PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA
Ministry of Higher Education and Scientific Research

Serial number: 20

University Kasdi Merbah Ouargla

Faculty of Hydrocarbons and Renewable Energies and Earth and Universe Sciences

**Hydrocarbon Production Department**

**MASTER THESIS**

**To obtain the Master's Degree**

**Major: Professional Production**

Presented By:

**YOUSFI Oualid, BOUAMARA Fatima, BENOUARZEG Moncef**

-THEME-

# OPTIMIZATION OF PRODUCTION IN RESERVOIRS WITH ASPHALTENE PRECIPITATION AND IRREVERSIBLE FLOCCULATION

Defended on: 10/06/2023 In front of the examination committee

Jury:

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Academic year 2022/2023

# Acknowledgments

***Bismi Allah Alruhman Alrahim***

*I would like to express my sincere appreciation and gratitude to the following individuals and organizations who have played a significant role in the completion of this thesis:*

*First and foremost, I am deeply grateful to my thesis advisor, Dr. Nabil.B, for their guidance, expertise, and unwavering support throughout the entire research process. Their valuable insights, constructive feedback, and continuous encouragement have been instrumental in shaping the direction and quality of this work.*

*I would like to extend my appreciation to the staff and librarians at Kasdi Merbah Ouargla for their assistance in accessing research materials, resources, and databases. Their support has been invaluable in conducting comprehensive literature reviews and gathering relevant data for analysis.*

*Furthermore, I am indebted to my family and friends for their unwavering encouragement, understanding, and patience throughout the ups and downs of this thesis. Their emotional support and belief in my abilities have been a constant source of motivation.*

*Lastly, I want to express my gratitude to any other individuals, not mentioned by name, who have provided support and guidance during the course of this research. Your contributions have made a meaningful impact on this thesis.*

*In conclusion, I would like to emphasize that any errors or shortcomings in this thesis are solely my responsibility. The support and assistance I have received from the aforementioned individuals and organizations have been invaluable, but any mistakes or omissions are mine alone.*

# Dedication

*This thesis is dedicated to my loving family, who has been my unwavering source of support, encouragement, and inspiration throughout my academic journey.*

*To my parents," **CHBAABAN**"and "**MAAMERI DALILA** ", your unwavering belief in my abilities and your endless sacrifices have made it possible for me to pursue my dreams. Your love, guidance, and sacrifices have shaped me into the person I am today. This thesis is a reflection of your unwavering support, and I dedicate it to you with profound gratitude and love.*

*To my siblings, your constant encouragement, friendship, and laughter have brought joy to my life. Your belief in me has fueled my determination, and I am grateful for the bond we share. This thesis is dedicated to you as a token of appreciation for the memories we have created together.*

*Dear « BENSEDDIK Mohammed Alhadj Ali », I want to express my heartfelt gratitude for your exceptional guidance and friendship. Your ceaseless endeavors in assisting us with the preparation of this thesis have been truly extraordinary. Your unwavering commitment, profound insights, and unwavering encouragement have played a pivotal role in enabling me to reach this significant accomplishment.*

*Lastly, I would like to dedicate this thesis to all the individuals who believe in the power of education and the pursuit of knowledge. May this work contribute to the collective wisdom and inspire future generations of scholars and researchers.*

***OUALID***

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*FATIMA*

# Dedication

## **Thank "god" before everyone;**

*To my loving family, who have been my unwavering source of support and encouragement throughout this journey.*

*To my parents, father* ***"MOSTEFA"*** *and mother* ***"SAMIRA HABIBATNI "****who sacrificed their own dreams to provide me with endless opportunities and a solid foundation for success. Your unwavering love and belief in me have fueled my determination and shaped the person I am today.*

*To my partner, who has been my rock, my sounding board, and my biggest cheerleader. Your unwavering belief in me, even during moments of self-doubt, has given me the strength to push forward and strive for greatness.*

*To my friends, both near and far, who have provided invaluable support, understanding, and encouragement. Your presence in my life has enriched my experiences and reminded me of the importance of meaningful connections.*

*To my mentors and teachers, who have shaped my intellectual growth and inspired me to think critically, pursue knowledge, and never settle for mediocrity. Your guidance and wisdom have been instrumental in shaping my academic and personal development.*

*To my dear mentor and friend,* ***"BENSEDDIK Mohammed Alhadj Ali",***

*Your tireless efforts in guiding us through the preparation of this thesis have been nothing short of remarkable. Your dedication, insight, and unwavering support have been instrumental in helping me achieve this milestone. I am deeply grateful for your generosity, expertise, and patience throughout this journey, and I dedicate this thesis to you as a token of my appreciation. Your impact on my academic and personal growth will always be remembered, and I hope to continue to carry your knowledge and wisdom with me as I embark on new challenges. Thank you for everything, and I am honored to have had you as my mentor.*

*This thesis is dedicated to each and every one of you. Your unwavering support, love, and belief in me have made this achievement possible. I am forever grateful for your presence in my life and for being my constant motivation.*

*MONCEF*

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# List of symbols

| **ADE** | **Asphaltene deposit envelope** |
|---|---|
| **APE** | Asphaltene precipitation envelope |
| **CII** | Colloidal instability index (%) |
| **MCII** | Modified Colloidal Instability Index (%) |
| **Pi** | Initial Pressure on (kg/cm$^2$) |
| **T** | Temperature(°C) |
| **Q** | Flow rate (m$^3$/day) |
| **SARA** | Saturate aromatic resin asphaltenes |
| **PVT** | Pressure volume temperature |
| **HMD** | Hassi Messaoud |
| **NNE** | North -North East |
| **NW** | North east |
| **SW** | South east |
| **$\phi$** | Porosity |
| **PI** | Productivity index |
| **$\mu$** | viscosity in centipoises (cP) |
| **C-O** | Carbone monoxide |
| **SDS** | Solids Detection System |
| **HPM** | High Pressure Microscope |
| **PSA** | Particle Size Analysis |
| **DBR** | Delay bubble rise |
| **BHS** | Bottom hole sample |
| **W** | Weight (kg) |
| **PSF** | Pressure of static fund (kg/cm$^2$) |
| **PDF** | Pressure of dynamic fund (kg/cm$^2$) |
| **$T_{res}$** | Reservoir temperature (°C) |
| **Pt** | Wellhead pressure (kg/cm$^2$) |
| **ID** | inner diameter (m) |
| **$MW_o$** | The molecular weight of the oil (g/mol) |
| **$\rho_o$** | Oil density (g/cm3) |
| **GOR** | Gas oil ratio (scf/bbl) |
| **Rw** | Radius of the well (in) |
| **$TH_z$** | thickness of the zone (ft) |
| **H** | height of reservoir (ft) |
| **Ct** | compressibility factor (m$^2$/N) |
| **B** | formation volume factor (SCF/STB) |
| **K** | Permeability (mD) |
| **KH** | Transmissibility (mD.m) |
| **WBS (C)** | Wellbore storage (m$^3$) |
| **$\Delta P$** | Loss of load (kg/cm$^2$) |
| **DST** | Drill stem test |
| **IPR** | Inflow performance Relationship |
| **VLE** | Vapor–Liquid Equilibrium (atm, kPa, or mmHg) |

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## ملخص:

ترسب الأسفلتين له تأثير ضار على عمليات النفط والغاز المختلفة، بما في ذلك استخراج النفط،والنقل، ومعالجة البترول. نظرًا للتكاليف الكبيرة المرتبطة بمعالجة ترسب الأسفلتين في إنتاج النفط الخام، فقد تم تطوير العديد من التقنيات لتقييم استقرار الأسفلت.

تهدف الدراسة الحالية إلى تطوير نهج تشخيصي لرواسب الأسفلت في المنطقة 1 من حقل نفط حاسي مسعود. أجريت الاختبارات المعملية مثل تحليل SARA لدراسة خصائص سوائل الخزان. تم استخدام مؤشر عدم الاستقرار الكولويدي (CII)، نسبة الأسفلت للريزين ، ومؤشر عدم الاستقرار الكولويدي المعدل (MCII) للتنبؤ باستقرار الإسفلت في النفط الخام. في هذا البحث، تم استخدام عينات من النفط الخام من قاع MDZ547 لتطوير نموذج ديناميكي حراري باستخدام برنامج PIPSIM لمحاكاة سلوك الخزان والتنبؤ ببدء ترسيب الأسفلتين باستخدام مغلف ترسيب الأسفلتين (ADE) وتم تحديد أن البئر في منطقة تشكل الاسفلتين. تم استخدام برنامج SAPHIR للتنبؤ بسلوك الترسيب وتقييم الأداء. زيادةskin تشير إلى أن التكوين قد تضرر بسبب الرواسب داخل المسام. تؤكد جميع النتائج التي تم الحصول عليها من التقنيات المختلفة وجود مشكلة ترسب الأسفلت (الأسفلت غير المستقر).

ستساهم نتائج هذه الدراسة في تحسين عمليات الإنتاج وضمان التدفق السلس والمستمر للنفط في حقل حاسي مسعود.

**الكلمات المفتاحية:**

Pipsim–SAPHIR–MDZ547 –الضغط –الأسفلتين–SARA .

## Résume :

Les dépôts d'asphaltènes ont un effet néfaste sur diverses opérations pétrolières et gazières, notamment l'extraction, le transport et le traitement du pétrole. En raison des coûts considérables associés au traitement des dépôts d'asphaltènes dans la production de pétrole brut, plusieurs techniques ont été développées pour évaluer la stabilité des asphaltènes

L'étude actuelle vise à développer une approche diagnostique des dépôts d'asphaltènes dans la zone 1 du champ pétrolifère de Hassi Messaoud. Des tests de laboratoire ont été effectués, tels que l'analyse SARA, afin d'étudier les propriétés des fluides de réservoir. L'indice d'instabilité colloïdale (CII), le rapport asphalte/résine et l'indice d'instabilité colloïdale modifié (MCII) ont été utilisés pour prédire la stabilité des asphaltènes dans le pétrole brut. Pour cette recherche, des échantillons de pétrole brut provenant du fond du MDZ547 ont été utilisés pour développer un modèle thermodynamique à l'aide du programme PIPSIM afin de simuler le comportement du réservoir et de prédire le début du dépôt d'asphaltènes à l'aide de l'enveloppe de dépôt d'asphaltènes (ADE) et il a été déterminé que le puits se trouvait dans la phase de précipitation des asphaltènes. Le programme SAPHIR a été utilisé pour prédire le comportement de sédimentation et pour évaluer la performance du puits. Le skin a augmenté, ce qui indique que la formation a été endommagée par des sédiments à l'intérieur des pores. Tous les résultats obtenus à partir des différentes techniques confirment la présence d'un problème de dépôt d'asphaltène (asphalte instable).

Les résultats de cette étude contribueront à améliorer les processus de production et à assurer un écoulement régulier et continu du pétrole dans le champ de Hassi Messaoud.

Les mots-clés :

Dépôts d'asphaltènes- Stabilité des asphaltènes- Analyse SARA- Indice d'instabilité colloïdale modifié (MCII)- Programme SAPHIR-Performance du puits-Transport

## Abstract:

Asphaltene deposition has a detrimental effect on various oil and gas operations, including oil extraction, transportation, and petroleum processing. Due to the considerable costs associated with processing asphaltene deposition in crude oil production, several techniques have been developed to assess asphaltene stability.

The current study aims to develop a diagnostic approach to asphaltene deposits in the zone 1 of Hassi Messaoud oil field. Laboratory tests were conducted such as SARA analysis to study the properties of the reservoir fluids. The colloidal instability index (CII), the ratio of asphalt to resin, and the modified colloidal instability index (MCII) were employed to predict the stability of asphaltene in crude oil. For this research, samples of crude oil from the bottom of the MDZ547 and utilized to develop a thermodynamic model using the PIPSIM program to simulate reservoir behavior and predict the onset of asphaltene deposition using the asphaltene deposit envelope (ADE) and it was determined that the well was in the asphaltene precipitation phase. The SAPHIR program was employed to predict its sedimentation behavior and to evaluate the well performancethe skin had increased, indicating that the formation was damaged by sediment inside the pores. All findings obtained from the different techniques confirm the presence of an asphaltene (unstable asphalt) deposition issue.

The results of this study will contribute to improve the production processes and ensure a smooth and continuous flow of oil in the Hassi Messaoud field.

**Keywords**

- Asphaltene deposition- Skin damage – Colloidal instability index (CII)- Asphaltene deposit envelope (ADE)- Crude oil analysis - MDZ547 well

# General Introduction

## Introduction:

In today's world, there is a significant rise in the demand for energy, particularly in industrial sectors, which indicates that we must accept a greater dependency on energy than before. While renewable energy sources can meet some of these requirements, humans still heavily rely on hydrocarbon resources as their primary source of energy. As a result, it is important to acknowledge that the significance of fossil fuels, especially oil and gas, has increased in recent years.

Within the framework of the development techniques for the exploitation and refining of oil, it is important to know with precision the structure and behavior of its various components. Indeed, crude oil is composed of four families (SARA): saturated hydrocarbons, aromatics, resins, and asphaltenes. This distribution is very broad; each part of crude oil is also composed of a range of molecules with varying structures and properties. The exploitation of this source of fossil energy and hydrocarbons is one of the pillars of the contemporary industrial economy because oil provides almost all liquid fuels, and this exploitation requires drilling equipment and surface installations. Very expensive, so the rock that retains the hydrocarbons is the subject of particular attention in order to ensure the longest possible life. **[1]**

In the oil industry, several problems have disrupted production. These problems are related to the reservoir on the one hand and to the well itself on the other.

One of these issues is the asphaltene deposits that are created during the extraction process. These molecules have the particularity to associate to form aggregates, limiting the diffusion of the molecules in the porous network of the catalysts and thus reducing their efficiency. These deposits represent a real catastrophe because they seriously affect the production and transportation of petroleum fluids. Asphaltene deposition can occur throughout the production chain: reservoirs, well pads, production tubing, wellheads, gathering systems, manifolds, crude processing facilities, separators, heat exchangers, storage tanks, and shipping lines. Asphaltene deposition causes reduced production rates, increased oil viscosity, and emulsion problems. **[2]**

In the reservoir rock, in the vicinity of the wells, the damage caused by the asphaltene deposits creates a reduction in the permeability of the porous medium. This situation leads to a decrease in the productivity of the deposit and, in the most serious case, can be the cause of well closure. **[3]**

The removal of asphaltene deposits from oil production facilities can be very costly. Thus, predicting the conditions that lead to asphaltene precipitation can help reduce these costs and mitigate issues in production facilities. However, it may not always be possible to prevent asphaltene deposition. Therefore, modeling fluid flow behavior can help identify optimal conditions that minimize blockages caused by asphaltene deposition.**[4]** Researchers have proposed several models for asphaltene deposition, including a model by **Ramirez et al(2006).**That considers both molecular diffusion and shear removal as competing mechanisms during asphaltene particle deposition. **[5]**

The main purpose of studying asphaltene precipitation is to:

1. Understand the phase behavior of petroleum fluids at the level of the HASSI MESSAOUD and the factors that influence asphaltene precipitation.

2. Predict and prevent operational issues caused by asphaltene precipitation, such as blockages, equipment fouling, and reduced oil quality.

3. Modeling of the Asphaltene Deposition Envelope (ADE).

4. Optimize production processes in the oil industry by adjusting parameters to minimize the impact of asphaltene precipitation.

5. Develop accurate models and simulation approaches to better predict and manage asphaltene behavior under different operating conditions.

This study's methodology will mostly consist of research, data gathering from the literature reviews, and data analysis. For this thesis, there are both experimental and modeling approaches. We followed the steps showed in figure 1 to find out the asphaltene ratio in the fluid and the sample.

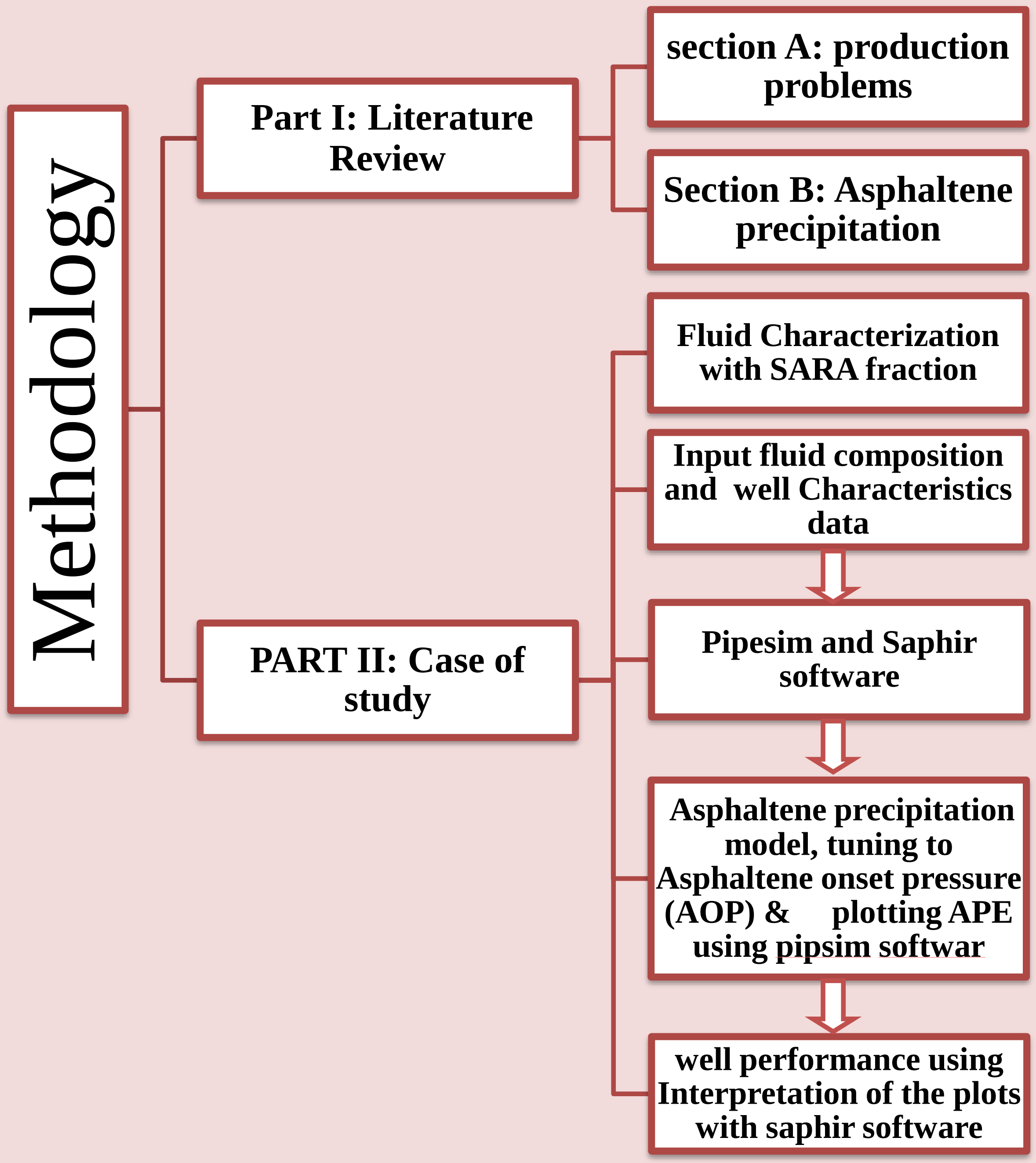


Figure 1 Schematic of research methodology

# PART 1:
# LITERATURE REVIEW

## Section A:

### I.A.1. Introduction

Formation damage in the Hassi Messaoud field is indeed a significant problem that impacts all operations and contributes to the low productivity or injectivity index of wells. This damage can arise from various sources and have multiple causes.

The purpose of this section is to identify and analyze the diverse types of formation damage that occur within the Hassi Messaoud oil field.

