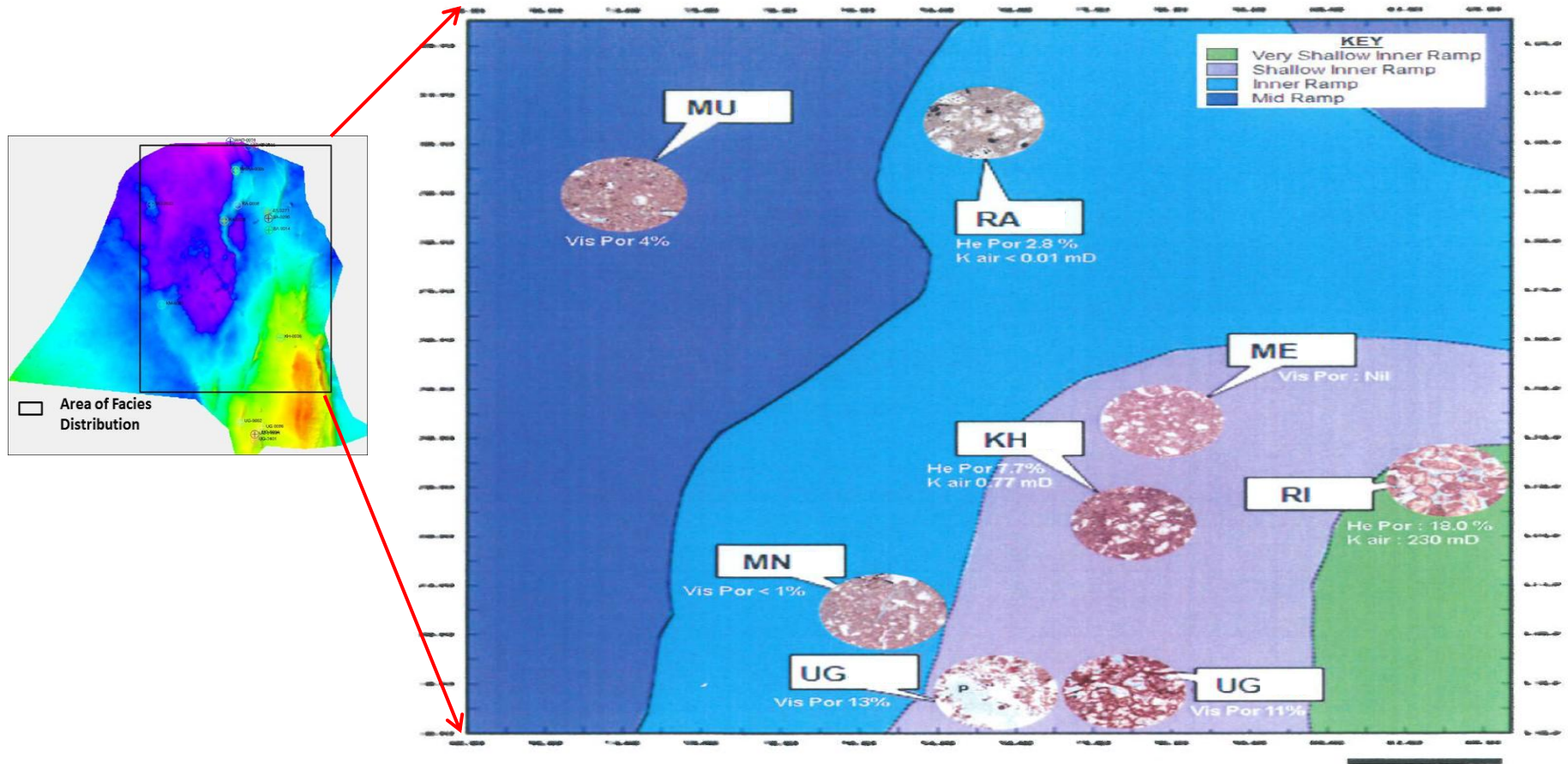
Reservoir Facies :Top part of Ratawi Limestone Member



Distribution of Facies and Reservoir Quality of Ratawi Limestone

- ❖ **Porosity improves from North to South** per depositional facies.
- ❖ **Porosity increases from South west-central part towards North**, restricted within shallow inner ramp environment.

