

# **An Integrated Study to Identify New Exploratory Target in the West Kuwait Carbonate Reservoir\***

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Search and Discovery Article #11156 (2019)\*\*

Posted January 28, 2019

\*Adapted from oral presentation given at the GEO 2018 13th Middle East Geosciences Conference and Exhibition, Manama, Bahrain, March 5-8, 2018

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## **Abstract**

As a part of the exploration campaign in Western Kuwait, single sensor 3D seismic data was acquired in the Kra-Al-Maru-Kahlula area. The area is located towards the northern part of Minagish Field. Middle Minagish carbonate reservoir is well developed and a prolific producer of hydrocarbon in the Minagish field. An attempt has been made to understand the porosity distribution and to explore the hydrocarbon prospectivity of Minagish reservoir in the Kra-Al-Maru-Kahlula area.

In the integrated study a comprehensive well log correlation, seismic interpretation and inversion study were carried out in the study area. In the inversion study, Geophysical and Petrophysical data were combined through deterministic seismic inversion, and an Acoustic Impedance volume was generated for the Minagish carbonate reservoir. In the inversion process, the low frequency component (0 to 10 Hz) was derived from well data and high frequency component (10 to 60 Hz) has been obtained from seismic data. A relationship between porosity and Acoustic Impedance was established using well data and applied in transforming impedance into Porosity.

In the study area, few wells were drilled over the present day structural high and it shows poor to moderate porosity development, but it does not show any commercial hydrocarbon accumulation. Seismic inversion and porosity modeling study suggest that the best-developed reservoir zone is away from the present day structural high. To gain a better insight of porosity development in the area, paleo-structural analysis was carried out. The analysis was done by carefully selecting key horizons and generating isopach maps to get a paleo-structure maps. Paleo-structural analysis shows that the best porosity has been developed over paleo-structural high axis.

Seismic inversion and porosity modeling study was found to be a useful tool to delineate reservoir facies. Paleo-structural analysis has helped in understanding that better developed porosity zone is associated with the paleo-high axis of that level. The integrated workflow has led to the identification exploration opportunities with a higher degree of confidence.



# **GEO 2018**

13<sup>th</sup> Middle East Geosciences  
Conference and Exhibition

CONFERENCE:

**5 – 8 March 2018**

BAHRAIN INTERNATIONAL EXHIBITION & CONVENTION CENTRE

EXHIBITION:

**6 – 8 March 2018**

## **An Integrated Study to Identify New Exploratory Target in the West Kuwait Carbonate Reservoir**

Presenter: Mohammed Hameed Shereef\*

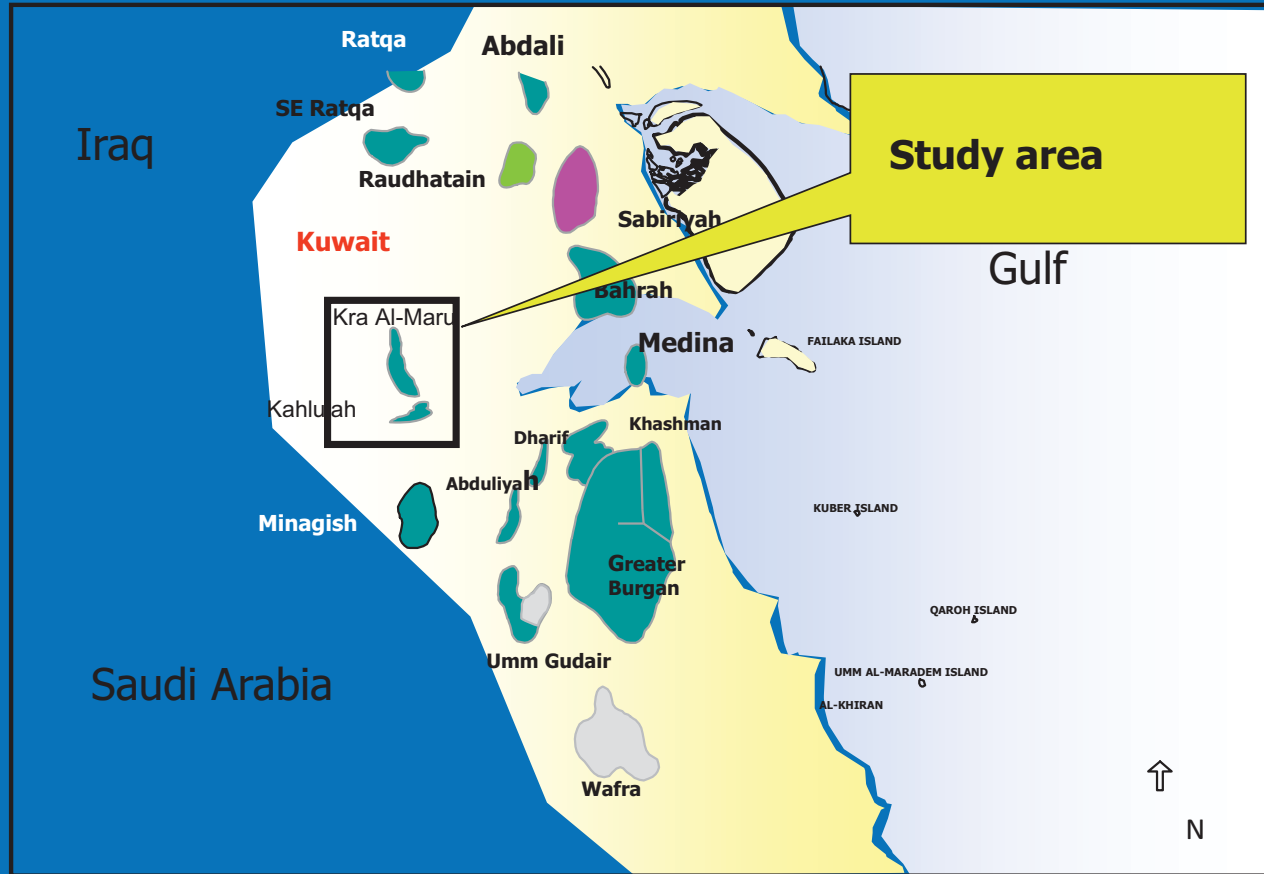
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# ***Presentation Outline***

- ❑ Introduction
- ❑ Data Analysis
- ❑ Methodology
- ❑ Interpretation and Results
- ❑ Conclusions

# Introduction



- Study area : SW of Kuwait. Kra al Maru, Kahlula.
- It is located to the north of Minagish field, where Minagish Formation is the prolific producer.

# Brief Geology

- The Minagish formation belongs to the lower part of the upper Jurassic to Lower Cretaceous Thamama Group.
- Minagish is divided into three layers Upper Minagish, Minagish Oolite & Lower Minagish.
- The Minagish field has several reservoirs with oil accumulated primarily in Lower Cretaceous of Minagish Oolite-middle member (MMO) rocks.

CHRONOSTRATIGRAPHY					AGE TIME (Ma)	LITHOLOGY	ROCK UNIT				
ERATHM	SYSTEM	PERIOD	SERIES	STAGE			GROUP	FORMATION			
CENOZOIC	TERTIARY	PALEOGENE NEOGE	MIOCENE	UP. MIOC. PLIO.	1.6		KUWAIT	DIEBIEBA			
				M.	10.5			L. FARAS			
				L.	16.5			GHAR			
			OLIGOCENE		25.5	ZAGROS EVENT					
			Eocene	M.	33.5		HASA	DAMMAM			
				L.	49.5			RUS			
			PALBOCENE		54.2			RADHUMA			
					60	Paleocene/Early Eocene					
MESOZOIC	CRETACEOUS	SENONIAN	MAAST.	65		ARUMA	TAYARAT				
			CAMPANIAN	71			HARTHA				
			SANTONIAN	80			SADI				
			CONIACIAN	85			MUTRIBA				
			TUROMAIN				89	PPREARUMA UNCONFORMITY			
			CENOMANIAN				92		WARSA	MISHRIF	
							94			FUMAILA	
							96			AHMADI	
		97.5				WARA					
		99.5				MAUDDUD					
		ALBIAN			100.5			BURGAN			
					105.5						
					112						
		APTIAN		115.5		AMA	SHUAIBA				
		BARREMIAN		115.5			ZUBAIR				
		NEOCOMIAN	HAUTERVIAN	128.5				THAM			
			VALANGINIAN	135	RATAWI						
			BERRIASIAN	136.5		MINAGISH					
				137		MAKHUL					
				143.5							
		JURASSIC	U.	TITHONIAN	145.5			HITH			
				KIMMIDJIAN	152.5			GOTWA			
					CALBATHIAN			164	NAJMAH		
								AAL.	176.5	SARGELU	
			L.	TOAR.	180			DHARUMA			
				MARRAT							

Upper Minagish  
Minagish Oolite  
Lower Minagish

Presenter's notes:

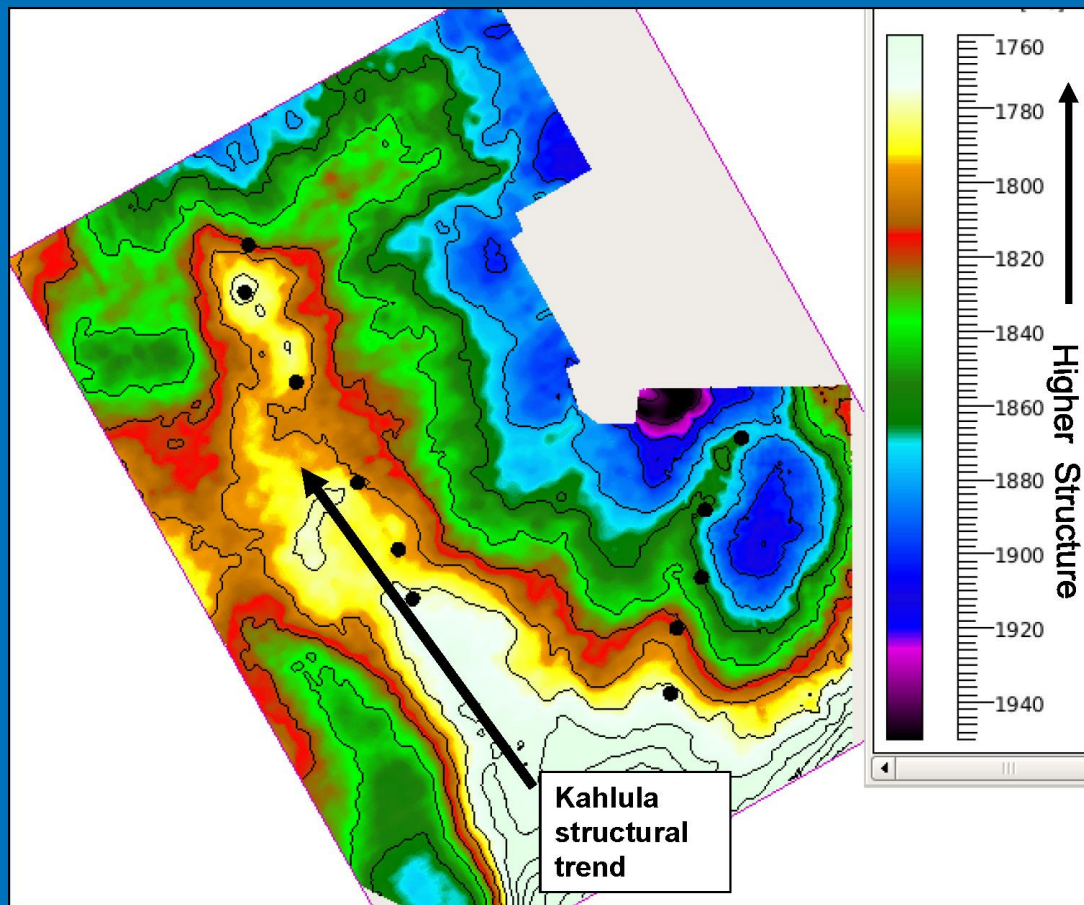
- The Minagish field is located on the south west flank of Kuwait Arch is 10 km away from the worlds largest clastic field, Greater Burgan.
- Oil was discovered in the Lower Cretaceous Minagish Oolite in 1962 and around 180 wells have been drilled on the structure.
- The area of study is East Umm Gudair 47 km<sup>2</sup>.

There is strong evidence of a southwestward lateral facies change into more argillaceous limestones ("marls") in the upper part of the Minagish Oolite. The Minagish Formation belongs to the lower part of the late Jurassic to Early (*Presenter's notes continued on next slide*)

*(Presenter's notes continued from previous slide)*

Cretaceous Thamama Group, which is largely defined on sections in Saudi Arabia and the southern Gulf countries. The discovery of new oil in the Lower Minagish (LMN) member is expected to significantly increase production rates as well as estimates of original oil in place in Minagish Field. Production rates observed from wells tested in the reservoir, far exceeded what would normally be expected from reservoir with low matrix K (<1mD) as evidenced from core data. The Lower Minagish member consists largely of peloidal packstones that were deposited in low energy epicontinental shelf or platform settings, equivalent to the outer ramp. There are 130 wells penetrating the LMN reservoir. Most of these wells are partially penetrating while some penetrate through all the layers. Cores are available from 6 vertical wells, while acoustic images are available from 5 vertical wells and 1 deviated well. Fifty-six wells have electrolog suites suitable for petrophysical analysis. The porosity of this reservoir ranges between as low as 2-3% to as high as 22%. The rock and reservoir quality degrades toward the south of the field except locally areas in the southern and southwestern parts of Minagish where porosity is well developed. The 3-D seismic attributes are in agreement with the petrophysical interpretation of wireline logs. The permeability of the reservoir ranges between very low K (less than 1 mD) to medium K in the order of hundreds of mD.

## Time Structure Map



- Two way time (TWT) map of Minagish Formation shows a NW-SE Kahlula Structural high trend.
- Drilled wells show poor to moderate porosity for Minagish Formation

Presenter's notes: As a part of the exploration campaign in Western Kuwait, single sensor 3D seismic data was acquired in the Kra-Al-Maruk-Kahlula area. Two-way time (TWT) map of Minagish Formation shows a NW-SE Structural high trend, it is called as Kahlula structural trend. In the study area, few wells were drilled over the present day structural high for deeper target. For Minagish Formation these wells show poor to moderate porosity development, but it does not show any commercial hydrocarbon accumulation. Seismic inversion and porosity modeling study carried out to understand the distribution of reservoir properties within the area.

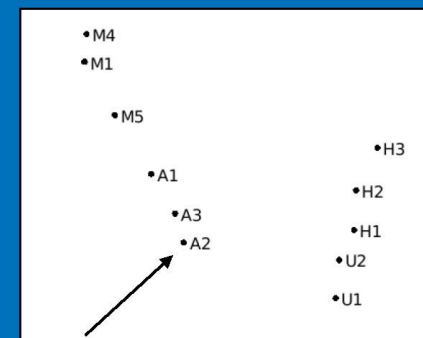
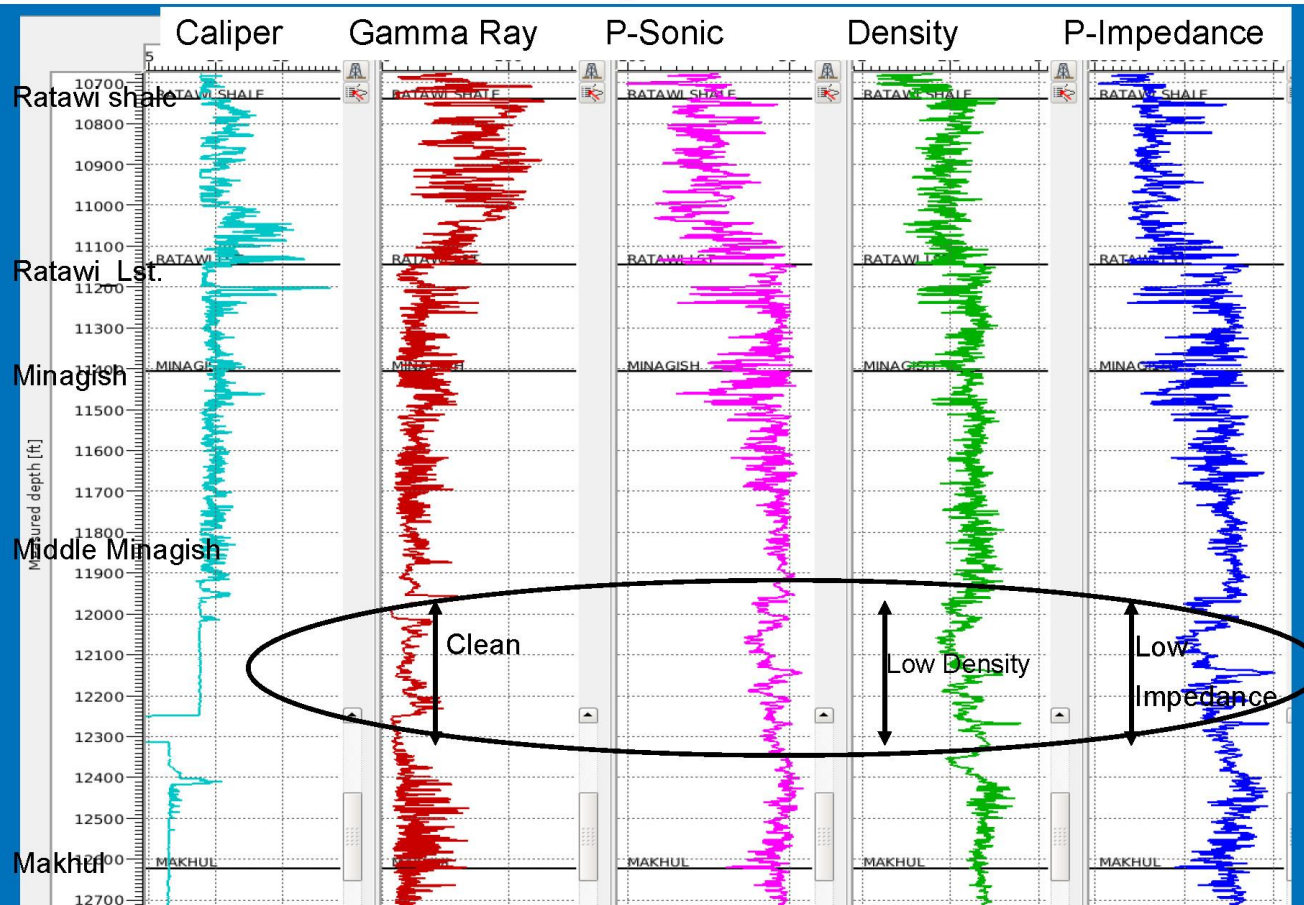
## ***Objective***

An attempt has been made to understand the porosity distribution and to explore the hydrocarbon prospectivity of Minagish reservoir in the Kra-Al-Marukahlula area.