### I.A.2. General Information on the Hassi Messaoud field

### I.A.2.1. Geographies situations

The Hassi Messaoud field, the largest oil field in the Algerian Triassic province, is located 700 km southeast of Algiers, covering an area of 2000 km$^2$ at an altitude of 142 m. With a desert climate, temperatures range from 0° C to 47° C on average. The field is known for its significant reserves and shares boundaries with neighboring deposits. Its precise location is specified in Lambert, South Algeria coordinates. Its location in Lambert South Algeria coordinates is

- ✓ 790 000 @ 840 000 East.
- ✓ 110 000 @ 150 000 North. **[7]**

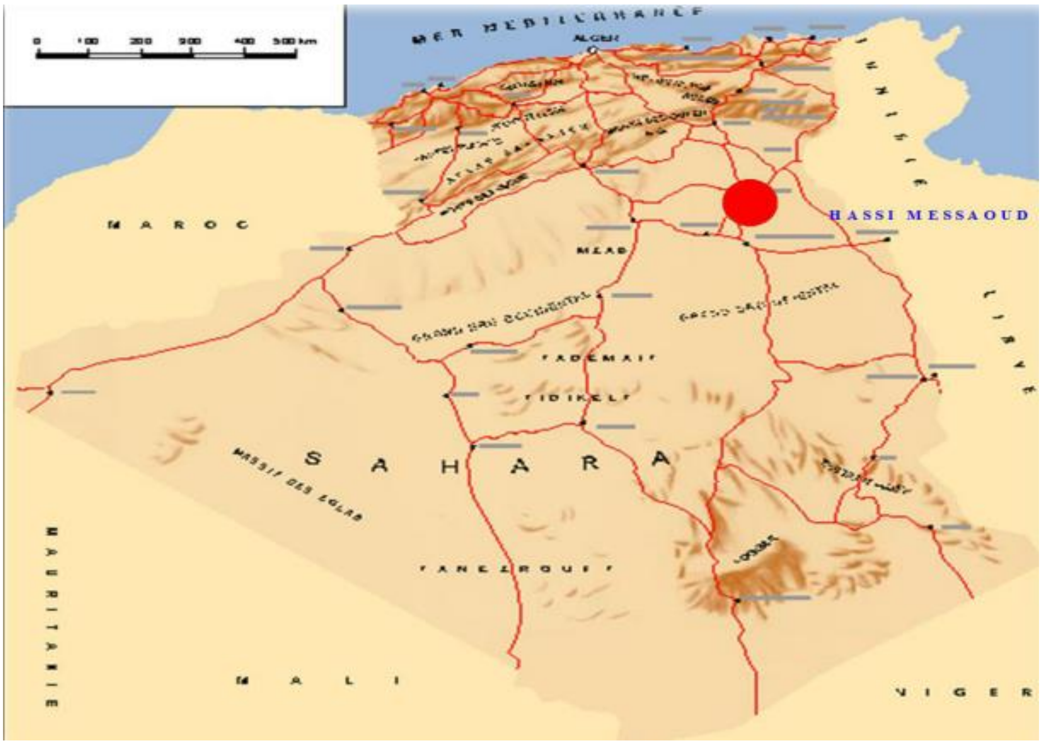


**Figure I.A.1:** Location geographic field of Hassi Messaoud **[7]**

### I.A.2.2. Description of the reservoir

The Hassi Messaoud deposit is at a depth that varies between 3100 and 3380 m. Its thickness goes up to 200 m; it includes three sandstone reservoirs of Cambrian age, resting directly on the granitic base. It is represented by a sandstone series, of which the Paleozoic post-erosive erosion affects a part in the center of the field. It is subdivided from top to bottom into:

- Ri: isometric zone with a thickness of 45 m, essentially fine-grained quartzite and tigillite. It corresponds to the D5 drain.
- Ra: an isometric zone with an average thickness of about 120 m composed of sandstone with silico-clay cement of medium to coarse grains. It is subdivided into drains, respectively, from bottom to top: D1, ID, D2, D3, and D4.
- R2: Clayey cement sandstone series, with an average thickness of 80 m.
- R3: About 300 m high, it is a very coarse to micro conglomerate sandstone series, very clayey, resting on the granitic base, which was met at a depth lower than 4000 m; it is pink porphyroid granite. It is divided into two sub-levels: R2c and R2ab**. [7]**

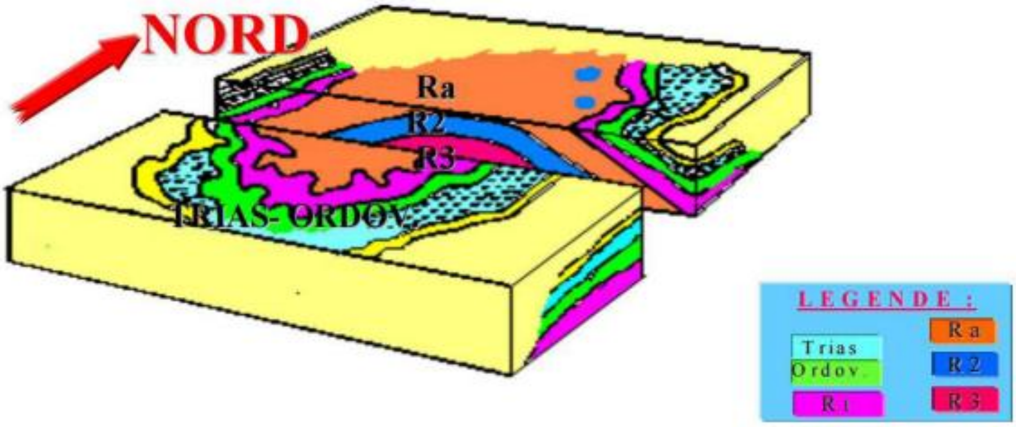


**Figure I.A.2:** Diagrammatic block of the geologic scarp beneath the Hercynian unconformity **[7]**

## I.A.3. most common and various types of formation damage of hassi Messaoud field

### I.A.3.1. Formation Damage definition

Wellbore fluids used during drilling, completion, injection, stimulation, and workover operations are the main cause of formation damage. This damage is divided into sections as shown in Figure I.A.3. It affects the characteristics of reservoir rocks, such as porosity and permeability, leading to a reduction in the natural productivity of reservoirs. Formation damage can have a significant impact on drilling operations and production, directly influencing economic viability. The severity of formation damage may vary from one well to another, and any reduction in fluid recovery potential is an undesirable problem in oilfields. **[8]**

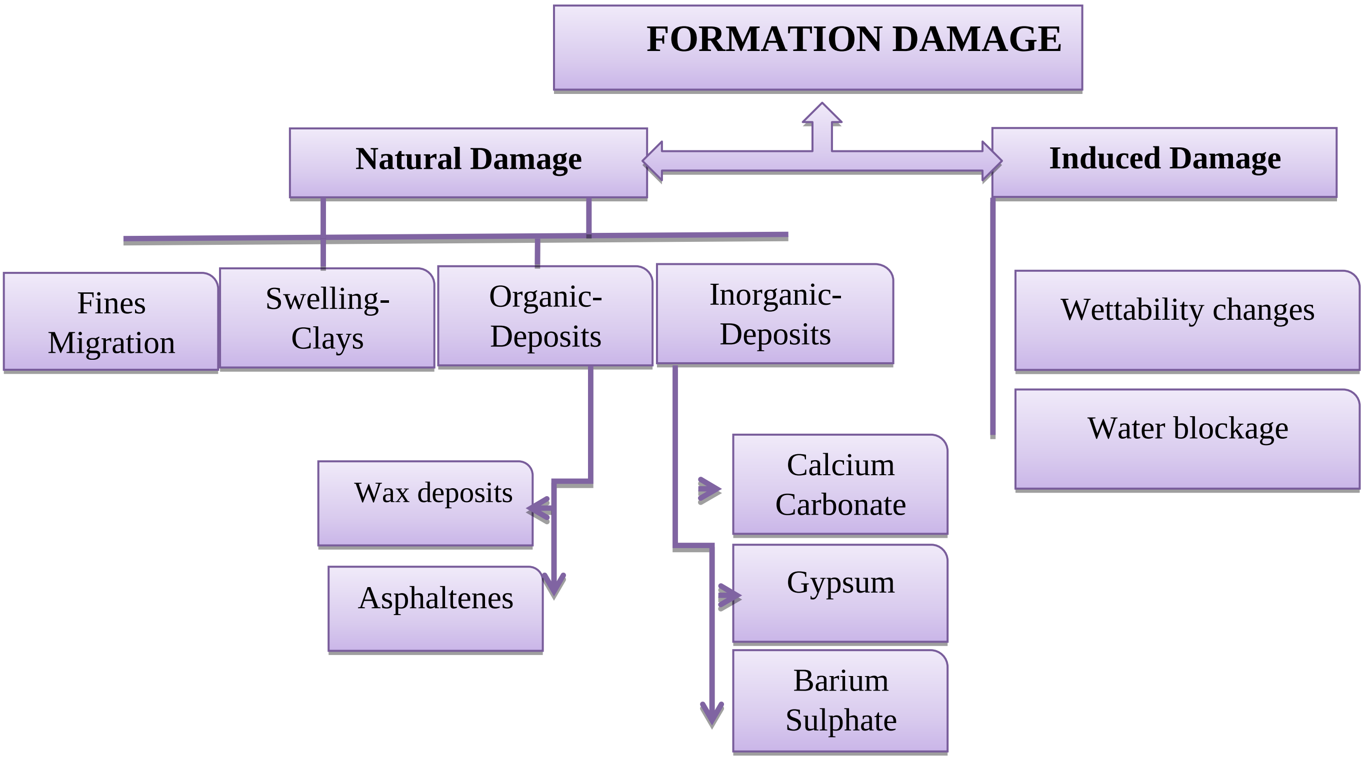


**Figure I.A.3:** Formation damage causes classified **[8]**

### I.A.3.2. Formation damage location

Formation damage can occur in various locations within an oil field, including the reservoir and the well itself. Here are some specific locations in Figure I.a.4 where formation damage can occur:

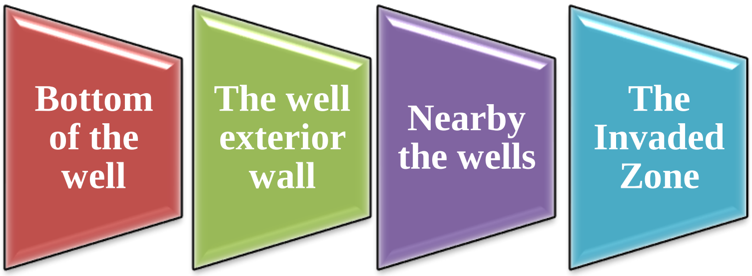


**Figure I.A.4:** formation damage main locations

### I.A.3.3. Natural damage

#### I.A.3.3.1. Fines migration

Fines are known as unconfined solid particles that are present in the pore spaces of formations. This migration, caused by fluid flow in the reservoir, can cause pore plugging and permeability reduction. **[9]**

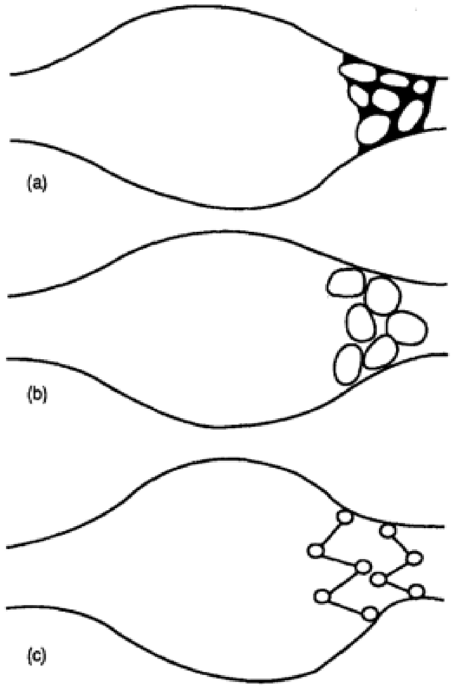


**Figure I.A.5:** Pore throat blocking by plugging and bridging**[9]**

#### I.A.3.3.2. Clay swelling

Clay minerals present in the reservoir can absorb water, causing them to swell and block pore spaces. This leads to reduced permeability and can result in formation damage**. [10]**

#### I.A.3.3.3. Organic deposits

##### I.A.3.3.3.1. Asphaltene disposition

Asphaltene deposition is a significant issue in Hassi Messaoud. It involves the formation of solid deposits composed of asphaltene molecules within oil reservoirs, production equipment, and transportation pipelines. These deposits can cause flow restrictions, reduced productivity, increased pressure differentials, and equipment damage. System changes leading to the agglomeration or precipitation of asphaltene particles**. [11]**

**Figure I.A.6:** asphaltene disposition inside tubing **[11]**

### I.A.3.3.3.2. Wax deposits

They appear most often at the wellhead. Their formation is generally linked to a drop in temperature; for example, when injected fluids are at a lower temperature than at the bottom of the well, the solution practiced is cleaning with reformat. [11]

### I.A.3.3.4. inorganic deposits

$BaSo_4$, $CaSo_4$, and $CaCo_3$; formed due to incompatibility between the formation water of the well and water injection or water wash. They can be present in tubing and perforations. [12]

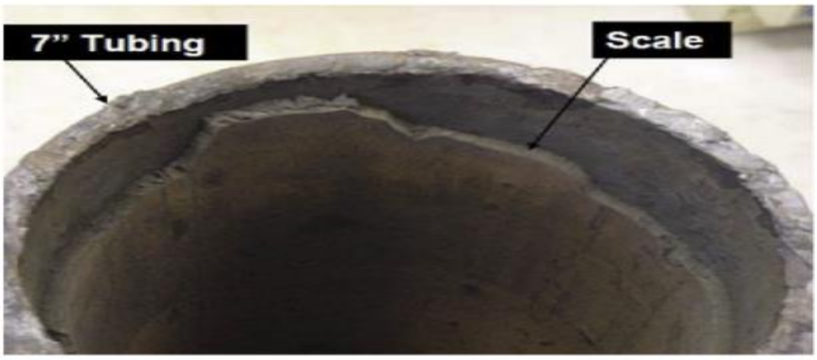


**Figure I.A.7:** scale disposition [12]

### I.A.3.3.5. Salt disposition

The presence of produced water with high salinity and the change in some reservoir conditions like temperature and pressure are the main causes of salt deposits.**[13]**

### I.A.3.3.6. Sulfate deposition

Sulfate deposits are a prevalent issue in the Hassi Messaoud field. These deposits are challenging to eliminate through chemical means. They primarily form due to the incompatibility between the injection water used for salt well softening or pressure purposes and the formation water. Sulfate deposits can be found in various locations, including tubing, perforations, and even within the formation itself. **[14]**

### I.A.3.4. Induced damage

### I.A.3.4.1. Water blocking

In some cases, the influx of water into the reservoir can result in water blocking, where water occupies the pore spaces and displaces hydrocarbons, leading to reduced production rates.

### I.A.3.4.2. Change of wettability

Wettability is a physical characteristic that refers to the ease with which a liquid can stick to or spread on a solid surface. Factors like surface chemistry, roughness, temperature, and pressure can affect wettability. The ability to comprehend and regulate wettability is vital for various applications, such as oil retrieval and microfluidics. Numerous techniques have been devised to alter the wettability of solid surfaces, such as changing their chemical composition, roughening their texture, or coating them with hydrophilic or hydrophobic materials. For instance, by treating silicon with octadecyl-trichlorosilane (OTS), the surface wettability can be switched from hydrophilic to hydrophobic. **[15]**

Or it is the ability of the reservoir rock to be covered preferentially with a desirable fluid (oil) or water film. It increases oil recovery because wettability has a significant impact on the effectiveness of fluid displacement in porous media. **[16]**

Changing the wettability of a naturally water-wet surface refers to oil composition, because any wettability-altering components are in the oil phase. A crude oil that is a poor solvent for its own surfactants will have a greater propensity to change wettability than one that is a good solvent. **[17]**

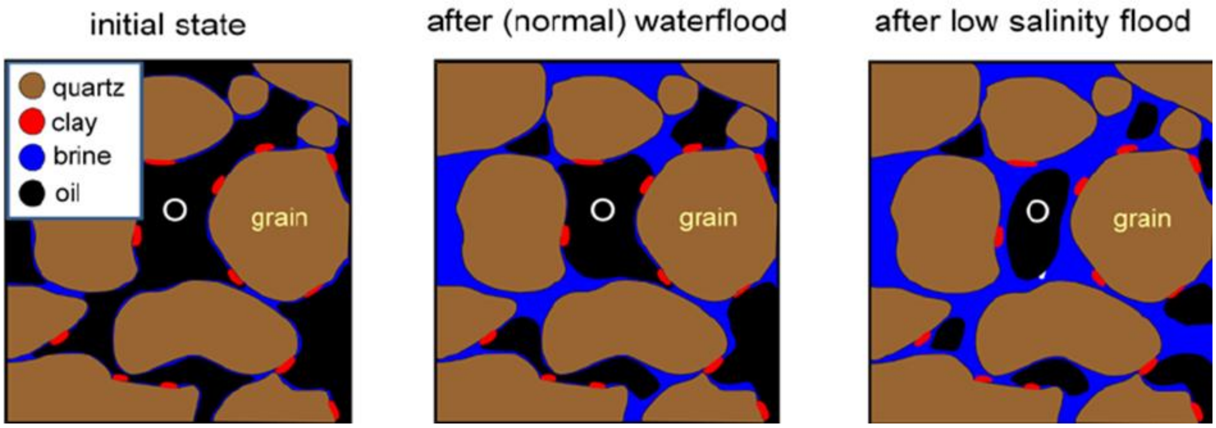


**Figure I.A.8:** Schematic sketch of the wettability change in a porous sandstone rock due to low salinity flooding **[17]**

## I.A.4. Damage Detection

### I.A.4.1. Well Testing

Conducting well tests, such as drawdown or buildup tests, can help determine reservoir properties and assess the presence of formation damage. Analyzing the pressure and flow rate data collected during these tests can provide valuable insights into the condition of the formation.

### I.A.4.2. Core Analysis

Core samples extracted from the reservoir can be analyzed in the laboratory to evaluate the permeability, porosity, and fluid saturation of the formation. Comparing these results with pre-damage values can help identify the extent and type of formation damage.

### I.A.4.3. Production Decline Analysis

Production decline analysis, utilizing nodal analysis, is a method employed by engineers to evaluate the complete production system. By monitoring production rates over time and analyzing the decline behavior, engineers can identify changes that may indicate the presence of formation damage. Sudden or abnormal declines in production can suggest the existence of damage near the wellbore. Nodal analysis allows for a comprehensive assessment of the production system, considering various components such as the reservoir, wellbore, tubing, and surface facilities, to gain insights into the causes of production decline.

### I.A.4.4. Well history

Serves as a valuable source of information to help identify and understand the causes of formation damage. By examining the complete well history, engineers can gather crucial data and insights that aid in detecting the factors contributing to the damage.

## Section B:

### I.B. Introduction

The aim of this section is to define asphaltene deposits, including their origin, composition, and structure; conditions of flocculation; experimental determination of asphaltene precipitation; and treatment method.