Reservoir Facies : Lower Part of Ratawi Limestone Member

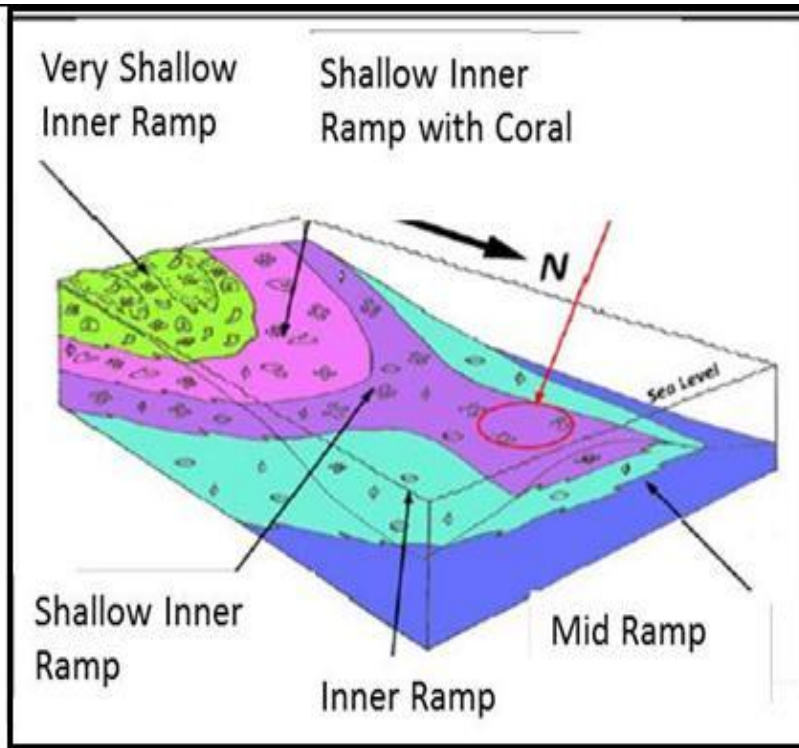


Distribution of Facies and Reservoir Quality of Ratawi Limestone Member

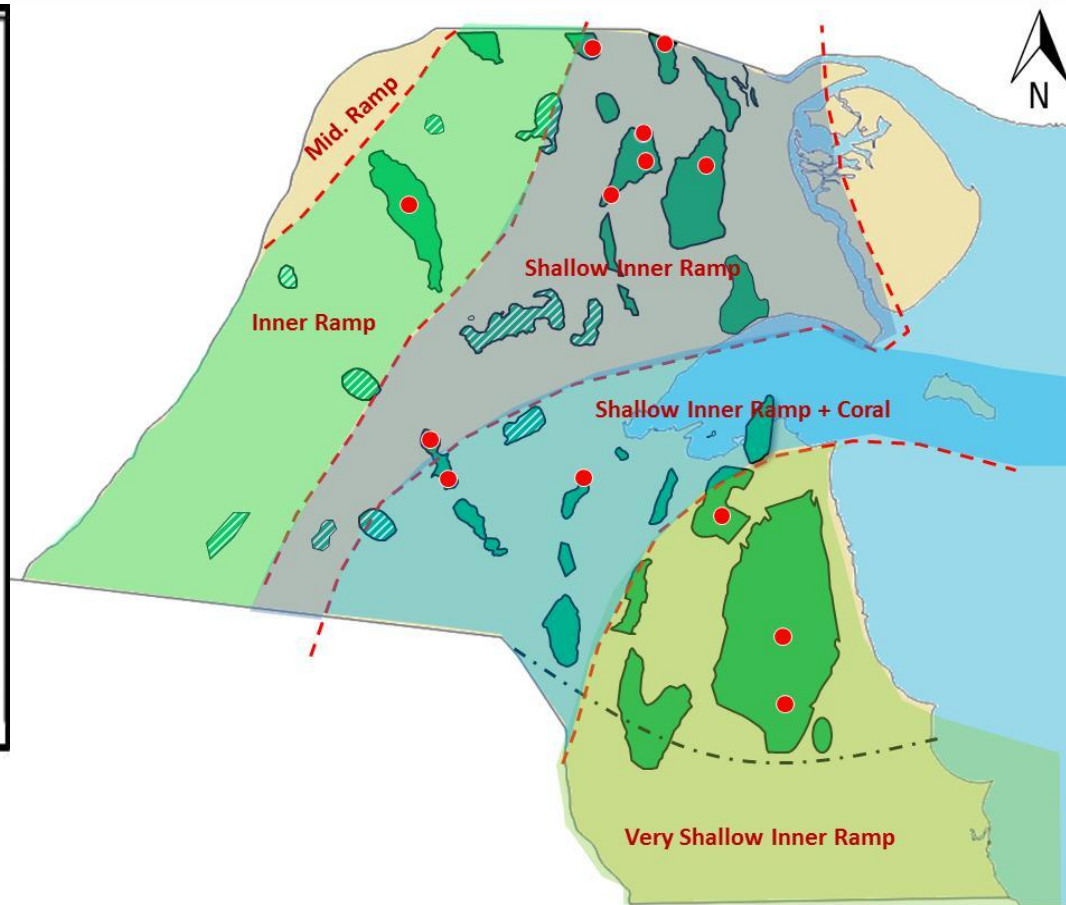
- ❖ **Porosity improves from 2-4% to 18% from North to Southeast**, per depositional Facies of shallow inner ramp environment. This porosity due to the grainstone within Ratawi Limestone Member deposited in shallow to very shallow inner ramp environment.
- ❖ There is a scope of **dual fractured porosity reservoir** towards Northwestern part within mid to inner ramp environment.



