Unconventional Petrophysical Workflows for Evaluation of Shale Plays: A Case Study from Kuwait*

Ahmed Rabie[1], Riyasat Husain[1], and Abdulaziz Mohamed Al-Fares[1]

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[1]Kuwait Oil Company, Ahmadi, Kuwait

Abstract

Our exploratory efforts focus on evaluating the unconventional shale-oil/gas resources of Kuwait (Figure 1). This paper aims to present a clear-cut petrophysical workflow interpreting different datasets for identification and evaluation of shale gas reservoirs.

The Najmah Formation of Upper Jurassic Oxfordian age has been tested and proven a source rock as well as a gas, condensate and volatile oil producer. Prospectivity analysis indicates the Najmah organic-rich shale member is an unconventional reservoir (Figure 2).

The Najmah Formation is a laminated black, organic-rich (kerogen), stained argillaceous mudstone and calcareous shale with high Type II kerogen. It lies in the late thermal maturity oil-condensate window, with high oil saturations, low matrix porosity, Ultra-low permeability, naturally fractured and is highly over pressured in nature. It also has a lack of seal and trapping mechanisms, no oil/gas migration, absence of gas/water contact and acts as natural gas/oil source rock and reservoir.

The Upper Jurassic Najmah organic-rich shale is overlain by impermeable Salt and Anhydrite of the Gotnia and Hith formations and underlain by the Middle Jurassic Sargelu Limestone and Dharuma Shale formations. The Najmah formation has two main members: U. Najmah clean Limestone member and L. Najmah organic-rich Shale member (Figure 3).

Discussion

The core matrix porosity ranged from to 4-6% (Figure 4) and the CMR free fluid porosity ranged from 4-5 pu (Figure 5) in the Najmah Shale member. The triple-combo was porosity 20%. The results of the test highlighted the problem of how to identify the productive zones in these unconventional reservoirs. Production tests in some intervals yielded no hydrocarbons.

The major challenge for the organic rich reservoirs is the evaluation of actual porosity, which appears very high due to the presence of the organic carbon/kerogen. We corrected the matrix density and then calculated the total organic carbon (TOC) and kerogen volume. We also factored in the mineralogy, rock composition, and accurate clay content. Then we determined the corrected porosity for the kerogen effect.

Our recommendation is to acquire a complete suite of advanced logs including ECS, CMR, UBI, OBMI and core examination to properly evaluate the lithology, porosity, fractures and to determine kerogen-corrected effective porosity in organic rich formations.

Summary

An integrated workflow approach involving interpretation of different datasets has evolved for identification and evaluation of shale gas reservoirs. The workflow includes the integration of open-hole well log data, core porosity, core grain density, core TOC, XRD data, ECS and CMR logs and calculate TOC from logs (Figure 6).

A study was initiated to identify a correlation that approximates the effective formation porosity as measured by the core. A new petrophysical model is being built by incorporating CMR, ECS, and core data to solve the complex lithology and to estimate reservoir volumes more confidently. Porosity and lithology model, core and CMR porosity determination, water saturation model, petrophysical interpretation, evaluate the Total Organic Carbon and corrected porosity from kerogen effect.