### I.B.1. Origin of asphaltenes

The origin of asphaltene is closely related to that of kerosene, which is the product of various transformations of chemical and biochemical organic matter accumulated and deposited in parent rocks. During burial, increased temperatures cause thermal degradation of kerosene and contribute to the formation of smaller-sized similar structures called asphaltene and resins; Figure I.B.1 below shows the stages of their formation. **[18]**

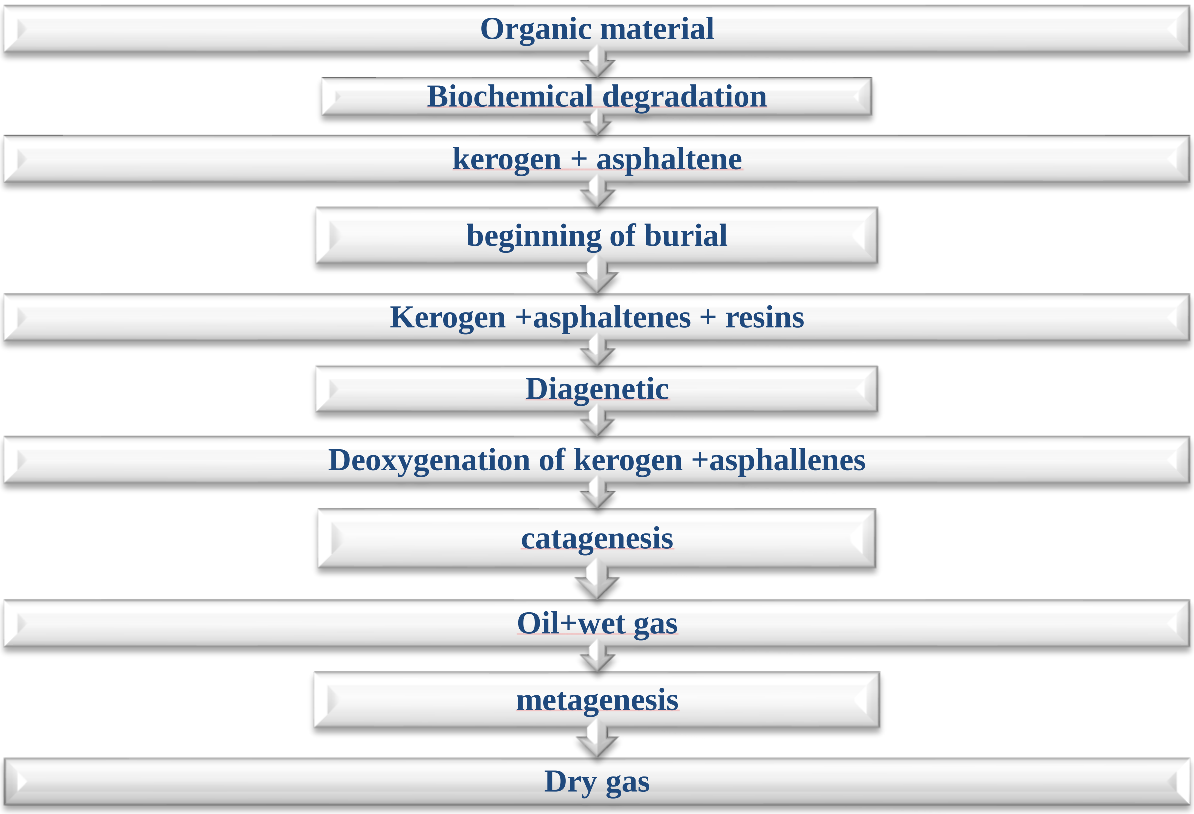


**Figure I.B.1:** Origin of asphaltenes and resins **[18]**

### I.B.2. Definition of asphaltenes

Asphaltenes are a class of hydrocarbons. Naturally occurring hydrocarbon liquids are compounds whose composition ranges from dry natural gas to tar. In this range, as the asphaltene content increases from 0 to nearly 20%, the density and viscosity increase sharply, and the color changes from transparent to dark brown. **[19]**

In 1973, Mitchell and Speight defined asphaltenes as all components of petroleum or petroleum residues that are insoluble in non-polar solvents (gas liquefied petroleum, petroleum ether, pentane, isopentane, hexane, etc.) but soluble in solvents with a surface tension greater than 25 dyne.cm-1 (pyridine, toluene, etc.). **[20]** The asphaltene obtained in this way is a dark, brittle solid with a density of about 1.2 grams per cubic centimeter. Additionally, it is infusible, which means it doesn't have a specific melting point but instead breaks down when heated, leaving a carbonaceous residue. Because the amount of asphaltene in crude oil affects how it will be processed and refined, a practical laboratory method has been devised to measure the asphaltene percentage. According to their solubility and polarity, saturates, aromatics, resins, and asphaltenes (SARA) are separated from dead oil, or oil that has lost its gaseous components, in this process.

**Figure I.B.2:** sample of asphaltene **[20]**

### I.B.3 Composition of asphaltenes

The major molecules in asphaltenes are **Carbon** and **Hydrogen.** They also contain considerable amounts of heteroatoms including **Sulfur**, **Nitrogen (N),** and **Oxygen**, as well as **Nickel** and **Vanadium**, which are also found in different amounts and proportions.**[21]**

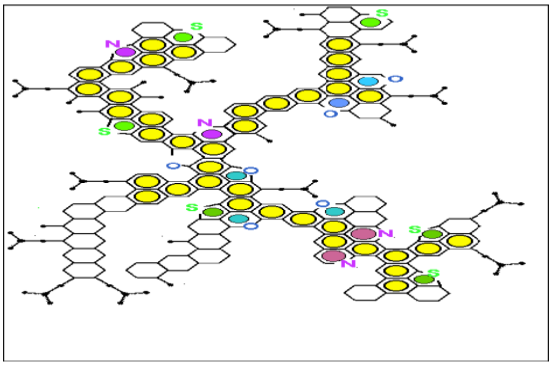


**Figure I.B.3:** Composition of asphaltenes

**Table I.B.1** Elemental Analysis of Hassi Messaoud Crude Asphaltenes

| Elementary Compositions | Contents (%) |
|---|---|
| 0C | **83.82** |
| H | **7.4** |
| N | **0.44** |
| O | **7.85** |
| S | **0.49** |
| H/C | **1.05** |

## I.B.4. Structure of asphaltenes

### I.B.4.1. Pfeiffer model

In 1940, Pfeiffer and al proposed a structural model for asphaltenes. According to these authors, asphaltenes form micellar entities surrounded and stabilized by resins and certain other petroleum constituents. They suggested that there is a continuous transition between the more polar species (the asphaltenes) and the less polar species (the aliphatic). When the quantity of resins decreases, attractive forces are created, which leads to an association of the micelles with each other and gives the medium a gel-type structure. **[22]**

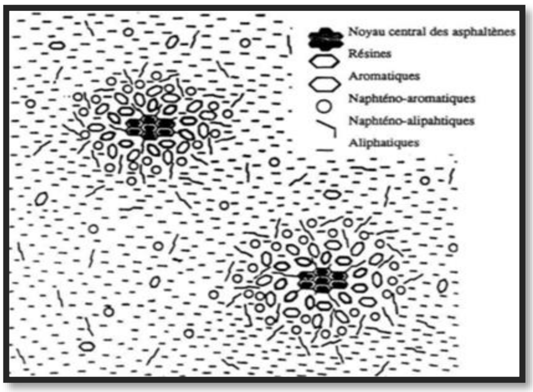


**Figure I.B.4:** Dispersed asphaltenes (before flocculation)

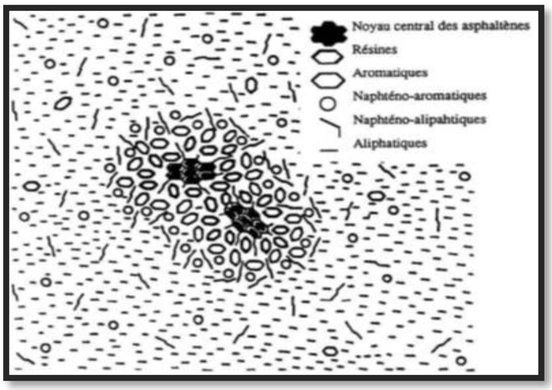


**Figure I.B.5:** Aggregated asphaltenes (after flocculation)

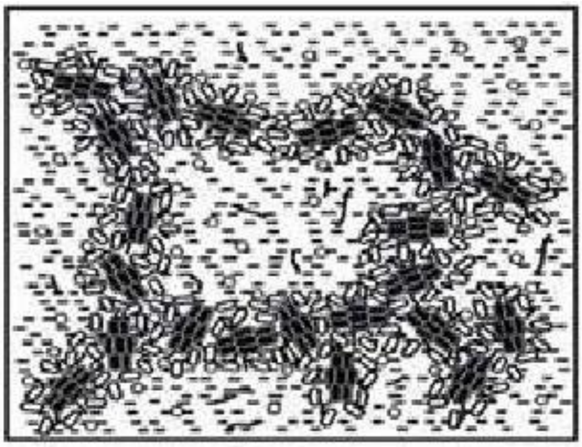


**Figure I.B.6:** asphaltenes in gel form **[22]**

### I.B.4.2. Yen model

The T.F.YEN model is the most widely used model to describe the structure of asphaltenes. It is based on the concepts of sheet, particles, micelles and agglomerates. **[23]**

**Sheets:** These will be the basic units of fused PAHs, 1 to 1.5 nm in size, composed of heteroatoms (O, N, and S) with functional groups and aliphatic chains.

**Particle:** A series of flakes (3 to 4) form a particle through molecular association.

**Micelles:** Particles associate in oil to form colloidal particles or micelles.

**Agglomerates:** The association of particles or micelles produces agglomerates.

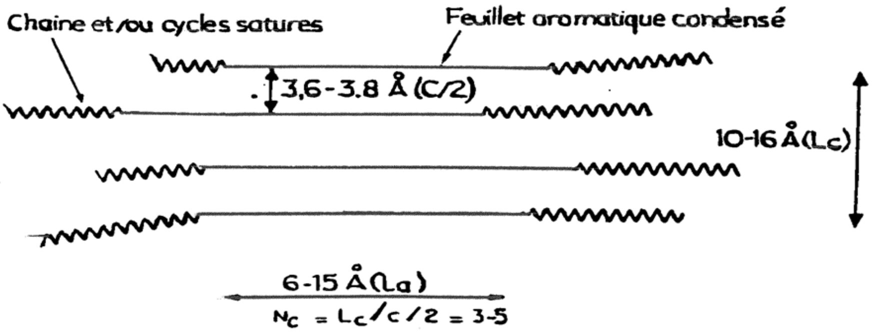
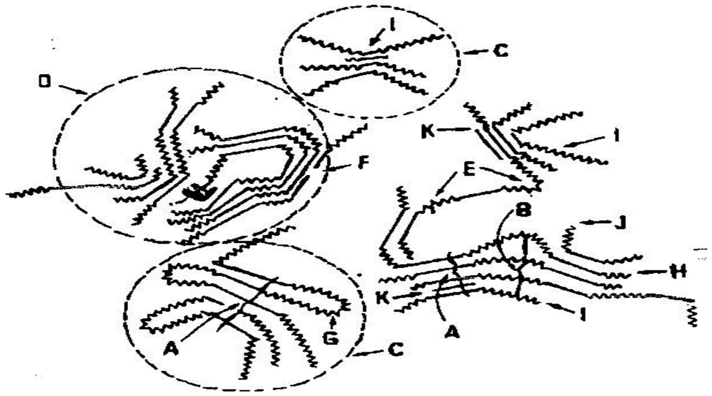


**Figure I.B.7:** Schematic representation of an asphaltene particle from X-ray diffraction data from YEN (1971) and SPEIGHT and AL (1979)



**A** – Particle; **B** – Micelle; **C** – Aggregate;

**Figure I.B.8:** YEN MODEL STRUCTURE OF ASPHALTENE MOLECULES

### I.B.4.3. Examples of some hypothetical molecular structures of asphaltenes

The state of chemical knowledge Due to the poor evolution of heavy compounds, we are still far from a precise formula for the molecular structure of asphaltene, but researchers in the field have been able to hypothesize the molecular structure of asphaltene from different oils, as shown in the following example**:**

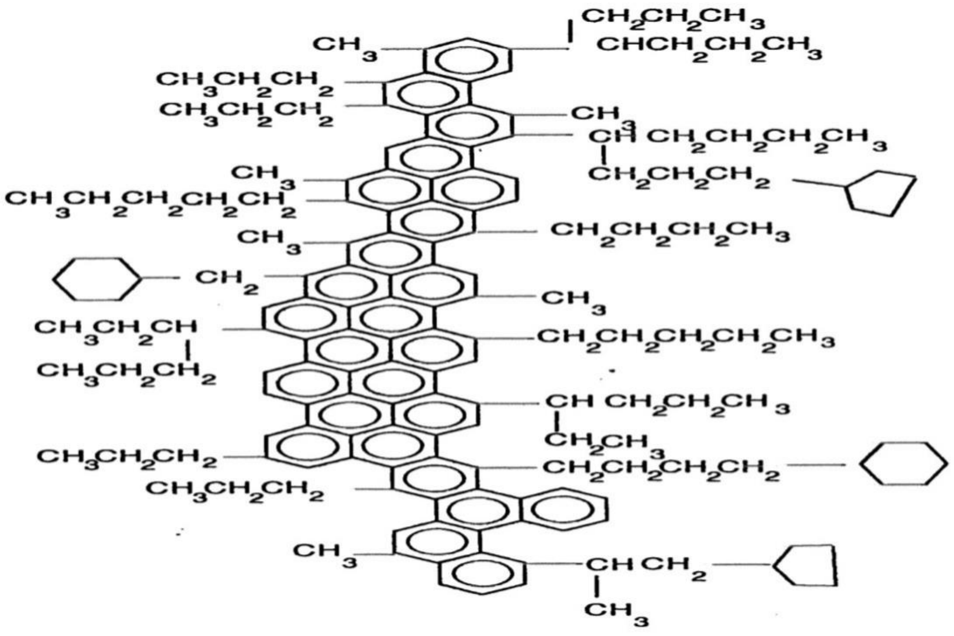


**Figure I.B.9:** Hypothetical structure of an Asphaltene molecule from an Iraqi crude proposed by James G. SPEIGHT and E. Moschopidis

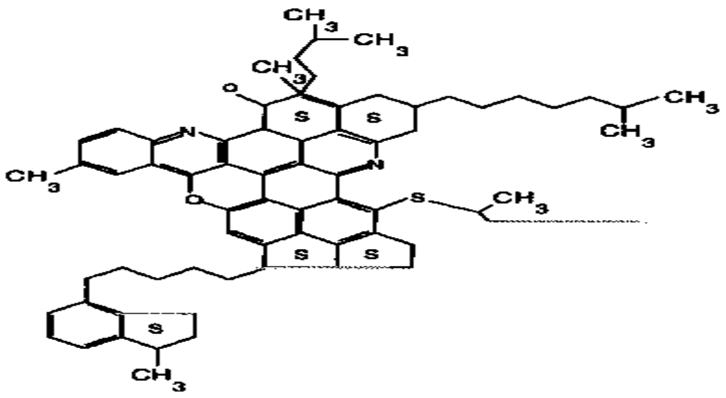


**Figure I.B.10:** YPOTHETICAL STRUCTURE OF AN ASPHALTENE MOLECULE FROM VENEZUELA CRUDE

### I.B.4.4. Asphaltenes in their natural environment

Asphaltene exists in oil in the form of a colloid, and its stability depends on the peptization ability of the resin in the oil. The addition of aliphatic hydrocarbons to the oil causes a change in the composition of the oil as resin molecules migrate from the surface of the asphaltenes into the oil phase to balance the aroma of the medium or restore the polarity of the asphaltenes to the oil after the addition of non-polar hydrocarbons. Thus, this migration of the resin leads to the surface depletion of asphaltenes in the resin, which allows the agglomeration and then flocculation of asphaltene colloids. **[24]**

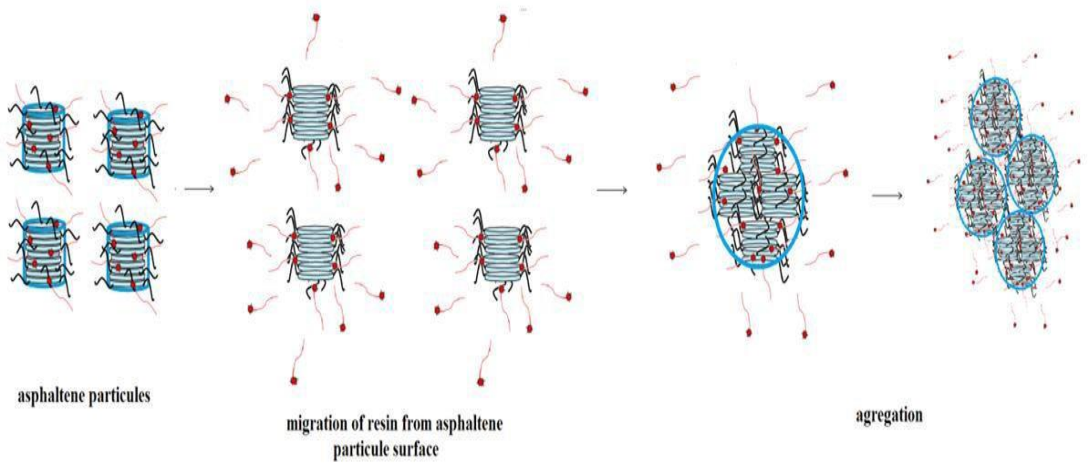


**Figure I.B.11:** Formation of asphaltene aggregate

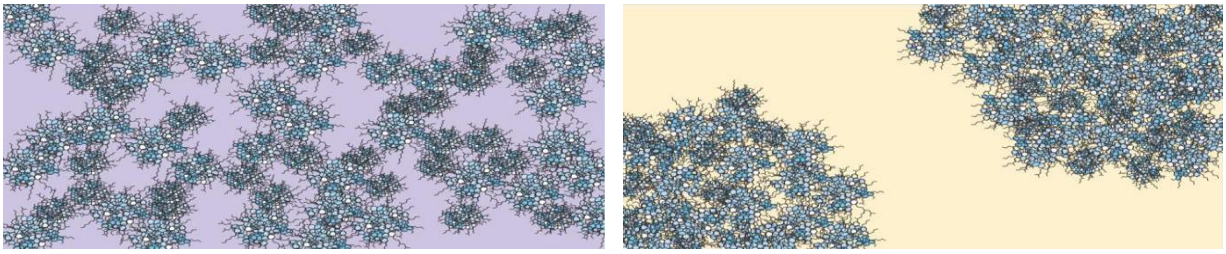


**Figure I.B.12:** Flocculation and agglomeration of asphaltenes **[24]**

The degree of dispersion of asphaltenes in oil depends mainly on the chemical composition of the latter. The deposition of these substances can be explained as a disruption of the existing balance due to the different composition of the various components that make up this oil. In complex hydrocarbon mixtures, the ratio of polar molecules to non-polar molecules is an important factor affecting the equilibrium of the medium. Adding a miscible solvent (nC5 or nC7) disrupts this ratio, as shown by various experiments performed.

The notion of the colloidal state of asphaltenes in their natural environment has been around for a long time. For Pfeiffer (Pfeiffer et al. 1940), asphaltenes constitute the center of micelles dispersed in resins. The evolution of certain arrangements depends on the ratio of the quantities of asphaltenes and resins. Indeed, if the proportion of resins is high enough to surround all the asphaltene particles, the latter are stabilized. It is the association between asphaltenes and resins due to hydrogen bonds of the acid-base type, which is favored over the asphaltene-asphaltene association. On the contrary, if this proportion of resin is too low, the system is unstable, and the micelles combine to form a structure of minimum energy, in which their cohesion is ensured; this gives rise to the formation of larger particles.

## I.B.5. Asphaltene deposition problem

### I.B.5.1. In the reservoir rock

Compositional changes caused by secondary or enhanced oil recovery processes can create asphaltene precipitation and deposition problems deep in the reservoir matrix. When chemicals and miscible solvents are injected into the reservoir, the buildup of asphaltene solids can damage or plug the porous media. Experiments have shown that almost all known miscible solvents cause asphaltene flocculation. Sedimentation is two distinct phenomena: flocculation can occur without significant in situ deposition if the flocculated particles can be entrained by the flow of the bulk liquid. It should be noted that flocculent materials contain a high amount of trapped oil, which makes them mobile and acts as a barrier against settling, but if it is deposited in the pores along with the asphaltenes, it will not be recoverable. **[25]**

### I.B.5.2. In surface facilities

Asphaltene flocculation in surface separation equipment and pipelines magnifies the problem because the flocculation material is deposited almost everywhere the crude oil enters the pipeline. The greatest impact of this problem is on safety and process control. At high pressure, the safety device may not activate, and if the safety valve is also blocked, the result may be disastrous. Identification and prediction of asphaltene flocculation potential crude oil before the planning and construction of production and processing facilities is absolutely basic.