Depositional Model of Ratawi Limestone Member



Schematic Diagram of Depositional Model of Ratawi Limestone



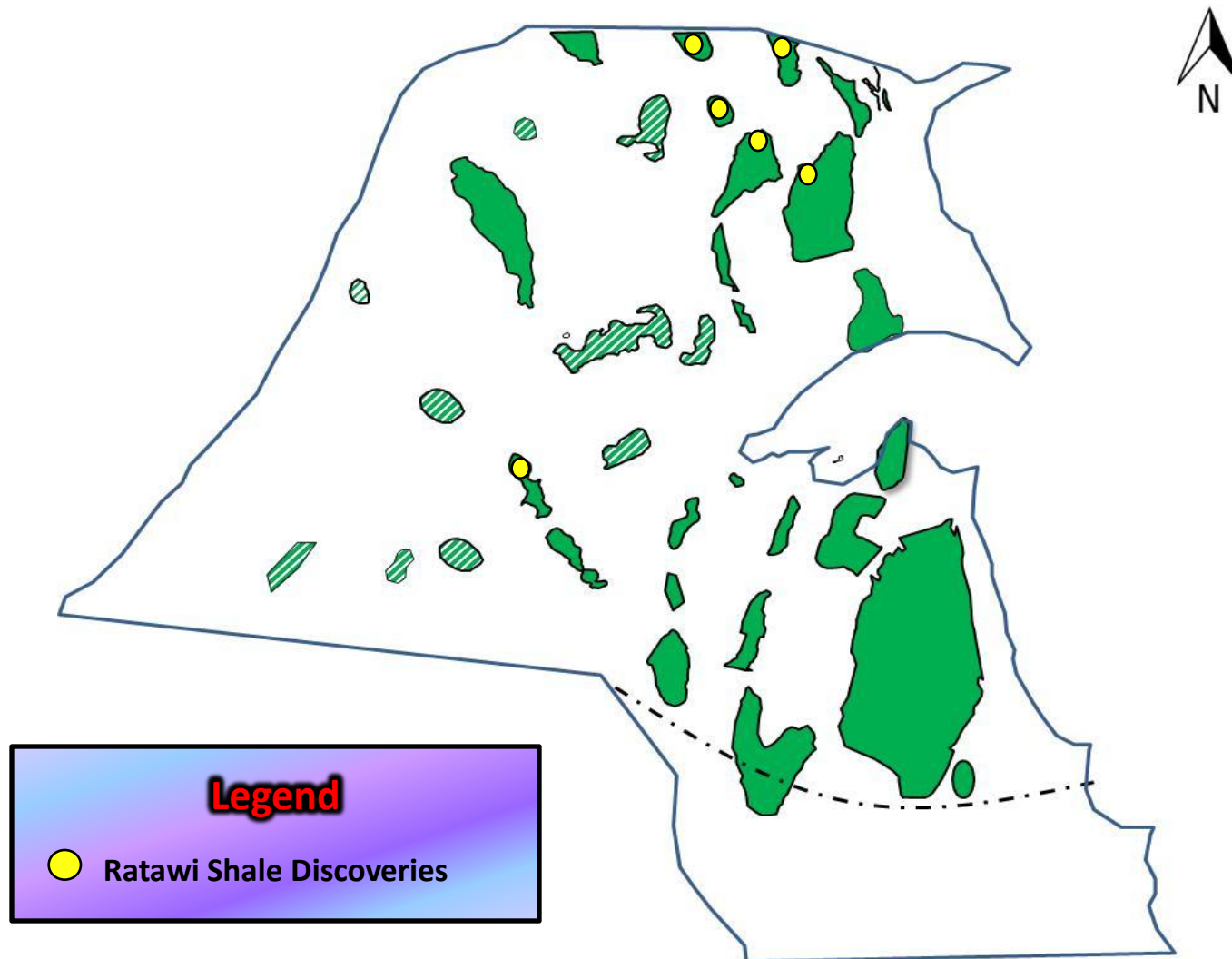
Depositional Model of Ratawi Limestone

- ❖ Ratawi Formation was deposited in Kuwait **in Ramp setting** with regional **Shallowing towards South**.
- ❖ Reservoir Facies Developed throughout Kuwait with some variation.
- ❖ **Better reservoir Facies developed towards South and Northeast.**

