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Mineralogical characterization using geochemical logging Spectroscopy of dry elements in the Cambrian reservoir West of Hassi Messaoud field

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Thème

Caractérisation minéralogique par la Spectroscopie de la digraphie géochimique des éléments secs dans le réservoir Cambrien Ouest de Hassi Messaoud

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Abstract:

A new application of Halliburton’s technology, the GEM: Geochemical Elemental Analysis Tool; provide accurate understanding of the elemental composition and mineralogical facies, of the formation which is essential factors in reservoir characterization and completion decision. Just in a single logging pass (all the -tools- for nuclear measurements run in single string).

The Mineralogical and sedimentological information for the Cambrian formation in the basin of Hassi Messaoud, play principal role in the accurate modeling of the reservoir.

This study aim to evaluate the subsurface elemental capture and inelastic spectroscopy analysis (high technology) of the different electrical facies (mineralogical facies and traces elements), sedimentary characteristics and reservoir clay minerals, which help in reservoir characterization and evaluation.

Keywords**:** Mineralogy, Facies, Spectroscopy, Dry elements, Cambrian reservoir, Clay mineral, High technology.

Résumé :

La nouvelle application de Halliburton Technologie, le GEM : Outil d'Analyse Elémentaire Géochimique fournisse une compréhension précise de la composition élémentaire et facies minéralogique, qui sont des facteurs essentiels dans la caractérisation des réservoirs et de la décision de complétion des puits juste dans une seul enregistrement diagraphique.

L’information minéralogique et sédimentlogique pour la formation Cambrienne dans le bassin de Hassi Messaoud, jouent un rôle principal dans la modélisation précise du réservoir.

L’objective de Cette étude est l’évaluation de la spectroscopie : capture et inélastique des éléments de subsurface des différents faciès électriques (faciès minéralogiques et des éléments en traces) ; les caractéristiques sédimentologiques et les minéraux argileux de réservoirs qui aident à l’évaluation et caractérisation du réservoir.

Mots-clés: Minéralogie, Faciès, sédimentologie, Spectroscopie, éléments secs, réservoir, Cambrien, Minéraux argileux, la haute technologie.

ملخص:

تستخدم شركة هاليبرتون تكلونوجيا جديدة يطلق عليها إسم: الجوهرة (GEM) وهي عبارة عن أداة للتحليل الجيوكميائي للعناصر البنيوية) هذه الأدات تمكن من الحصول على بيانات ومعلومات في غاية الأهمية في شوط واحد من التسجيلات الكهربائية

تلعب المعلومات في الجانب المعدني و الرسوبي لتكوينات عصر الكمبري في حوض حاسي مسعود ، دورا رئيسيا في وضع نماذج مضاهات دقيقة للمكمن أو الخزان.

تهدف هذه الدراسة إلى تقييم وتفسير التحليل الطيفي للطاقة (والناتجة عن الأشعة الممتصة و المنعكسة (الغير مرنة) من طرف العناصر البنيوية بعد القصف الإشعاعي النووي للتكوين الرسوبي) في السحنات الكهربائية (السحنة المعدنية و العناصر البنيوية النادرة) ، الخصائص الرسوبية و المعادن الطينية المميزة للخزان المدروس وهذا مما يساعد في توصيف و تقييم المكامن البترولية.

الكلمات المفتاح: المعادن ، السحنات ، الترسبات ، التحليل الطيفي ، والعناصر الجافة ، خزان الكمبري والمعادن الطينية ، التكنولوجيا العالي

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General introduction

In this memory we will look to one of the high technology used for geochemical logging spectroscopy in subsurface reservoir where the most of operator company use it now day in the detailed reservoir characterization.

The objective of this study is the evaluation and quantify of the Mineralogical elements Capture and spectroscopy measurement using the wireline geochemical logging techniques which it a key in the mineralogical, sedimentological characterization and those play principal steps in complete reservoir modeling and evaluation.

The material used to perform this study based essentially on:

- Wirline logging data (electrical data measurement) recorded in candidate well.
- Sophisticated processing and analysis system.
- Powerful workstation handle this system.
- Specialized geoscientist interpreter.

This thesis is divided on four chapters:

- ✓ First, Geological scope for the studied field.
- ✓ Second, Wireline logging spectroscopy theory & Measurement tool.
- ✓ Thired, Field data acquisition, Re-processing, Interpretation workflow & Quality control.
- ✓ Fourth, Mineralogical facies analysis & Sedimentological characterization.

Chapter One

Geological Scope

1.1. Geographical situation

Hassi Messaoud field is located 800 km southeast of Algiers, between the meridians 5°30 6°00 and the parallels 31°00 and 32°00N (Fig. 1.1). It is 350km from the Algero-Tunisian frontier and 80 km East of Ouargla.

Hassi Messaoud field is considered as the largest oil field in the Triassic province. Due to its size and its reserves, it is the largest Algerian oilfield and the area is around 2200 Km^2. It is limited to:

- NW by the deposit of Ouargla, Guellala, Benkahla and Haoud Berkaoui.
- SW by the deposit of el Gassi, Zotti and El Agreb.
- SE by the deposit of Rhoude-El-Baguel and Mesdar.
- East by the deposit of Ghadames.

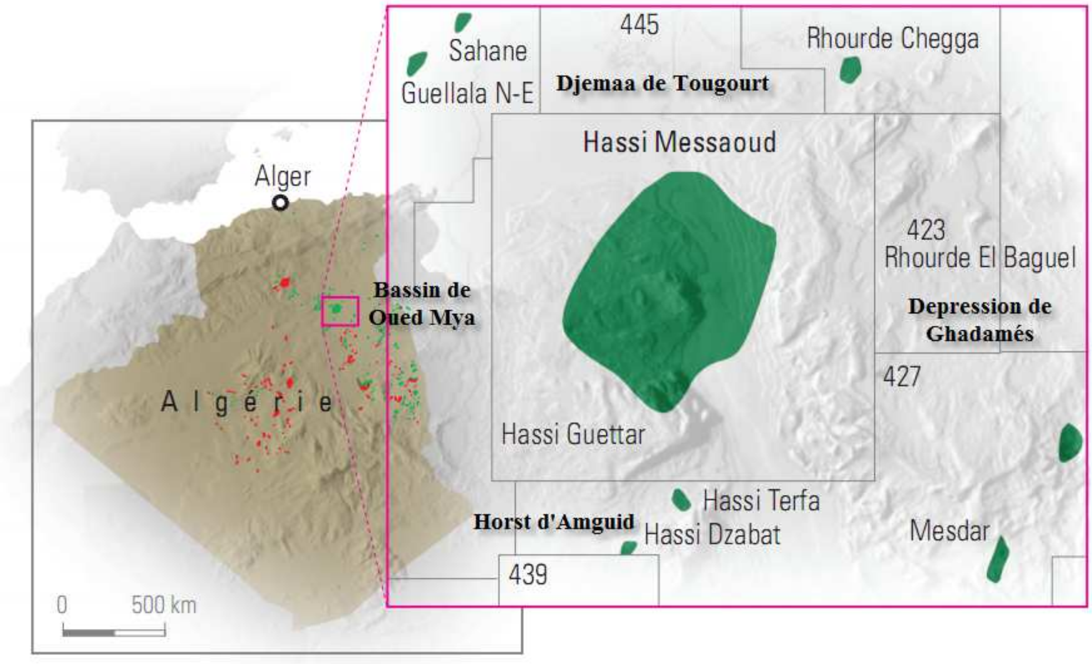


Fig. 1.1: Location map of the Hassi Messaoud field, (Wec, 2007).

1.2. Geological context

1.2.1. Stratigraphical aspect

The Hassi Messaoud field is as wide mole, which an important part of the Paleozoic stratigraphic series is absent, removing any witnesses of geological history for 230 million years (Fig. 1.2).

1.2.1.1. The Crystalline Basement:

It was observed in wells MD2 at 3658m and OM81 at 3533m, and it has been described as a porphyritic granite pink and altered at the top.

1.2.1.2. Infracambrian:

It is the oldest lithologic unit encountered by the well OMG47 at a depth of 4092 m; it consists of red argillaceous sandstone.

1.2.1.3. Paleozoic:

The Paleozoic formations are unconformably overlie the basement; it is the Panafricain unconformity. From the top to the bottom, we distinguish:

A. Cambrian:

Essentially consists of heterogeneous sandstone, fine to very coarse interspersed by argillaceous siltstones laminae, micaceous. Average thickness is 590m.

B. Ordovician:

Regionally, the Ordovician is composed of several lithological units with incomplete series. For Hassi Messaoud field, from the top to the bottom we have only four (4) lithological units:

1) Alternance Zone:

The average thickness is 20 meters. An irregular alternance of black silty clay fine isometric quartzitic sandstone and abundance of Tigillites and some Lingulidae (Ordovician-Actual), the mineral fraction comprises of glauconite and siderite.

2) Clay of El Gassi:

The average thickness is about 50 meters. This formation consists of silty clay, soft with black and green color, rarely red. This clay can be carbonated or glauconieuse containing a fauna (Graptolites) indicating a marine depositional environment. This is mostly encountered on the peripheral areas of the field.

3) El Atchane Sandstone:

The average thickness varies from 12 to 25 meters. This formation consists of fine to very fine sandstone grey-beige to dark grey. This sandstone can be clay with several silty clay laminae.

4) Hamra Quartzite:

The average thickness varies from 12 to 25 meters. It is fine quartzite sandstone, silty light grey to beige with rare intercalated silty clay, micaceous and soft of glauconite, anhydrite and several Tigillites.

1.2.1..4. Mesozoic:

A. Trias:

It unconformably overlies the Cambrian in the center and the Ordovician to the flanks of the structure. It is a very diverse set result from the transgression with lagoon marine character accompanied by with eruptive lava. It is divided into four (4) units:

1) Eruptive Triassic:

The thickness varies between 0 and 92 meters. Locally we find eruptive lava interbedded with Trias sandstone, this indicates the presence of several volcanic outpourings intercalated into the clastic facies. These flows have often occurred in Hercynian valleys.

2) Triassic Shaly sandstone:

Its average thickness is 35 meters. It is the first deposit of the Paleozoic relief and divided into several units, which differ according to the lithology and logging responses. Found, locally on eruptive lava filling the deep Hercynian erosion valleys:

- ✓ ***Upper sandstone*****:** fine sandstone with argillaceous cement.
- ✓ ***Lower sandstone:*** consists of sandstone with fine to medium abundant argillaceous cement.

3) Shaly Trias:

The average thickness is 113 meters. It consists of dolomitic clays or silty intercalated with brown-red salt bench.

4) Salifere Trias:

The average thickness is 340 meters. Plays the role of cap rock, it consists of massif salt bench present, at the top, intercalations of anhydrite and clay benches slightly silty and dolomitic, it consists of three (3) units:

- ***Salifere Trias « 3 » or « ST3 »: thickness is 202 meters.***

At the base of salifere Trias, it consists of massif salt bench present at the top intercalations of anhydrite and clay benches slightly silty and dolomitic.

- ***Salifere Trias « 2 » or « ST2 »: thickness is 189 meters***

It consists of massif salt bench with intercalations of anhydrite and gypsiferous clay.

- ***Salifere Trias « 1 » or « ST1 »: thickness is 46 meters***

Consists of salts with predominance of anhydrite and dolomitic clay.

B. Jurassic:

The average thickness is 844 meters. It is a group of clayey sandstone with an intercalation of limestone at the top (Malm) and alternance of lagoon and marine facies at the base (Dogger and Lias).

1) Lias:

The average thickness is 300 meters. The transition from Trias to Lias is characterized by a dolomitic marls zone known as "Horizon B" which is a seismic landmark. The Lias is divided into five (5) distinct levels intercalated between them through the entire thickness:

- ***Dolomitic Lias «DL3 »:***

Thickness of 31 m, it consists of grey marl with grey dolomite stringers.

- ***Salifere Lias «SL2 »:***

Thickness of 58 m, it consists of translucent salts and brown red clay laminae.

- ***Dolomitic Lias «DL2 »:***

Thickness of 55 m, it consists of intercalation of massive dolomite benches fine grained, greyish with slightly grey dolomitic marl laminae.

- ***Salifere Lias «SL1 »:***

With an average thickness of 90 m, it consists of brown clays with salt and anhydrite white stringers.

- ***Dolomitic Lias «DL1 »:***

Thickness of 66m, it consists of dolomite benches and anhydrite with clay and limestone laminae.

2) Dogger:

The average thickness is 320 meters. The Dogger is divided into two (2) formations, the Dogger lagoon at the base and clayey Dogger at the top.

✓ ***Dogger Lagooner:***

It is represented by a Lagoon series at the base essentially anhydrite and dolomite about 210m thick.

✓ ***Dogger Clays :***

Thickness of 107 m, it consists of soft clay, silty with fine sandstone laminae and argillaceous carbonate cement.

3) Malm:

The average thickness is 226 meters. It is characterized by clay deposits and marl with interbedded limestone and dolomite benches accompanied by anhydrite traces.

C. Cretaceous:

The average thickness is 1624 meters. It consists of seven stages, from top to bottom are:

1) Neocomian:

The average thickness is 182 meters. It has two levels, at the base is sandy consists of sandstone and some clay laminae, at the top argillaceous represented by clays with several limestone and dolomite intercalations.

2) Barrémian:

The average thickness is 280 meters. It is consist of fine to medium carbonate sandstone big amount of anhydrite, alternating with sandy clay and dolomitic levels.

3) Aptian:

The average thickness is 25 meters. It is represented by two dolomitic layers covers clay intervals. The Aptian-Barremian boundary coincides with the limestone-dolomite bar, which represent good seismic marker.

4) Albian:

The average thickness is 350 meters. Consists of sandstone and sand fine with intercalations of silty clay, it includes a huge aquifer.

5) Cenomanian:

The average thickness is 145 meters. Alternance of anhydrite and brown red clay, grey marls and dolomites. The Cenomanian-Albian boundary coincides with the passage of evaporate sequences with more sandstone sets of the Albian.

6) Turonian:

The average thickness ranging from 70 to 120 meters. Alternance of argillaceous limestone, dolomitic limestone and chalky limestone; at the top appear limestone benches. The Turonian represents salt water table.

7) Senonian:

The average thickness is 230 meters.

- ✓ ***Senonien lagooner:***

Thickness of 350m, at the lower part consists of salt massive benches salts with clay intercalation and interbedded of anhydrite, clays and dolomite at the top.

- ✓ ***Senonien carbonate:***

Thickness of 110m, it is characterized by a succession of clayey dolomitic limestone bench and benches of anhydrite with gypsum dolomite laminae.

1.2.1..5. Cenozoic:

The average thickness is 360 meters. It consists of dolomitic limestone in the Eocene and coarse sand in Mio-Pliocene.