### I.B.5.3. Asphaltene Flocculation

Asphaltene flocculation occurs when the oil solubility of Asphaltene decreases maybe caused by changes in composition, pressure drop ,temperature etc. In general, it is reported that the parameters are in descending order actors affecting asphalt flocculation include:

- Change in oil composition: gas injection, co-production of incompatible fluids, etc.
- Pressure reduction above bubble point: reservoir primary depletion
- Change in temperature: production pipelines
- Others (pH, water-cutting, electro-kinetic effects, etc.)**[26]**

## I.B.6. Experimental Determination of Asphaltene Precipitation

### I.B.6.1. Sampling Considerations

The best samples for asphalt testing are uncompressed samples. Single-phase samples collected from the well using a pressure-compensated single-phase sampler. In the lab, the samples were stirred at reservoir pressure and temperature for about five days before being transferred. This conditioning process helps dissolve any solids that may have settled during shipping. Reconstituted separator samples are not suitable for solid-related laboratory analysis. Due to the large pressure and temperature drops experienced by the reservoir fluid between the formation and the test separator, it is likely that some solids have settled and been lost in the production line or the test separator. **[27]**

### I.B.6.2. Asphaltene Precipitation Laboratory Test

A laboratory testing program for asphaltene precipitation is typically designed to provide one or more of the following:

- ✓ Asphaltene onset pressure at reservoir temperature and some other temperatures to cover the temperature range of the wellhead and surface separation facilities. Data from these tests are used to generate asphaltene precipitation envelope (APE) on a p-T phase diagram. This type of tests is known for isothermal de-pressurization test.

- ✓ Fluid compatibility, i.e., maximum concentration of a fluid or solvent allowed to be injected into the reservoir fluid without asphaltene precipitation. This test is called titration and usually performed at reservoir conditions to investigate the compatibility between the reservoir fluid with an injected solvent (natural gas or CO2, N2, etc.) or another reservoir fluid when they are commingled (co-production).
- ✓ Chemical/inhibitor screening test: If a reservoir fluid cannot avoid asphaltene precipitation under normal production scenarios, a chemical or inhibitor is used. The chemical screening tests are typically similar to above tests but the reservoir fluid is pre-treated with the chemical.
- ✓ Filtration test: This test is intended to quantify the amount of precipitated solids by flowing the oil through a filter to capture any solids larger than the filter size (typically 0.2 µm).

The laboratory equipment for the above tests, designed and manufactured by Oil-phase-DBR, includes the following:

- Solids Detection System (SDS). This is a laser-based technology used to detect organic solids (wax and asphaltene) precipitation from reservoir fluids.
- High Pressure Microscope (HPM).
- Particle Size Analysis (PSA)/ a software scans digital HPM photomicrograph images in real time at a high sampling rate and simultaneously discretizes**. [27]**

## I.B.7. Asphaltene Precipitation Modeling

### I.B.7.1. Asphaltene Phase Behavior

The behavioral envelope of the asphaltene phase in Figure I.B.13 is represented by the pressure-temperature diagram of the reservoir. Above the asphaltene upper limit, only a liquid phase is found. Here, asphaltenes and light components dissolve into the crude phase. As the reservoir is depleted, the asphaltene molecules begin to agglomerate, forming stacks that eventually aggregate and then fall off, forming a two-phase phase of solid asphaltenes and liquid crude oil. This point is the asphaltenes upper limit. When the pressure reaches the boiling point, the amount of asphaltene particles reaches a maximum. All light components leave the liquid phase at the saturation point, forming a three-phase environment, solid asphaltenes, liquid oil, and light vapor components. Since the light components have left the oil phase, the heavy fatty components in the oil are again suitable solvents for asphaltenes. . Asphaltene particles will be redissolved into the oil phase until the last asphaltene particle comes into the solution at the Lower Asphaltene Boundary.

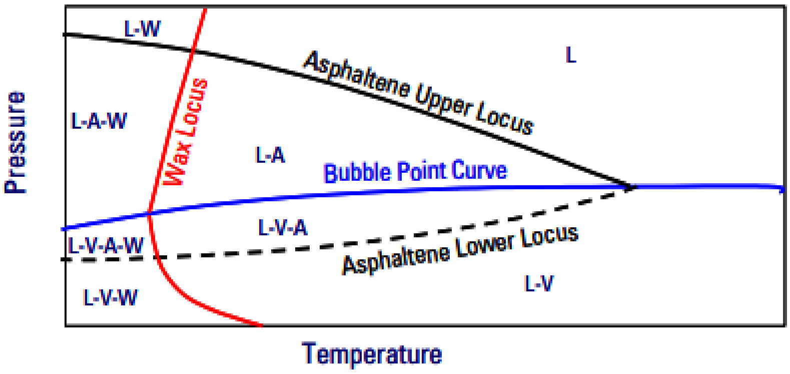


**Figure I.B.13:** Asphaltene phase envelope, pressure-temperature diagram. **[28]**

## I.B.7.2. Thermodynamic Models

Due to the ambiguous definition of asphaltenes and the complexity of their structures, experimental achievements for accurately and cost-effectively determining asphaltene precipitation are still limited. For that reason, it is necessary to develop thermodynamic relationships that can predict the behavior of asphaltene precipitation in terms of independent variables such as pressure, temperature, and the composition of the components in the crude oil. These PVT relationships have been studied for many years; however, no unique model has been developed to predict uniform asphaltene results for crude oils and all types of solvent injections. The most popular theories that postulate asphaltene precipitation models are the solubility and colloidal models. The colloidal model assumes that asphaltenes are micelles stabilized by polar-polar interactions with resins. Under this approach, if the concentration of resins/asphaltenes is too low, asphaltenes precipitate from the bulk phase. In the second group, the solubility models, it is believed that asphaltenes are soluble in the oil phase either partially or totally. A solubility parameter is defined and will depend on the weak van der Waals interaction forces rather than the colloidal model's solid polar-polar interactions.

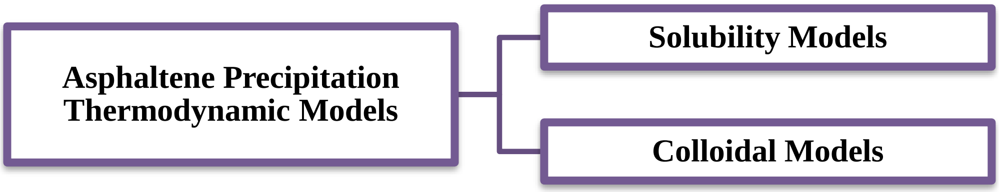


**Figure I.B.14:** Asphaltene precipitation thermodynamic models **[29]**

### I.B.8. Control and Remedy of Asphaltene Solids in Production

Once the asphaltene precipitation conditions are determined, it is desirable to control the production scenario such that the asphaltene precipitation conditions are avoided. This can be achieved by the following methods:

- Maintain reservoir pressure above the onset pressure.
- Avoid the co-production of incompatible reservoir fluids.
- Adjust injection gas or lift gas composition.
- Inject inhibitors or dispersants.

In cases where asphaltene precipitation is not avoidable, the damaged near-wellbore area is typically treated by solvent/chemical injection, such as benzene, toluene, or xylene. Whereas in the wellbore or the production facilities, some mechanical methods like cutting or jetting, in addition to the chemical cleaning, can be used. [30]

# Part II: case of study

# Well MDZ547

## II.1. Introduction

By examining the characteristics and factors contributing to asphaltene precipitation, effective strategies can be developed to mitigate its impact and optimize production performance. This part focuses on the analysis of current conditions and experimental data from well MDZ547. Various variables, such as temperature variations and pressure differentials, will be examined. Laboratory testing, reservoir simulation, and performance evaluation will be conducted to gain insights into asphaltene properties, predict flocculation conditions, and assess formation damage.

### II.1.1. Problem of the well

From the intervention history in Figure II.1, a clear and consistent pattern can be observed following each treatment operation (coiled tubing, wire line, snubbing). Initially, there is a significant rise in flow rate, indicating a successful intervention. However, this improvement is short-lived, as productivity rapidly declines. This sharp decrease strongly suggests the mobilization of asphaltenes during the treatment process, leading to their subsequent redeposition on the reservoir matrix. The deposition of these asphaltenes creates blockages and barriers that hinder the flow of oil, ultimately resulting in a noticeable decrease in production rates.

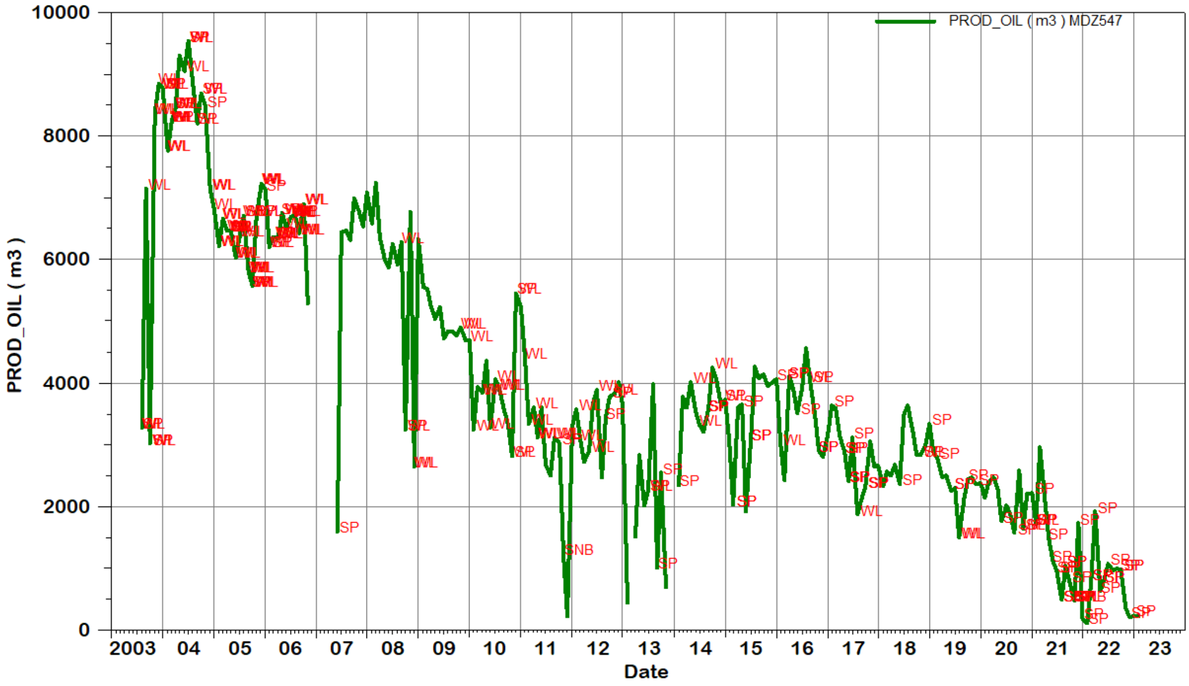


**Figure II.1:** MDZ547 Intervention history

### II.1.2. Well description

The current state of the well, as described in the technical sheet (Annex n°1), includes the following details: Date of drilling: 10/06/2003. NP = 854229,57 m3. Completion tubing of 4"1/2 New Vam anchored. The reservoir is covered by an LPP 4"1/2 top liner at 2985 m CS. The well's bottom parameters are TD = 4455 m and TVD = 3395m. Currently, the well is producing deposits of water. On May 12, 2013, a WO operation was conducted, involving a clean-out of LPP 4"½ from 3365m to 4455m. Additionally, there was a multiple SP clean-out and TRT performed at Reformat (39 SP). The position of the well is indicated in Figure II.1 below:

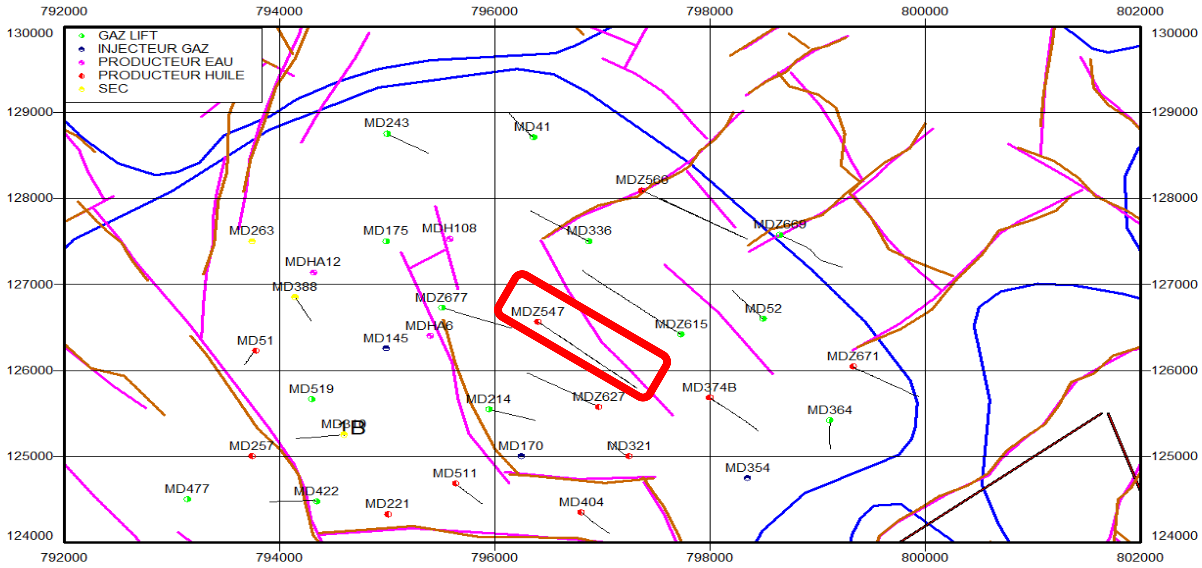


**Figure II.2:** the position of the well

### II.1.3. Reservoir data

Experimental and reservoir data were used in this study to simulate asphaltene precipitation. The simulation program for modeling uses the experimental data from compositional analysis and fluid behavior as input. For this investigation, a well MDZ547 in the Hassi Messaoud oil field was chosen, and oil samples were collected from there. Table II.1 below shows the reservoir data collected from the Well MDZ54.

**Table II.1:** Reservoir Data.

| Parameters | Value |
|---|---|
| Formation | HMD |
| Reservoir fluid | Oil |
| Reservoir pressure, psi | 5419 |
| Reservoir temperature, F° | 248 |

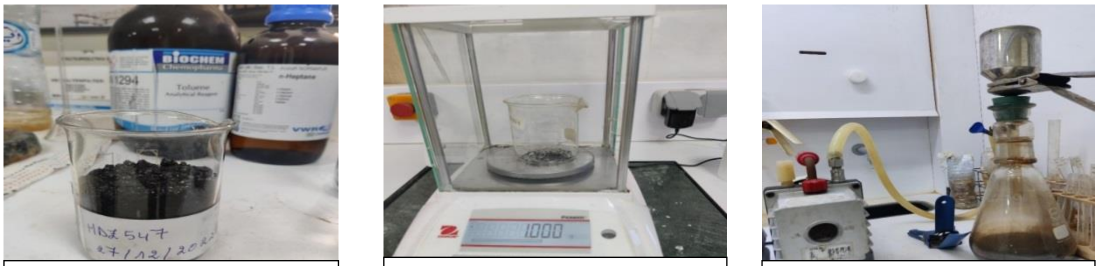
| | |
|---|---|
| Wellhead Pressure | 1829 |
| Wellhead Temperature | 134 |
| Choke size | 32/64 |
| Sample | BHS (live oil) |

## II.2. Experimental Work

This research focuses on utilizing SARA analysis and solubility testing. By investigating composition and solubility behavior under various conditions, we aim to establish relationships between molecular composition and solubility.

### II.2.1. Solubility test

To perform a solubility test on an asphaltene sample deposit, the following procedure can be followed: First, place the sample in a sediment beaker for qualitative testing. Next, dissolve the sediment sample (referred to as W) in a suitable solvent such as reformate, toluene, xylene, or similar at a temperature of 80°C. Stir the mixture continuously using a stirrer for 30 minutes. Afterward, transfer the solution into a filter and take note of the weight of the filter before filtration (denoted as W1). Subsequently, dry the filter and measure its weight again (designated as W2) after the filtration and drying process using a vacuum pump. Finally, calculate the weight difference (W) as the increase in weight. This weight difference can be used to determine the weight of undissolved asphaltenes in the solvent. The material used in this test can be observed in Figure II.2.



**Beaker** **Balance** **Vacuum pump**

**Stirrer** **Grew** **Filter**

**Figure II.3:** laboratory materials

### II.2.1.1. Qualitative test

An X volume of n-heptane is added to the sample in an appropriate vial. After stirring, a change in the color of the mixture is observed, as is the precipitation of a solid part of the asphaltenes with the dissolution of the paraffin.

### II.2.12. Quantitative test

Dissolve a test portion (W1 = 1g) of the organic deposit in n-heptane at 80°C with continuous stirring for 30 minutes. Next, filter the solution using a previously weighed filter (Wf1 = 0.130g) and dry the filter. After filtration and drying, the weight of the filter is Wf2 = 0.803g. The weight difference, P1, is calculated as follows: P1 = W1 - Wf2 - Wf1 = 1g - 0.803g - 0.130g = 0.067g. P1 represents the weight of undissolved paraffin in n-heptane.

Proceed by dropping another test element and filtering the solution using a previously weighed filter (Wf1 = 0.130g). In this case, the test element has a weight of W1 = 1g, and the solvent used is toluene at 80°C with continuous stirring for 30 minutes. After filtration and drying, the weight of the filter is Wf2 = 0.166g (thus, W = 0.166-0.130 = 0.036g). Dry the filter and weigh it again. The weight of the filter after drying is W2 = 1-0.036 = 0.964g. W2 represents the weight of asphaltenes and paraffin that would dissolve.