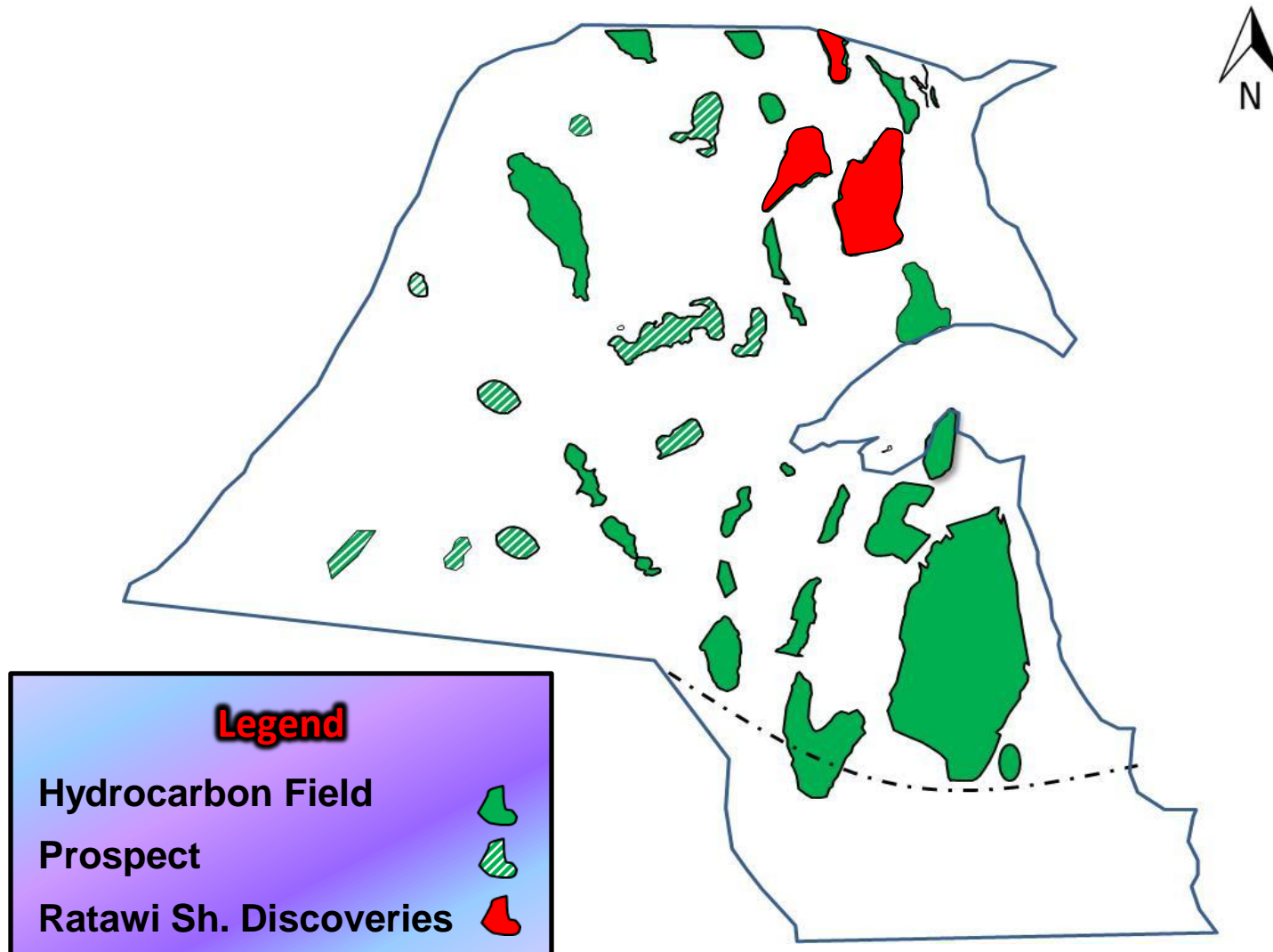


Prospectivity of Ratawi Shale Member

Oil Discoveries in The Ratawi Shale Member in Kuwait



Test Results of Ratawi Shale Member