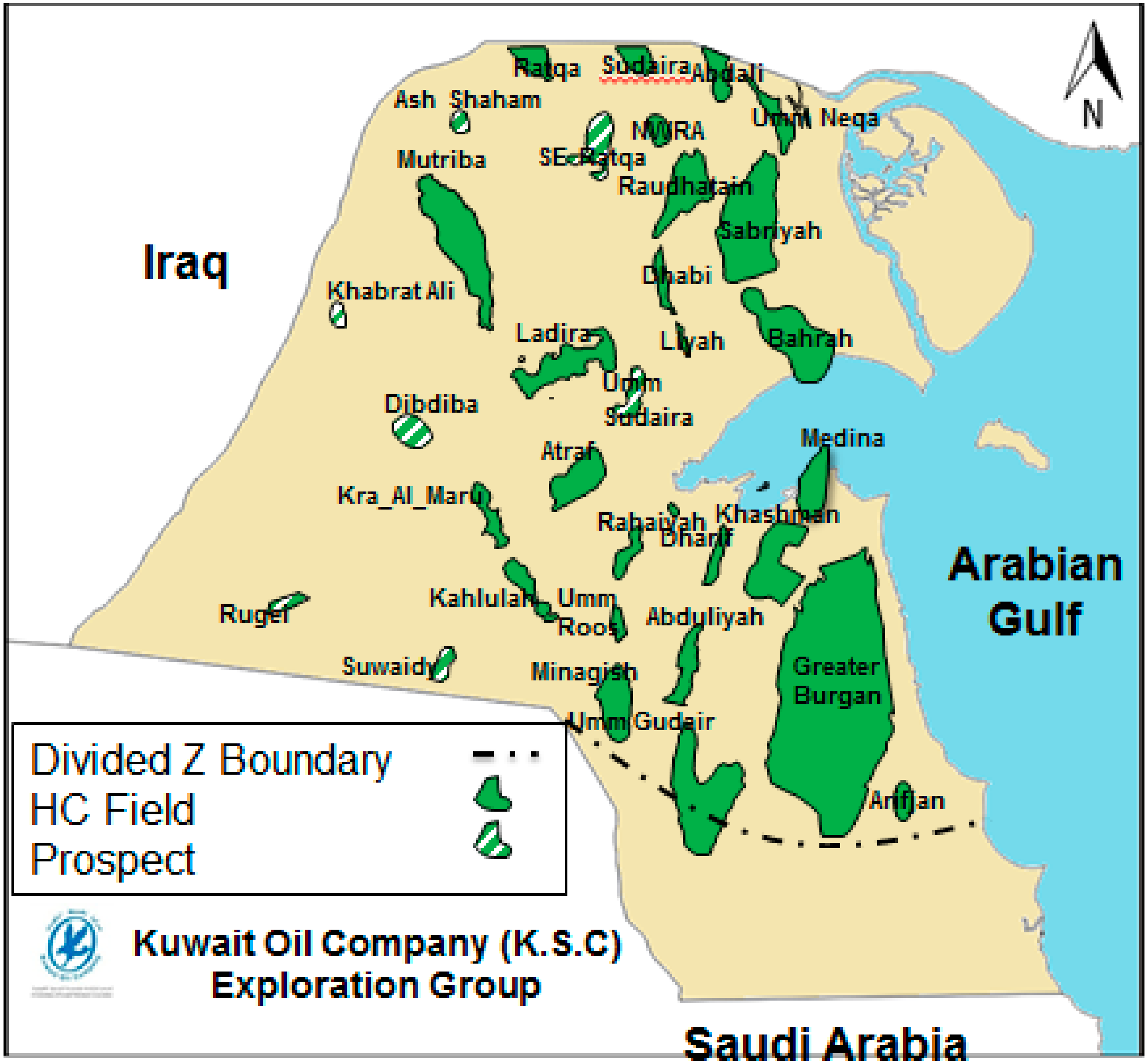

Figure 1. Kuwait field map.