Finally, calculate W3 as follows: W3 = W2 - P1 = 0.964 - 0.067 = 0.897g. W3 represents the mass of asphaltenes in 1g of the sample. The results are summarized in the table below:

**Table II.2:** Deposits Percentage

| Deposits | Asphaltenes | Paraffin | Remains (Salt-Sandstone) |
|---|---|---|---|
| Percentage | 89% | 6.7% | 3.6% |

### II.2.2. SARA analysis (Saturates, aromatics, resins, and asphaltenes analysis)

One of the main approaches for compositional analysis of crude oils is SARA fractionation, in which the sample is separated into saturate, aromatic, resin, and asphaltene fractions based on their polarity. The sample is separated into four fractions by selective retention through interactions with the solvent mobile phases and the column stationary phases (Fig.II.4). Additionally, SARA analysis would aid in estimating asphalting stability, fouling tendency for crude oil blends' tendency, and product stability. The original and common approach used for SARA separation is gravimetric adsorption chromatography. The separation of the asphaltene fraction occurs in the first step of this procedure by adding an excessive amount of an alkane solvent, such as n-pentane, n-hexane, or n-heptane. Maltenes are the portion that has been dissolved in the alkane solvent following deasphalting. The figure II.4 below represents the SARA fractionation flow chart:

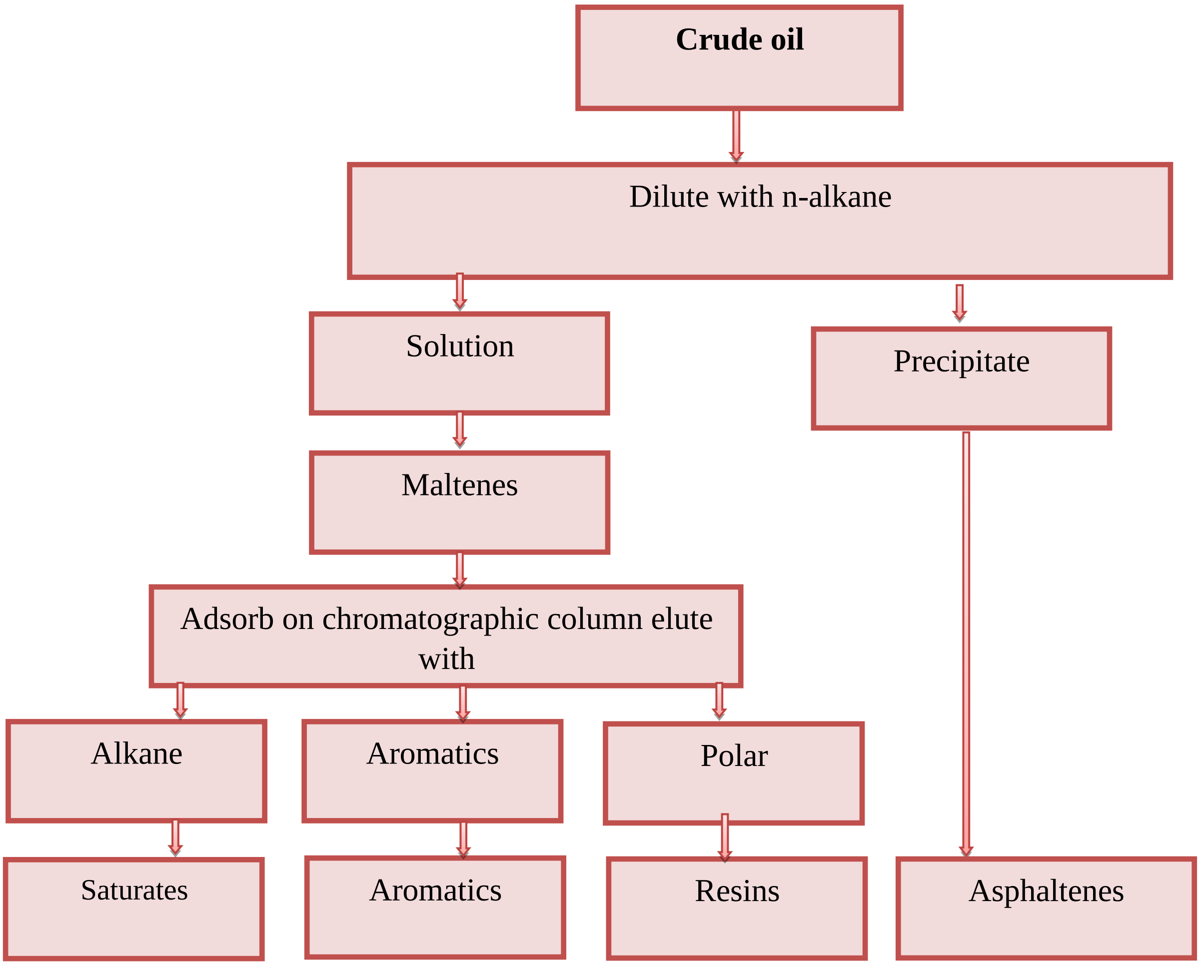


**Figure II.4:** SARA Fractionation Flowchart

### II.2.2.1. chemical materiel

To remove the precipitated asphaltenes from the crude oil, two different methods can be employed: filtration and centrifugation. The following equipment is essential for the filtration process: a suction bottle, filter paper, a borosilicate filter funnel, and a vacuum pump. The filtration process involves passing the crude oil through the filter paper using the suction bottle and vacuum pump to separate the asphaltenes.

Alternatively, the centrifugation method utilizes a centrifuge and centrifuge tubes. The crude oil is placed in the centrifuge tubes and subjected to high-speed rotation, causing the heavier asphaltenes to settle at the bottom of the tubes, allowing for their separation from the rest of the crude oil.

To further purify the asphaltene fraction, the asphaltenes can be redissolved in toluene while separating the resin component through adsorption. This process helps eliminate impurities and isolate the desired asphaltene fraction.

### .II.2.2.2. Asphaltenes separation (filtration technique)

In a 1-liter jar, mix 850 mL of hexane with 85 mL of crude oil and shake vigorously for 60 seconds. Allow the asphaltenes to settle for 45 minutes. Once the asphaltenes had settled for 45 minutes, an additional 200 mL of hexane was added to the jar containing the precipitated asphaltenes, shaken vigorously again for 60 seconds, and the supernatant was decanted and filtered to extract the asphaltenes from the supernatant. Remove asphalt with a vacuum filter. The asphaltene that accumulated on the filter paper was then removed with n-hexane. Leave the bitumen on the filters as you continue vacuuming and let them air dry. Then, by mixing 1.0 g of dry asphaltene with 10.4 ml of toluene, you can prepare a 10% (w/w) solution of asphaltene in toluene and evaporate it.

After toluene evaporation, the obtained asphaltenes were weighed. The asphaltene content was calculated as the ratio of the weight of asphaltenes to the weight of the original crude oil, multiplied by 100 to express it as a percentage:

$$\textbf{Asphaltenes content (\%wt)} = \frac{W_{asphaltenes}}{W_{crude\ oil}} \times 100$$

### II.2.2.3. Resins separation (filtration technique)

The procedure involves filling a column with 100 g of clay absorbent and placing a 25-mm-thick glass wool on top to prevent agitation during solvent feeding. A consistent solution is created by measuring 5 g of maltene and diluting it with 25 mL of n-heptane solvent. Sedimentation or flocculation should be absent at this stage. Residues generated during asphaltenes production aid in eliminating phenolic substances.

To ensure clay adhesion, 25 mL of n-heptane is added, followed by flushing the reduced maltene through the column. By carefully pouring 500 mL of n-heptane, the saturated portion of the sample is separated from the adsorbents. The first fraction is obtained through evaporation, recovering saturates and solvent. Subsequently, a combination of 50% n-heptane and 50% toluene is added to the column. After collecting fractions and evaporating n-heptane and toluene, the remaining fraction consists of aromatics with residual saturates.

The remaining components in the column include resins and other polar substances. The nearly colorless effluents are purified by gradually pouring a 50/50 mixture of toluene onto the column. The obtained fractions are transferred to a separatory funnel, where 10 g of anhydrous calcium chloride is added and stirred for approximately 30 seconds. After allowing the mixture to sit for a minimum of 10 minutes, anhydrous calcium chloride is separated using filter paper. The high-density wastewater settles near the bottom of the separatory funnel.

To obtain the resin fraction, a mixture of toluene and acetone is evaporated in an evaporator. The obtained resins are weighed, and the resin contents are calculated using the formula:

$$\textbf{Resins contents (\%wt)} = \frac{W_{resins}}{W_{asphaltenes} W_{maltenes}} \times 100$$

Table II.3: SARA Fraction

| **Saturated** | **Resins** | **Aromatic** | **Asphaltene** |
|---|---|---|---|
| 61.47% | 9.52% | 14.01% | 15% |

### II.2.3. Asphaltene Resin (A/R) Ratio Approach

The Asphaltene Resin (A/R) Ratio Approach is a widely used method for assessing the stability of asphaltenes in crude oil. It involves calculating the ratio between the percentage of asphaltenes and resins present in the crude oil. A lower A/R ratio indicates higher asphaltene stability, indicating that the asphaltenes are less likely to precipitate. Conversely, a higher A/R ratio suggests a greater propensity for asphaltene precipitation. This approach is extensively employed in both research and industry to gain insights into asphaltene behavior and to predict their precipitation tendencies.

### II.2.4. Colloidal Instability Index (CII)

In order to quantify the stability of the asphaltenes in the maltene phase, the colloidal index (CII) was calculated for the asphalt binders using Equation (1).

$$\mathbf{CII} = \frac{\text{Asphaltenes in wt\% + Saturates in wt\%}}{\text{Resins in wt\% + Aromatics in wt\%)}} \mathbf{(1)}$$

Where a lower value of (CII) represents a higher stability of asphaltene micelles in the asphalt binder. In this regard, according to Lesueur (Lesueur, D. 2019), for CI values greater than 1.2, the asphaltene fraction tends to be unstable within the maltene matrix. When the CII value is between 0.7 and 1.2, the asphaltene stability is uncertain, while for CII indices less than 0.7, the asphaltene fraction is stable.

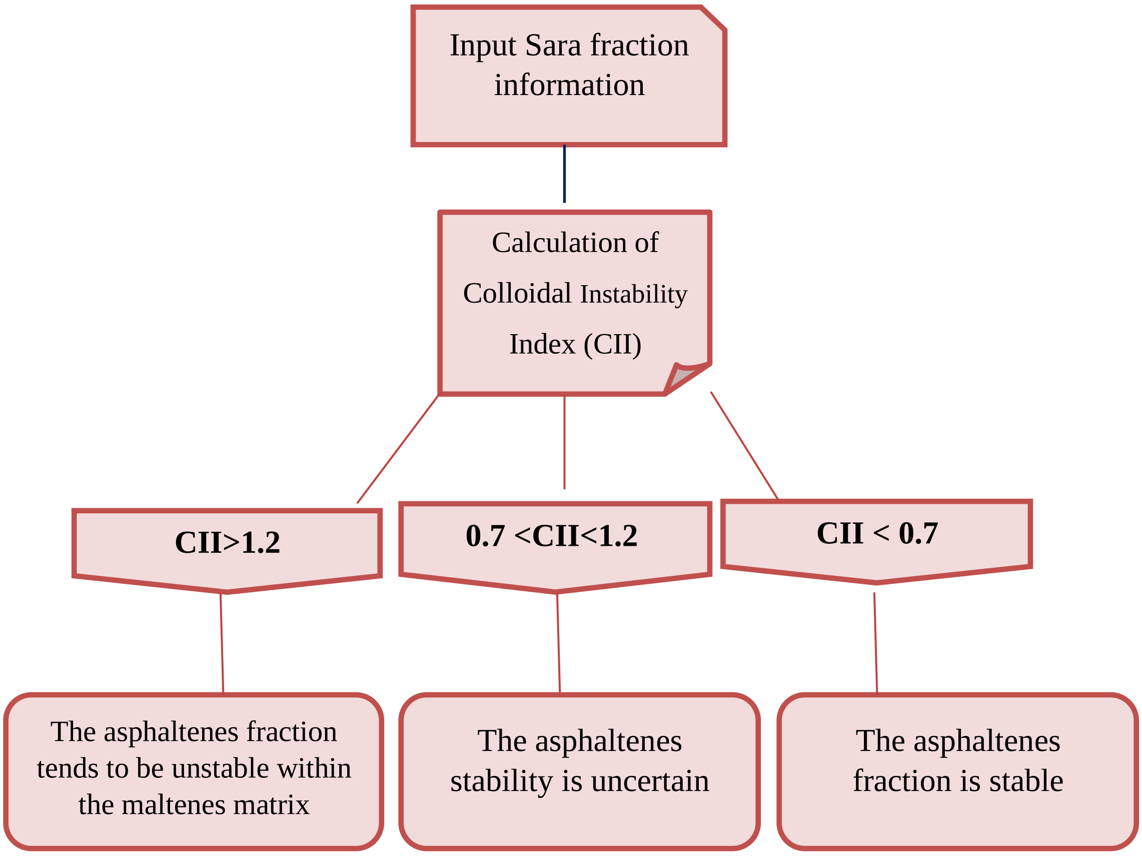


**Figure II.5:** Flow chart to determine stability of asphaltene (Chamkalani et al., 2012)

### II.2.5. Modified Colloidal Instability Index (MCII)

The Modified Colloidal Instability Index (MCII) is an empirical approach based on PVT data to predict asphaltene precipitation in crude oil. It is a modification of the Colloidal Instability Index (CII) proposed by Yen and Wu in 1985. MCII offers cost and time savings compared to traditional SARA analysis, as it only requires PVT data routinely collected during reservoir studies. However, it has limitations and may not be suitable for all crude oils. The MCII equation, represented by Eq. 2, The MCII values determines asphaltene issues as follows:

- MCII $\leq$ 0.7 indicating no problem,
- MCII > 0.9 suggesting an asphaltene problem
- 0.7 $\leq$ MCII $\leq$ 0.9 indicating a potential issue.

The equation incorporates mole percentages of hydrocarbon components identified through PVT analysis, assigning them to equivalent SARA fractions based on molecular weight (Table II.4). Non-hydrocarbons compensate for the absence of resins, ensuring compatibility with the original CII inputs. $\mathbf{MCII} = \frac{Lc+Mc}{Hc+Nc}$ **(2)**

Table II.4: SARA Fractions Related to Hydrocarbon Components

| The Name | Component group | SARA corresponding |
|---|---|---|
| Light component | C1-C5 | Aromatices |
| Medium component | C6-C8 | Saturates |
| Heavy component | C9 + | Asphaltene |
| Non-hydrocarbon | CO2, H2, N2, H2S | Resins |

### II.2.6. Results and Discussion

### II.2.6.1. Asphaltene -Resin (A/R) Ratio SARA fractionation

Analytical technique of dividing oil into four parts according to their polarity: saturates, aromatics, resins, and asphaltenes. It is one of the finest ways to describe an oil mixture. The SARA fraction values from an oil sample recovered from Well MDZ547 are shown in Table.II.3. The weight percentage of asphaltene is 15 wt%, whereas the weight percentage of resin is 9.52 wt%. The results indicate that the Asphaltene is unstable as well as the possibility of asphaltene precipitation.

### II.2.6.2. Investigation of Asphaltene stability using Modified Colloidal Instability Index (MCII)

To use Eq. 2, we must first compute the mole percentage of each group (Lc, Mc, Nc, &Hc) for well MDZ547, as given in Table II.3and Table II.4. Table 3 was divided into four groups, as indicated in Table II.5.

$$\mathbf{MCII} = \frac{Lc+Mc}{Hc+Nc}, = \frac{60.99+12.33}{23.52+3.14} = 2.75$$

The MCII value is 2.75, which is greater than 0.9. This suggests the presence of an asphaltene problem in the well MDZ547 based on the MCII prediction.

**Table II.5** Classification of Components Corresponding to SARA Analysis

| Component | Mole % | The Group | Colonne1 |
|---|---|---|---|
| **H2** | **0** | | 0 |
| **N2** | 1.52 | Nc (non-hydrocarbons) | 3,14 |
| **CO2** | 1.62 | Nc | 3,14 |
| **H2S** | 0.00 | Nc | 3,14 |
| **C1** | 26.38 | Nc | 60,99 |
| **C2** | 12.61 | Nc | 60,99 |
| **C3** | 10.78 | Nc | 60,99 |
| **i-C4** | 1.42 | Nc | 60,99 |
| **n-C4** | 5.46 | Nc | 60,99 |
| **i-C5** | 1.50 | Nc | 60,99 |

| | | | |
|---|---|---|---|
| **n-C5** | 2.84 | Nc | 60,99 |
| **C6** | 3.49 | Mc (medium hydrocarbons) | 12,33 |
| **Mcyclo-C5** | 0.55 | Mc | 12,33 |
| **Benzene** | 0.69 | Mc | 12,33 |
| **Cyclo-C6** | 0.50 | Mc | 12,33 |
| **C7** | 2.74 | Mc | 12,33 |
| **Mcyclo-C6** | 0.87 | Mc | 12,33 |
| **Toluene** | 0.56 | Mc | 12,33 |
| **C8** | 2.93 | Mc | 12,33 |
| **C2-Benzene** | 0.41 | HC(heavy hydrocarbons) | 23,52 |
| **mp-Xylene** | 0.61 | HC | 23,52 |
| **o-Xylene** | 0.14 | HC | 23,52 |
| | | | |
| **C9** | 2.25 | HC | 23,52 |
| **C10** | 2.95 | HC | 23,52 |
| **C11** | 2.25 | HC | 23,52 |
| **C12** | 1.91 | HC | 23,52 |
| **C13** | 1.66 | HC | 23,52 |
| **C14** | 1.40 | HC | 23,52 |
| **C15** | 1.30 | HC | 23,52 |
| **C16** | 1.02 | HC | 23,52 |
| **C17** | 0.88 | HC | 23,52 |
| **C18** | 0.81 | HC | 23,52 |
| **C19** | 0.72 | HC | 23,52 |
| **C20** | 0.61 | HC | 23,52 |
| **C21** | 0.56 | HC | 23,52 |
| **C22** | 0.46 | HC | 23,52 |
| **C23** | 0.42 | HC | 23,52 |
| **C24** | 0.37 | HC | 23,52 |
| **C25** | 0.33 | HC | 23,52 |
| **C26** | 0.29 | HC | 23,52 |
| **C27** | 0.26 | HC | 23,52 |
| **C28** | 0.24 | HC | 23,52 |
| **C29** | 0.21 | HC | 23,52 |
| **C30** | 0.19 | HC | 23,52 |
| **C31** | 0.17 | HC | 23,52 |
| **C32** | 0.15 | HC | 23,52 |
| **C33** | 0.13 | HC | 23,52 |
| **C34** | 0.12 | HC | 23,52 |
| **C35** | 0.11 | HC | 23,52 |
| **C36+** | 0.59 | HC | 23,52 |
| **Calculates MW** | 82.80 | HC | |
| **Mole percent** | 39.43 | | |

### II.2.6.3. Investigation of Asphaltene stability using Colloidal Instability Index (CII)

This approach utilizes Eq. 1, considering a saturated weight percent of 61.47 wt percent, an aromatic weight percent of 14.01 wt percent, a resin weight percent of 9.52 wt percent, and an asphaltene weight percent of 15 (as provided in Table II.3). Based on these values, the calculated CII is 3.24, which is greater than 0.9. And that indicates the asphaltenes fraction tends to be unstable within the maltenes matrix.

The calculation is as follows:

$$CII = \frac{\textbf{Asphaltene wt\%+Saturate wt\%}}{\textbf{Aromatic wt\%+Resin wt\%}} = \frac{\mathbf{15+61.47}}{\mathbf{9.52+14.01}} \mathbf{= 3.24}$$

### II.2.6.4. Summary of Results

Based on the results obtained from the analysis

1) Asphaltene-Resin (A/R) Ratio: Asphaltene is unstable based on the A/R ratio. This indicates a higher concentration of asphaltene compared to resin, suggesting the potential for asphaltene instability within the system.

2) Colloidal Instability Index (CII): The CII result indicates the presence of an asphaltene problem, as it suggests asphaltene precipitation and instability within the system. This can lead to issues such as blockages or reduced flow rates.

3) Modified Colloidal Instability Index (MCII): The MCII result also indicates unstable asphaltene behavior and an asphaltene problem within the system. This suggests the presence of asphaltene deposition and potential flow restriction.

These results collectively indicate that the system is experiencing challenges related to asphaltene instability and precipitation.

## II.3. Pipesim optimization software

Pipesim is a simulator to carry out the following functions: The description of the operational parameters for our case study is as follows: Pwf, Qliq Oil density, water cut, GOR, skin surrounding the well, well radius, drainage radius, well equipment optimization, well performance analysis, and production optimization are some of the fluid and reservoir metrics.

### II.3.1. Functioning of the software

Following the selection and creation of the well model, Put the reservoir's specifications here, like pressure of the static fund (PSF), pressure of the dynamic fund (PFD), reservoir temperature (Tres), and flow rate (Q). After that, enter the well's specifications: well head pressure (Pt), surface temperature (T), length and inner diameter of the casing (ID), length between the packer and the well's bottom, and inner diameter of the casing. Finally, describe the fluid type: black oil in our example.