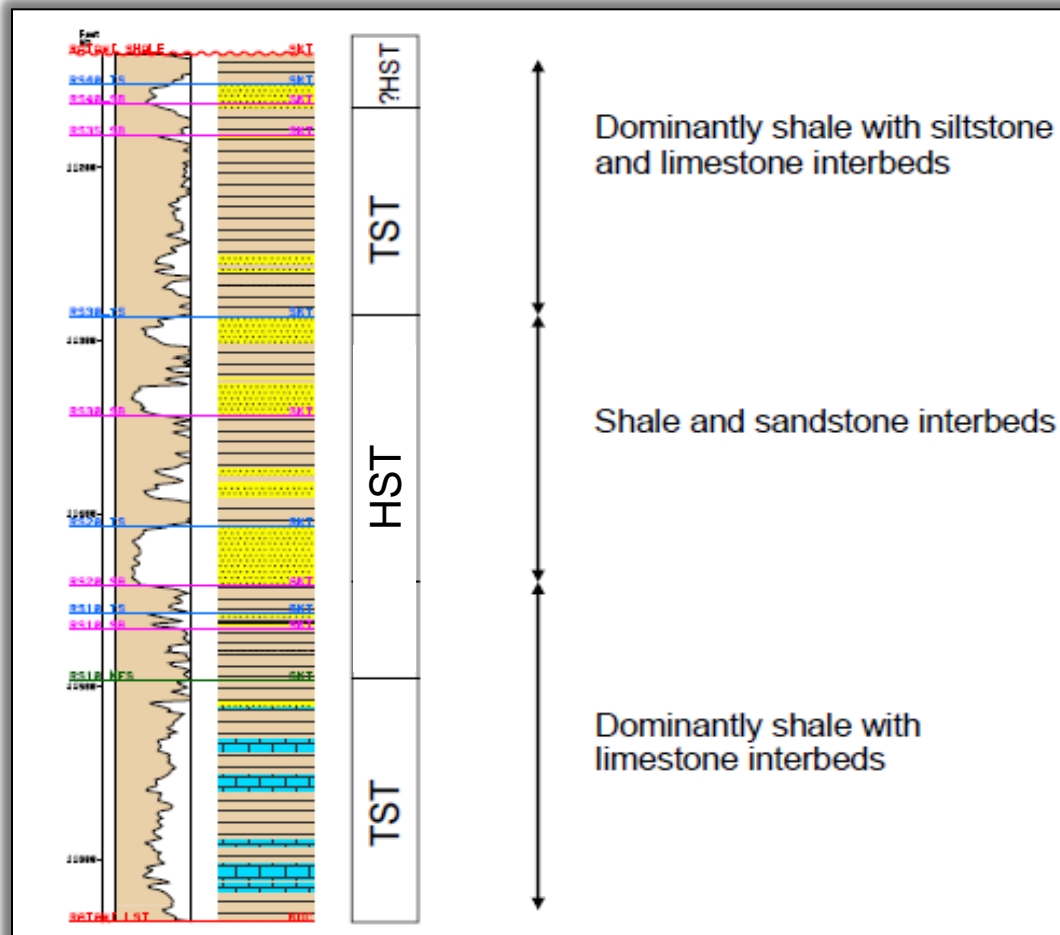


The test result: Oil @ **2200** to **4000** BOPD.

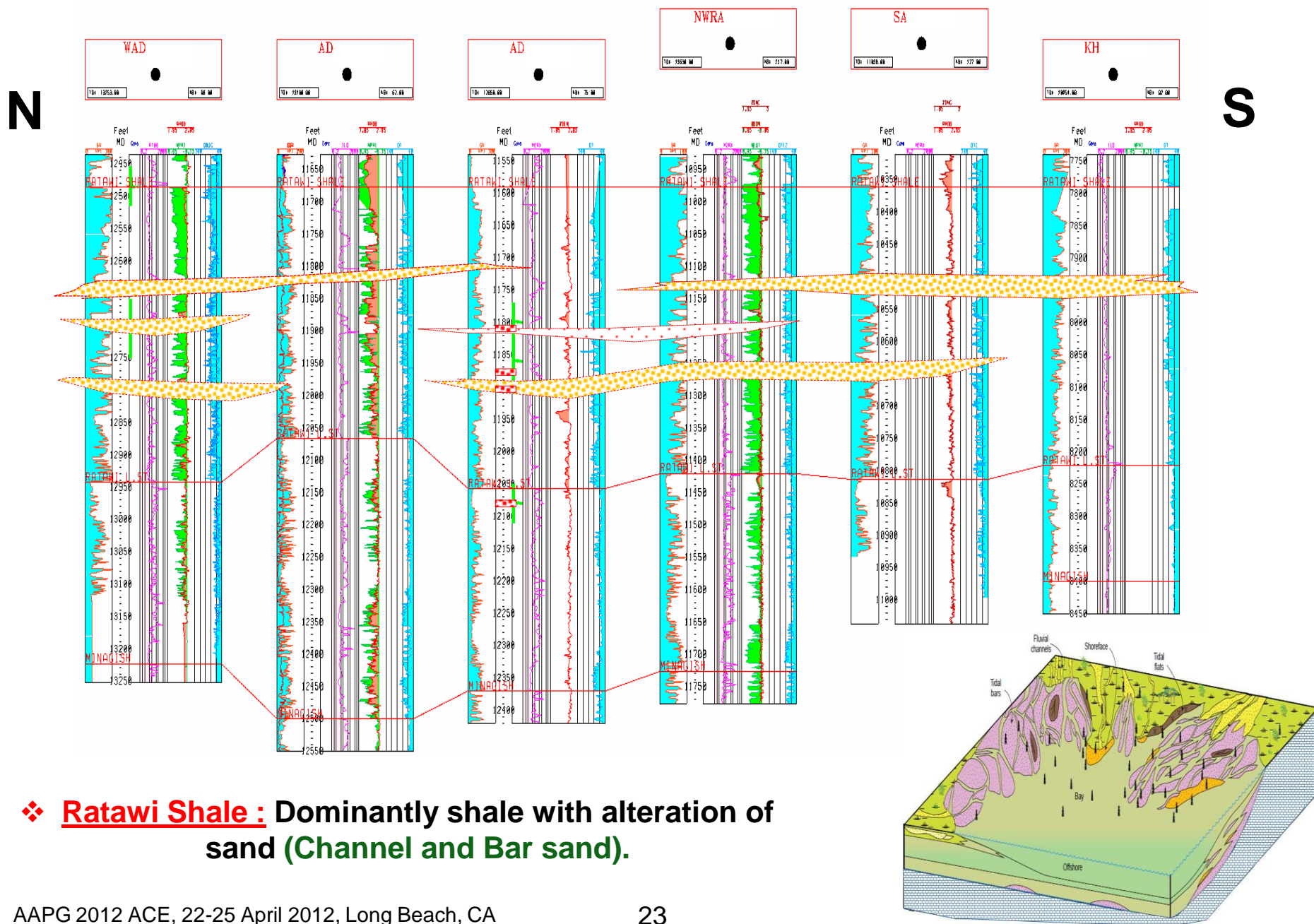
Prospectivity Analysis of Ratawi Shale Member