# Data Analysis

Well log A2

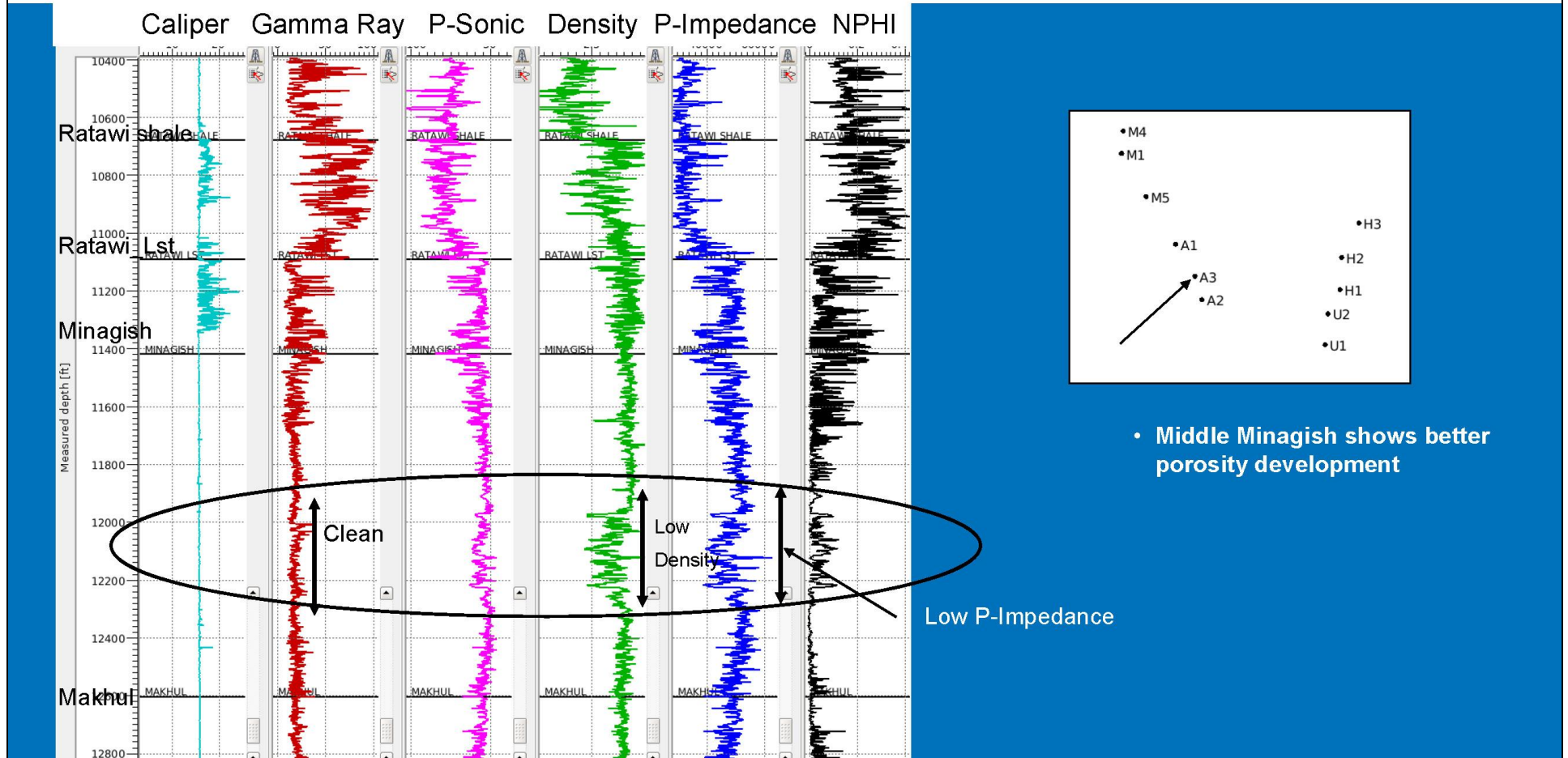


- Middle Minagish shows better porosity development

Presenter's notes: Well log curve of well A2 has been shown. Our zone of interest is Minagish Formation. Gamma Ray curve shows upper part of Minagish Formation is shalier, whereas Middle Minagish shows mostly clean deposition. Within the Middle Minagish clean Formation, low density and P-Impedance indicate the possibility of better porosity development.

# Data Analysis

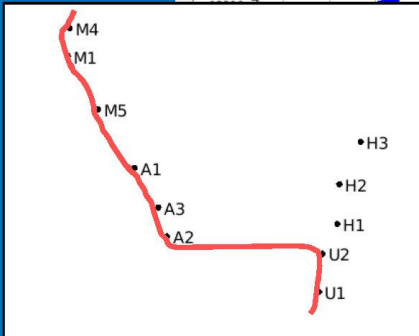
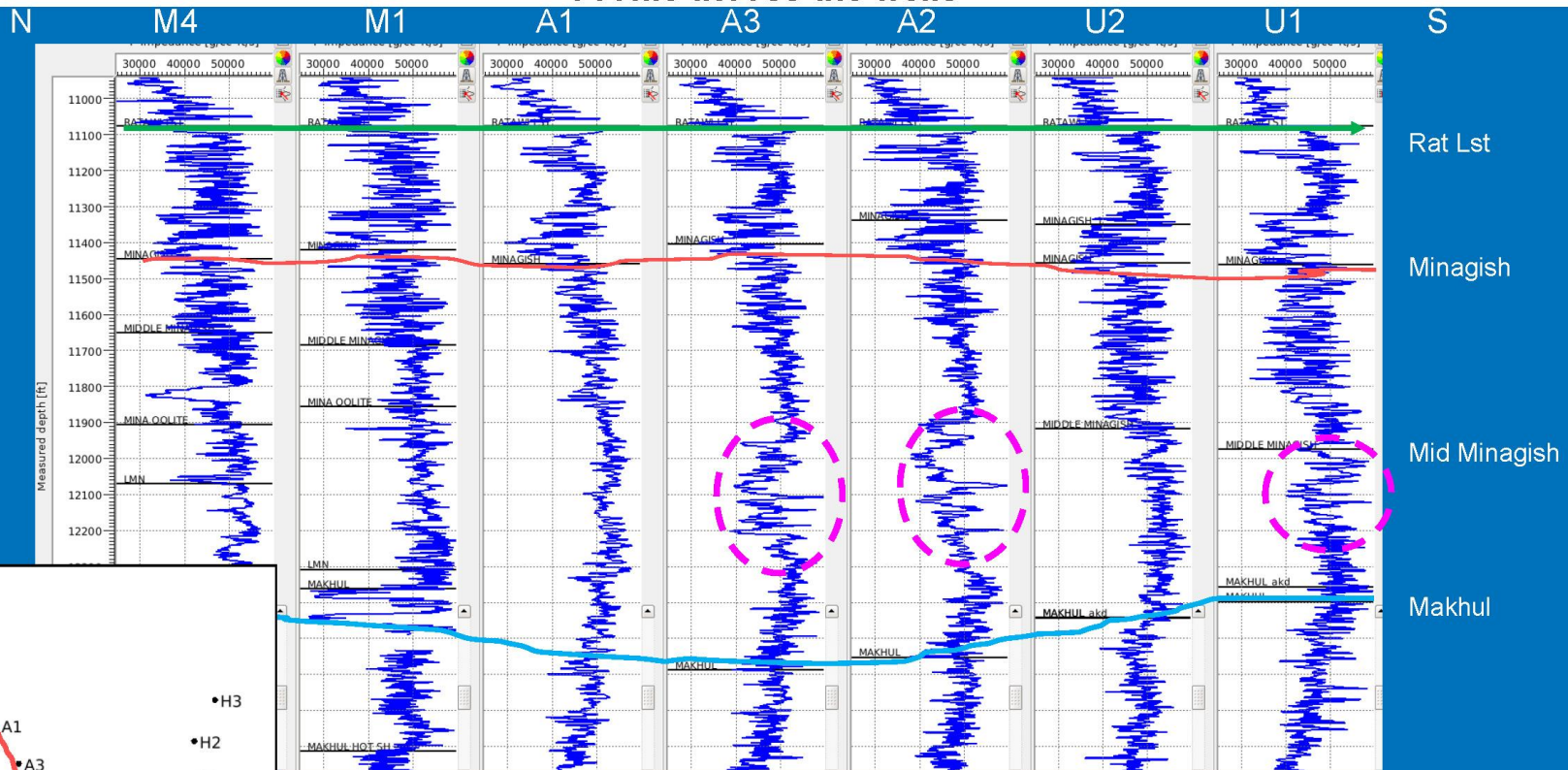
Well log A3



Presenter's notes: Well log curve of well A3 has been shown. Our zone of interest is Minagish Formation. Gamma Ray curve shows upper part of Minagish Formation is shalier, whereas Middle Minagish shows mostly clean deposition. Within the Middle Minagish clean Formation, low density; low P-Impedance and higher NPHI indicate the better porosity development.