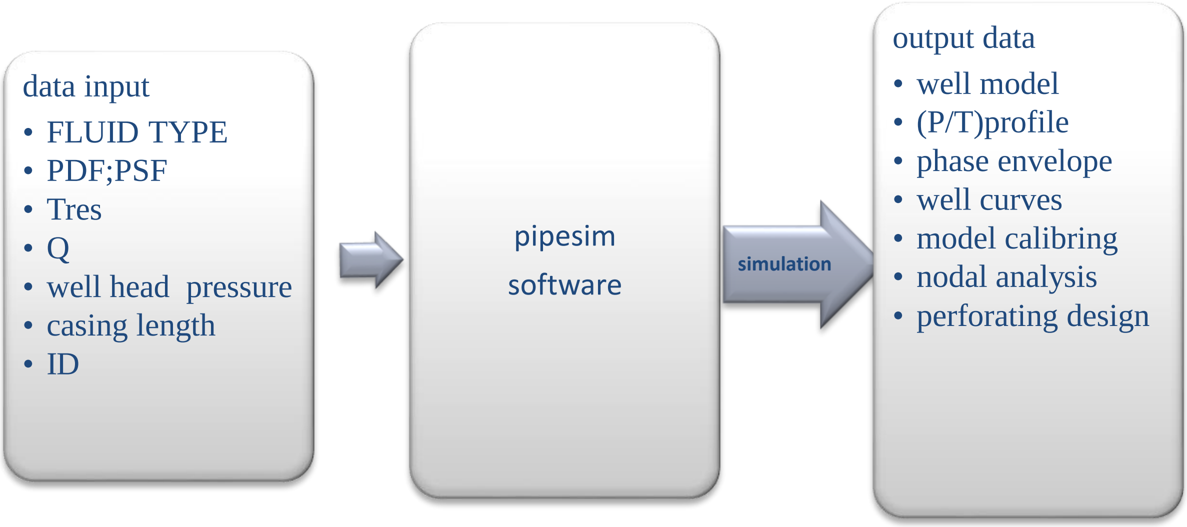


**Figure II.6:** Schematic of PIPSIM functions

### II.3.2.Well design

The model of the well MDZ 547 is already simulated in the model presented in Figure II.7. Which is characterized by a vertical section combined between different sections (tubing from the well head to 2984m) and equipment of isolation (packer) and liner 7’’ from 2980m to 3357 m. Horizontal section (open hole) from 3357m to 4450m, which is equipped with a crimped and perforated liner.

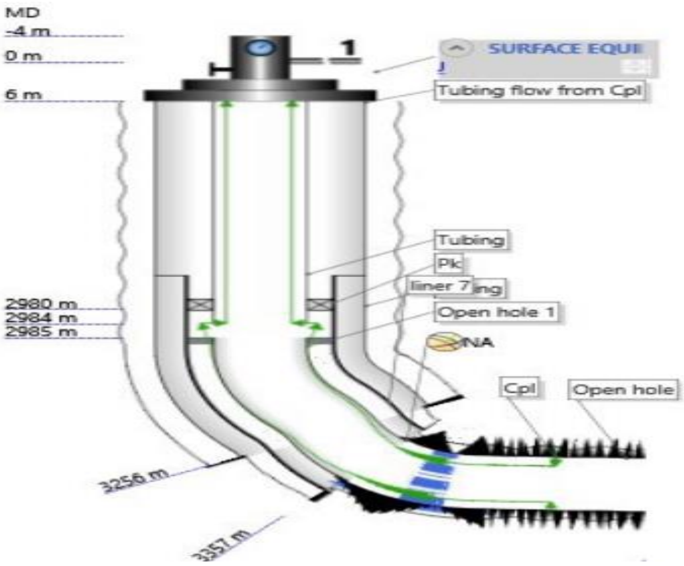


**Figure II.7:**MDZ547Well design

### II.3.3. ADE envelope

This program is used in our case study to specify the well MDZ547's asphaltene precipitation circumstances. By the modeling of the asphalt deposit envelope (ADE) (see annex 3). The asphalt deposit envelope is an effective tool for evaluating the potential and severity of asphalt problems. The ADE indicates the thermodynamic path that must be followed when oil is recovered from the tank to avoid or minimize asphalt problems. If possible, the oil should be kept outside or as far away as possible from the ADE center (Figure II.8).

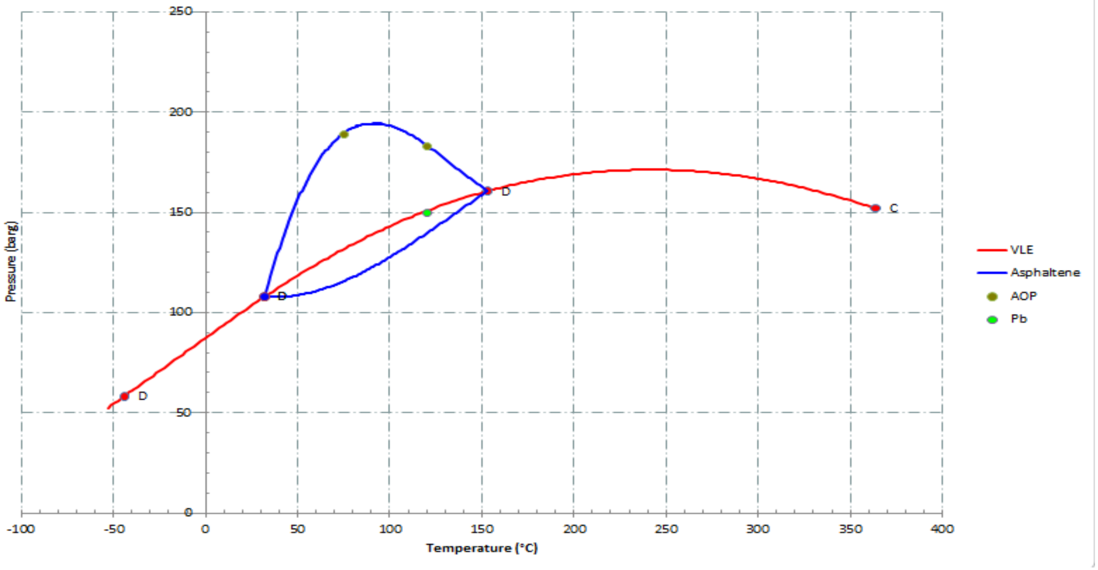


**Figure II.8:** PHASE ENVELOPE MDZ547

During the deployment isotherm of the reservoir fluid, as long as the pressure does not reach the PAOP (180 bar to 190 bar), the flocculation pressure threshold, asphaltene remains in the liquid phase, and there is no flocculation of asphalts. Asphaltene instability occurs when the pressure is between the upper onset points (P = 190 bar; T =75°C) and the bubble point [pressure = 150 bar; temperature = 120°C]. The substance has two phases: asphalt oil, and between the bowl point and the lower onset point, we have three phases: gas, oil, and asphaltenes. When the tank pressure drops below the lower onset point, the asphalt particles are completely redissolved into the liquid phase, where the fluid is in the diphasic zone (gas-oil). The bubble point in conditions of pressure (150 bar), temperature (120° C), and asphaltene on set pressure (AOP) (180 to 190 bar) as presented in Figure II.8

### II.3.4. Result

The well is a candidate for damage caused by asphaltenes because it is in the precipitation zone of asphaltenes when pressure is between 150 and 190 bar and temperatures are between 75 and 120 °C.

### II.3.5. PVT DATA

All crude oils contain asphaltenes in their composition. The content of asphaltenes does not determine whether or not they will precipitate. This complex thermodynamic equilibrium depends on the pressure, temperature, and composition of the crude oil components. Many laboratory studies are frequently carried out using reservoir oil samples in a PVT cell, simulating the circumstances that the fluids are subjected to during production, in order to determine how these volumetric changes would occur. Our PVT data for the well MDZ 547 gives us the following values in Table II.6:

**Table II.6:** properties of oily well mixture MDZ547

| bubble pressure | $P_b$ | 150 kg/cm$^3$ |
|---|---|---|
| Well storage Pressure | PWS | 373 kg/cm$^3$ |
| Temperature | $T_r$ | 120°c |
| The molecular weight of the oil | $MW_o$ | 161,61g/mol |
| Oil density | $\rho_o$ | 0.808g/cm3 |
| Gaz Oil Ratio | GOR | 181.9sm3/sm3 |

### II.3.6. Nodale analysis

The nodal analysis method is applied at two main node points (wellbore and wellhead), where inflow and outflow performances are carefully reviewed with sensitivity analysis. The two nodal points are selected because of the high-pressure drops they observe (Sohaib Z. Khan).

In our case study, we simulate the model of our well and get these curves, which are presented in two axes: pressure at the Nodale analysis point (bar) and stock tank at the Nodale analysis point (sm$^3$/d), as presented in FigureII.9.

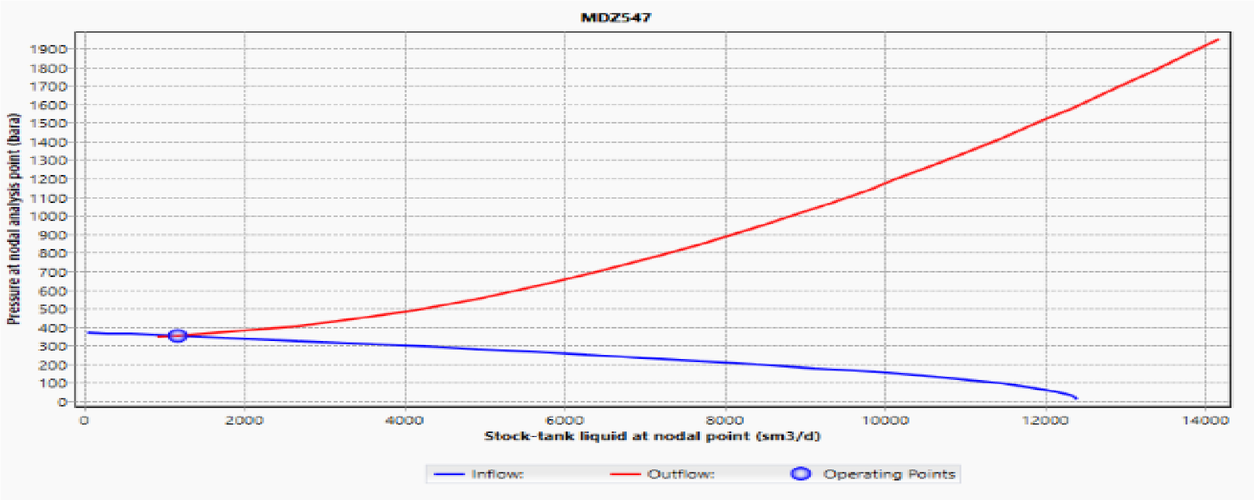


**Figure II.9:** Nodal analyses of the well MDZ47

The nodal analysis gave the Q and PFD values transferred to the following table;

**Table II.7:** Point of operation of the well

| Parameters | Flow rate ($m^3/d$) | PDF ($Kg/cm^2$) |
|---|---|---|
| Fund point | 1003.3 | 359.69 |

## II.4. Well performance using Saphir software

Saphir is software that we used in our case study for the well MDZ547 to compare the measured data to the model while taking into consideration the whole production history. The interpretation of Saphir is carried out as follows:

Insert in the test records and well characteristics data (height of reservoir (H), viscosity (µ), porosity (ϕ), flow (Q), compressibility factor (Ct), formation volume factor (B), pressure (P), well radius (Rw), and the thickness of the zone ($TH_z$)) calculated at the average reservoir pressure. The chart below summarizes the process (Figure II.10). A simple example of well-testing analysis on Ecrin Saphir is explained gradually in Annex 4.

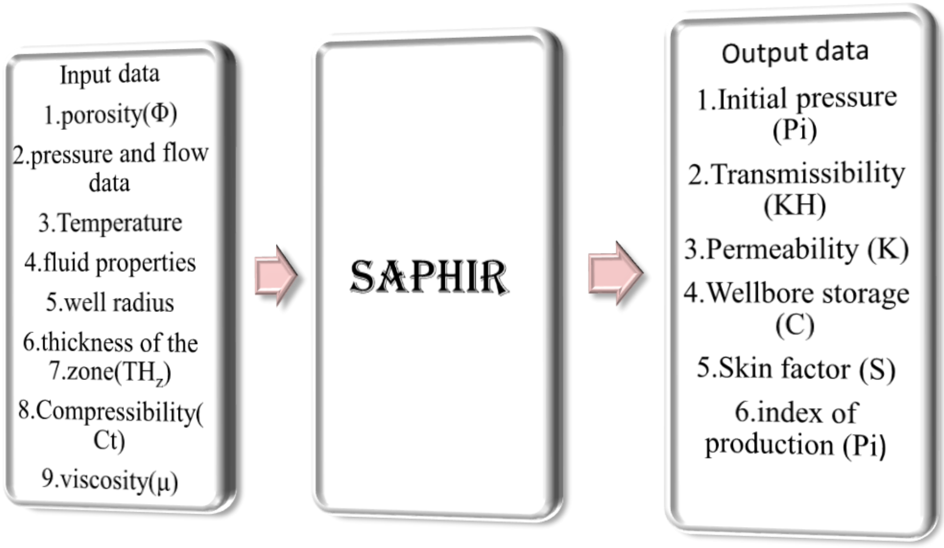


**Figure II.10:** schematic of Saphir functions

### II.4.1. Integrated Equations in the software

Wellbore storage: $$C = \frac{qB}{24}\frac{\Delta p}{\Delta t} \quad (3)$$

Transmissibility: $$Kh = 162.6 = \frac{q\mu B}{m} \quad (4)$$

Skin factor: $$S = 1.51\left[\frac{P1hr - Pwf(\Delta t=0)}{m} - \log\left(\frac{k}{\varphi \mu C r w^2}\right) + 3.23\right] \quad (5)$$

### II.4.2. well testing

### II.4.2.1. Drill stem test (DST)

Several types of tests are presented, and each one is dedicated to a specific stage. During the appraisal stage and exploration, in our case study, a drill stem test (DST) was run (see annex 2). Shut-in data is being used that is measured by a drill stem test. The Saphir software analyzes the pressure responses from shut-ins to provide information about the reservoir, such as permeability and skin factor. However, the following table summarizes all the properties used as inputs.

**Table II.8:** Reservoir properties of MDZ547

| Reservoir properties (unit) | |
|---|---|
| Thickness (ft) | 26 |
| Well radius (in) | 7.62 |

| | |
|---|---|
| GOR (scf/bb) | 140 |
| Compressibility (psi-1) | 0.0004 |
| Temperature (°F) | 134.6 |
| Pressure (psi) | 379.78 |

After loading pressure and flow rate data, the software shows the history plot, including both flow rate and pressure. There are two phases of build-up. The second one, however, is used as the basis for the interpretation because it is more reliable (longer) and supported by the first one.

Figure II.11 represents the pressure difference (psi) in function of the time DST (hr) in the wellbore storage and reservoir and the limit boundary.

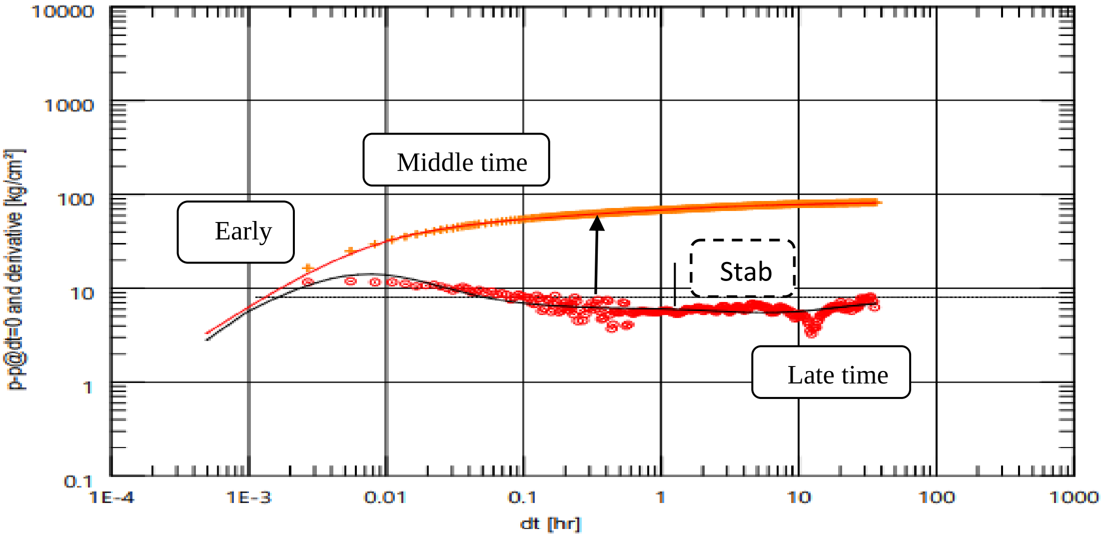


**Figure II.11:** Log-Log plot of Bourdet derivative and extracted pressure from DST versus time of MDZ547

A decrease in the radial flow stabilization is observed in FigureII.11, which can be explained by an increase in the skin factor due to the damage of the formation and needs to be stimulated to confirm that we will use the results of the two buildups to see the changes in skin, permeability, and transmissibility.

The table below summarizes the parameters selected for the model.

**Table II.9:** Model of well MDZ547

| Model properties | |
|---|---|
| Wellbore model | Standard model |
| Well model | Horizontal |
| Reservoir model | Homogenous |
| Boundary model | Infinite |

The transient test with the possible best model has given the following results:

Table II.10: Well test MDZ547 output

| Property | Pi (kg/cm) | Hutile (m) | K (md) | KH (md.) | kz/kr | Δ*p*Skin (kg/cm²) | Skin factor | C($m^3$.cm²/kg) |
|---|---|---|---|---|---|---|---|---|
| Results | 358.056 | 67 | 2.94 | 197 | 0.0168 | 26.7 | 1.66 | 0.00239 |

### II.4.2.2. Buildup

A pressure build-up test was conducted on a horizontal well, MDZ547, for 12 hours on June 21, 2008. And another was conducted on the same well for 12 hours on August 25, 2019. Afterwards, the results of pressure data versus time as well as flow rates were brought in as input to be used on Saphir Ecrin. In addition, properties such as well radius, thickness of the productive layer, and fluid type were also added to the model. However, the following table summarizes all the properties used as input.

**Table II.11:** Reservoir properties of MDZ547

| Reservoir properties (unit) | Colonne1 |
|---|---|
| Thickness (ft) | 25 |
| Well radius (in) | 7.62 |
| Oil saturation (%) | 0.068 |
| Formation volume factor (cf/stb) | 1.6050 |
| Porosity | 0.08 |
| GOR (scf/bb) | 416 |
| Compressibility (psi-1) | 0.0003 |
| Temperature (°F) | 236 |
| Pressure (psi) | 255 |
| Viscosity (cp) | 0.2850 |

After loading pressure and flow rate data, the software shows the history plot, including both flow rate and pressure. Pressure buildup is the subject of this transient test analysis; there are two buildup periods. However, the interpretation is based on the second one since it is more reliable (longer) and confirmed by the first one.

### II.4.2.2.1. Buildup 2008 MDZ547

The Bourdet derivative is displayed together with the extracted pressure buildup on a log-log plot. Exhibit three different regions shown in figure II.12 below:

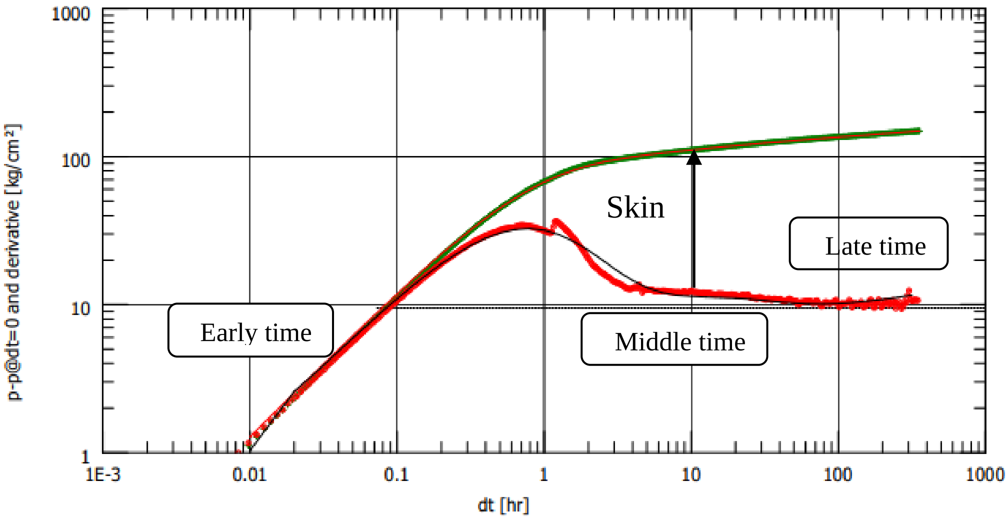


**Figure II.12:** Log-Log plot of Bourdet derivative and extracted pressure buildup versus time of MDZ547

From Figure II.12, we can extract information about the wellbore storage (WBS) and skin from the early time region (from the straight line and the following hump). As we can see in the figure, the Bourdet point values in the beginning do not perfectly fit the straight line, so in our case we have a changing WBS. This could be a consequence of asphalt's disposition. After the wellbore storage effect has vanished, the middle time region takes place, which describes the radial flow regime where we can get information about the kh. The table below summarizes the parameters selected for the model.