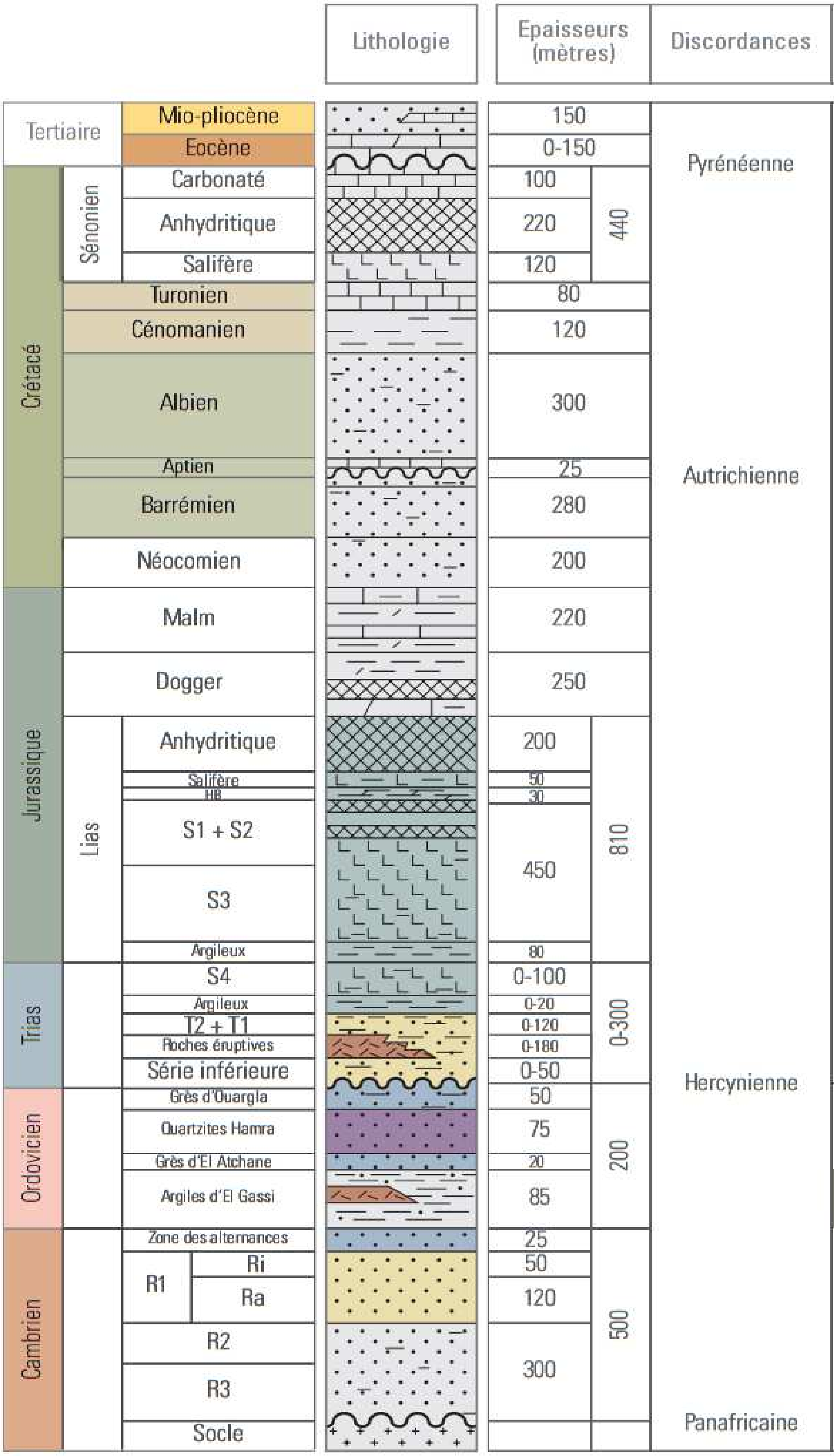


Fig. 1.2: Stratigraphic startotype column of the Hassi Messaoud field (Wec, 2007).

1.2.2. Cambrian litho-stratigraphic characterization

A. Cambrian

It is the main reservoir of Hassi Messaoud divided into four distinct sedimentary groups (LHOMER 1966). (Fig. 1.3).
This division is based on petrographic, petrophysical and wireline logging criteria. We notice from bottom to top:

1) Lithozone R3:

The average thickness is 370 meters. The lithozone R3 based on the Infracambrian or directly on the basement. It consists of feldspathic sandstone and micaceous medium grain very coarse conglomeratic at the base, abundant argillaceous cement, with ferruginous sandstone and silty clay. It has no petroleum benefits because of its weak matrix properties and its deep position above the water table.

2) Lithozone R2:

The average thickness is 100 meters. The lithozone R2 consists of sandstone medium to coarse micaceous poorly sorted with abundant argillaceous cement and interbedded siltstones. Stratifications are often oblique.

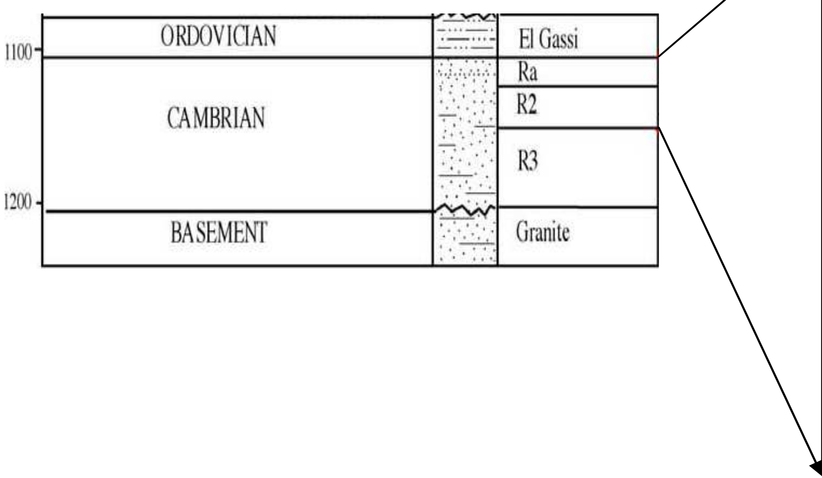
3) Lithozone Ra:

The average thickness is 125 meters. It consists of quartzite sandstone to sandstone anisometric medium to coarse, with argillaceous and siliceous cement with several centimetric and decimetric siltstone laminae.
The stratifications are often oblique to cross-bedding, sometimes horizontal. The Tigillites are present in the upper part of the serie. The "Ra" has been weathered at the center of the field. According to LHOMER 1966, The "Ra" is divided into three granulometric classes:

- ✓ The lower coarse zone or lower Ra: divided into drains[1]: « D1, ID, D2 » they are coarse sandstone, poorly sorted with oblique stratifications.
- ✓ The fine middle zone: drain « D3 », it consists of fine grained materials to very fine, well sorted with abundance of Tigillites and interbedded of clay and siltstone.
- ✓ The upper coarse zone: corresponds to the lithozone « D4 », it consists almost the same sandstone as the lower "Ra".

4) Lithozone Ri (Cambro-ordovician):

The average thickness is 42 meters. The passage between the Cambrian and Ordovician is not well marked, so we can distinguish a transition zone called "Cambro-Ordovician." It consists of quartzitic sandstone isometric fine well sorted glauconitic with argillaceous and siliceous cement with abundance of Tigillites. This zone considered as secondary reservoir.



Reservoir	Drain	Thickness
Ri	D5	42 m
RA	D4	42 m
	D3	21 m
	D2	25 m
	ID	24 m
	D1	32 m
R2	R2ab	36 m

Fig. 1.3: Detailed column of the four productive zones R3, R2, Ra, Ri of the Cambrian of Hassi Messaoud field (Balducchiand Pommier, 1971).

1.2.3. Structural aspect and geodynamic evolution

Hassi Messaoud field structure presented as vast flat anticlinal dome with general direction North-Est – South-West (Fig. 1.4).

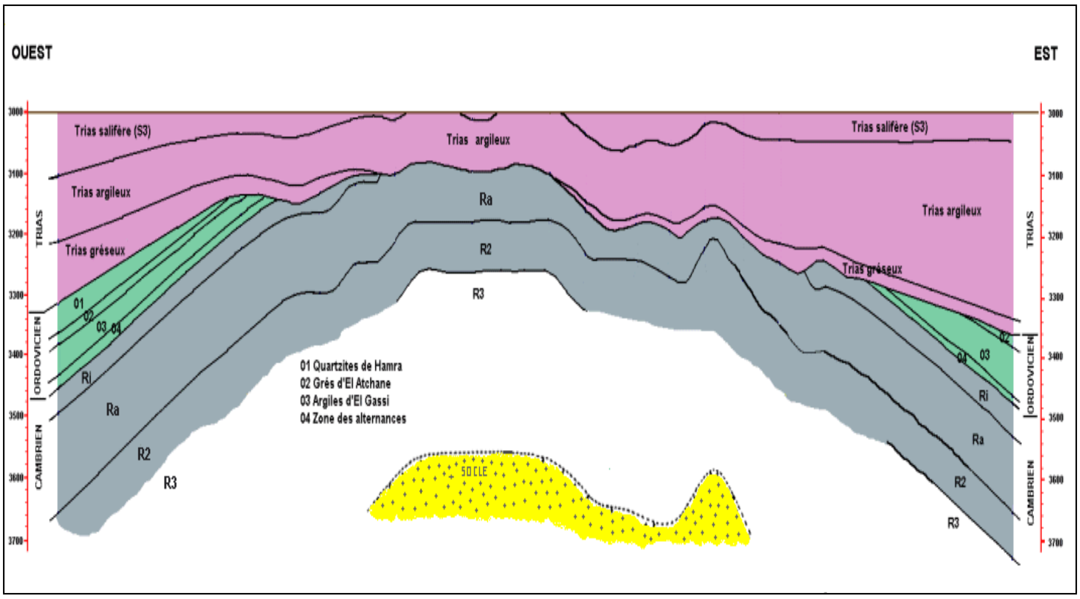


Fig. 1.4: Structure of Hassi Messaoud field

Two type of accidents affecting the reservoir (Fig. 1.5).

- Submeridian Faults with direction North-North-Est–South-South-West and other Faults are perpendicular direction North-West – South-Est. This is related to the horst and graben tectonic structure.
- Faults without movement that had a great effect on the reservoir fracturation.

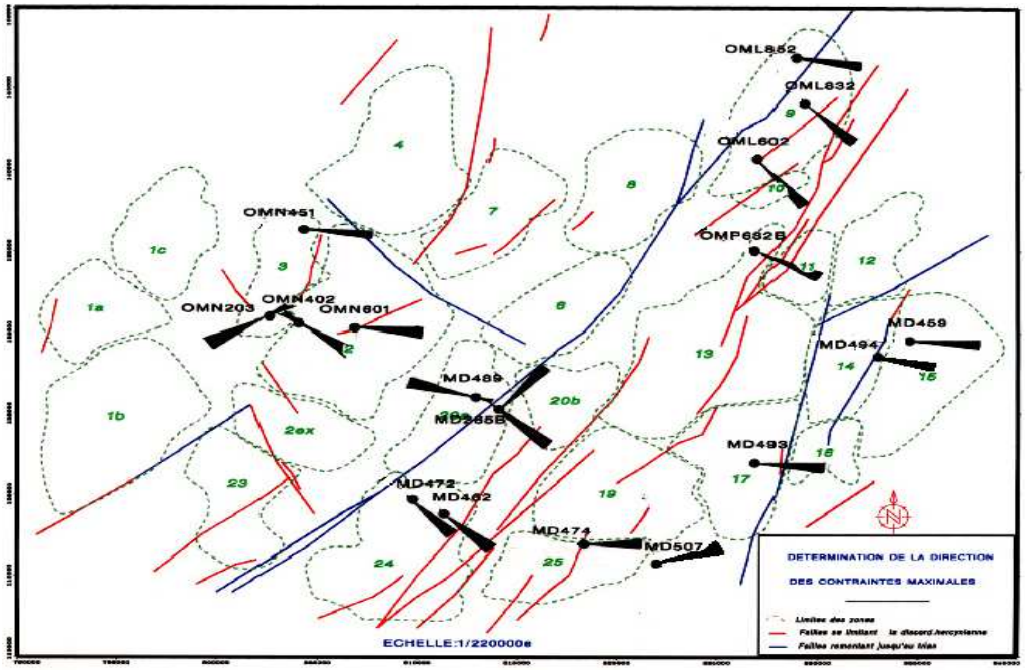


Fig. 1.5: Hassi Messaoud field structural map (Sonatrach, 2005)

1.2.3.1. Anti-Triassic Structuration:

a) Panafricain phase:

It is compressive phase with East – West direction due to continental collision between rigid west African craton and the Est African plastic unit (Bertrand et R.Caby 1978), induce faulty tectonic represented by a fault grid of directions Northeast Southwest, Northwest - Southeast followed by a severe erosion that has settled to the Cambrian leading to the formation of pediplanation surface called infra-Tassilian surface. This peneplain marks the beginning of Sahara cratonic history.

Extensional movements of Northwest – Southeast directions take place in Cambro Ordovician, which are the source of the stretching of continental crust followed by tectonic subsidence, and thermal afterwards; this distension causes a normal fault (Northeast Southwest) pre-existent in the basement, accompanied by volcanism.

b) Eo-Caledonian precocious phase or Taconic phase:

Dated about 500 MY, this phase occurs at the end of anisometric reservoir deposit "Ra". It is substantiate by the transgression of isometric sandstone on the flanks of the structure result the beginning of a structuration at this period.
Later there was a belated Cambrian structuration with erosion and faults already initiate as northeast -southwest direction with volcanic lava.

c) Caledonian major phase:

Dated about 400 MY, this phase is known regionally by the absence of Devonian and Carboniferous sediments in all El Biod area.
This phase has started in the Silurian or lower Devonian (MASA - NICOL -1971).

d) Hercynian phase:

Dated about 225 to 250 MY, this phase is with significant importance at the regional level and particularly in Hassi Messaoud. It is responsible for the overall direction southwest northeast of actual structure; this is proved by the Triassic sandstone series with 150m additional thickness between the flanks and the top of reservoir, which played the role of filling series.

1.1.3.2. Post-Triassic Structuration:

Post-triasic structurations are relatively less compared to the Paleozoic.
The deformations are followed by a tilt about 200 meters between the South-east and North-west of the gisement, this is the compressive tectonic phase with Nord-Nord-West –South-South-East direction which generated the elevation of the North-East part.

a) Autrichian phase:

Dated about 100MY, this phase is almost synchronous with the development of hydrocarbons as geochemical studies of the region showing that the implementation of hydrocarbons began in the early Jurassic and continued through the Cretaceous, geochemical studies of the region showing that the introduction of hydrocarbons began in the early Jurassic and continued through the Cretaceous. It corresponds to an East-West shortening phase; the influence on the reservoir as follow:

- Accentuation of the structural closure.
- Dextral strike-slip along the Northeast-Southwest faults which the importance of these movements occurs at the fracturation.

b) Atlasic phase:

Age of Cretaceous to Eocene, this phase is compressive with NNE-SSW direction, resulting by local erosion of Eocene deposits and lack of the Miocene.
This phase is subsequent to the formation of hydrocarbons; It is probably the origin of permeability barriers due to shift of reservoir levels which promoted the creation of plugged fractures and therefore contribute the improvement of reservoir petrophysical characteristics.

Chapter Two

Wireline logging spectroscopy theory
&
Measurement tool

2.1. Physics principal

Geochemical logging was introduced over 30 years ago, starting with a wireline tool based on a pulsed-neutron generator (PNG) and a thallium-doped sodium iodide (NaI(Tl)) scintillation detector (Hertzog, 1980).

Transforming the spectra acquired by the tool into petrophysical quantities is an involved process. In brief, neutrons-induced- are emitted from the chemical source and produce gamma rays. The pulse height spectra of the detected gamma rays are recorded. Each spectrum is decomposed into a linear combination of standard spectra from individual elements (Fig. 2.1). The coefficients of the linear combination are converted to elemental weight fractions (dry or wet mode), which may be further analyzed to produce mineralogy.

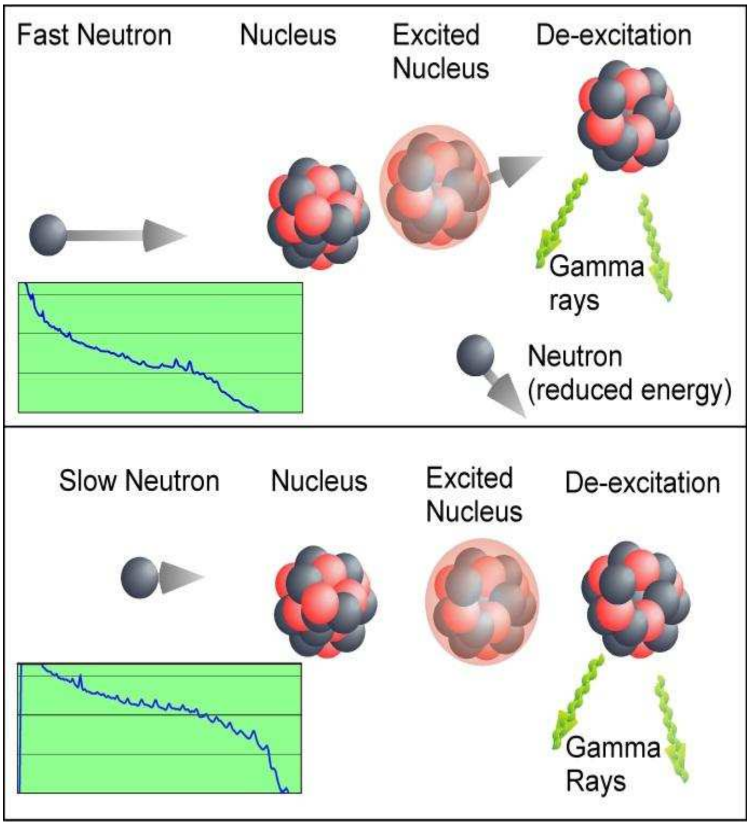


Fig. 2.1: Conceptual sketches of the two primary neutron gamma interactions in geochemical logging, showing a fast neutron undergoing inelastic scattering (top) and thermal neutron capture (bottom)

2.2. Tool description

GEM™(*) Elemental Analysis Tool (fig 2.2 & 2..3) offers quick, continue (the core give only punctual points for analyses) and precise evaluations of complex mineralogy using proven interpretation processes and integrated petrophysical analysis. A neutron-induced capture gamma ray spectroscopy logging system, it is designed to derive elemental contributions contained within the total measured gamma ray energy spectrum.