➤ Ratawi Shale is divided into three units:

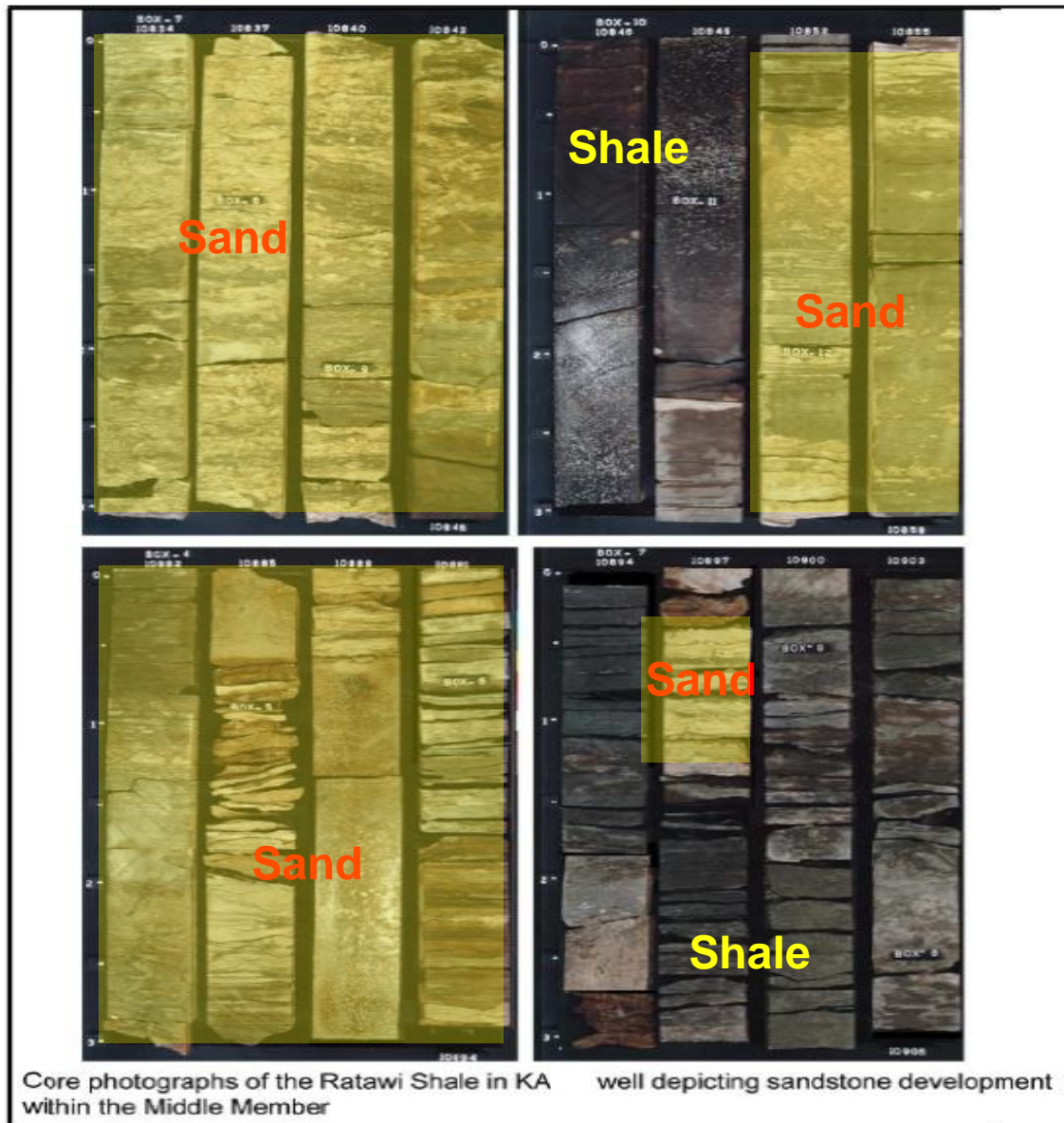
- The lower unit: **consisting dominantly of shale with limestone interbeds.**
- The middle unit: **consisting of interbedded shale and sandstone.**
- The upper unit: **dominantly shale with siltstone and limestone interbeds.**