# Data Analysis

## Profile across the wells



- Middle Minagish shows better porosity development in the wells U1, A2 & A3

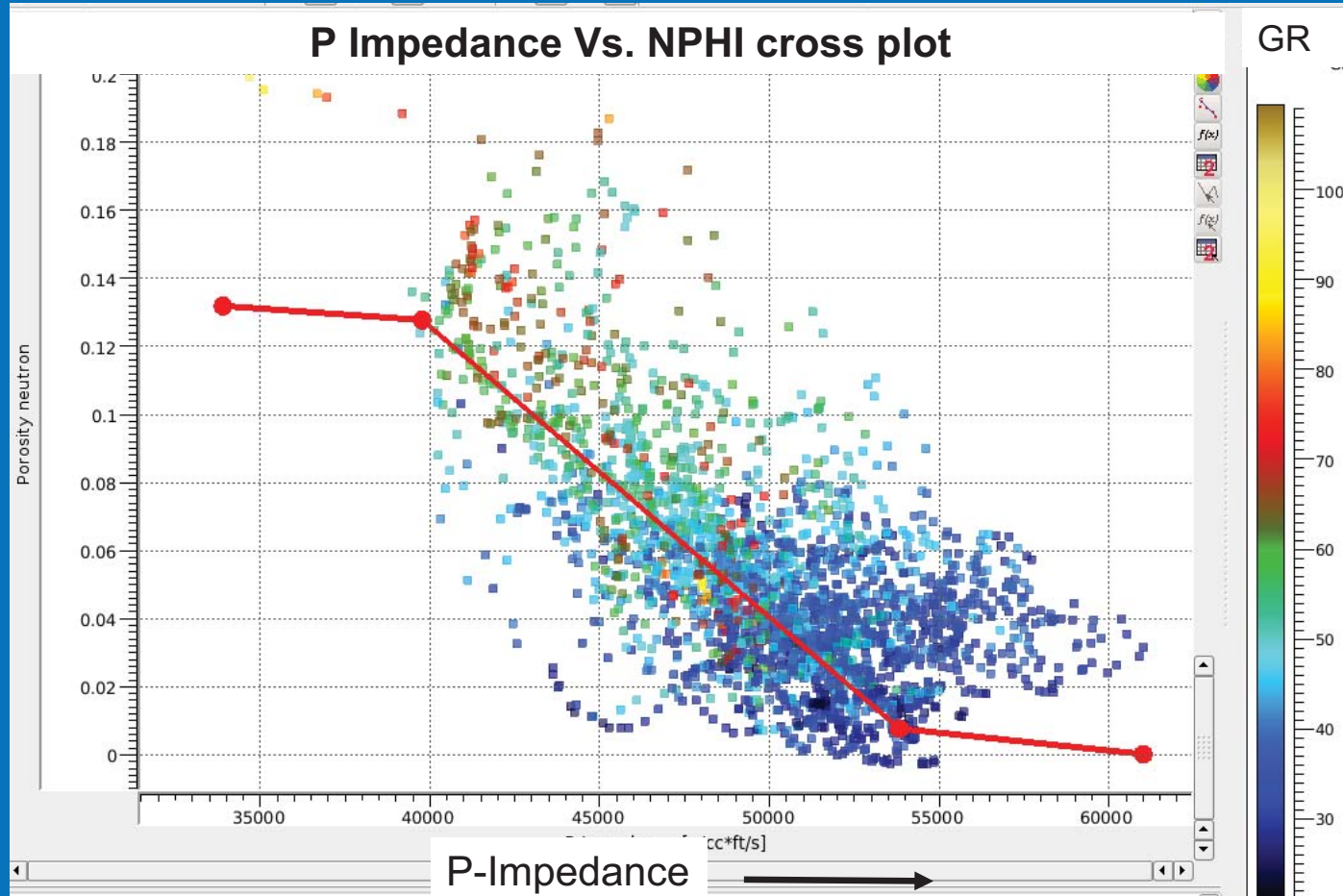
P Impedance log profile

Presenter's notes: P-Impedance well log profile has been shown from North to South direction. The wells A3, A2 and U1 show relatively low impedance development at the Middle Minagish level. Therefore, these wells expected to have better porosity development in Middle Minagish.



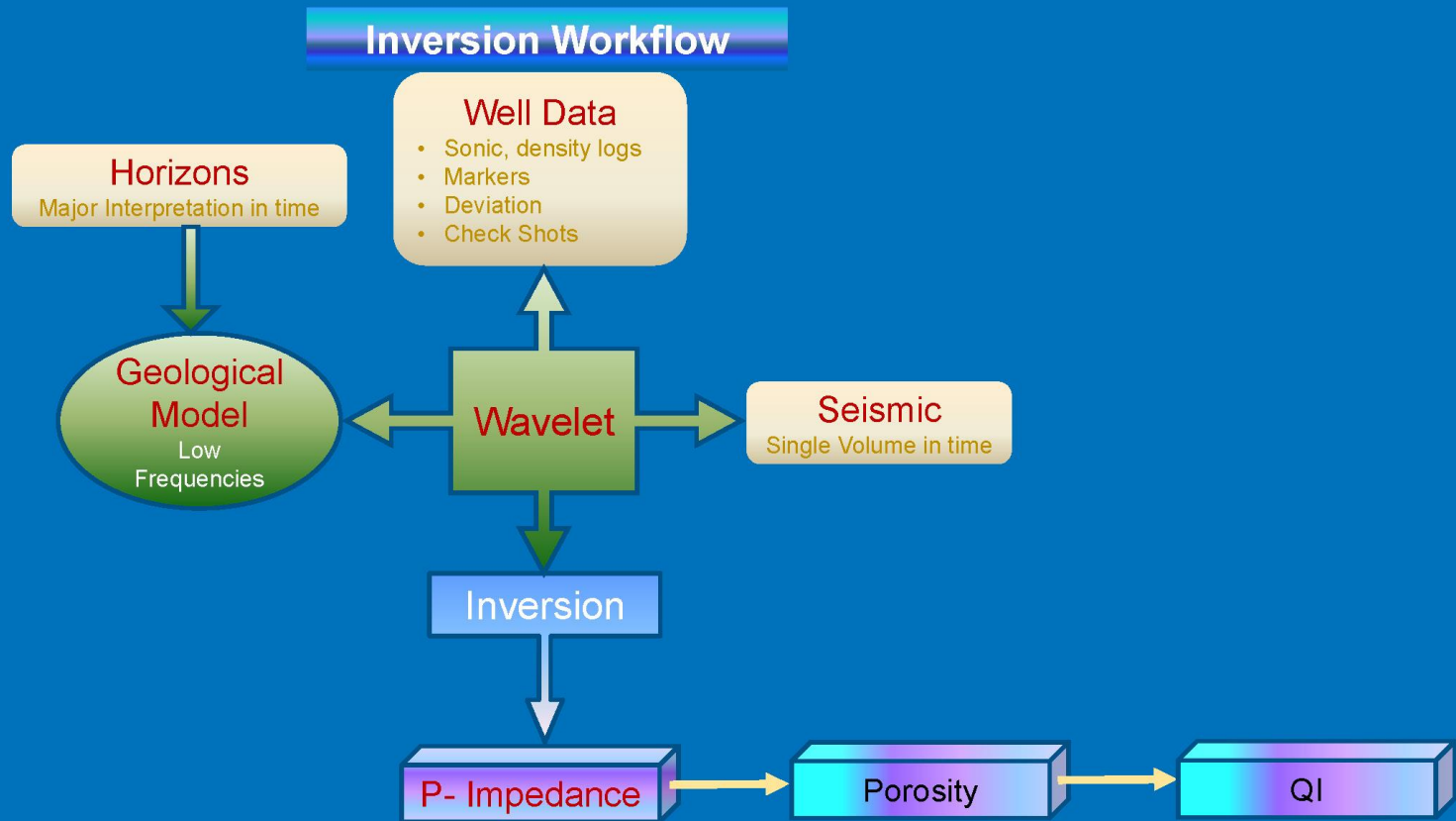
# Data Analysis

NPHI ↑



**P Impedance Vs. NPHI cross plot for Middle Minagish Formation**

# Seismic Inversion Workflow



Presenter's notes:

- The slide shows the general workflow for the post stack inversion.
- Seismic inversion is one of the important tool used to estimate rock and reservoir properties from the seismic data
- Two of the main effective parameters of seismic inversion are
  - Low Frequency Model
  - and wavelet