The GEM tool (one of the openhole / cased hole- spectroscopy tool measurements) can measure elemental yields that are important to mineralogical evaluations in open holes (or even cased hole) to accurately assess the reservoir and complete the well.

The logging software (for more details see the next chapter) calculates elemental concentration logs using an oxides closure methodology which can be used for quick-look or detailed mineralogical evaluations. These elemental concentrations can be used to identify geochemical stratigraphic correlations from well-to-well. Elemental concentrations can also be used to calculate matrix grain density and thermal neutron absorption (sigma) properties.

This tool uses a chemical source to promote wider application due to cost savings associated with its durability, shorter length, and simple usage requirements. The detector is enclosed in a flask with a eutectic heat sink to allow extended operation at downhole conditions. In addition, the software provides onsite (pre-processing) or remote visualizations of the resulting data quickly and accurately (Fig 2.3).

The elemental analysis tool(GEM) attachable cooling system and insulating flask allow the tool to run for long periods of time downhole in conditions up to 350 degrees F and 20,000 psi. Fewer trips downhole reduces operating costs and improves tool redeployment time (Fig 2.3).

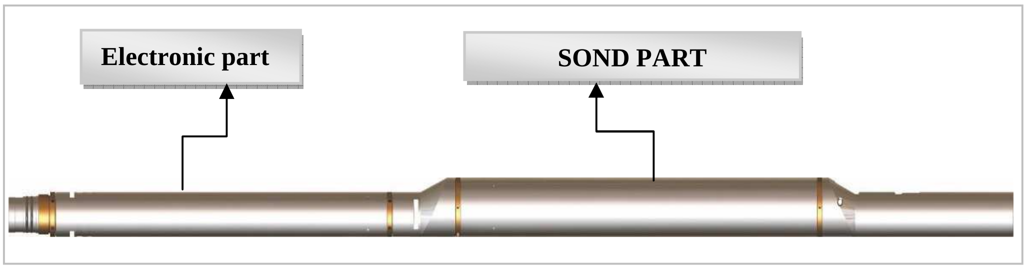
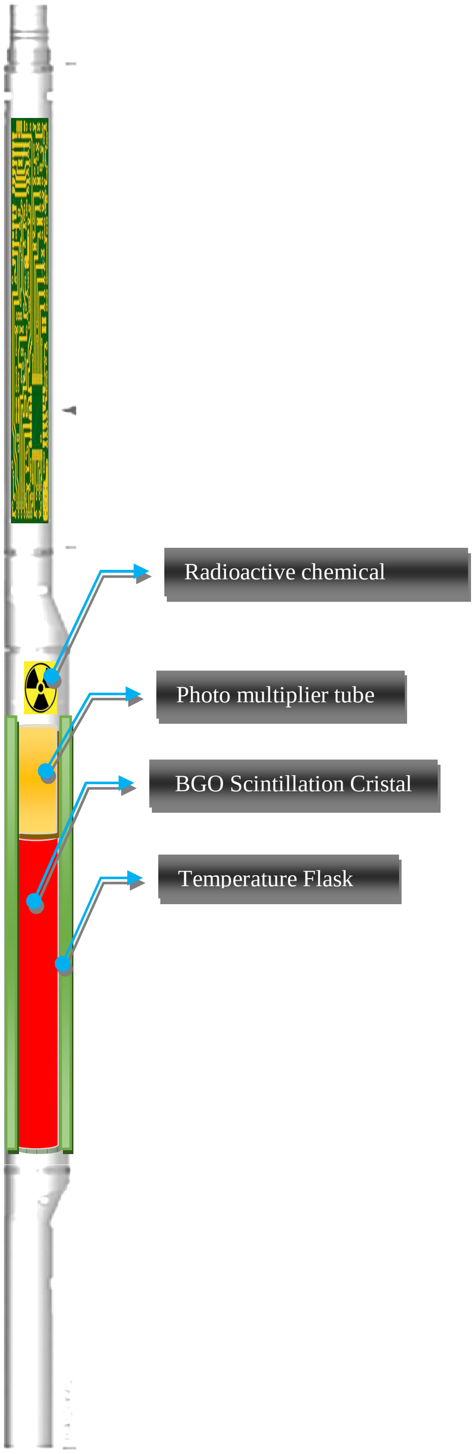


Fig. 2.2: GEM tool parts

*mark of Halliburton



Dimensions and Ratings			
Maximum Temperature	350°F (177°C)	**Maximum Pressure**	20,000 psi (137,895 Kpa)
Maximum OD	5 in. (12.70 cm)	**Minimum Hole**	6 in. (15.24 cm)
Length	9.64 ft (2.94 m)	**Maximum Hole**	20 in. (50.80 cm)
		Weight	300 lb (136 kg)—Approximately

Borehole Conditions	
Borehole Fluids	Salt ■ Fresh ■ Oil ■ Air ■
Recommended Logging Speed	15 ft/min (4.6 m/min)
Maximum Logging Speed	30 ft/min (9.1 m/min)
Tool Positioning	Centralized □ Eccentralized ■

Hardware Characteristics	
Source Type	15-Ci Americium-Beryllium
Sensor Type	One BGO Scintillation Counter
Sensor Spacings	Proprietary
Sampling Rate	4 samples/ft (10 samples/m)
Combinability	LOGIQ standard

Measurement	
Principle	Elemental yield based on neutron-induced capture gamma ray spectroscopy
Range of Measurement	800 keV to 9.5 MeV
Vertical Resolution (90%)	18 in. (45.72 cm)
Depth of Investigation (50%)	6 in. (15.24 cm)
Output Curves	Mg, Al, Si, S, K, Ca, Ti, Mn, Fe, and Gd elemental weight fractions from oxides closure

Statistical Precision*

	Mg (Wt. %)	Al (Wt. %)	Si (Wt. %)	S (Wt. %)	K (Wt. %)	Ca (Wt. %)	Ti (Wt. %)	Mn (Wt. %)	Fe (Wt. %)	Gd (ppm)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

* From stationary logs recorded at 15 ft/min simulated logging speed in Halliburton's Sonde Acceptance Wells
‡ Freshwater-filled 8-in. borehole
† 166 Kppm saltwater-filled 8-in. borehole

Calibration	
Primary	None
Wellsite Verifier	Stainless/polyethylene with 0.5 Ci Americium-Beryllium source

Physical Strengths*

Hardware	**Tension**	**Compression**	**Torque**
Tool Joints	130,000 lb	130,000 lb	600 ft-lb
	(59,000 kg)	(59,000 kg)	(814 N-m)

* Strengths apply to new tools at 70°F (21°C) and 0 psi.

Fig. 2.3: GEM Tool specifications

2.3. Operating principal

The GEM data is acquired in Total Spectrum and every Total Spectrum is a composite of elemental spectra. The acquired Total spectrum data is then converted to relative elemental yields by using Spectral Fitting (Fig. 2.4). Those relative elemental yields were then converted to elemental weight fractions using an Oxides Closure Model and then to minerals using an Error Minimization Solver (Fig. 2.5).

GEM Spectral Standards:

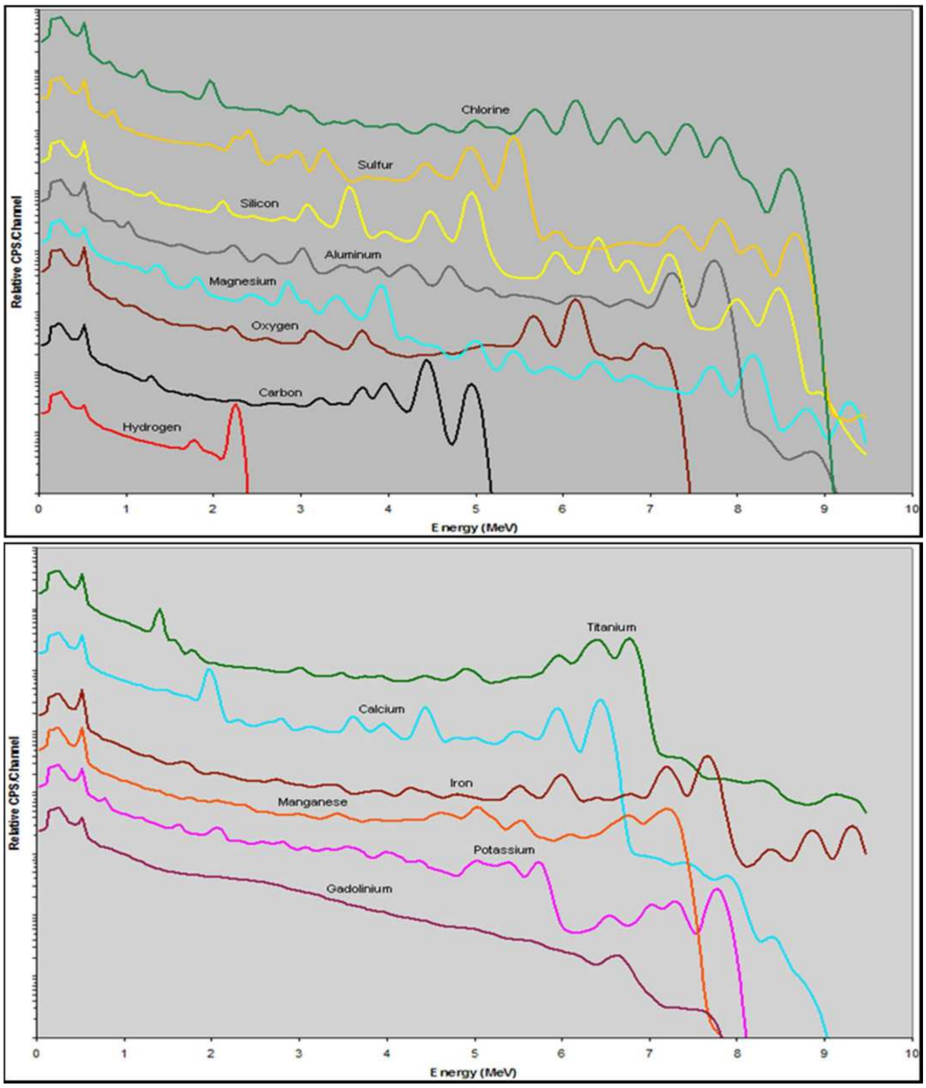


Fig. 2.4: GEM spectral fitting standards

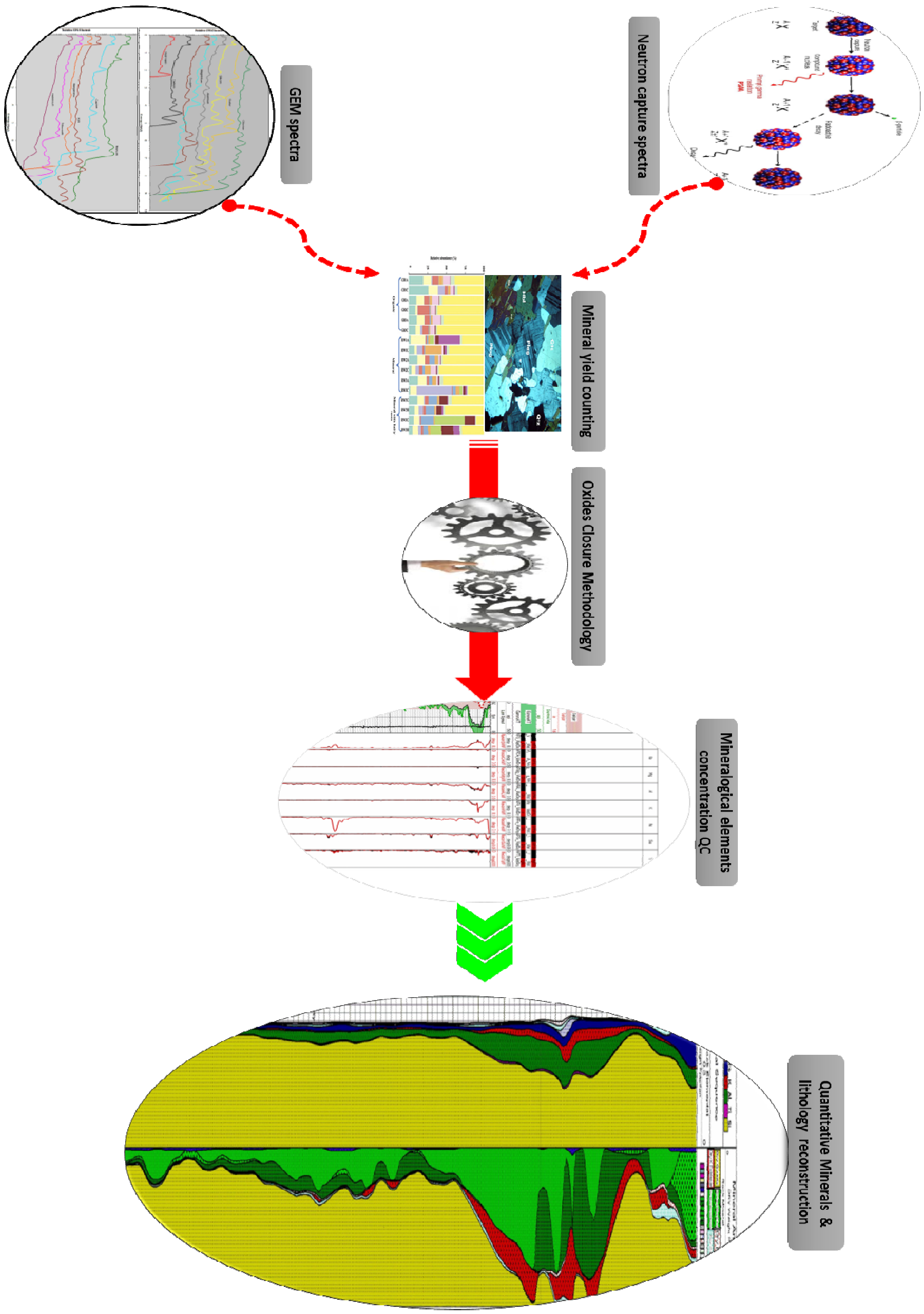


Fig. 2.5: GEM operating physics, spectral Capture and processing general workflow chart *(A. Benhabireche, 2015*)

2.4. Tool application

Add to standard use (outputs) of this tool as nuclear logging tool The GEM tool improves the measurements of magnesium in carbonates and aluminum in clays and shale, which until now were the most difficult elements to measure but very important for describing the reservoir. An industry first, the GEM tool also can measure manganese, a common constituent of carbonates and sheet silicates. Measurement of magnesium, aluminum and manganese can help asset teams determine mineralogy to improve estimates of porosity, saturation, permeability, detection of swelling clays and rock mechanical properties. Operators are now able to obtain more accurate estimates of their reserves, design optimal completion and stimulation programs, and maximize production (R. MacDonald, 2010). (Fig. 2.5).