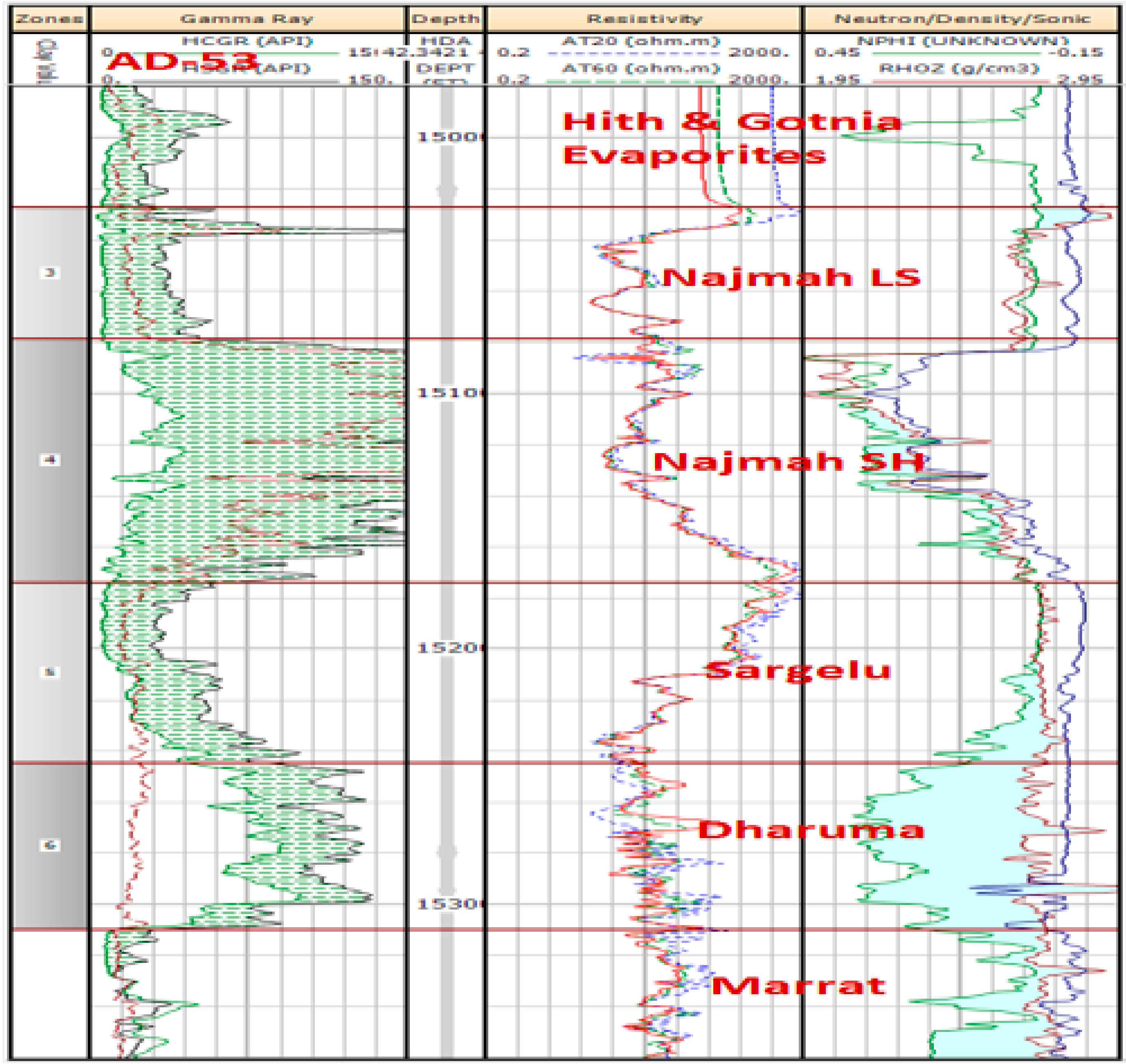

Figure 2. Log character of the Najmah Shale.