**Table II.12:** Model of well MDZ547

| Model properties | |
|---|---|
| Wellbore model | Standard model |
| Well model | Horizontal |
| Reservoir model | Homogenous |
| Boundary model | One fault |

The transient test with the possible best model has given the following results:

Table II.13: Well test MDZ547 output

| **Property** | **Pi (kg/cm$^2$)** | **H**$_{utile}$ (m) | **K** (md) | **KH** (md.m) | **kz/kr** | ΔP Skin **(kg/cm$^2$)** | **Skin factor** | **C($m^3$cm$^2$/kg)** |
|---|---|---|---|---|---|---|---|---|
| Results | 379.954 | 67 | 1.28 | 86 | 0.0201 | 46.6174 | 2.64 | 0.0979 |

### II.4.2.2.2. Buildup 2019 MDZ547

The Bourdet derivative is displayed together with the extracted pressure buildup on a log-log plot. Exhibit three different regions shown in figure II.13 below:

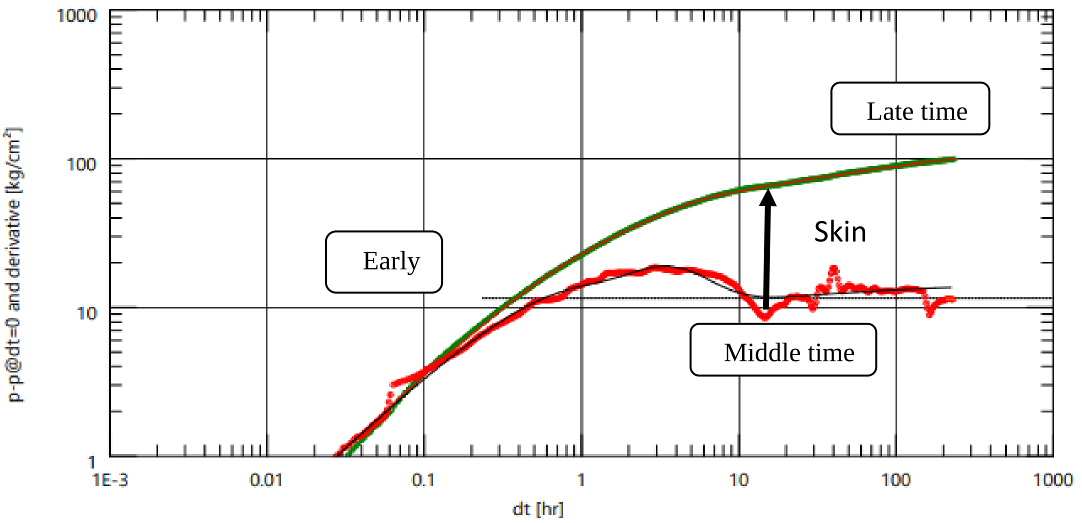


**Figure II.13:** Log-Log plot of Bourdet derivative and extracted pressure buildup versus time of MDZ547

The early time region exhibits a changing WBS like in the previous test conducted in 2008, but we can observe that the gap between the horizontal radial flow of the derivative and the Bourdet shown by an arrow on Figure II.13curve is less large than the one during the previous test, which means that the skin has been reduced. As we know, the stabilization of the radially flowing middle time region is proportional to the transmissibility T= kh/μ, so a lower transmissibility, which is the case in this test, means lower permeability and thus additional pressure drop. And that means that the treatment with the reformat has reduced the skin but has had no effect on the transmissibility or permeability because the range of the asphalts inside the formation is more than two feet. During the late-time region, the scattered dots deviated upward, and the slope almost doubled from the radial flow. The table below summarizes the parameters selected for the model.

**Table II.14:** Model of well MDZ547

| **Model properties** | |
|---|---|
| Wellbore model | Changingstorage (hegeman) |
| Well model | Horizontal |
| Reservoir model | Homogenous |
| Boundary model | Infinite |

The transient test with the possible best model has given the following results:

**Table II.15:** Well test MDZ547 output

| **property** | **Pi (kg/cm$^2$)** | **$H_{utile}$** (m) | **K** (md) | **KH** (md.m) | **kz/kr** | ΔP Skin **(kg/cm$^2$)** | **Skin factor** | **C($m^3$cm$^2$/kg)** |
|---|---|---|---|---|---|---|---|---|
| Results | 254.88 | 67 | 0.40 | 27 | 1.71E-4 | 38.3062 | 1.67 | 0.0431 |

### II.4.2.2.3. Comparative discussion of results builds up

The conventional build-up analysis by using the log-log plot approach and comparing them is as follows:

**Table II.16:** Well test MDZ547 output (2008 and 2019)

| **Property** | **Build** up 2008 | **Build** up2019 |
|---|---|---|
| K | 1.28 md | 0.40 md |
| KH | 86md.m | 27 md.m |

From the table, we notice that there is a decrease in the permeability from 1.28 md to 0.40 md and a decrease in the transmissibility from 86 md to 27 md, which means that our formation is damaged by the deposition of asphaltene inside the pores of the formation.

## II.5. Effect of asphaltene on Permeability

The presence of asphaltene deposition can have a significant impact on permeability within the reservoir. Figure II.14 shows the effects of the asphaltene cumulation on the reservoir:

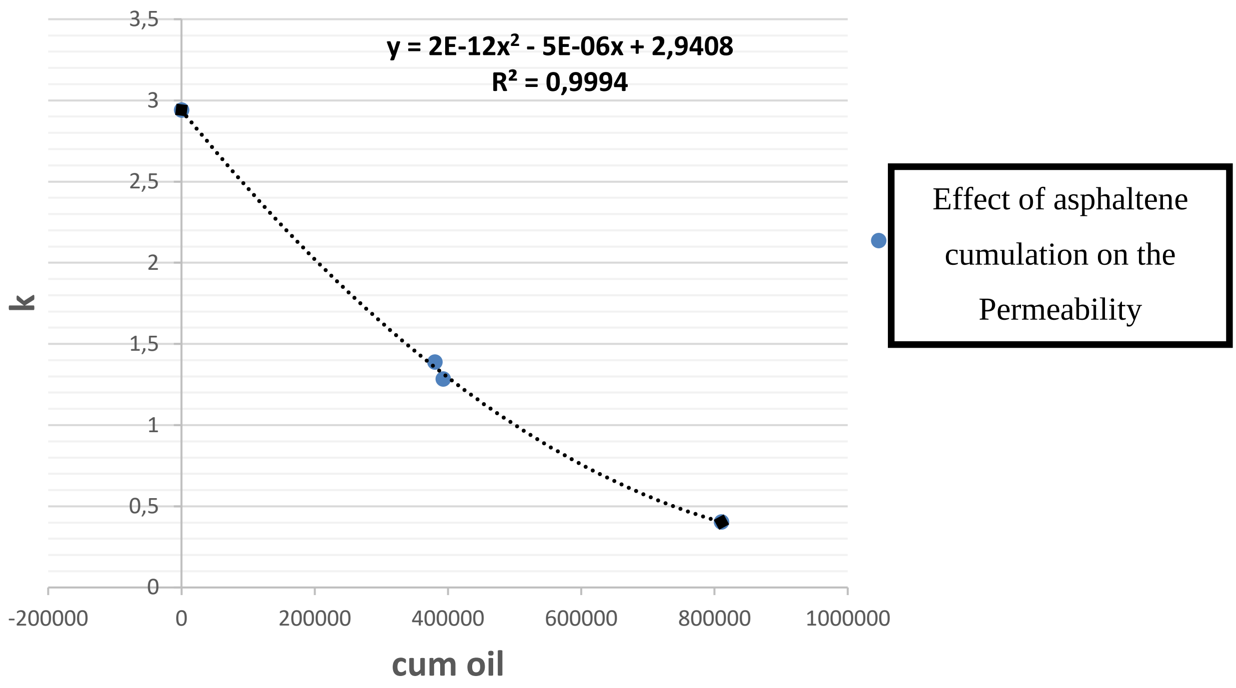


**Figure II.14:** Effect of asphaltene cumulation on the Permeability

Several key effects on permeability can be observed

•The increase in oil production leads to a decrease in reservoir permeability due to the accumulation of asphaltene on the matrix.

• In a low-permeability reservoir, an increase in asphaltene particle size due to aggregation results in higher permeability damage.

• Conversely, a decrease in asphaltene particle size in the same low-asphaltene reservoir increases damage caused by clogging from fine particles.

## II.6. Proposed solution

### II.6.1. Production Optimization

The MDZ547 well suffers from asphaltene problems. It gave during the DST a flow rate of Q= 10.67 m3/h with a PG of 379.78 kg/cm2 and PT = 127.6 kg/cm2 on choke of 12.7 mm.

• But after it went into production its throughput fluctuated and dropped even after reformat cleanings.

• MDZ547 lost more than 14000 $m^3$ unfortunately they could not understand the behavior of this well and it was not treated in a good way.

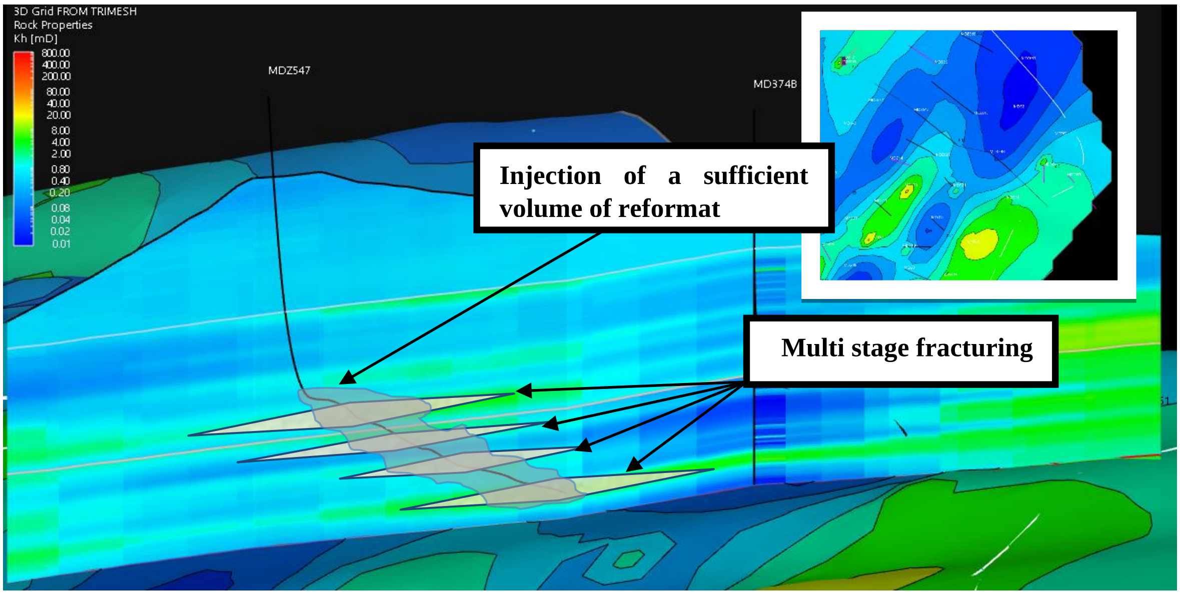
For the optimization of the production for this well we proposed:

1/ Matrix processing with Squeeze large volume of reformat (adequate).

2/ multi stage fracturing to bring the conditions back to 3 $m^3$/h.

### II.6.2. Simulation of the proposed solution

The MDZ547 well is experiencing irreversible flocculation, where the asphaltenes have already formed solid aggregates that cannot be easily dispersed or dissolved. Squeezing a large volume of reformate may have limited effectiveness in resolving the issue. With the consultation of petroleum engineering experts and consideration of alternative strategies, such as using specialized chemicals or techniques, a simulation of a multi-frac stage was chosen to improve and ameliorate the production rate.



**FigureII.15:** Simulation of reformat treatment and multi-stage fracturing

Fracturing can be tailored to optimize production based on reservoir characteristics. Parameters such as injection pressure, fluid composition, and proppant selection can be adjusted to create fractures that maximize the flow of hydrocarbons. Optimizing the fracture design can lead to improved well performance, increased ultimate recovery, and extended production life. **[31]**

### II.6.3. Modularization ADE of the simulation module

From figure II.16, it is evident that there has been a significant increase in pressure, ranging from 280 to 320 bars. This increased pressure keeps the well far from the ADE (Asphaltene Deposition Envelope), indicating that asphaltene remains in the liquid phase and there is no flocculation of asphalts. The observed pressure increase can be attributed to the expansion of an effective contact area between the reservoir and the wellbore. The enhanced contact area facilitates greater fluid flow, potentially leading to higher production rates.

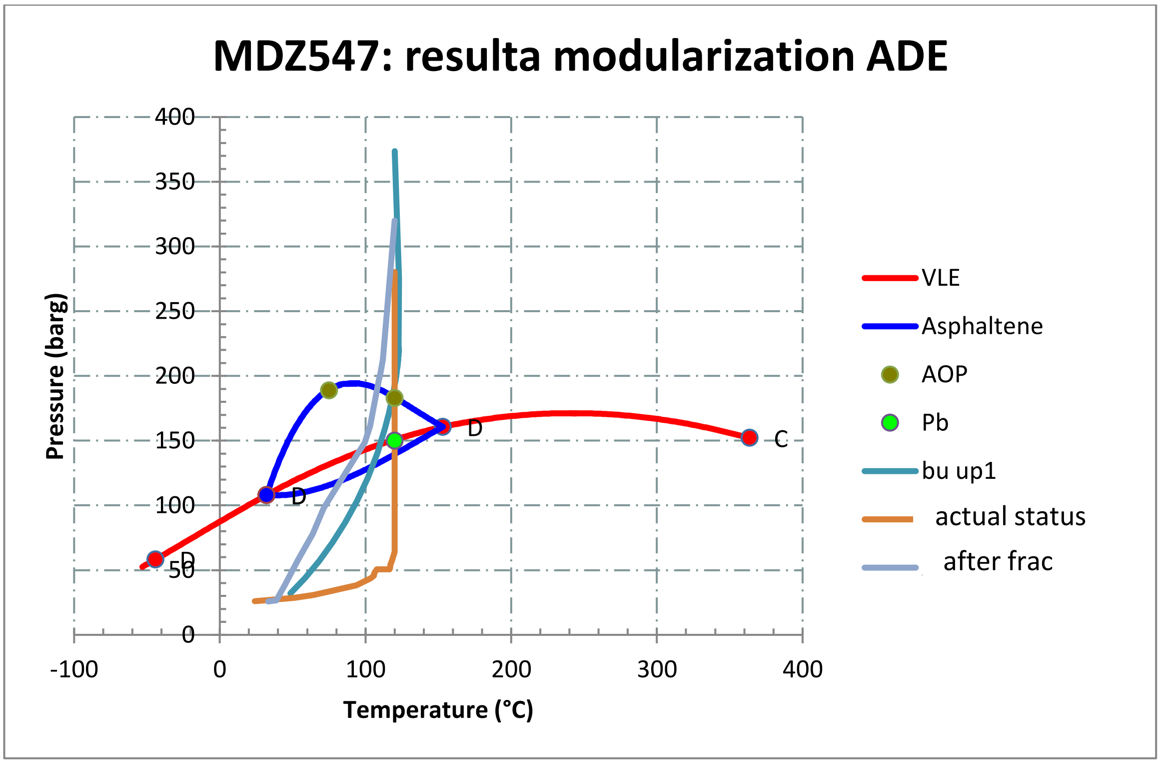


**Figure II.16:** Asphaltene Deposition Prediction

Before and after the multi stage fracturing versus temperature (°C) of the MDZ547

## Conclusion

The method used in this research contributes to preventing asphalt formation before it occurs. Laboratory tests were conducted such as SARA analysis to study the properties of the reservoir fluids. The results of the colloidal instability index showed that the CII is 3.24, indicating an unstable asphaltene condition. The Pipsim software was used and simulations were performed to validate that the pressure and temperature values at the bottom of the well within the asphaltene deposition envelope (ADE) and it was determined that the well was in the asphaltene precipitation phase when pressure is between (150 and 190) bar and temperatures are between 75 and 120 °C. To evaluate the performance of the well, Saphir Kappa was utilized, and the results showed that the value of the skin had increased from 1.66 to 2.64, indicating that the integrity of the formation was compromised due to the accumulation of asphaltene particles within the pores, resulting in damage.

Based on thrilling research findings, a solution has been proposed: a state-of-the-art multi-stage fracturing technique. This approach aims to ramp up productivity by injecting high-pressure fluids into the reservoir, creating fractures that turbocharge the flow of hydrocarbons. This approach is intended to mitigate the negative effects caused by asphaltene deposition and clogging.

## Recommendation

Optimizing production in reservoirs with asphaltene precipitation and irreversible flocculation can be a complex task. However, here are some general recommendations that can help improve production efficiency and manage these challenges:

1. Characterize the Reservoir: Obtain a thorough understanding of the reservoir's fluid properties, including the nature and concentration of asphaltenes, their deposition tendencies, and the conditions under which irreversible flocculation occurs. This knowledge will help in devising effective mitigation strategies.

2. Effective Chemical Treatment: Develop and implement a comprehensive chemical treatment program to manage asphaltene precipitation and flocculation. This may involve the use of asphaltene dispersants, solvents, and inhibitors to prevent asphaltene deposition and promote stability of the reservoir fluids

3. Injection Optimization: Optimize injection strategies to maintain reservoir pressure and control fluid flow. Consider using water or gas injection to maintain reservoir pressure above the asphaltene onset pressure (AOP) and prevent asphaltene precipitation.

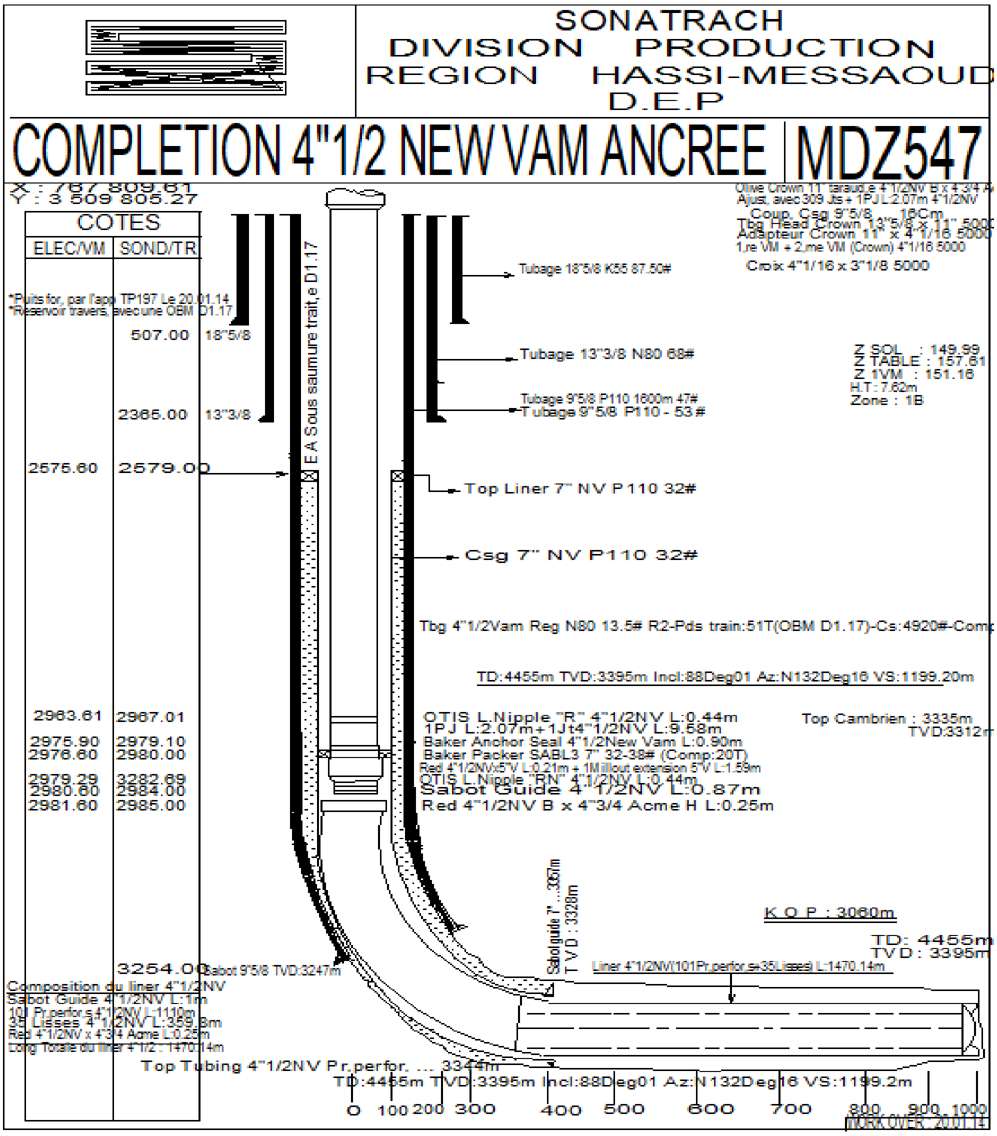
4. Production Management: Implement production strategies that minimize the risk of asphaltene deposition. This may involve adjusting production rates, maintaining flow velocities above critical limits, and utilizing artificial lift techniques to prevent stagnant zones.