And we can resume the benefits of the tool as below:

- Improves accuracy of integrated petrophysical analysis
- Mineral fractions such as gypsum or anhydrite, carbonate, coal, pyrite, salt, siderite, Quartz, feldspar, mica and clay from complex formation analyses.
- Matrix density values for more accurate porosity calculation
- Sigma matrix for cased and open-hole sigma saturation analysis and improved neutron Porosity environmental corrections.
- Improves permeability estimates based on mineralogy.
- Quick cool-down of eutectic heat sink for rapid job turnaround.
- Borehole shielding for reduced sensitivity to borehole fluids

Chapter Three

Field data acquisition,
re-processing, interpretation workflow
&
Quality Control

3.1. Well site data Acquisition & QC details

The GEM™ Elemental Analysis Tools data were recorded and processed in the ***WELL-01*** located in the West of Hassi Messaoud field (Name of the well is confidential due to company policy) with openhole section length of 113m. The bit size was 6”, borehole fluid was 0.86g/cc (7.17 ppg) oil based mud type with 0% of K (Potassium) as additive element, and the well was vertical. the tool diagram (Figure 3.1) is illustrated below. The intervention objectives were to analyze and quantify the mineral elements fraction distribution throughout the log in the *Cambrian Reservoir:* ***Ra Reservoir***.

Logged interval length (m)	113m
Bit size (in)	6
Tool Vertical Resolution (in)	18
Logging speed (ft/min)	13-15
Mud type	Oil Base Mud
Mud weight (g/cc)/ (ppg)	0.86/7.17
Max Bottom hole temperature (C°)	121°

Table 3.1: Service details

3.1.1. Necessary nuclear wireline logging tools combination:

As one of the necessary requirement and important point for the complete quality control process (borehole environment conditions and oxide effects corrections) and interpretation steps, it is very recommended (obligatory for the logging company) to combine the following tools (note that the cited tools are manufactured by Halliburton) in single logging string (Figure 3.1) and for the others measurement (classic measurement) like acoustic (sonic) and resistivity help in the interpretation stage:

a. Natural gamma ray radiation recorder tool;

b. Compensated Natural spectral gamma ray radiation measurement tool of the main radioactive elements: Thorium, Potassium and Uranium;

c. GEM elemental analysis tool

d. Porosity measurement tool

e. Formation or lithology density measurement tool (SDLT: spectral density logging tool).
f. And as default tool temperature recorder where we found it in the bottom of the string integrated in the bottom blug Bull nose.

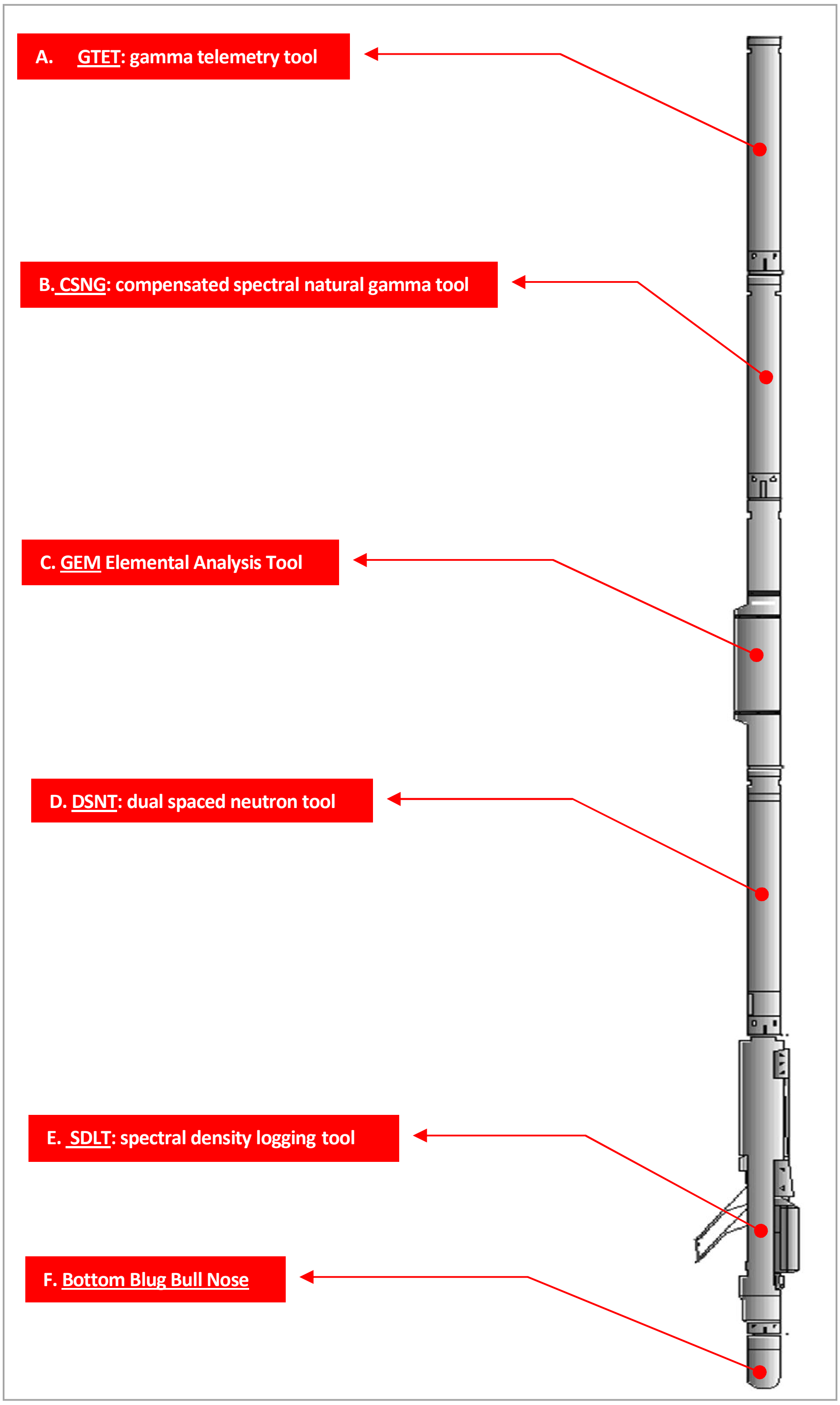


Fig.3.1: Openhole GEM tool and Nuclear wireline logging tools combined in single tool string

3.1.2. Well site GEM™ Data Acquisition & QC

The logging data (Main and repeat Pass) were depth checked and correlated before re-processing by the field engineer (in well site) and log analyst (in the processing and interpretation center) in the logging company.

For this case the repeat section log was recorded also and shows very good repeatability with the main pass log which confirms good log quality (see Fig3.3.).

The Raw data quality was very good and all the quality control curves (well site QC) responses are normal and QC indicators are within expected parameters. Chi Square Fit (<0.005), Resolution degradation factor (<4) and Gain (close to 1), were within the tolerance limit (Fig. 3.2).

An additional quality control involves the identification of casing by using the high percentage of Pure Iron (Fe) show perfect semblance with depth of the operator company casing shoe (mean the tool well calibrated) and the casing shoe identified by the other open hole logs over the logged interval. The GEM data was acquired at the recommended logging speed of 13-15ft/min within requirements of less than 60 ft/min. Repeatability is also excellent as indicated in (Fig. 3.2). The flask temperature was about 113-115°C (Fig. 3.2).

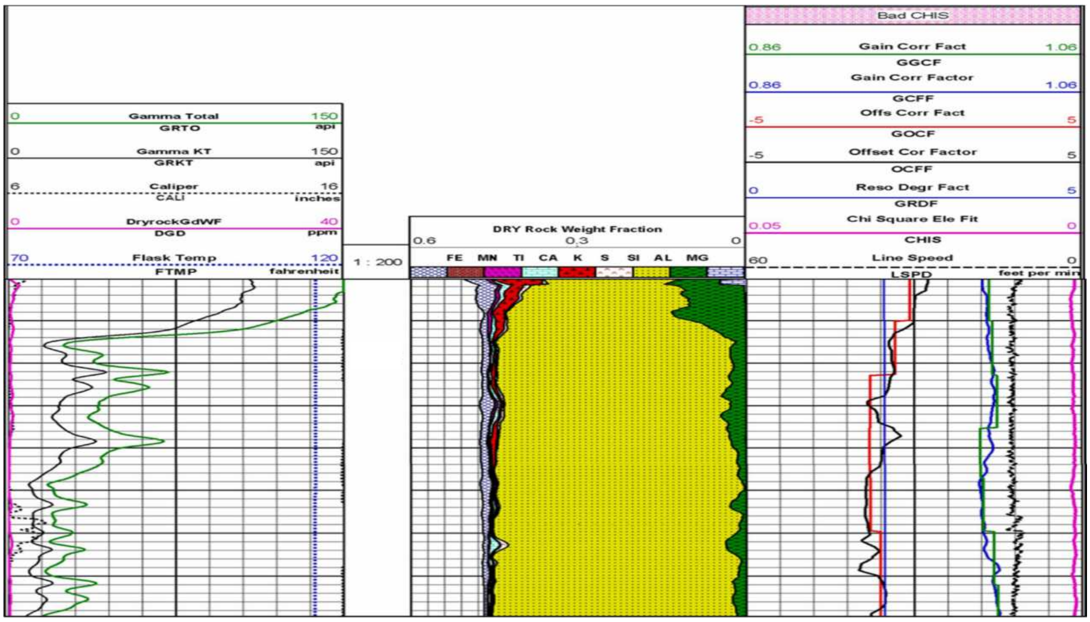


Fig.3.2: QC of field Log plot presentation for GEM Pure data.

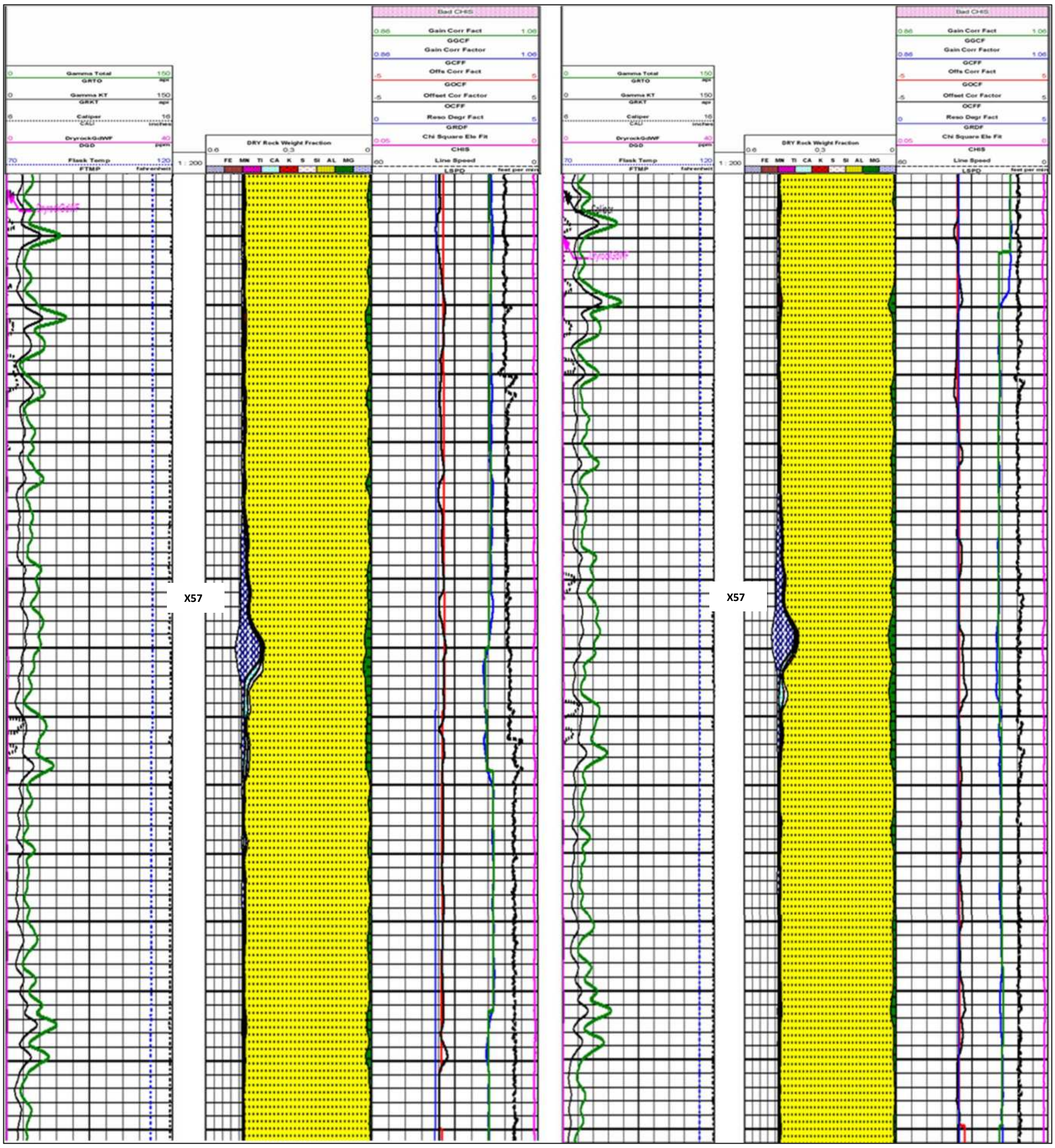


Fig.3.3: Repeatability of Curves (Main –Right vs. Repeat log-Left)

3.2. Re-Processing and interpretation Workflow steps & Data quality control

GEM data along with resistivity, nuclear porosity and spectral gamma ray was loaded in Halliburton processing software (insite: petrophysics frame work). The resistivity logs were run centralized and the spectral gamma ray and porosity logs along with GEM were run decentralized. Data quality in general is good with no tool or hole problem.

The re-processing of GEM data use the Sophisticated software named above, where the steps can be resumed in two major steps: first environmental correction and QC; second Elements yield spectral Fitting Correction and QC (see the figures below 3.5-3.9).

3.2.1. GEM Data Preparation and Environmental Correction QC Steps

As a standard procedure for the environmental corrections were applied to Neutron porosity, spectral and natural gamma ray data. GEM data was “re-fitted” taking the corrected potassium value from the corrected spectral gamma ray data (Fig.3.4)

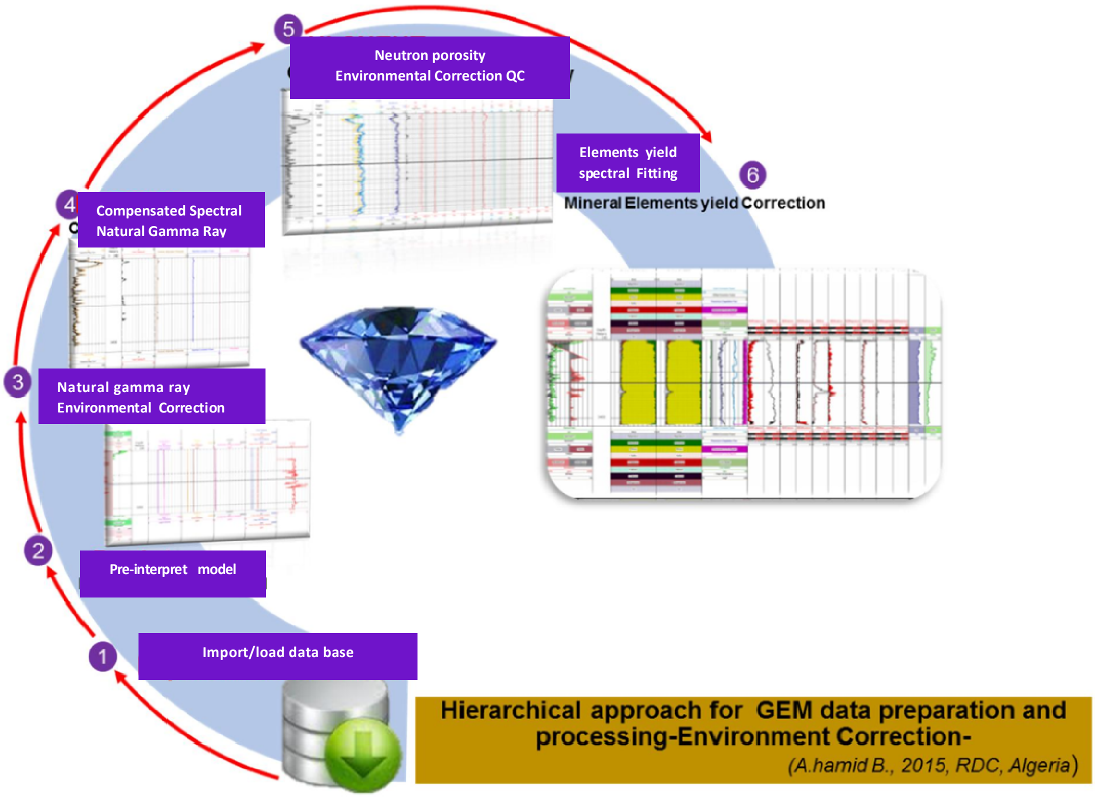


Fig3.4: GEM data preparation: Environmental Correction QC detailed processing work flow chart.