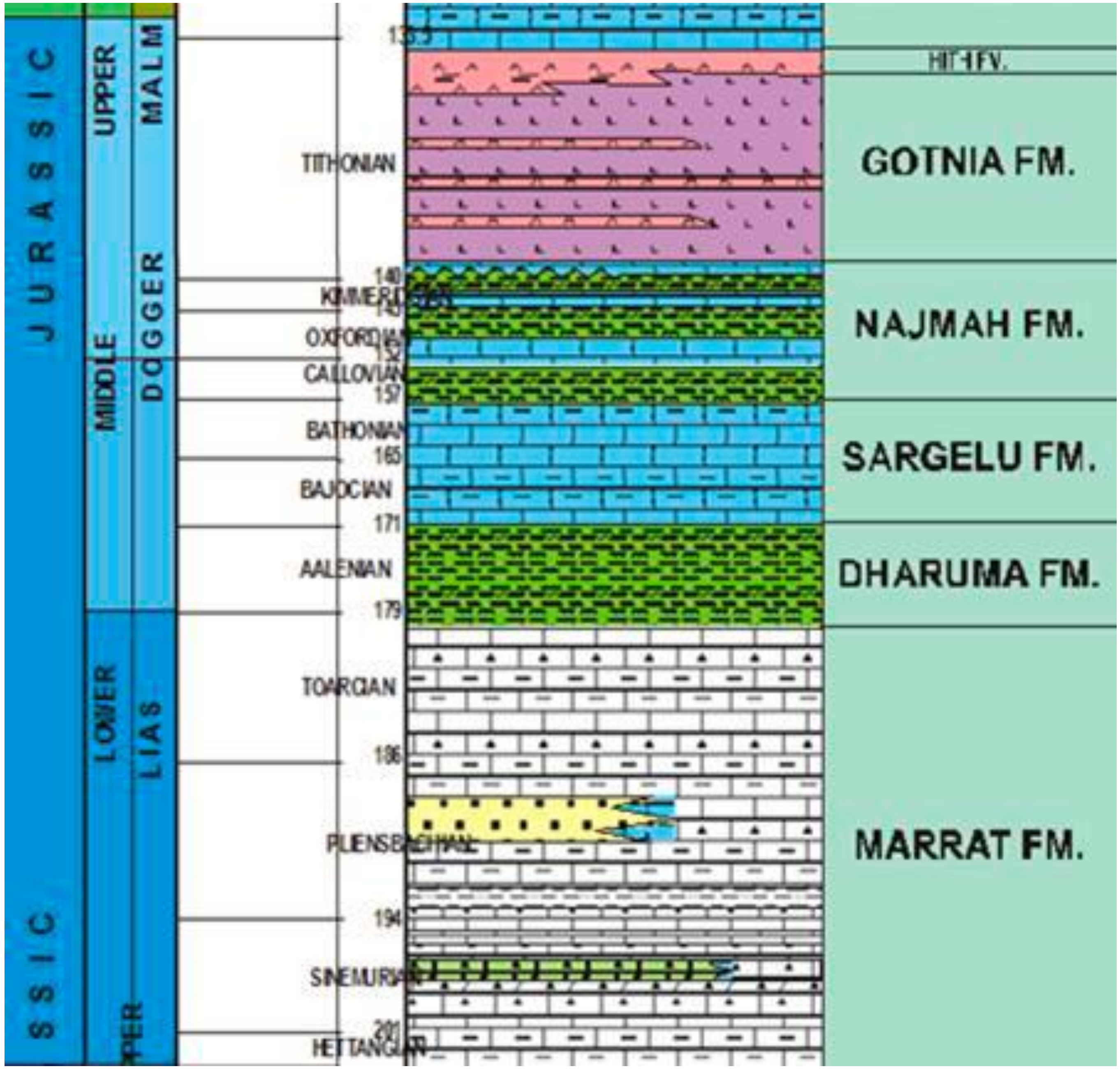

Figure 3. Study area stratigraphic column.

CORE ANALYSIS RESULTS

Sample No.	Depth (ft)	Ø(He) (800psi) %	Permeability(800 psi) K(inf) (Hz) md	Permeability(800 psi) Kair (Hz) md	Grain Density gm/cc	Description
CORE # 7 DEPTH INTERVAL(13022.00 - 13066.00 FEET)						
213	13022	3.6	2.07	2.11	2.65	Ls, mud wk, st, gry, vf - f gr, intxln, hd,styl, frac
223	13063	8.3	0.02	0.04	2.69	Ls, mud wk, st, gry, vf - f gr, intxln, hd,styl
CORE # 8 DEPTH INTERVAL(13066.00 - 13118.00 FEET)						
224	13066	2.1	<0.01	<0.01	2.64	Ls, mud wk, st, gry, vf - f gr, intxln, hd,styl
225	13070	7.9	0.007	0.01	2.67	Ls, mud wk, st, gry, vf - f gr, intxln, hd,styl
227	13078	4.2	2.5	2.7	2.57	Ls, mud wk, st, gry, vf - f gr, intxln, hd,styl, lam
228	13082	4.2	<0.01	<0.01	2.60	Ls, mud wk, st, bu, vf - f gr, intxln, hd,styl
229	13086	5.5	0.02	0.03	2.68	Ls, mud wk, st, bu, vf - f gr, intxln, hd,styl
230	13090	3.3	<0.01	<0.01	2.62	Ls, mud wk, st, gry, vf - f gr, intxln, hd,styl, lam
231	13094	1.8	<0.01	<0.01	2.66	Ls, mud wk, st, bu, vf - f gr, intxln, hd
232	13098	1.9	<0.01	<0.01	2.66	Ls, mud wk, st, bu, vf - f gr, intxln, hd
233	13102	8.3	0.05	0.07	2.70	Ls, mud wk, st, bu, vf - f gr, intxln, hd
234	13106	3.2	<0.01	<0.01	2.62	Ls, mud wk, st, gry, vf - f gr, intxln, hd
236	13114	3.9	<0.01	<0.01	2.68	Ls, mud wk, st, bu, vf - f gr, intxln, hd
237	13118	3.1	<0.01	<0.01	2.68	Ls, mud wk, st, bu, vf - f gr, intxln, hd
CORE # DEPTH INTERVAL(13129.00 - 13181.00 FEET)						
240	13129	6.3	0.79	0.97	2.68	Ls, mud wk, st, bu, vf - f gr, intxln, hd, styl
241	13133	2.2	<0.01	<0.01	2.66	Ls, mud wk, st, bu, vf - f gr, intxln, hd
242	13137	6.9	0.15	0.23	2.44	Ls, mud wk, st, bu, vf - f gr, intxln, hd,styl(Carb)
243	13141	6.7	0.17	0.21	2.34	Ls, mud wk, st, bu, vf - f gr, intxln, hd,styl(Carb)
245	13149	5.1	0.09	0.12	2.51	Ls, mud wk, st, bu, vf - f gr, intxln, hd,styl(Carb)
246	13153	3.1	<0.01	<0.01	2.67	Ls, mud wk, st, bu, vf - f gr, intxln, hd,styl
247	13157	3.6	0.03	0.04	2.60	Ls, mud wk, st, gry, vf - f gr, intxln, hd
248	13161	5.8	0.04	0.07	2.50	Ls, mud wk, st, bu, vf - f gr, intxln, hd,styl
249	13165	5.2	0.39	0.41	2.63	Ls, mud wk, st, gry, vf - f gr, intxln, hd