Channel Sand Geometry Within Ratawi Shale Member



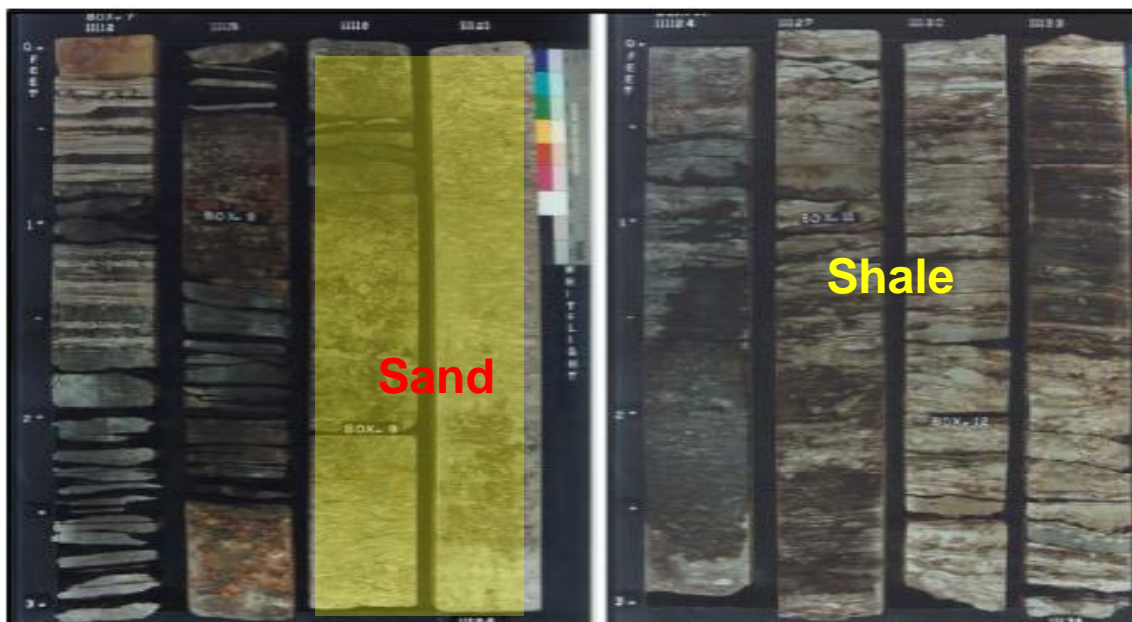
Core Photographs & Characteristic Feature of Ratawi Shale



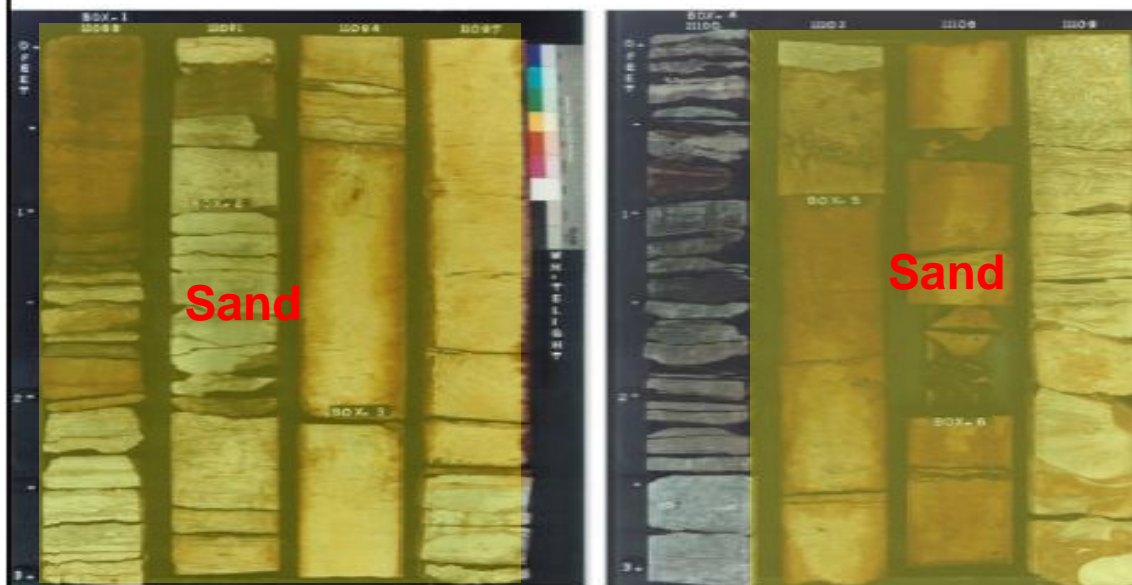
Core showing
dominantly sand
with **alternation of shale**



Core Photographs & Characteristic Feature of Ratawi Shale Member



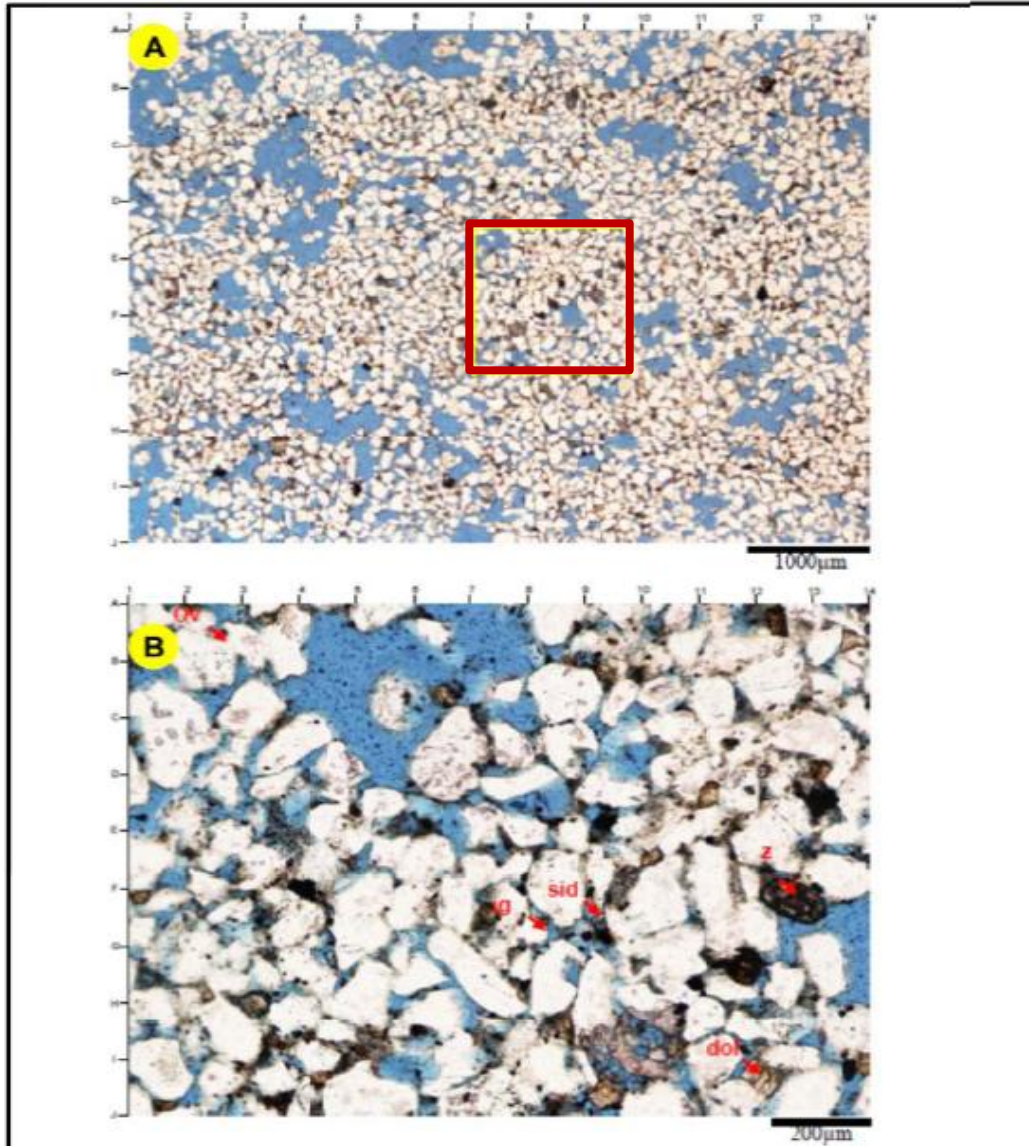
Core Photographs showing **shale** & **argillaceous sandstone**.