3.2.1.1 GEM™ Environmental Correction QC of the Well-01:

A. Pre-interpret model Environmental Correction QC:

Before the progress to the advanced steps of the final re-fitting for the GEM recorded data a very important step of the Environment correction and raw data preparation: take in consideration the temperature, pressure, pore pressure and overburden pressure, in the figure below we can control the quality of our data where we must concentrate in the shift between the curves and it will show sheading in all the figures for facilitate the QC of the original GEM data and the reconstructed or re-corrected data; and this steps are mandatory for any analysis (Fig3.5).

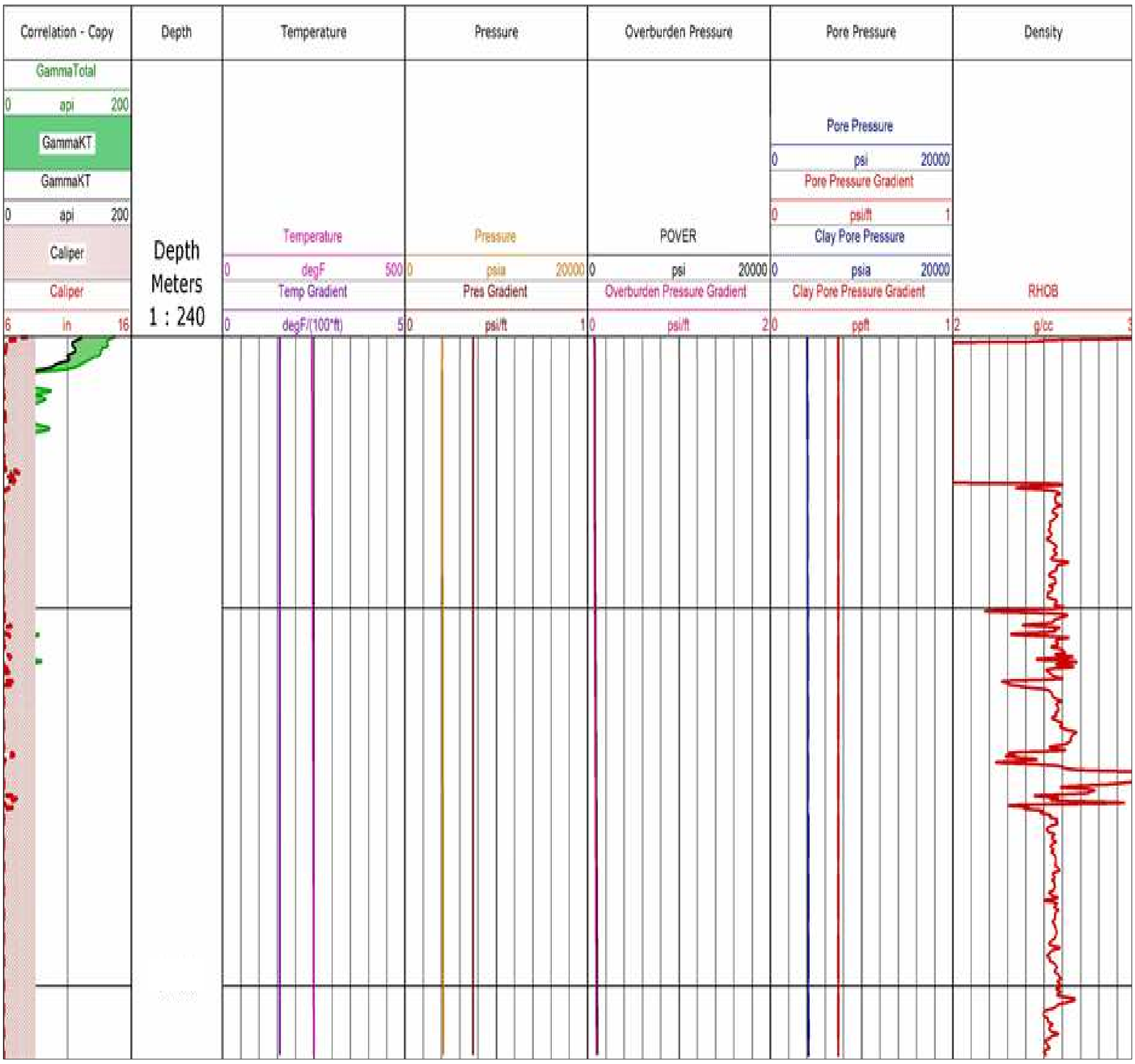


Fig3.5: GEM™ Pre-interpret model Environmental Correction QC.

B. GEM™ Natural gamma ray Environmental Correction QC:

After the step (A) the natural gamma ray Environment correction: take in consideration the borehole absorption, borehole correction factor and the borehole fluids potassium correction, in the figure 3.6 we can assess and control the quality (QC) of our data.

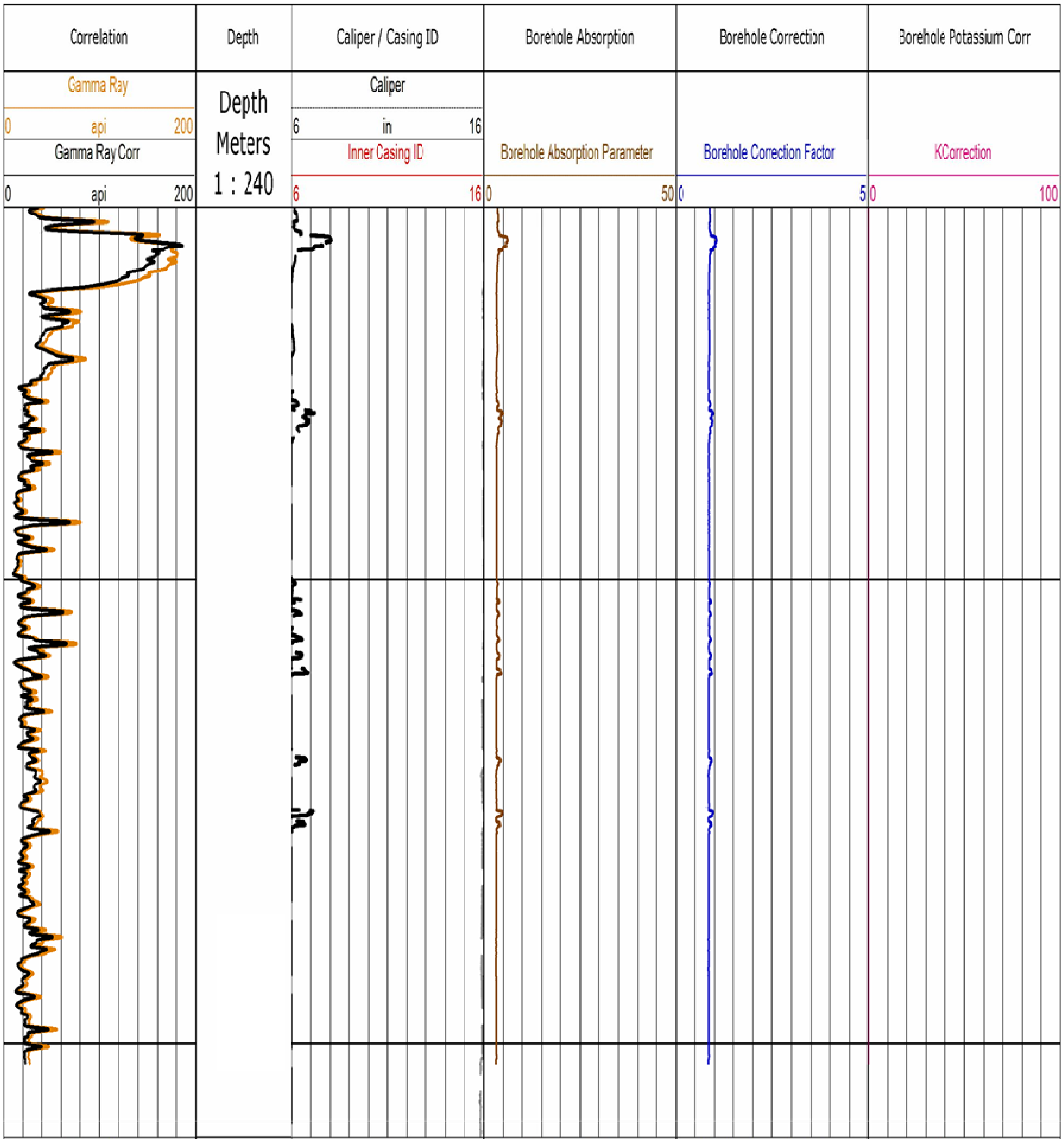


Fig3.6: GEM™ Natural gamma ray Environmental Correction QC.

C. GEM™ Compensated Spectral Natural Gamma Ray Environmental Correction QC:

After the step (B) compensated spectral natural gamma ray Environment correction is recommended: take in consideration all shown items in the QC plot below; where, as mention before the GEM detector can measure the spectral of the naturel gamma ray (the main three radioactive elements).

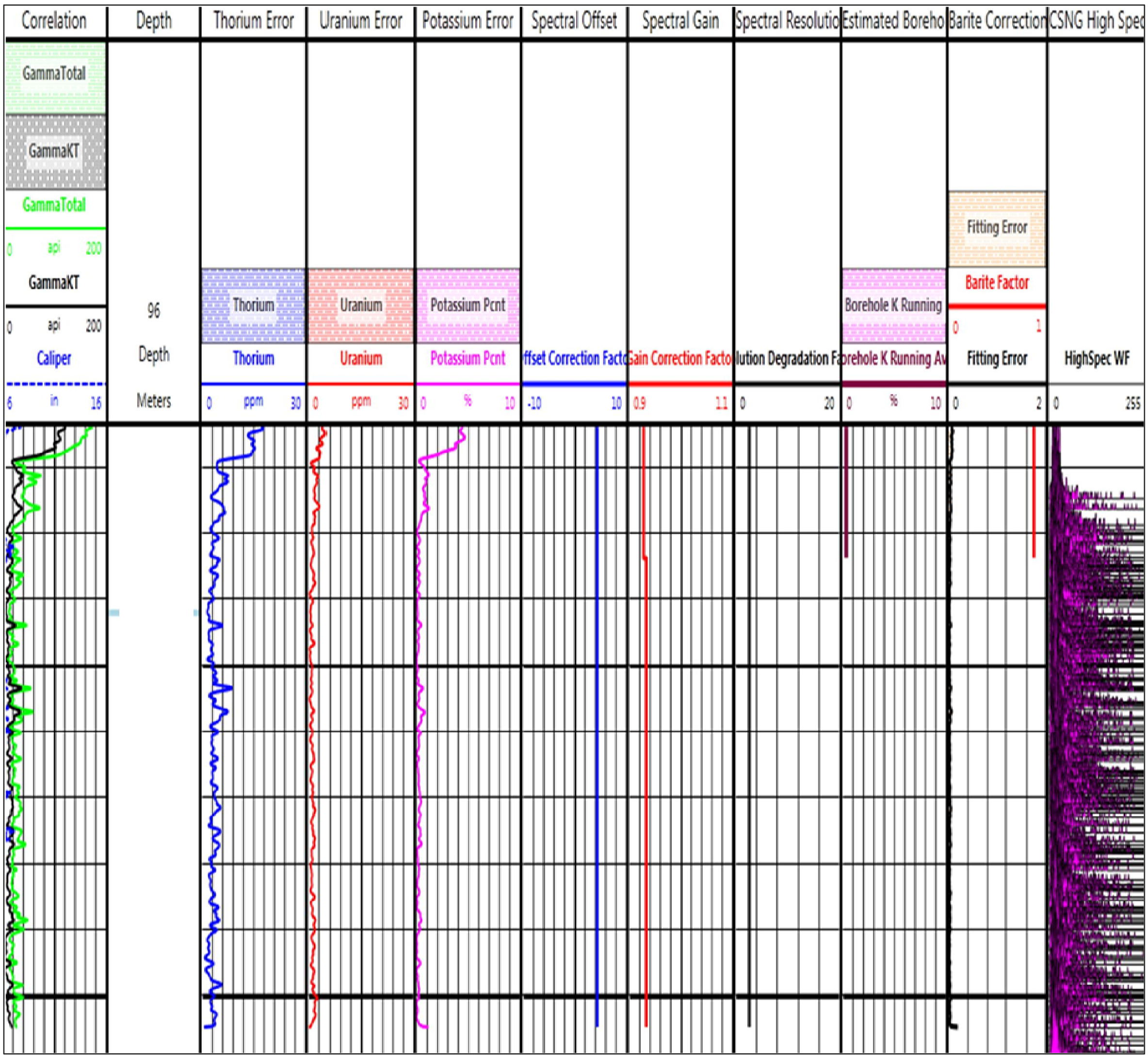


Fig3.7: GEM™ Compensated Spectral Natural Gamma Ray Environmental Correction QC

D. GEM™ Neutron porosity Environmental Correction QC:

After the step (C) Neutron porosity Environment correction QC is very recommended: take in consideration all shown items in the QC plot below; where, as mention before the GEM Tool use Neutron radioactive chemical source for the bombardment of the formation.

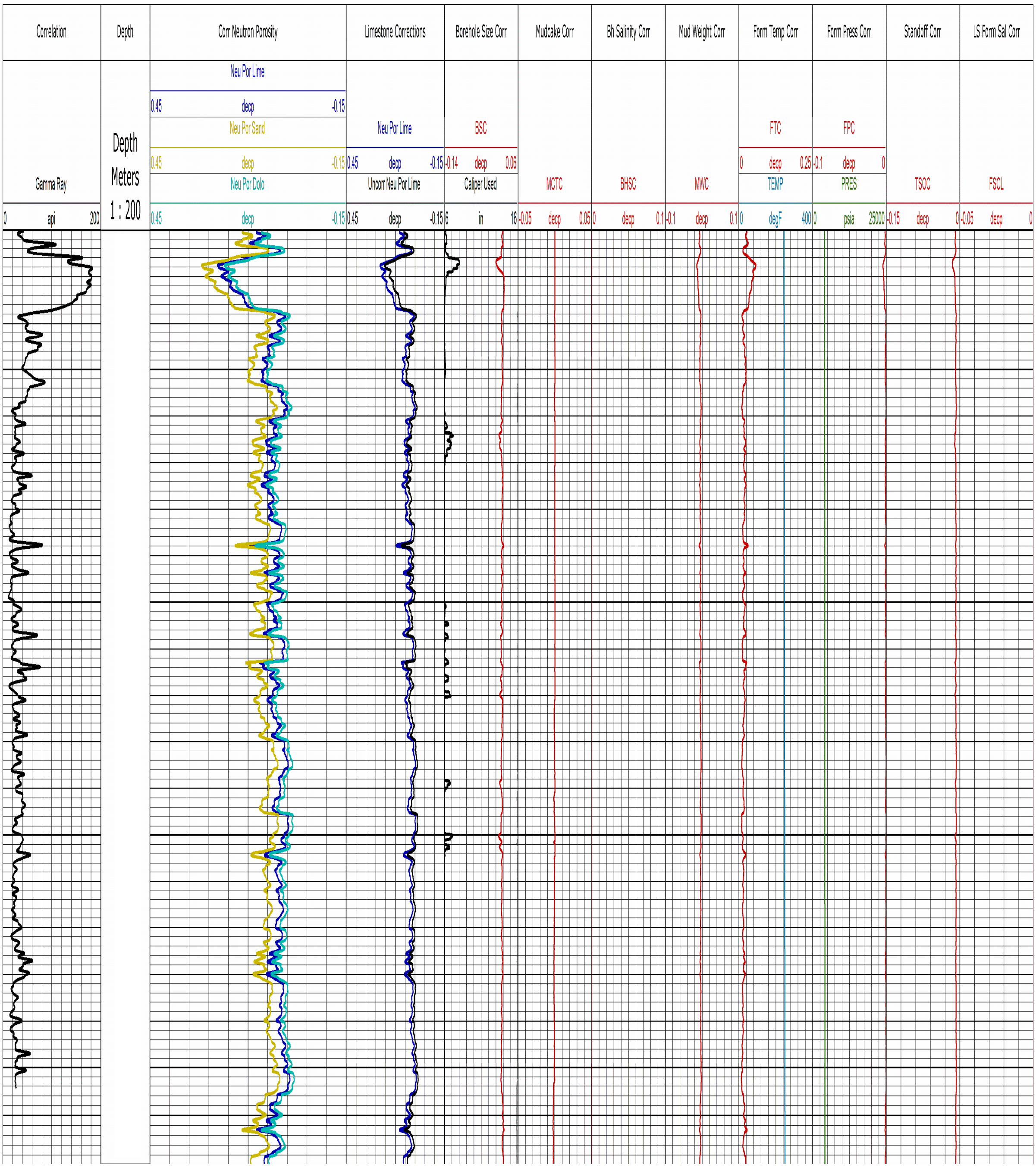


Fig3.8: GEM™ Neutron porosity Environmental Correction QC.