Figure 4. Core porosity ranged up to 4-6%.

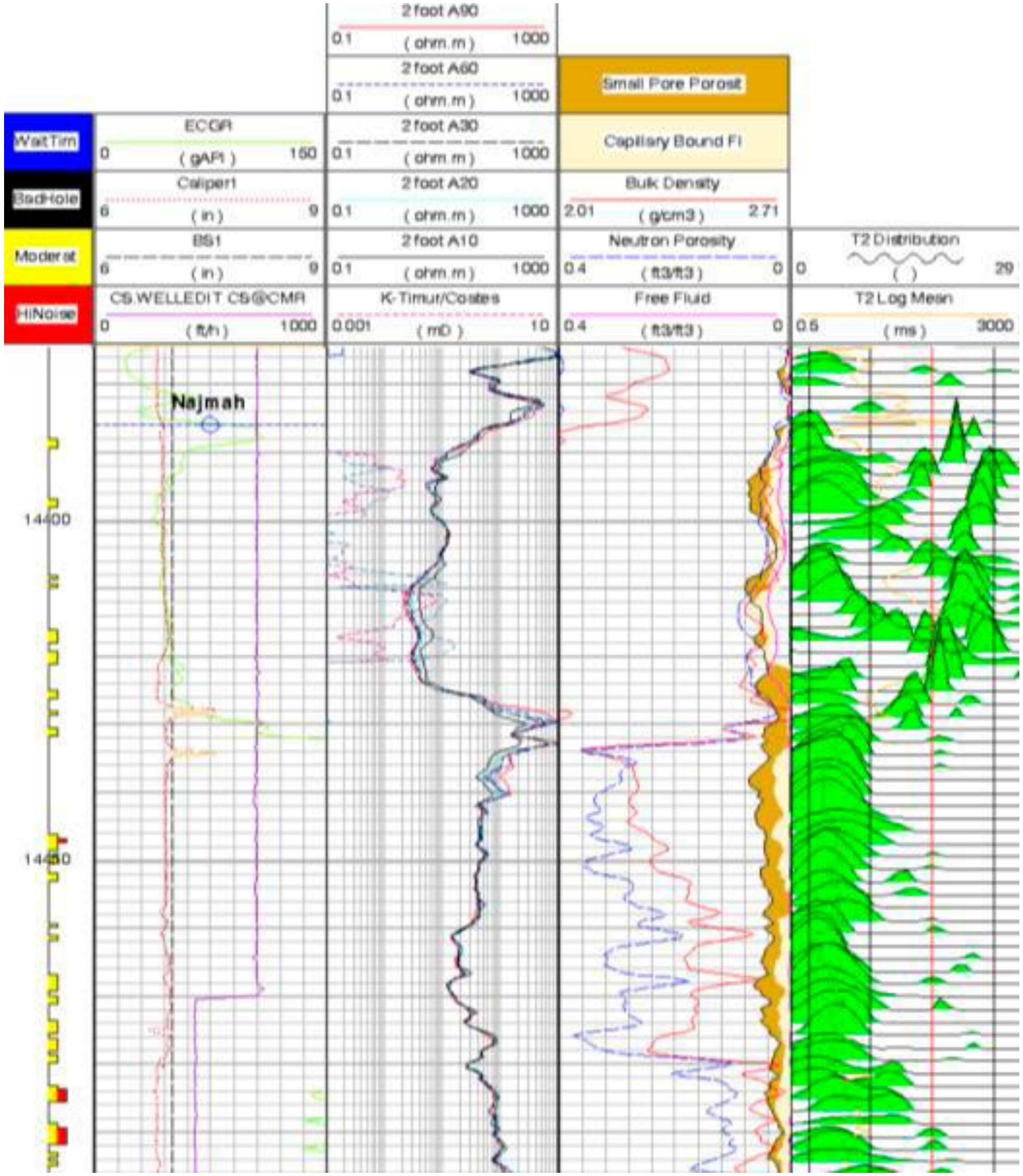

Figure 5. CMR FF porosity up to 4-5%.