Core Photographs showing **medium- to coarse-grained sandstone development** in the Middle zone.

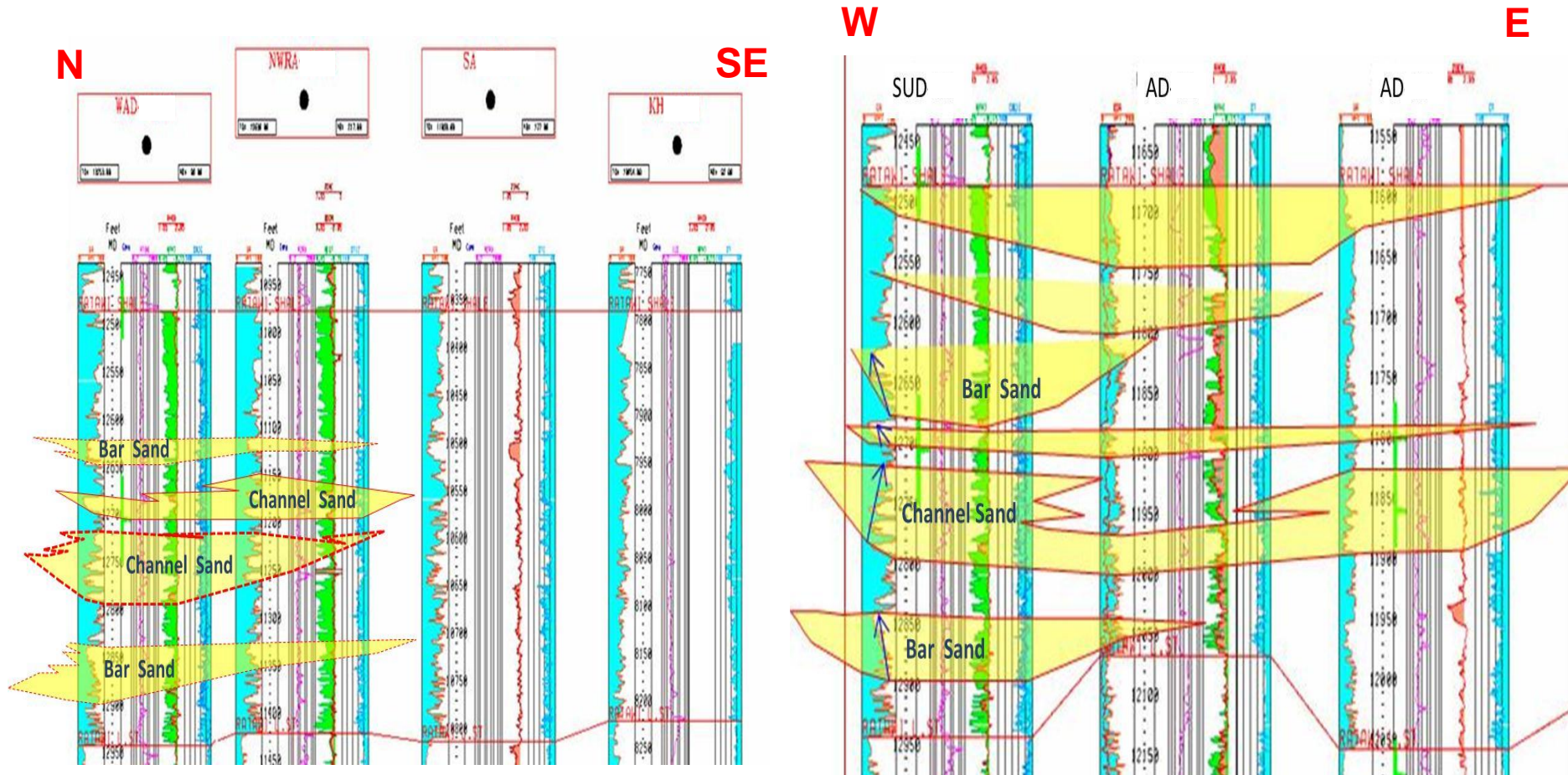


Petrography of Ratawi Shale Member Northeast Part of Kuwait



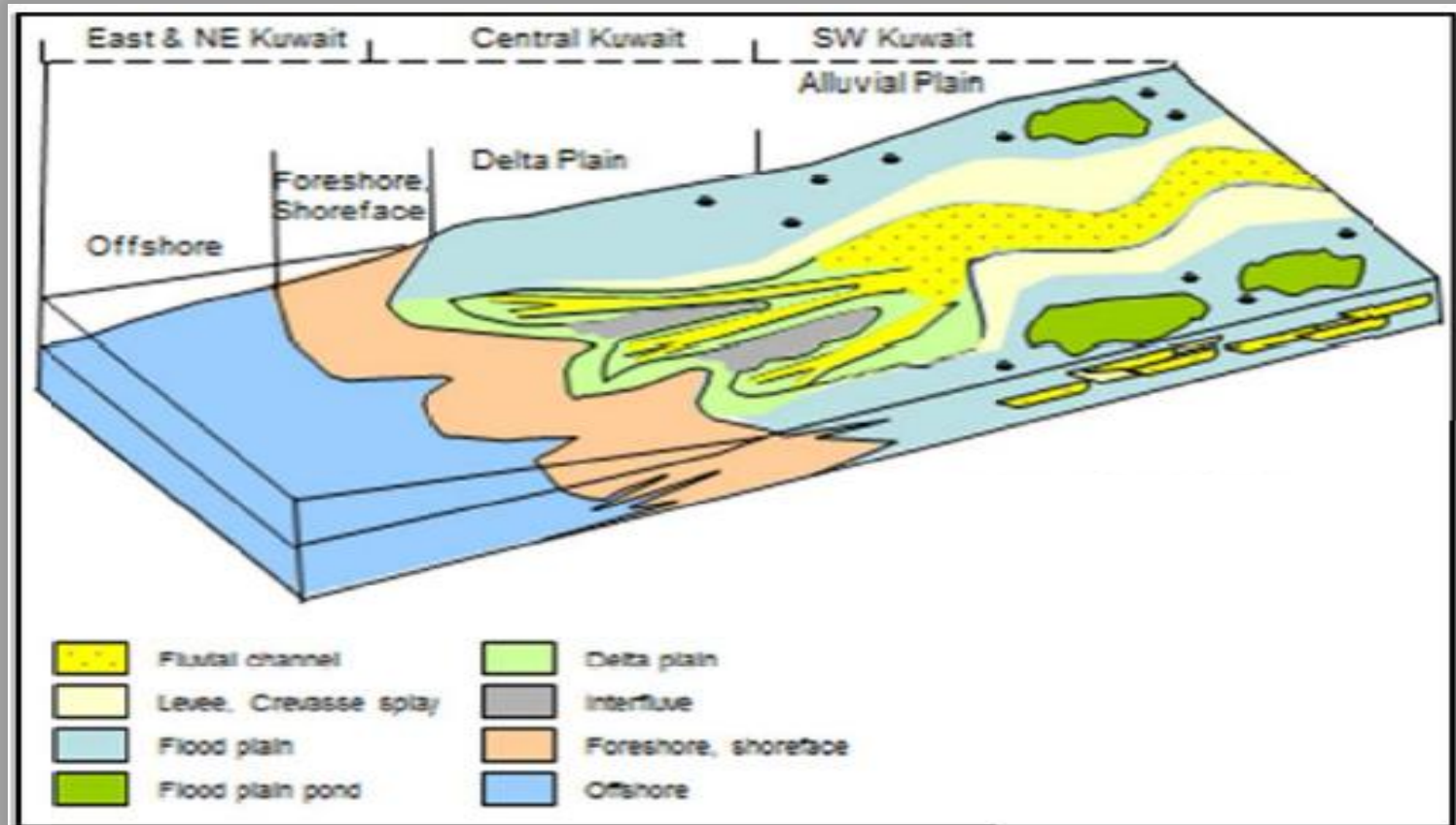
- Photomicrographs of **sandstone** within Ratawi Shale.
 - Fine- to medium-grained, **well sorted sandstone**.
 - **20 to 25% porosity**.
-
- Dolomite rhombs, quartz overgrowths, grain contacts and siderite cement.
 - **Cementation** occ. reduces the intergranular porosity.

Depositional Environment of Ratawi Shale Member in Kuwait



- **Lower part** of Ratawi Shale Member dominated by shale, siltstone and calcareous limestone.
- **Middle part** of Ratawi Shale Member dominated by shale and sandstone.
- Sand mainly **channel and bar sand** representing shifting of channels.
- Vertical stacking of channels and bars indicates presence of fair to good clastic reservoir.

Cartoon of Environmental Setting For The Ratawi Shale Member in Kuwait



- **In Southwest**, Fluvial Facies dominate.
- **In Central** Kuwait, it is transitional marine environments.
- **In East & Northeast**, Marine environment prevailed.

Conclusion

- ❖ Ratawi Formation defined based on lithostratigraphy and sequence stratigraphy.
- ❖ Ratawi Formation more or less uniform thickness ,deposited in ramp setting in Kuwait.
- ❖ It is characterized by carbonate facies as well as clastic facies of mixed environment.
- ❖ Reservoir facies of Ratawi Limestone developed throughout Kuwait, but better developed in the Southern and Northeastern part of Kuwait.
- ❖ Reservoir facies of channel and bar sand of Ratawi Shale developed in the northern part of Kuwait.
- ❖ Hence, Ratawi Limestone member has better prospectivity towards southern Kuwait while Ratawi Shale member is a better exploration target in the Northern part of Kuwait.
- ❖ The exploration effort should be focused in accordance with this understanding.



- ❖ As per KOC's 2030 strategy, Ratawi Formation is to be taken as a major intensive exploration target.
- ❖ Detail G & G studies will be carried out to understand the spatial distribution of channel and bars of Ratawi Shale Member.
- ❖ For Ratawi Limestone, reservoir characterization, including fractures and rock physics, are to be carried out for proper reservoir management and its development.
- ❖ The role of fractures in reservoir property will also be studied, especially for Ratawi Limestone Member in northern Kuwait.



Thank YOU