E. GEM^{TM} Mineralogical Elements yield spectral Fitting Correction QC.

The step (E) come as final step in data preparation & Environment correction QC, the elements concentration fitting (between the original concentration without correction and reconstituted after correction, see figure below) presented in the plot could be adjusted depending the field or reservoir mineralogical model (from XRD measurements performed in the laboratory), any noticeable shift must be corrected by adjusting the parameters.

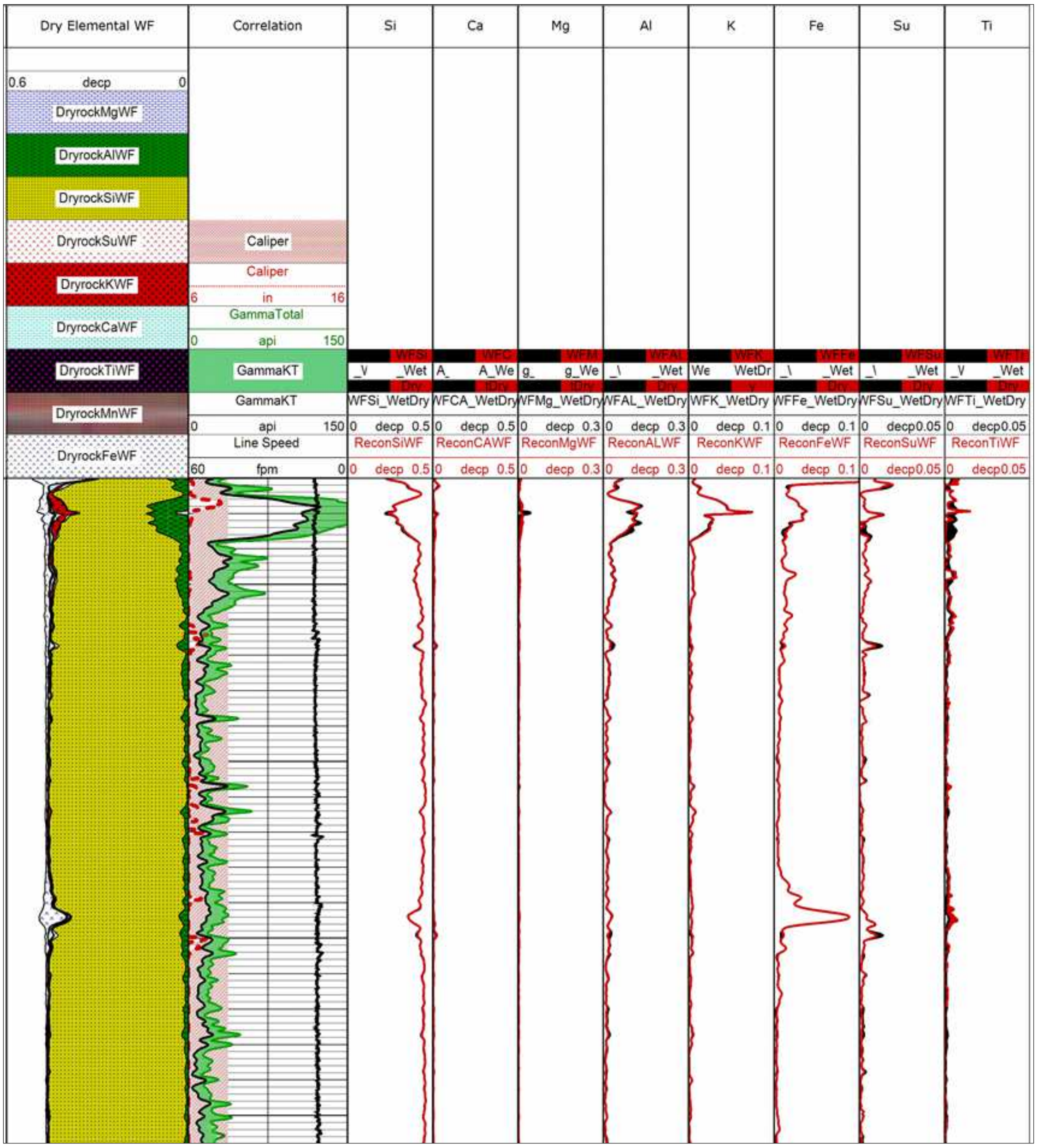


Fig3.9: GEM^{TM} Mineralogical Elements yield spectral Fitting Correction QC**.**

3.2.3 GEM™ Mineral Elements Evaluation & Interpretation Steps

The GEM tool record elemental yield of H, C, O, Na, Mg, Al, Si, S, Cl, K, Ca, Ti, Mn, Fe, Ba and Gd. The elementals yield of Mg, Al, Si, S, K, Ca, Ti, Mn, Fe and Gd are then converted into elemental weight fractions using Industry's Oxide Closure model. These elemental yields were then converted into mineral volume fractions using an error minimization program. The figure below (Fig.3.9) shows the mineralogical interpretation using the GEM, and combining with resistivity, neutron, density and spectral gamma ray data from the well-01.

<u>Note: in this case study we use only dry mode so no fluid will be analyzed.</u>

Using Halliburton's DecisionSpace PetroPhysics Framework (DSPF) software "Fame", GEM data was processed to get a comprehensive continuous quantitative evaluation of mineralogy across the logged section (Fig. 3.8).

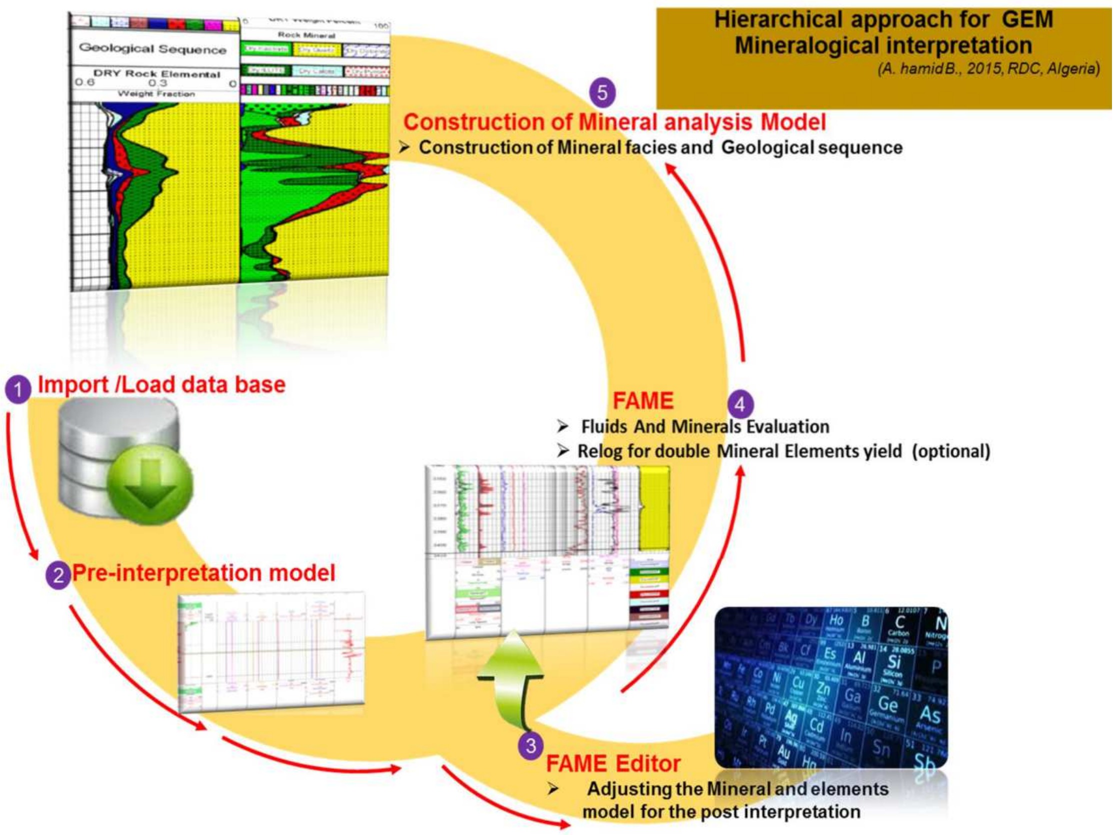


Fig 3.10: GEM FAME detailed processing & interpretation workflow chart (A.H. Benhabireche, Hesp (RDC), 2015)

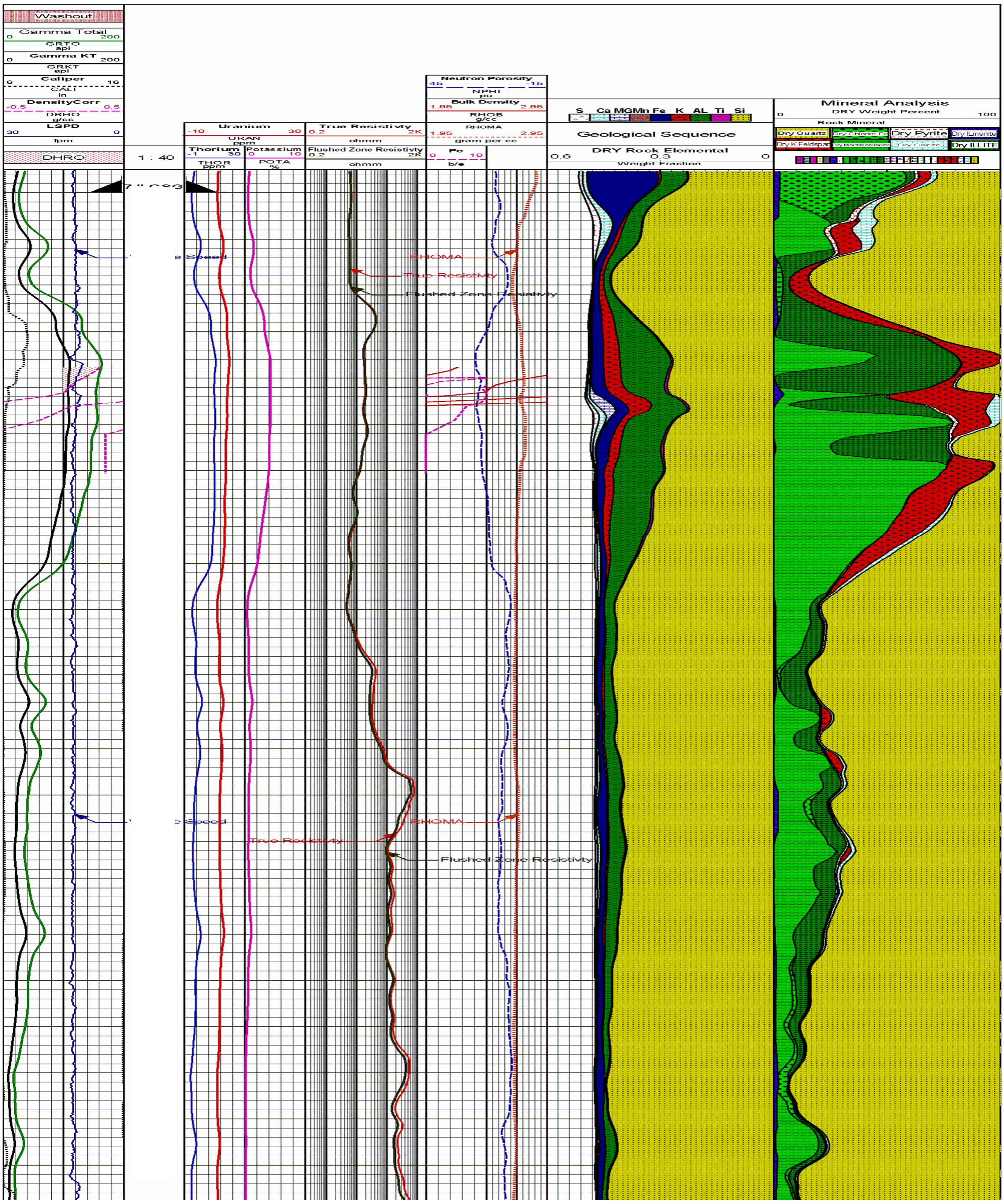


Fig3.11: GEM FAME Mineralogical Interpretation Presentation.

Chapter Four

Mineralogical Facies Analysis
&
Sedimentological Characterization

4.1. GEM™ FAME Mineralogical Facies Analysis & Sedimentological Characterization

Stratigraphically, the rock succession in well-01 comprises four main rock units being from top to base:

- Reservoire Ra:
  1. Drain 3 (D3)
  2. Drain 2 (D2)
  3. Inter Drain (ID)
  4. Drain 1 (D1)
  5. ZPSG (this unit not included in the logged interval

Formation	Thickness (m)
D3	18
D2	22
ID	27
D1	28
ZPSG	-

Table 4.1: Ra reservoir units

The GEM data from the well-01 was solved for Quartz, Calcite, Chlorite (Fe-chlorite: chamosite), Illite, montmorillonite, Pyrite/iron pyrite, Ilimnite and K-feldespath The following are the main interpreted zone of the mineral facies and traces elements finding from the GEM Interpretation.

4.1.1. Reservoir D3 Formation

4.1.1.1 The Zone A (Thickness: 0.61m):

Mineralogical facies founded in this zone is pure quartzes with Fe-Chlorite, ilmenite, moderate amount of calcite and Shale/Clay minerals. Illite and montimorillonite are the dominate clay mineral, the Matrix Density (Rhoma) computed from tool was between 2.72-2.82 gm/cc with a mean value of 2.77 gm/cc.

This two principal different mineral facies (Fe-Chlorite & ilmenite) could be interpreted as eruptive or volcanic formation products in the top of this zone due to the noticeable presence of the Fe- chlorite (exactly the Mineral Chamosite: $(Fe^{2+};Mg;Fe^{3+})_5Al(Si_3Al)O_{10}(OH;O)_8$: where the chlorite group is commonly found in the igneous rocks as an alteration product of mafic minerals, the Ilmenite $FeTiO_3$: Fe of this mineral is coming generally from the weathering of old igneous or metamorphic rocks.

Add to those two mineralogical facies above the pyrite/iron pyrite (FeS_2) where the Fe of Iron pyrite has the same source like the Fe in the ilmenite. Much of the pyrite contained in sediments and sedimentary rocks is authigenic, formed in the depositional environment, or early diagenetic, formed during the transformation of the sediment into rock (lithification). The formation of pyrite requires the presence of organic material in the sediment, sulphate (the element trace of sulphate can observed clearly in the dry rock elemental log match perfectly with the occurrence of the pyrite/iron pyrite in the Mineral Analysis plot) in solution in the pore water, and locally anerobic (reducing) chemical environment. The significance of pyrite for oil- finders is that its presence proves the chemically reducing conditions (rather than oxidising conditions) prevailed at some time in the past. Reducing conditions allow organic carbon to be preserved, whether in the form of plant or animal remains, coaly sediments or petroleum.

This followed by interbedded (or hetherolithics sandstone quartzitic and shale) of sandstone quarzitic (the percentage of quartz increase from top to bottom) illite and/or montmorillonite in the bottom.

The Bentonite is the most abundant of all clays. The term "bentonite" is a catch-all for numerous variations of smectite absorbent (swelling) clays derived from weathered volcanic ash. A Bentonite often contains a high percentage of Montmorillonite, Illite or Kaolin clays. For the most part Bentonites are classified as Sodium Bentonites, Potassium Bentonites or Calcium Bentonites.