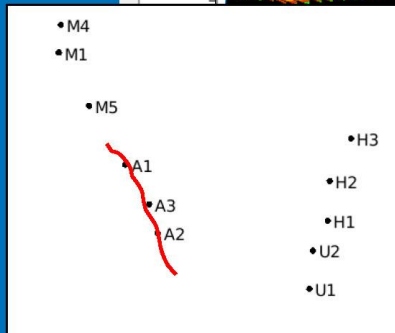
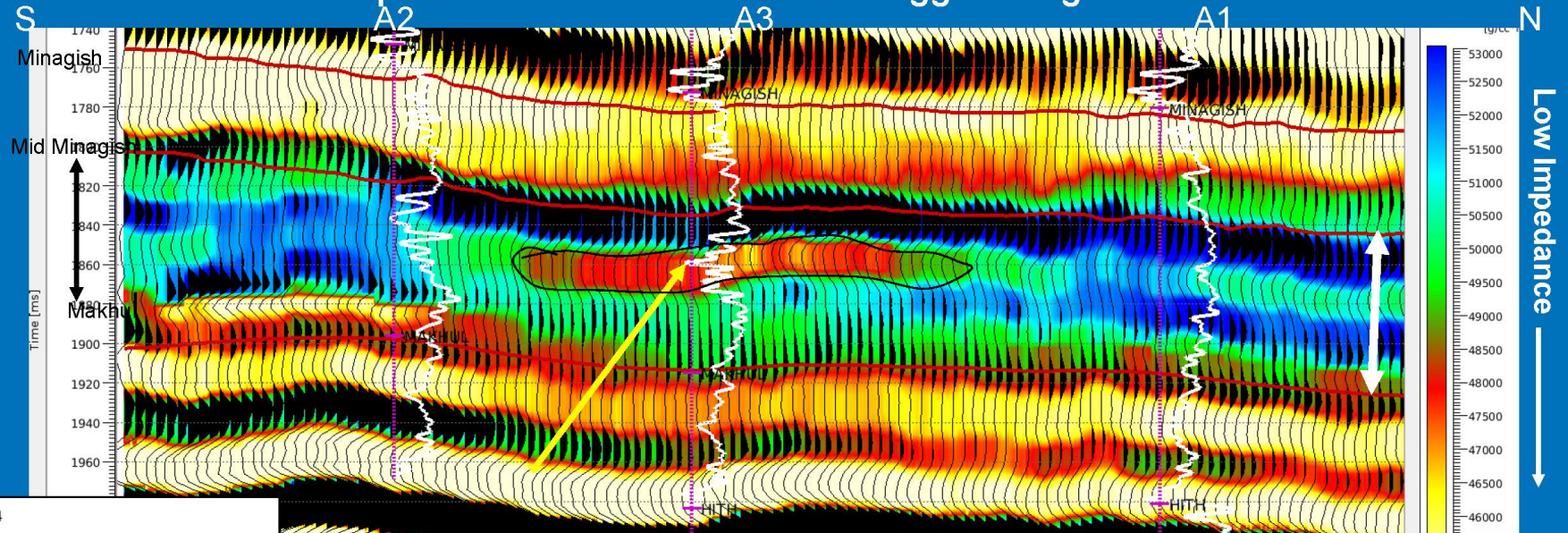
*(Presenter's notes continued on next slide)*

*(Presenter's notes continued from previous slide)*

- In the inversion study, Geophysical and Petrophysical data were combined through deterministic seismic inversion and an Acoustic Impedance volume was generated for the Minagish carbonate reservoir. In the inversion process, the low frequency component (0 to 10 Hz) was derived from well data and high frequency component (10 to 60 Hz) has been obtained from seismic data.

# Results

## Absolute Impedance section with seismic wiggle along KA field



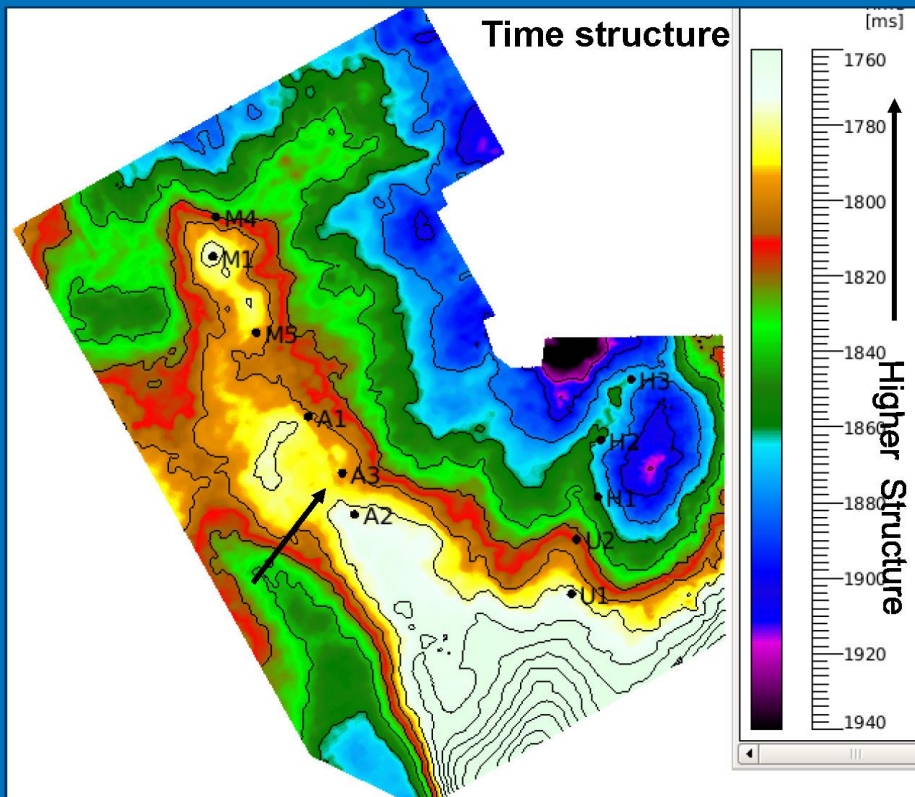
Absolute Impedance with seismic wiggle, focusing Middle Minagish level, overlaid with P impedance logs

Low Impedance (Higher porosity ) expected to be developed around the well A3

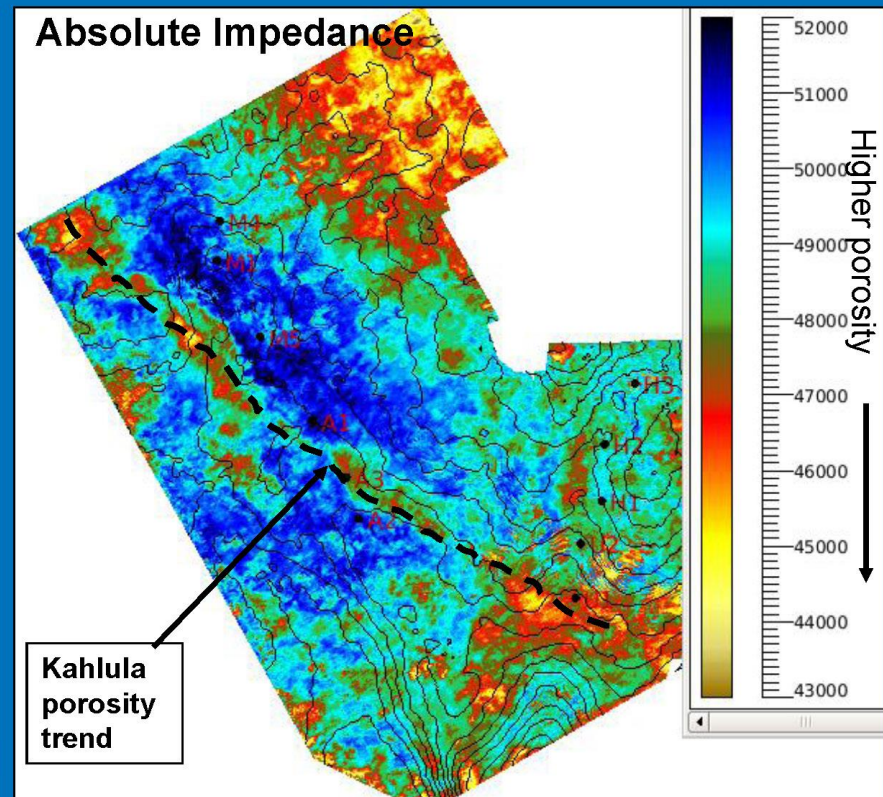
Presenter's notes: From the inversion output volume, absolute P-Impedance section has been shown along the drilled wells. Bright color indicates lower P-Impedance means better porosity.