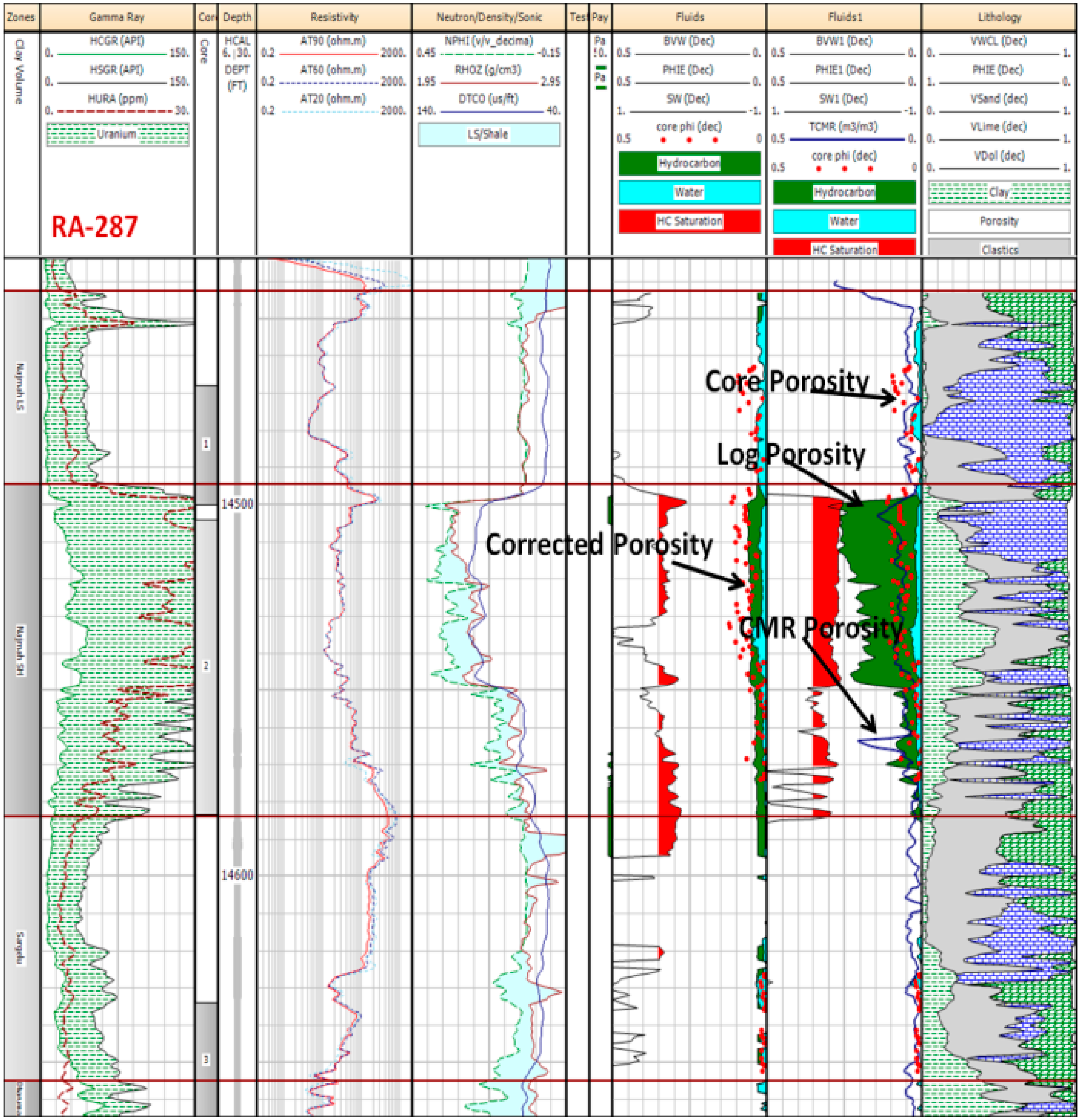

Figure 6. Najmah Shale member with log interpretation before and after kerogen effect porosity correction. It validated the corrected porosity to core porosity and CMR porosity.