Calcium Bentonite has a dominant quantity of calcium in its mix of minerals. When the Bentonite has weathered to a microscopic size of 1 micron or less it is referred to as Calcium Montmorillonites. In this zone we can flow the increase of the calcium quantity parallel to the occurrence of the montmorillonite this one is the explication of the important presence of calcium in this zone where cannot be only cement or calcitic fill material exist in the fracture.

Potassium Bentonite It contains a high percentage of Illite Clay. Since it absorbs less moisture than other Bentonites.

4.1.1.2. The Zone B (Thickness: 0.61m):

The zone B formation is dominantly Sandstone with Shale and minor Pyrite. Calcium Montmorillonites is the dominant clay type. Small amounts of Pyrite are present in this zone B formation, calcite also presents as component of Calcium Montmorillonites composition and probably as cement (we can confirm the type of calcite existence if it is cement or filling material). The Matrix Density (Rhoma) computed from the tool was between 2.70-2.73gm/cc with a mean value of 2.71 gm/cc.

4.1.1.3. The Zone C (Thickness: 1.14m):

The zone C formation is dominantly Sandstone with Shale and minor Fe-chlorite & ilmenite. Illite is the dominant clay type. small amounts of chamosite (Fe-chlorite) & ilmenite are present in this zone C formation; very low amount of calcite also present probably as cement. The Matrix Density (Rhoma) computed from the tool was between 2.70-2.73gm/cc with a mean value of 2.71 gm/cc.

4.1.1.4. The Zone D (Thickness: 6.58m):

The zone D formation is dominantly Clay with Shale and moderate sandstone quartzitic in the top and bottom part of this zone Fe-chlorite, pyrite & ilmenite. Calcium Montmorillonites, Montmorillonites and Illite are the dominant clay type. Small amounts ilmenite and very low amount of of chamosite (Fe- chlorite) is present in this zone. Magnesium, Ti and Fe present with moderate amount this make the occurrence of the ilmenite in the Mineral analysis plot. Calcite also presents as component of Calcium Montmorillonites composition and probably as cement. The Matrix Density (Rhoma) computed from the tool was between 2.67-2.77gm/cc with a mean value of 2.74 gm/cc.

4.1.1.5. The Zone E (Thickness: 9.06m):

The zone E formation is hetherolithics sandstone quartztic and shale, dominantly Sandstone with Shale and minor Fe chlorite, rarely very low amount of Ilemnite at the bottom of the interval and pyrite/Iron pyrite. Montmorillonites, Illite and rarely calcium Montmorillonites are the dominant clay type. Calcite also presents as cement (no fractures exist in the Ultrasonic & resistivity image log recorded for the detected calcite, Plz. Refer to Image log). The Matrix Density (Rhoma) computed from the tool was between 2.68-2.71gm/cc with a mean value of 2.79 gm/cc.

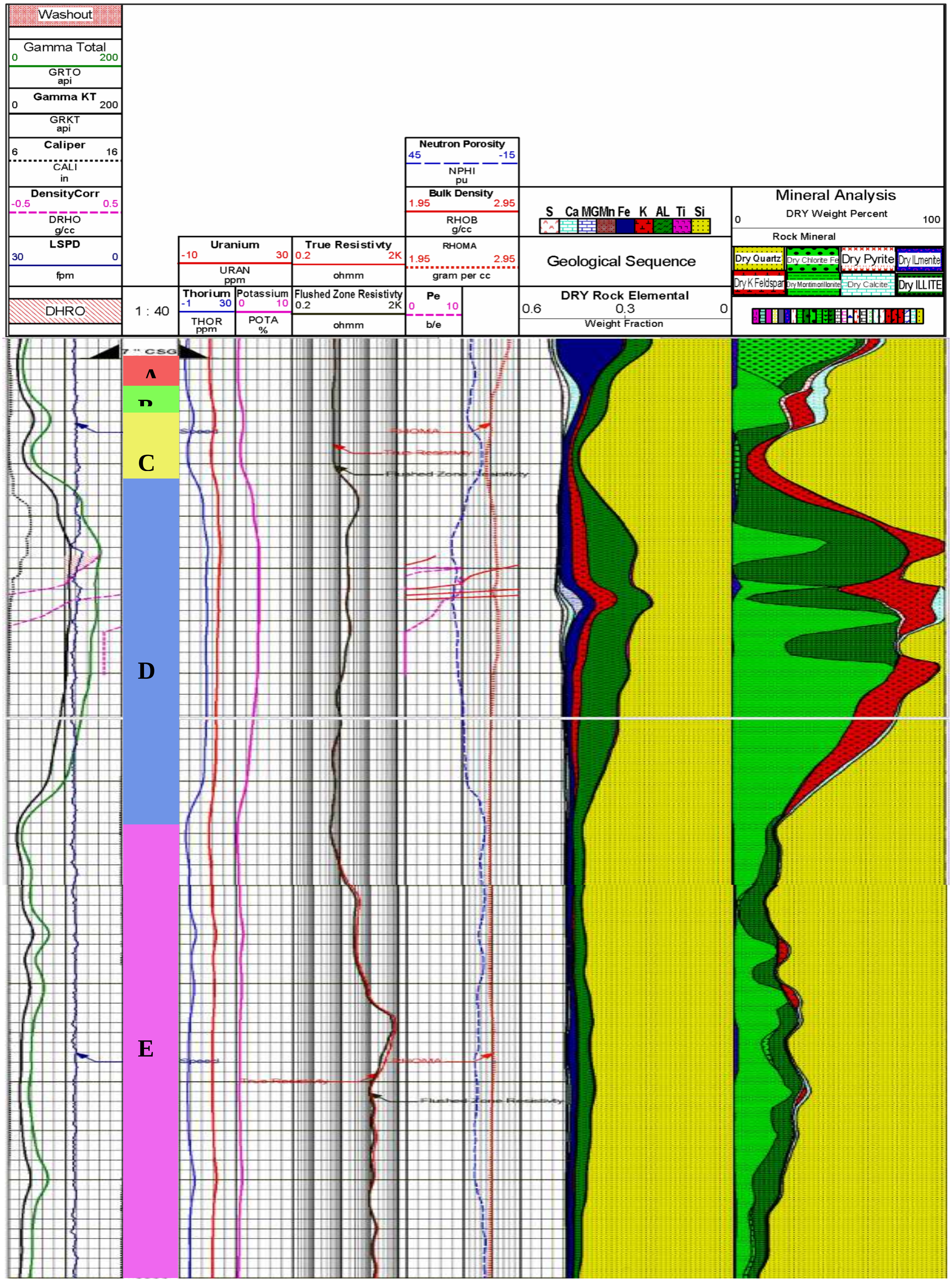


Fig 4.1.: Reservoir RA-D3 Formation units.

4.1.2. Reservoir D2 Formation

4.1.2.1. The Zone A (Thickness: 13.3m):

The zone A formation is hetherolithics sandstone and shale, dominantly Sandstone quartztic with Shale and minor Fe chlorite, very low amount of Ilemnite at the top of this interval and small amount of pyrite/Iron pyrite in some selective depths. Montmorillonites, Illite and in one selective depth calcium Montmorillonites are the dominant clay type. Calcite also presents as cement. The Matrix Density (Rhoma) computed from the tool was between 2.66-2.70gm/cc with a mean value of 2.68 gm/cc.

4.1.2.2. The Zone B from (Thickness: 0.58m):

The zone B formation is sandstone, dominantly Sandstone quartztic with minor Fe chlorite. Bentonite Clay rock disappear in this interval. No Calcite presents. The Matrix Density (Rhoma) computed from the tool was between 2.65-2.66gm/cc with a mean value of 2.65 gm/cc.

4.1.2.3. The Zone C (Thickness: 8.12m):

The zone C formation is hetherolithics sandstone and shale, dominantly Sandstone quartztic with Shale. Montmorillonites, Illite are the dominant clay type. Calcite also presents as cement. The Matrix Density (Rhoma) computed from the tool was between 2.65-2.68gm/cc with a mean value of 2.66 gm/cc.

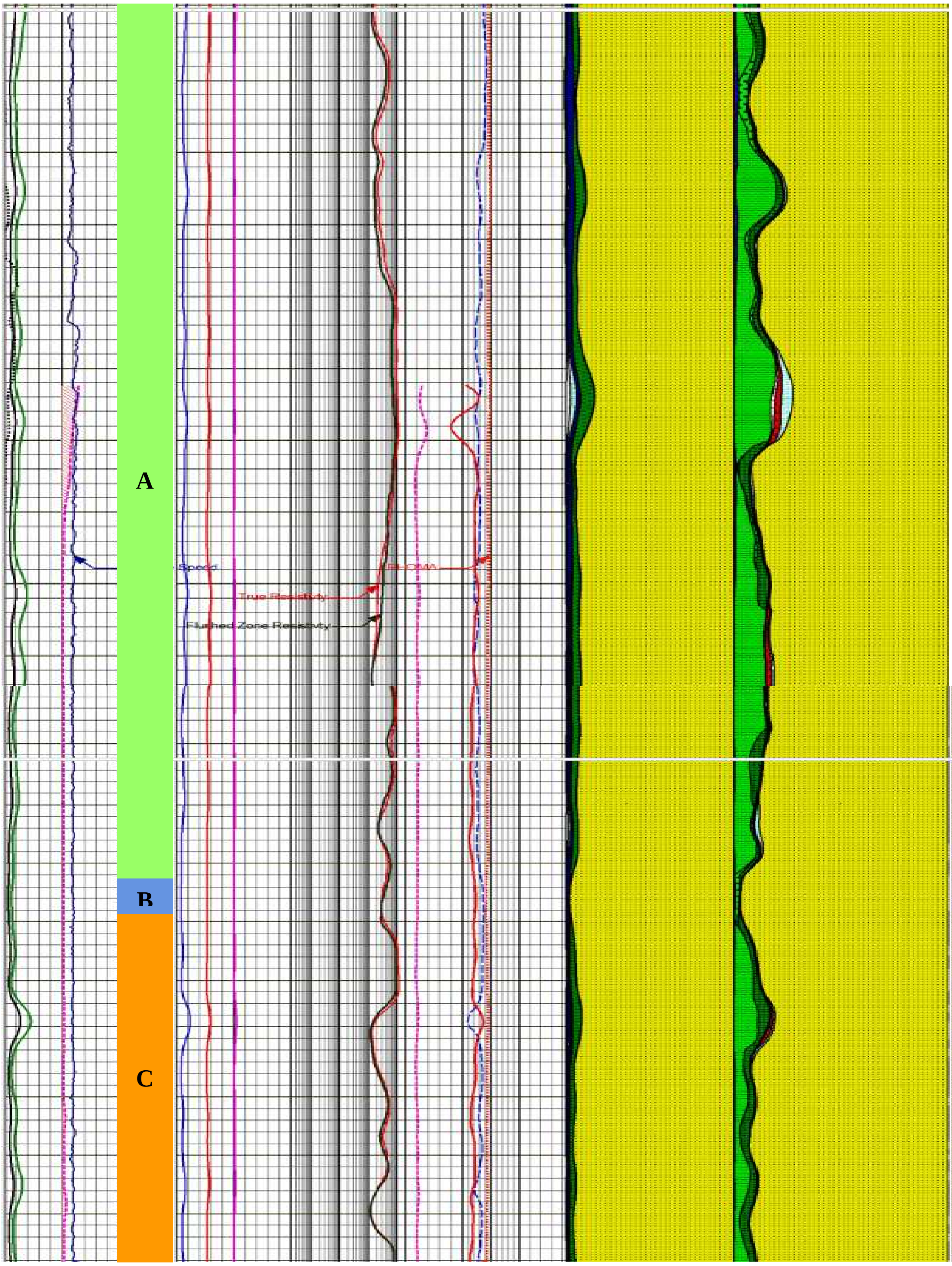


Fig 4.2.: Reservoir RA-D2 Formation unit.

4.1.3. Reservoir ID Formation

4.1.3.1. The Zone A (Thickness: 16m):

The zone A formation is hetherolithics sandstone and shale, dominantly Sandstone quartztic with Shale and trace of Ilemnite at the top of this interval. Montmorillonites, Illite are the dominant clay type. Calcite also presents as cement. The Matrix Density (Rhoma) computed from the tool was between 2.65-2.67gm/cc with a mean value of 2.66 gm/cc.

4.1.3.2. The Zone B (Thickness: 11m):

The zone B formation is hetherolithics sandstone and shale, dominantly Sandstone quartztic with Shale and moderate to hight amount of Fe-chlorite, low amount of Ilemnite at same point where the higher amount of Fe-chlorite detected and very small amount of pyrite/Iron pyrite in some selective depths. Montmorillonites, Illite are the dominant clay type. Calcite also presents as cement and fill material. The augmentation of the Fe-chlorite in this specific interval accompanied by the Ilmenite, Iron pyrite and calcite (as cement & as a fracture fill in one selective depth) could explained with this scenario: after final stage of sedimentation the formation and by all the condition of lithification exist will be consolidate and diagentic, the pyrite must be formed under this conditions, the second stage is made by the regional structural stress applied to this formation and generate fractures in this rock unite presenting in different structural forms like structural breccia which be later cemented by the product of alteration derived from pre-exist eruptive or igneous rock. The Matrix Density (Rhoma) computed from the tool was between 2.66-2.75gm/cc with a mean value of 2.69 gm/cc.

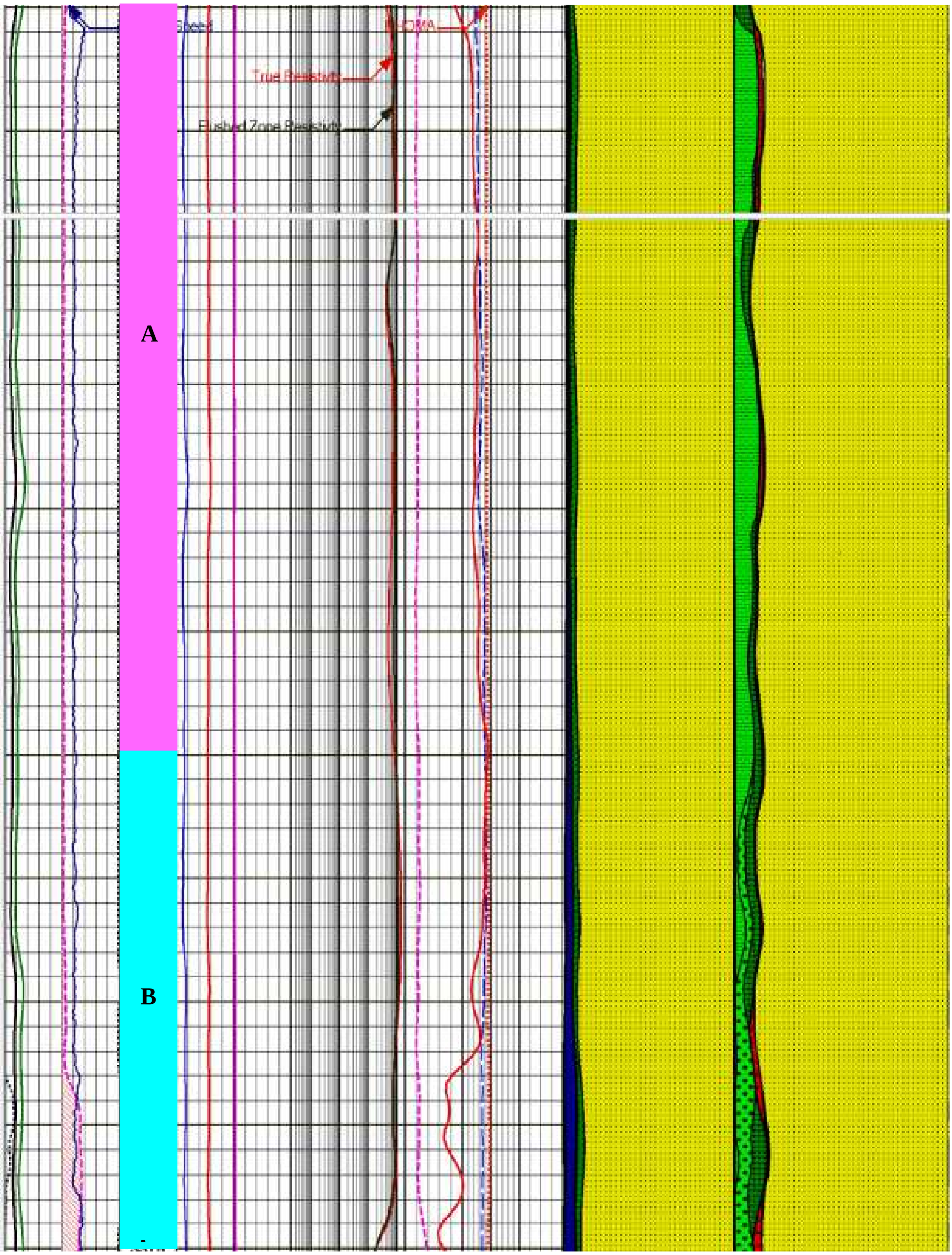


Fig 4.3.: Reservoir RA-ID Formation unit.