## Results



Time structure at Middle Minagish level

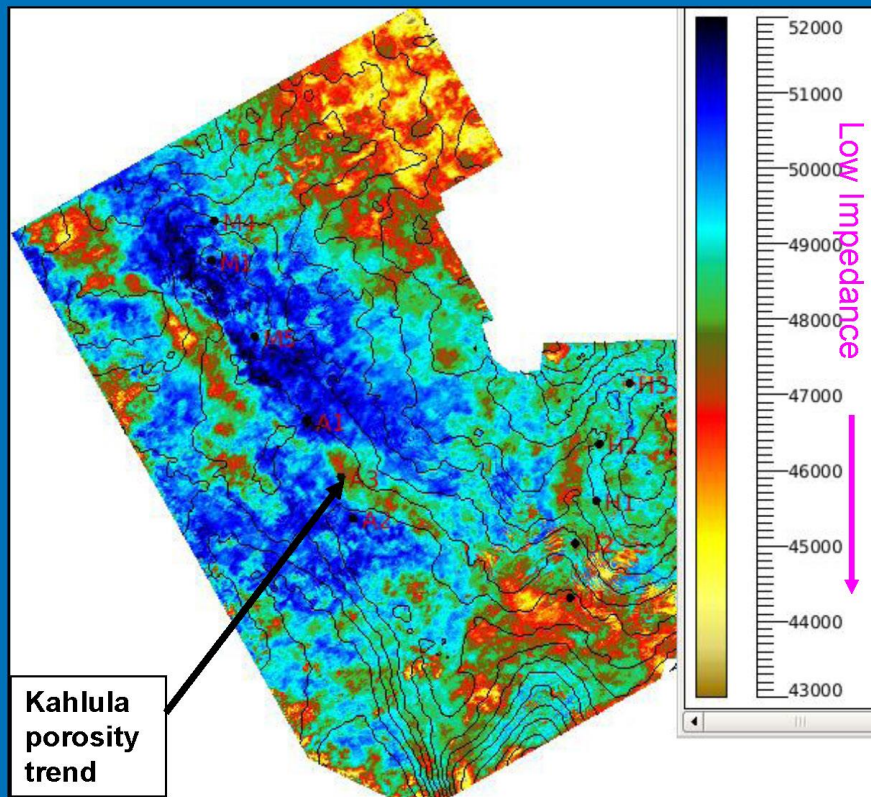


Absolute Impedance at Middle Minagish level

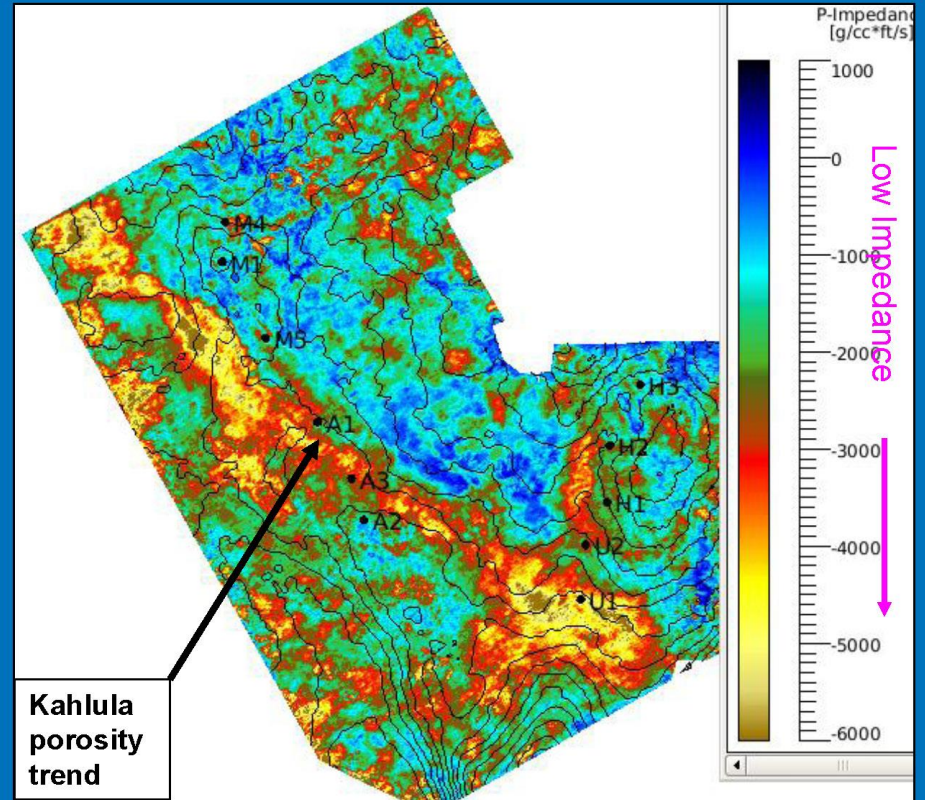
Presenter's notes: In the left, TWT time map of Minagish level has been shown. In the right, Absolute Impedance map corresponding to Mid Minagish level has been shown. Impedance map shows NW-SE low Impedance trend and it is equivalent to higher porosity trend, we will call it Kahlula porosity trend.



## Comparison Total & Banpass Impedance



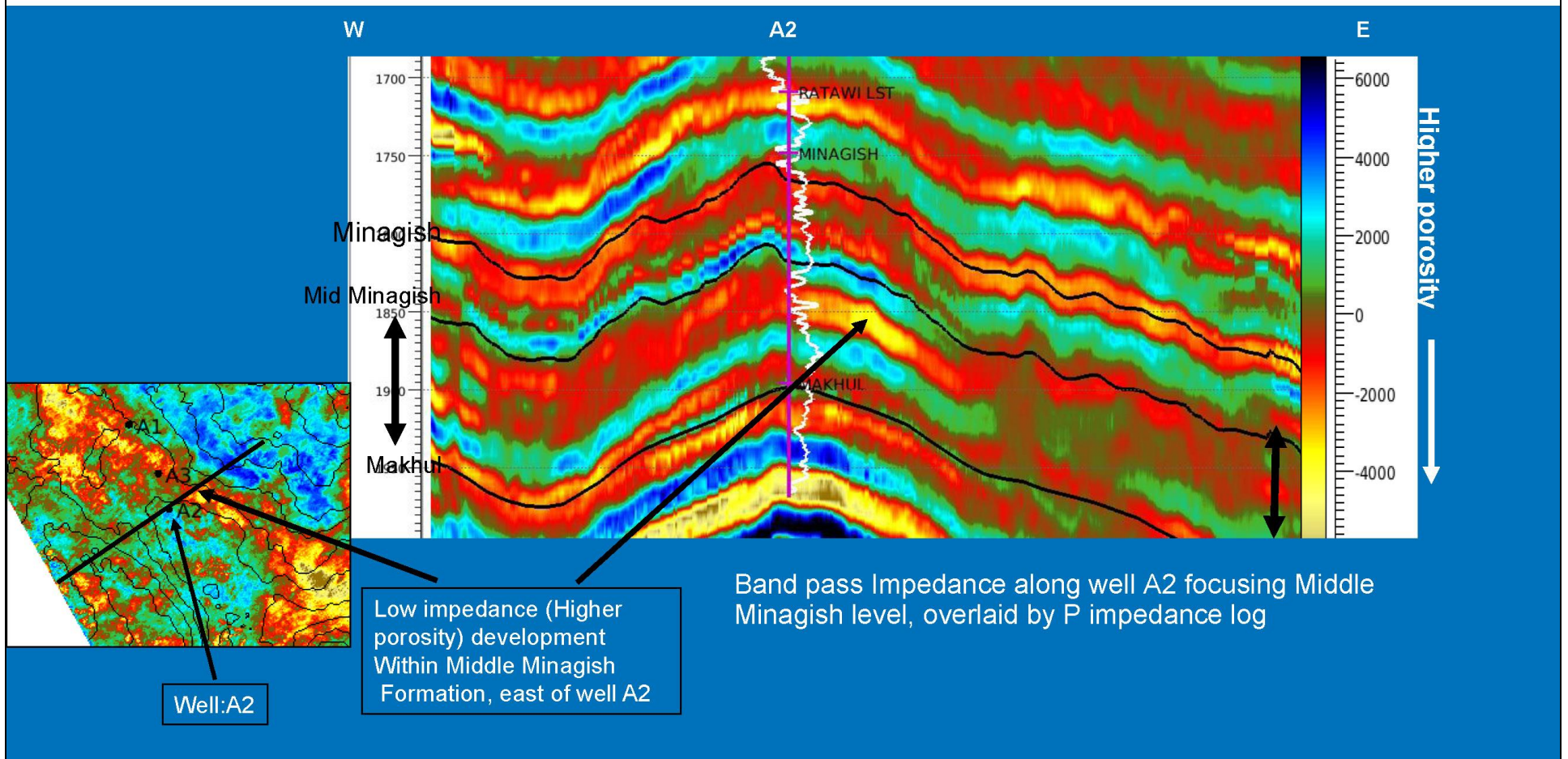
**Absolute Impedance Middle Minagish level**



**Bandpass Impedance at Middle Minagish level**

Presenter's notes: Let us compare the Absolute P-Impedance and band pass component of P-impedance. The low impedance trend observed in the left absolute impedance map is still more prominent in band pass impedance map. The wells drilled in the area are mostly for deeper level and the quality of the well logs at target level are not of excellent quality. So seismic derived band pass impedance has been given more importance in our further study instead of full bandwidth (absolute).