4.1.4. Reservoir D1 Formation

4.1.4.1. The Zone A (Thickness: 25m):

The zone A formation is hetherolithics sandstone and shale, dominantly Sandstone quartztic with Shale and small amount of Fe-chlorite. Montmorillonites, Illite are the dominant clay type. Calcite also presents as cement. The Matrix Density (Rhoma) computed from the tool was between 2.65-2.68gm/cc with a mean value of 2.66 gm/cc.

4.1.4.2. The Zone B (Thickness: 3m):

The zone B formation is hetherolithics sandstone and shale, dominantly Sandstone quartztic with Shale and moderate amount of calcite at the bottom of this interval and very small amount of Ilmenite in one selective depths. Montmorillonites, Illite and in the bottom calcium Montmorillonites are the dominant clay type. Calcite also presents as component of calcium Montmorillonites and as cement. The Matrix Density (Rhoma) computed from the tool was between 2.65-2.68gm/cc with a mean value of 2.66 gm/cc.

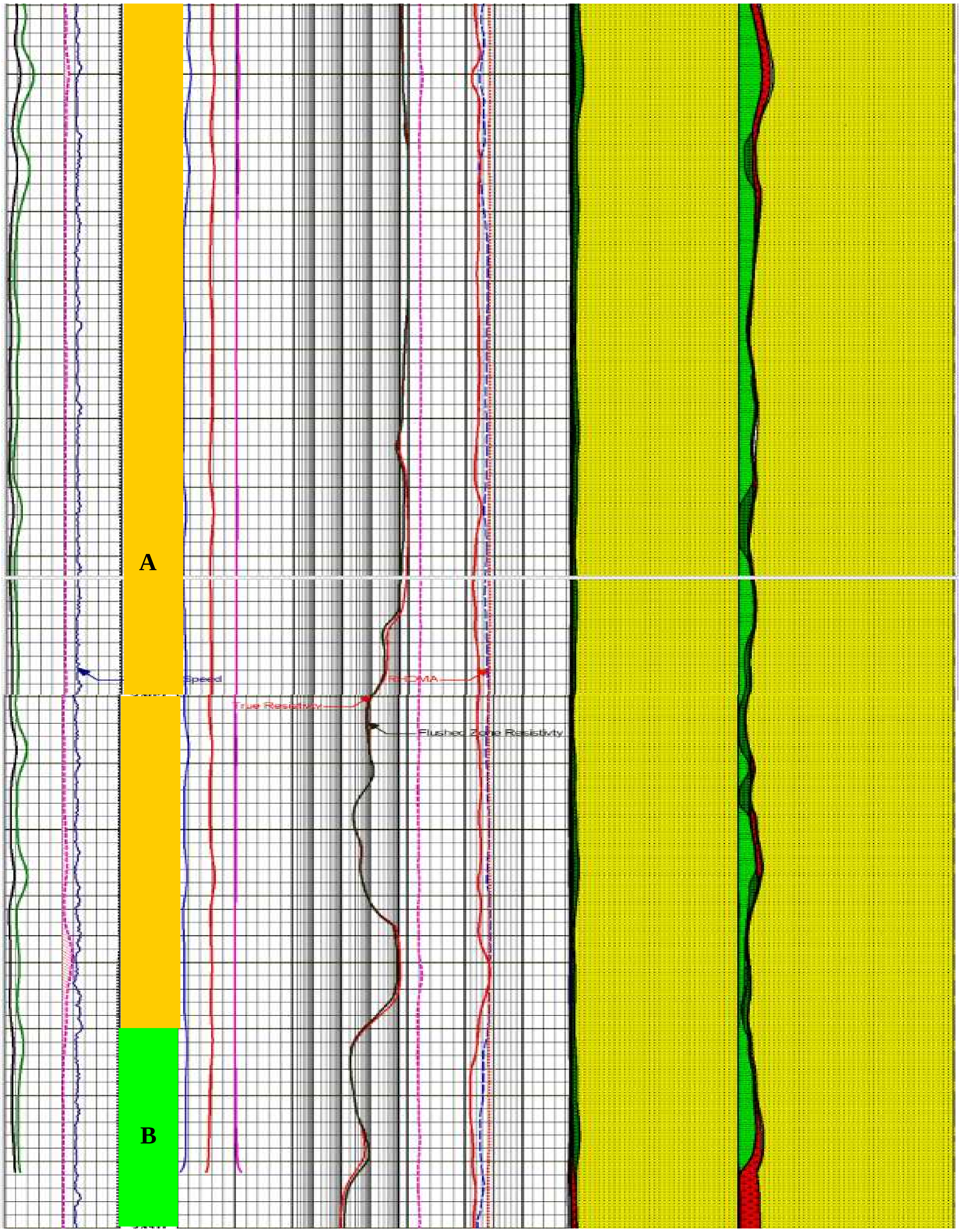


Fig 4.4.: Reservoir RA-D1 Formation unit.

4.2. Conclusion:

The following mineralogical facies, traces element and sedimentological characteristics are the main findings from the elemental spectroscopy analysis Interpretation:

- ***The Cambrian RA-D3:***
  Is Eruptive or volcanic rock, interbedded (hetherolithics), Bentonite clay, Sandstone with Shale and minor Pyrite, Fe- chlorite & ilmenite; the volcanic product could have interpreted as results of alteration and re-sedimentation due to the presence of ilmenite,

- ***The Cambrian RA-D2:***
  Is hetherolithics sandstone and shale intercalation (dominantly Sandstone quarzitic (referring to the density) with Shale and minor Fe chlorite).

- ***The Cambrian RA-ID:***
  Is hetherolithics sandstone and shale interbedded (dominantly Sandstone quartzitic with Shale),

- ***The Cambrian RA-D1:***
  Is intercalation of hetherolithics sandstone and shale (dominantly Sandstone quartzitic with Shale and small amount of Fe-chlorite, calcite at the bottom of this interval.

General Conclusion

General conclusion:

The Mineralogical Analysis dry rock weight fraction by the GEM Tool in aim to mineralogical facies identification in the Camberian reservoir (***Ra Reservoir***) give very good results for the mineralogical facies exist in the different Formation Rock units of the reservoir.

After the re-processing and interpretation of the mineralogical facies and Elements continues distribution throughout the log, and after the reconstruction of mineralogical sequence arrangement many geological and sedimentlogical information gathered this information give very guided help to the reservoir Engineer to best production enhancement for this reservoir.

The Eruptive rock or in other word the fingerprint of the pre-existence of the eruptive formation in this area in the top of D3 formation appear clearly with very important presence of Chamosite (Fe-Chlorite) and this help clearly for the reservoir tops determination and Well to well correlation.

The deep Mineralogical analysis gives very clear image to the reservoir clay minerals which help in reservoir characterization and evaluation.

The Accessory minerals detected carefully in this report like the pyrite Could help the client reservoir engineer to know many information about the Oil migration, quality and even the structural and diagenetic story in this formation.

The sedimentological characterization from the mineralogical fraction elements and the reconstructed mineralogical (lithological electrical core) help and conduct to clear image about the sedimentary environments and the paleo- environment conditions.

Another very important sedimentological characterization interpretation could be conducted too from the precise mineralogy log is the alteration and weathering process in the studied well as the finger-point of the eruptive formation and this help very well the geologist to connect the puzzles of the environment conditions existing in this sedimentary environments.

Understanding reservoir mineralogy is critical information to quantify the effect of the matrix on well log response for petrophysical analysis.

The recognition of the mineralogical variation associated with sequence stratigraphy may also facilitate well to well Correlation.

References

A. Balducchi & G. Pommier; 1971,Cambrian oil field Hassi Messaoud, Algeria, Memoir 14: Geology of Giant Petroleum Fields, Tulsa: AAPG, pp.

A. Benakcha.A , Y. Kerai; 2008, Caractérisation et évaluation des réservoirs des Quartzites de Hamra dans la structure du Hassi Tarfa ;(bloc 427). Mémoire ingénieur FHC.

A. Boudjema; 1987, Evolution structurale du bassin pétrolier (Triasique) de Sahara Nord Oriental (Algérie), Thèse doctorat. Université de Pierre et Marie Curie. Paris IV.

A. Chatterjee, H. Datir, M. H. Baig, J. Horkowitz, J. Grau, J. Goonting, H. Haneferd, D. Tompkins, B. Wendt; 2015, Evolving Petrophysics of the Overburden, A Spectroscopy Approach, SPWLA 56th Annual Logging Symposium, 18-22 July, Long Beach, California, USA.

A.H. Benhabireche; 2015, GEM interpretation report, Hesp (RDC).

A. Younis, A. A. Rahman; 2013, Clay Lithofacies and Depositional Environment, as Deduced from Natural Gamma-Ray Spectrscopy and Petrographical Data of the Abu Roash “E” Member, GPT Field, Western Desert, Egypt, Middle-East Journal of Scientific Research 16 (8): 1027-1036.

B. Le Compte, F. Mendez, D. Jacobi, J. Longo, 2008, Defining Clay Type Using Nmr And Geochemical Logging Measurements, 49th Annual Logging Symposium, 25-28 May, Austin, Texas.

C. A. Gonçalves, L. Ewert; 1998, Proceedings of the Ocean Drilling Program, Scientific Results, Vol. 159.

C. Larriestra; August 26, 2013, Soft Inorganic Geochemistry: A New Concept for Unconventional Resources Modeling, Search and Discovery Article #80311.

F. BESSA; 2004. Reservoir characterization and reservoir modeling in the NorthWestern part of Hassi Messaoud field. ALGERIA. Mémoire phd University of Hamburg.

J.L. Colson, J.A. Grau, M.M. Herron, J.S. Schweitzer, R.C. Hertzog, W.E. Preeg, R.D. Nurmi, J. Johnston; 1989, Applications Using Geochemical Logs, Middle East Oil Show.

K. Schwartz, G. Muscio, P. Nester, I. Easow, M. Javalagi; 2014, Petrophysical and Geochemical Evaluation of an Avalon Shale Horizontal Well in the Delaware Basin, Unconventional Resources Technology Conference, 25-27 August, Denver, Colorado, USA.

M. Rider; 1996, The geological interpretation of well logs, Second edition, Petroleum exploration consultant, Rider –French consulting LTD, Aberdeen and Sutherland.

M. Herron; January 1986, Mineralogy from Geochemical Well Logging, Schlumberger Limited.

M. M. Herron, S. L. Herron, R. V. Everett, J. E. McDonald; 1990, Enhanced Resistivity Interpretation In Three Wells Using Geochemical Log Data, SPWLA 31st Annual Logging Symposium, 24-27 June, Lafayette, Louisiana.

R. Hertzog and Al; June 1989, Geochemical Logging With Spectrometry Tools, SPE Formation Evaluation.

R. Freedman, S. Herron, V. Anand, M. M. Herron, D. H. May, D. A. Rose; 2014, New Method for Determining Mineralogy and Matrix Properties from Elemental Chemistry Measured by Gamma Ray Spectroscopy Logging Tools, SPE Annual Technical Conference and Exhibition, 27-29 October, Amsterdam, The Netherlands.

R. MacDonald, D. Hardman, R. Sprague, Y. Meridji, W. Mudjiono, Saudi Aramco; J. Galford, M. Rourke, Halliburton; M. Dix, M. Kelton, Core Laboratories; June 19-23, 2010, using elemental geochemistry to improve sandstone reservoir characterization: a case study from the unayzah a interval of saudi arabia, SPWLA 51 stAnnual Logging Symposium.

R.J. Van Den Cord; January 1991, Evaluation Of Geochemical Logging, The Log Analyst.

R.J. Van Den Cord; 1990, Experience With Geochemical Logging, SPWLA 31st Annual Logging Symposium, 24-27 June, Lafayette, Louisiana.

S. Herron, M. Herron, I. Pirie, P. Saldungaray, P. Craddock. A. Charsky, M. Polyakov, F. Shray, T. Li ; 2014, Application and Quality Control of Core Data for the Development and Validation of Elemental Spectroscopy Log Interpretation, SPWLA 55th Annual Logging Symposium, 18-22 May, Abu Dhabi, United Arab Emirates.

S. L. Herron, M. J. C. Petricola, R. E. Dove; November 1992, Geochemical Logging of a Middle East Carbonate Reservoir, Journal of Petroleum Technology.

WEC; 2007. Well Evaluation Conference, Schlumberger/Sonatrach.Algeria.

ملخص

تستخدم شركة هاليبرتون تكلونوجيا جديدة يطلق عليها إسم: الجوهرة (GEM) وهي عبارة عن أداة للتحليل الجيوكميائي للعناصرالبنيوية) هذه الأدات تمكن من الحصول على بيانات ومعلومات في غاية الأهمية في شوط واحد من التسجيلات الكهربائية
تلعب المعلومات في الجانب المعدني و الرسوبي لتكوينات عصر الكمبري في حوض حاسي مسعود ، دورا رئيسيا في وضع نماذج مضاهات دقيقة للمكمن أو الخزان.

تهدف هذه الدراسة إلى تقييم وتفسير التحليل الطيفي للطاقة (والناتجة عن الأشعة الممتصة و المنعكسة (الغير مرنة) من طرف العناصر البنيوية بعد القصف الإشعاعي النووي للتكوين الرسوبي) في السحنات الكهربائية (السحنة المعدنية و العناصرالبنيوية النادرة) ، الخصائص الرسوبية و المعادن الطينية المميزة للخزان المدروس وهذا مما يساعد في توصيف و تقييم المكامن البترولية.

الكلمات المفتاح: المعادن ، السحنات ، الترسبات ، التحليل الطيفي ، والعناصر الجافة ، خزان الكمبري والمعادن الطينية ، التكنولوجيا العالي

Résumé:

La nouvelle application de Halliburton Technologie, le GEM : Outil d'Analyse Elémentaire Géochimique fournisse une compréhension précise de la composition élémentaire et facies minéralogique, qui sont des facteurs essentiels dans la caractérisation des réservoirs et de la décision de complétion des puits juste dans une seul enregistrement diagraphique.

L'information minéralogique et sédimentlogique pour la formation Cambrienne dans le bassin de Hassi Messaoud, jouent un rôle principal dans la modélisation précise du réservoir.

Cette étude vise à évaluer la capture des éléments de subsurface et l'analyse spectroscopique inélastique (haute technologie) des différents faciès électriques (faciès minéralogiques et des traces d'éléments), les caractéristiques sédimentaires et les minéraux argileux de réservoirs qui aident à la caractérisation et à l'évaluation du réservoir.

Mots-clés: Minéralogie, Faciès, sédimentologie, Spectroscopie, éléments secs, réservoir, Cambrien, Minéraux argileux, la haute technologie.

Abstract

A new application of Halliburton's technology, the GEM: Geochemical Elemental Analysis Tool; provide accurate understanding of the elemental composition and mineralogical facies, of the formation which is essential factors in reservoir characterization and completion decision. Just in a single logging pass (all the -tools- for nuclear measurements run in single string).

The Mineralogical and sedimentological information for the Cambrian formation in the basin of Hassi Messaoud, play principal role in the accurate modeling of the reservoir.

This study aim to evaluate the subsurface elemental capture and inelastic spectroscopy analysis (high technology) of the different electrical facies (mineralogical facies and traces elements), sedimentary characteristics and reservoir clay minerals, which help in reservoir characterization and evaluation.

***Keywords*:** Mineralogy, Facies, Sedimentology, Spectroscopy, Dry elements, Cambrian reservoir, Clay mineral, High technology.