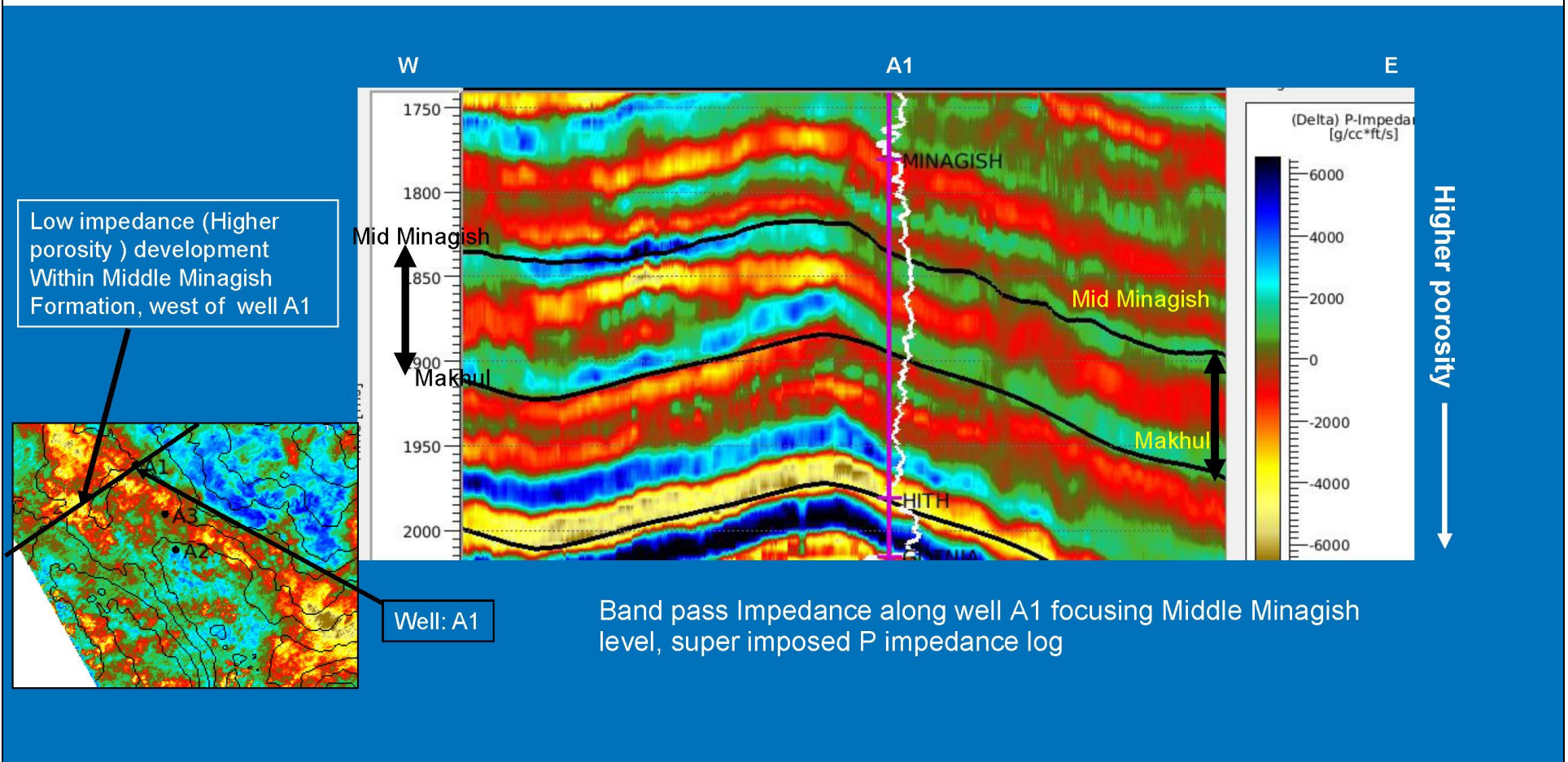
# Results



Presenter's notes: Now let us study the band pass impedance section around some of the drilled wells. The well A2 has been drilled almost at the structural high, but the Impedance section shows better porosity is developed away from the structural high



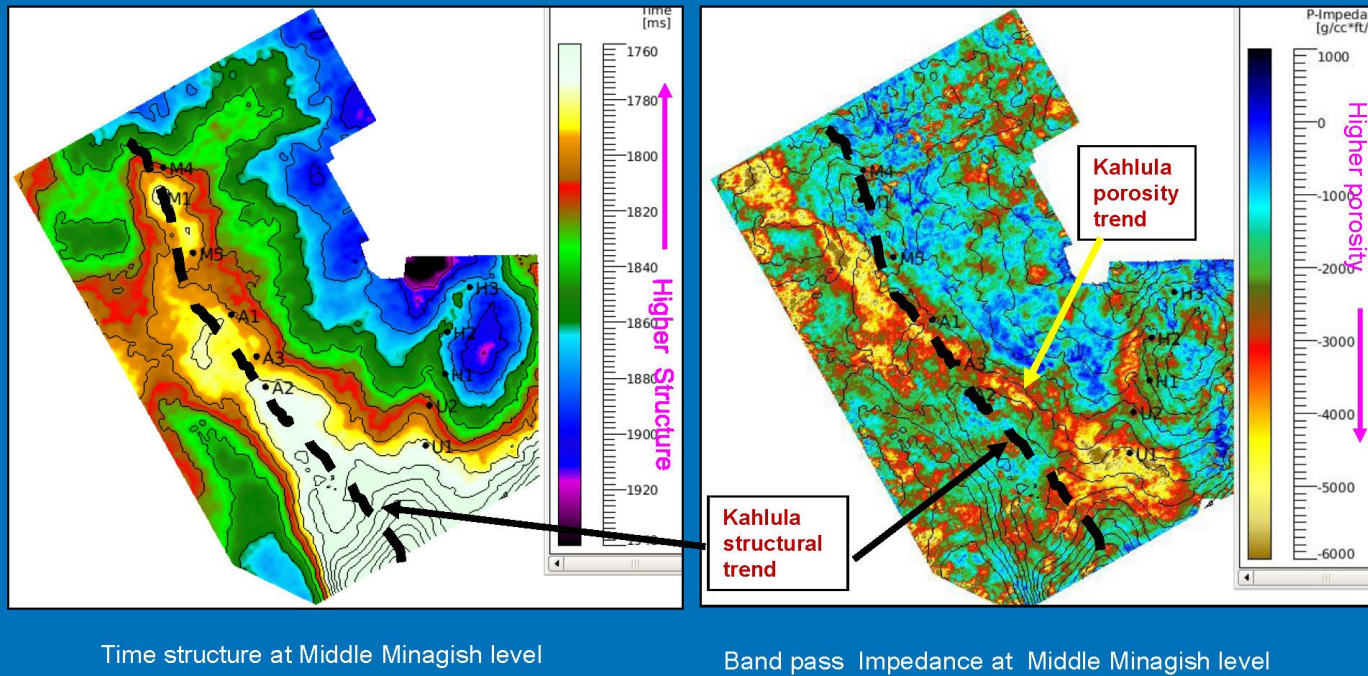
# Results



Presenter's notes: Again, the impedance section along the well A1 shows, better porosity is expected away from structural highest part. Now let us study the band pass impedance section around some of the drilled wells. The well A2 has been drilled almost at the structural high, but the Impedance section shows better porosity is developed away from the structural high.

## Interpretation

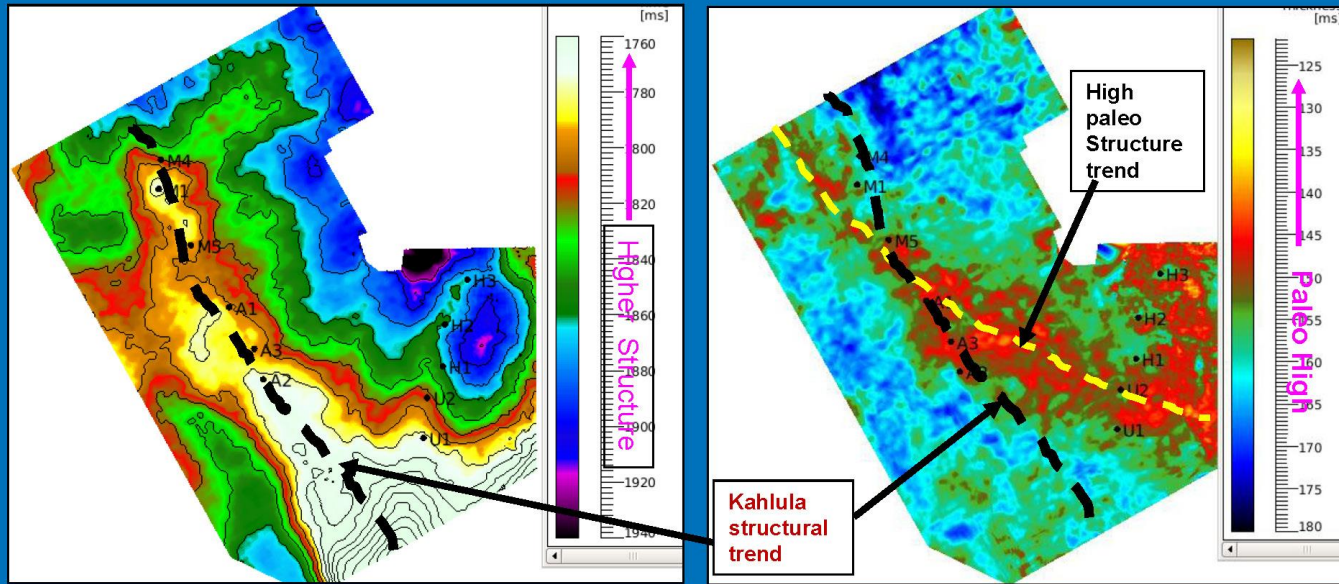
### Comparison of structural porosity trend



Presenter's notes: It is the comparison of structural trend and porosity trend. The left map time structure map and the right-side map is the band pass impedance map showing the Kahlula porosity trend. Let us superimpose the Kahlula structural trend over the porosity trend map. It is showing the present-day structural trend does not align with the porosity trend.

## Interpretation

Comparison of present day Time structure & Paleo-structure map of Minagish



Present day Time structure

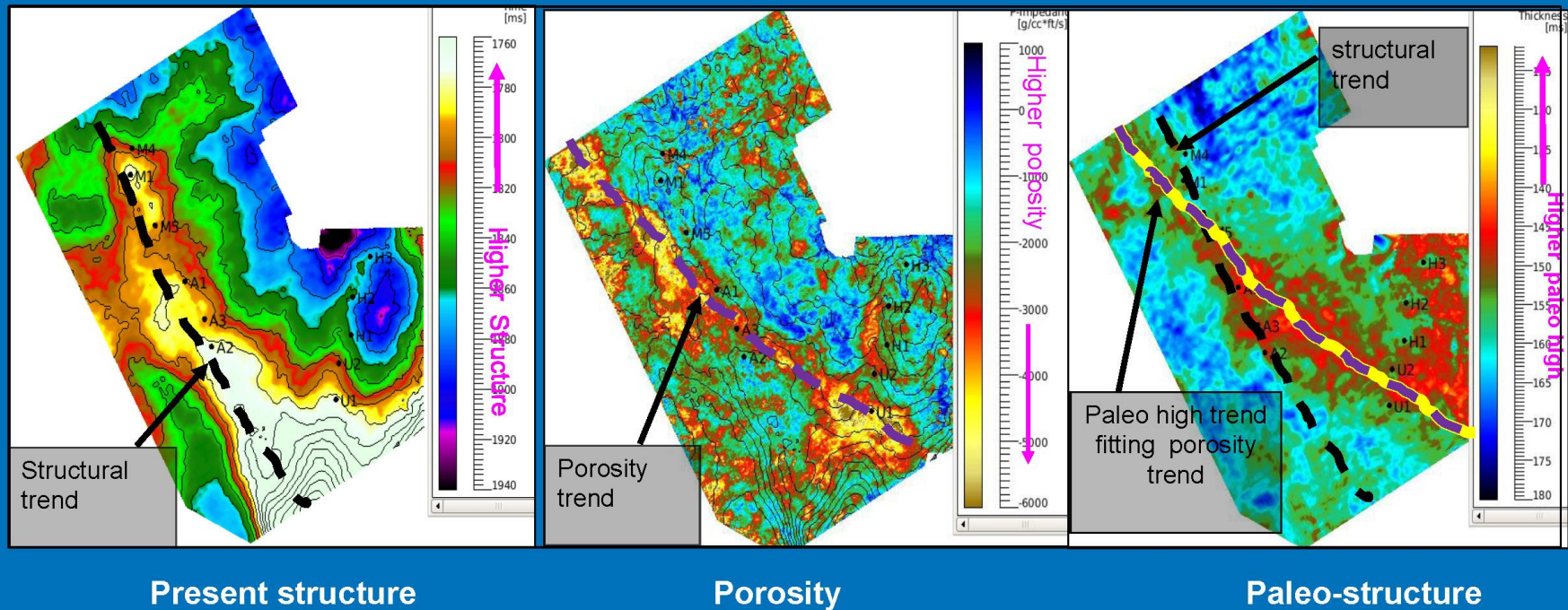
Paleo-structure map

Presenter's notes: Now we have carried out some paleo-structural analysis. The analysis was done by carefully selecting key horizons and generating isopach maps to get a paleo-structure maps. The paleo-structure map for Minagish level has been created by creating isopach map between Hith and Minagish level. Left side map is time structure map and right-side map is paleo-structure map. If we superimpose the Kahlula structural trend over the paleo-structural trend map. It shows the present-day structural trend does not align with paleo-structural trend.



## Interpretation

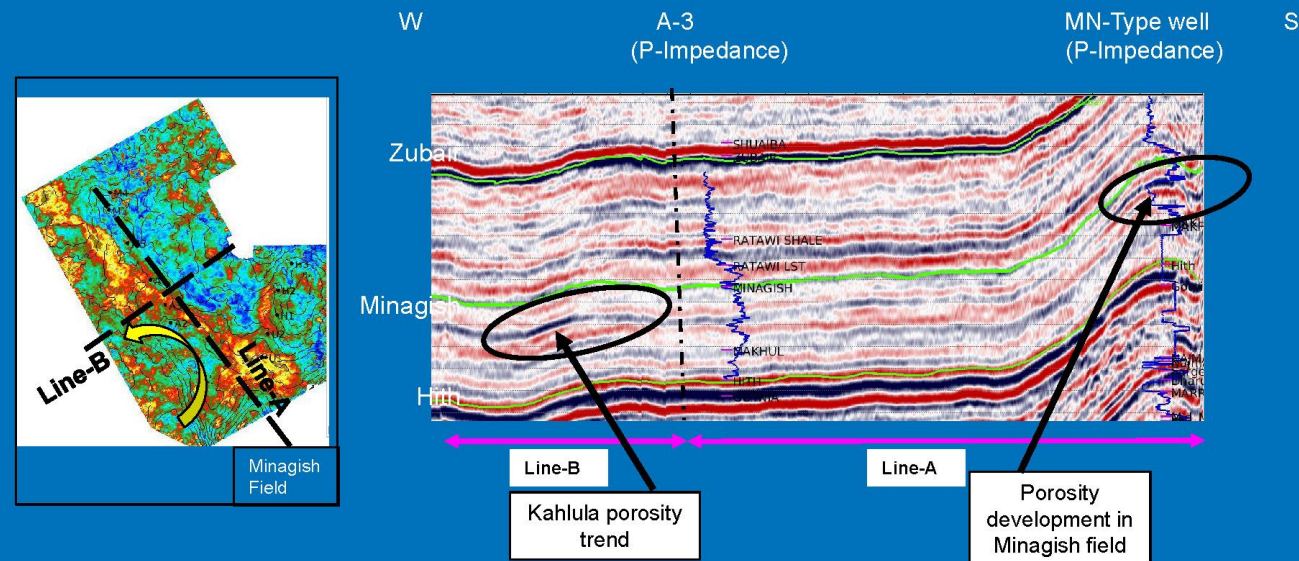
### Comparison of present structure, porosity trend and paleo-structure



Presenter's notes: It is the comparison of present-day structure, porosity and paleo-structure. Here trends have been marked as per map. At first, superimpose present structural trend over paleo-trend. Next, superimpose porosity trend over paleo-high trend. We have noticed Porosity trend is exactly fitting paleo-high trend. It shows that the best porosity has been developed over paleo-structural high axis. For future exploration in the area, paleo-high axis needs to be considered in addition to present day structure.

# Interpretation

Seismic Section connecting Minagish field with seismic line-A & line-B

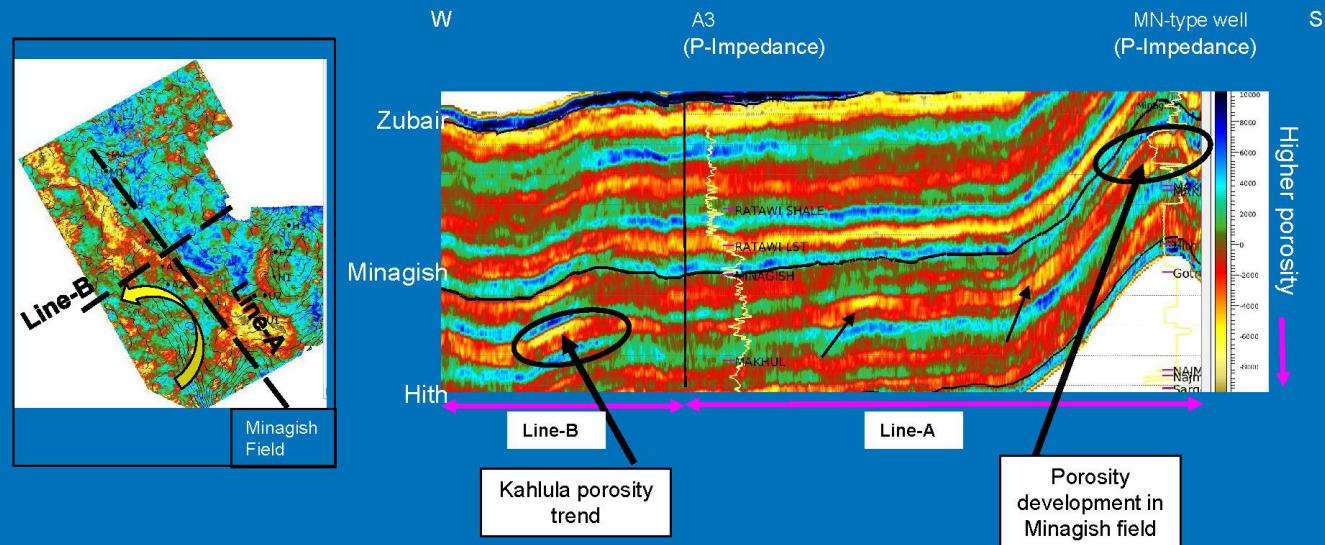


- Middle Minagish Porosity development in Minagish field shows with high amplitude in seismic.
- Middle Minagish Kahlula porosity trend also shows with high amplitude seismic.

Presenter's notes: Minagish field has been connected with Kahlula porosity trend using regional seismic lines Line-A and Line-B. In Minagish field, Mn type well shows a big lowering of P-Impedance and the seismic shows the development of strong peak (black color). Again around the Kahlula trend the seismic shows the development of similar strong peak at Minagish level. It is re-confirming the presence Kahlula porosity trend.

# Interpretation

Bandpass Impedance Section connecting Minagish field  
shows Middle Minagish porosity development



- Middle Minagish Kahlula porosity trend as it is observed in 3-D study, is validated in 2-D seismic lines connecting Minagish field.

Presenter's notes: It is the Band pass P-Impedance section, connecting Minagish field with Kahlula trend. In Minagish field, it shows low P-Impedance development (bright color). Again, around the Kahlula trend it shows the development of similar low P-Impedance at Minagish level. It is re-confirming the presence Kahlula porosity trend.



# Conclusions

- 1. Seismic inversion and porosity modeling study is found to be a useful tool to delineate reservoir facies.*
- 2. Paleo-structural analysis has helped in understanding that better developed porosity zone is associated with the paleo high axis of that level.*
- 3. The integrated workflow has led to the identification exploration opportunities with a higher degree of confidence*