5. Regular Monitoring: Continuously monitor reservoir conditions and production performance to identify any deviations and take timely corrective actions. This can be achieved through regular sampling and analysis of produced fluids, as well as monitoring pressure and temperature profiles.

6. Wellbore and Surface Facility Management: Pay attention to wellbore and surface facility design and operations. Optimize well completions, tubing sizes, and flowline configurations to minimize pressure drops and fluid stagnation, which can exacerbate asphaltene deposition and flocculation.

7. Simulation and Modeling: Utilize reservoir simulation and modeling tools to predict the behavior of asphaltene deposition.

## Annex n°1: Technical well file



The current state of the well

- Date of drilling: 10/06/2003.
- NP= 854229.57 m3.
- Completion tubing 4"1/2 NewVam Anchored.
- Reservoir covered by LPP 4"1/2 top liner at 2985 m CS.
- Bottom: TD = 4455 m, TVD = 3395 m.
- Production of deposit water.

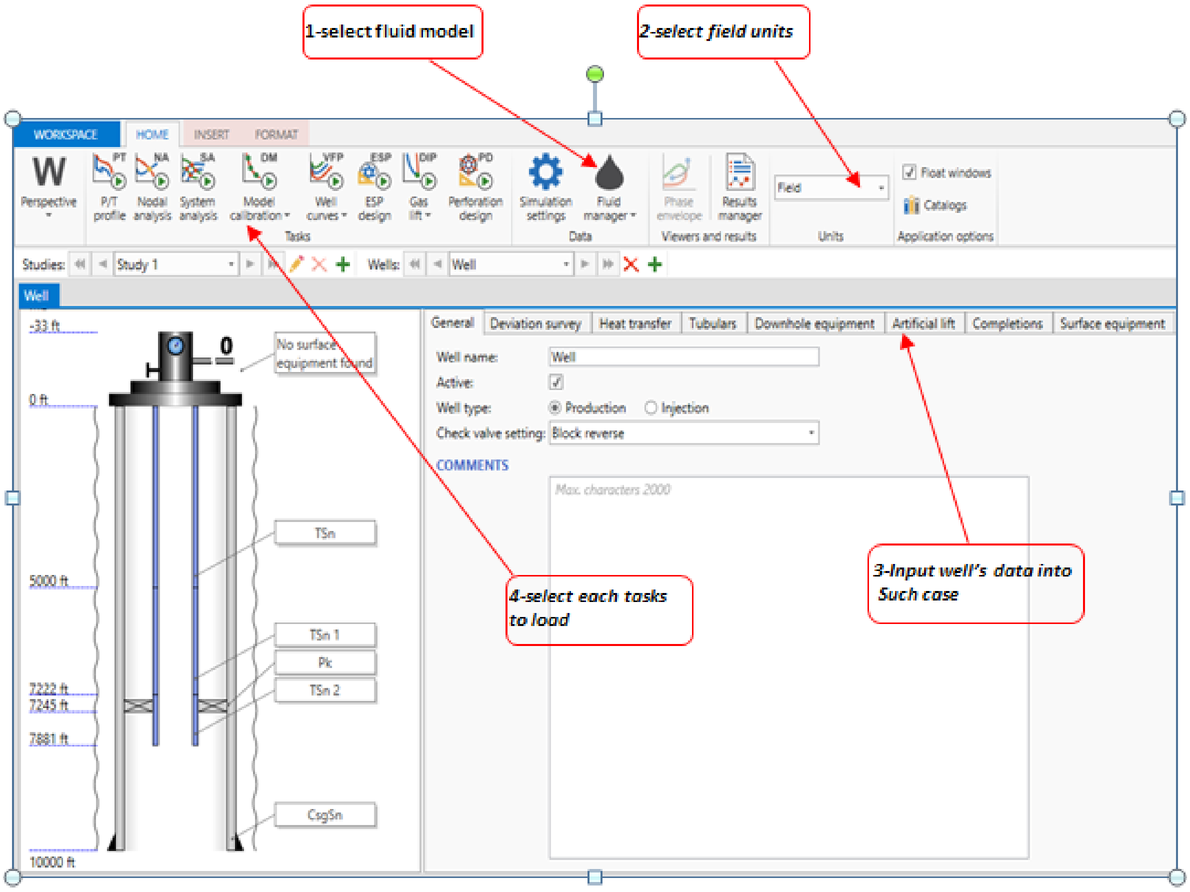
- WO operation on 05/12/2013 LPP 4"½ clean out from 3365m to 4455m.
- Multiple SP Clean Out and TRT at Reformat (39 SP).

## **Annex n° 2:** Well testing history

| **Type de Test** | **Date** | **Pression (kg/cm$^2$)** | | | **Débit (m$^3$/h)** | | **Index Prod.\| Inj.** | **HK** | **Skin** | **Duse** | **Remarque** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **DST** | **21/06/2003** | **379.78** | **274.31** | **127.6** | **Huile** | **10.67** | **.127** | **197** | **1.66** | **12.7** | **Puits horizontal, depl tot=1199.19 m, Az N132.16, Incl 88.01.** |
| **BUILD UP** | **21/10/2008** | **347.01** | **157.71** | **32** | **Huile** | **9.2** | **.056** | **93** | **1.69** | **12.7** | **-** |
| **BUILD UP** | **19/12/2008** | **346.58** | **156** | **32** | **Huile** | **7.99** | **.048** | **86** | **2.46** | **12.7** | **TEST DE CONFIRMATION** |
| **BUILD UP** | **25/08/2019** | **279.91** | **62.8** | **26** | **Huile** | **2.97** | **.015** | **27** | **1.54** | **11** | PFD@-2833.7m |

## **Annex n° 3: Creation of the asphaltene deposit envelope**

The following steps are taken to create the asphaltene envelope:
Asphaltene model creation and definition
1. Select Setup "MFL File.
2. Select Create New.
3. Select "Model set" from the Multiflash toolbar.
4. Select the Asphalt tab.
5. Define the Transport properties (viscosity, surface tension, thermal conductivity) by choosing their correlation.
6. Select the hydrocarbon phases for the asphaltene model which are:
Gas, liquid (oil) and asphaltenes.
7. Click on Define model



1-select fluid model

2-select field units

3-Input well's data into Such case

4-select each tasks to load

Well name: Well

Active: ☑

Well type: ● Production ○ Injection

Check valve setting: Block reverse

**Fig.1.** Creation of the asphaltene model

## Characterization of the petroleum fluid

1. Go to PVT Analysis.

2. Define the method of analysis Infochem Data Bank Infodata.

3. Set the Start pseudocomponents to C6 and the Number of pseudo components Required.

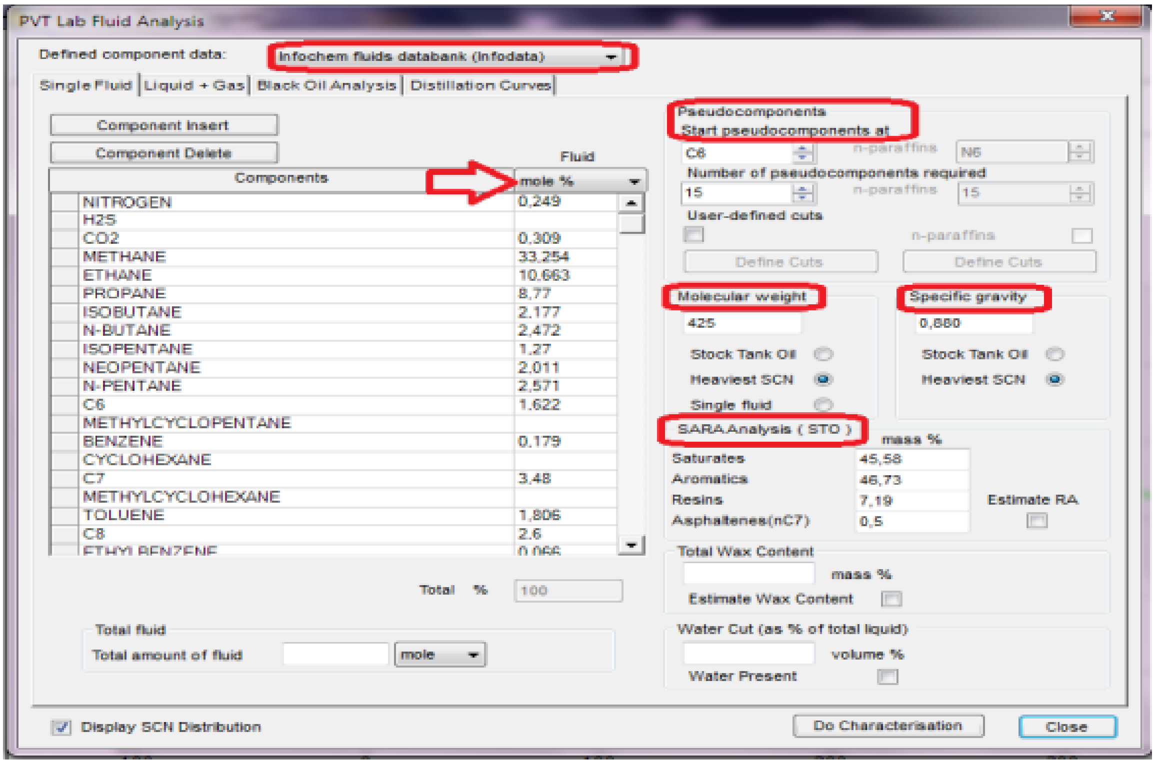
4. Insert the total chemical composition of the petroleum fluid (in mol %).

5. Insert Specific Gravity and Molecular Weight.

6. Insert SARA analysis.

7. Click on Do Characterization.

8. After seeing the message box the characterization has been successfully completed click on OK.



Defined component data: Infochem fluids databank (Infodata)

| Components | Fluid mole % |
|---|---|
| NITROGEN | 0,249 |
| H2S | |
| CO2 | 0,309 |
| METHANE | 33,254 |
| ETHANE | 10,663 |
| PROPANE | 8,77 |
| ISOBUTANE | 2,177 |
| N-BUTANE | 2,472 |
| ISOPENTANE | 1,27 |
| NEOPENTANE | 2,011 |
| N-PENTANE | 2,571 |
| C6 | 1,622 |
| METHYLCYCLOPENTANE | |
| BENZENE | 0,179 |
| CYCLOHEXANE | |
| C7 | 3,48 |
| METHYLCYCLOHEXANE | |
| TOLUENE | 1,806 |
| C8 | 2,6 |
| ETHYLBENZENE | 0,066 |

Total % 100

Total fluid
Total amount of fluid mole

Pseudocomponents
Start pseudocomponents at C6 n-paraffins N6
Number of pseudocomponents required 15 n-paraffins 15
User-defined cuts ☐ n-paraffins ☐

Molecular weight 425
Stock Tank Oil ○
Heaviest SCN ●
Single fluid ○

Specific gravity 0,880
Stock Tank Oil ○
Heaviest SCN ●

SARA Analysis ( STO ) mass %
Saturates 45,58
Aromatics 46,73
Resins 7,19
Asphaltenes(nC7) 0,5
Estimate RA ☐

Total Wax Content
mass %
Estimate Wax Content ☐

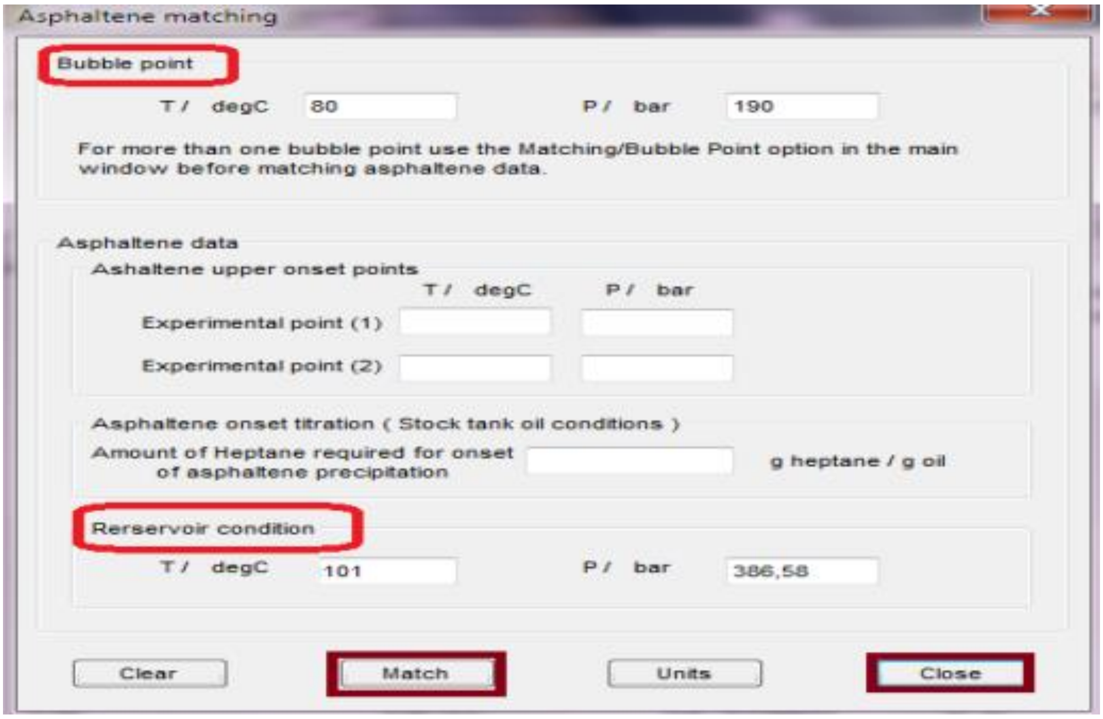
Water Cut (as % of total liquid)
volume %
Water Present ☐

☑ Display SCN Distribution

Fig.2. Characterization of petroleum fluid

## Data matching

1. Select Tools "Matching" asphalt phase, to display the dialog box and Insert the appropriate values.
2. Insert the necessary data and click on Match and Close.



Bubble point
T / degC 80 P / bar 190

For more than one bubble point use the Matching/Bubble Point option in the main window before matching asphaltene data.

Asphaltene data
Ashaltene upper onset points
T / degC P / bar
Experimental point (1)
Experimental point (2)

Asphaltene onset titration ( Stock tank oil conditions )
Amount of Heptane required for onset of asphaltene precipitation g heptane / g oil

Rerservoir condition
T / degC 101 P / bar 386,58

Fig.4. Inserting data for matching

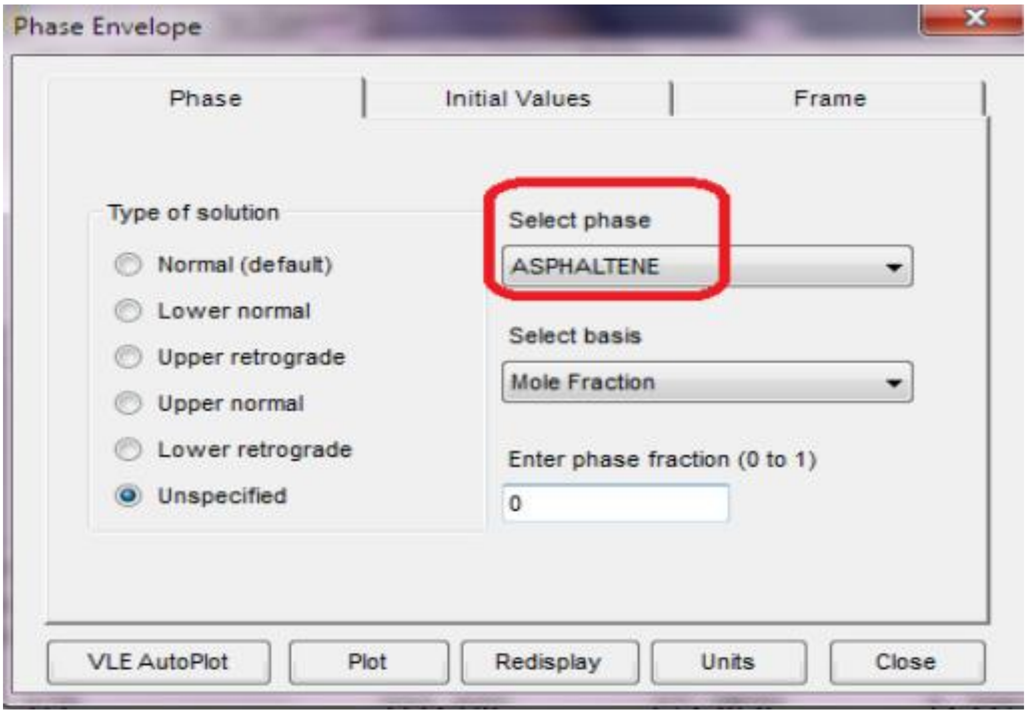
**Determination of the flocculation conditions of asphaltenes**

After introducing the parameters and defining the model, we can now carry out flocculation calculations.

1. Use Calculate "Phase envelope .and choose oil

2. Choose the initial pressure value

3. Go to Phase envelope and choose ASPHALTENE, and a fraction value equal to 0. (To plot the envelope of asphaltene deposition)



Select phase: ASPHALTENE

Select basis: Mole Fraction

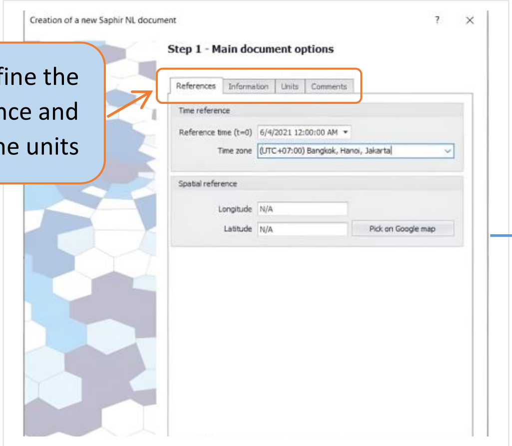
Enter phase fraction (0 to 1): 0

**Fig. 5.Creation of the envelope of asphaltene deposits**

4.Click on Plot, the asphaltene deposition envelope will be displayed with its limits intercepting the intercepting the envelope of phase behavior.

# Annex n° 4:Ecrin Saphir tutorial

This is a simple tutorial explaining basic features of SaphirEcrin while conducting a build up and drill stem tests.



Define the reference and the units

Creation of a new Saphir NL document

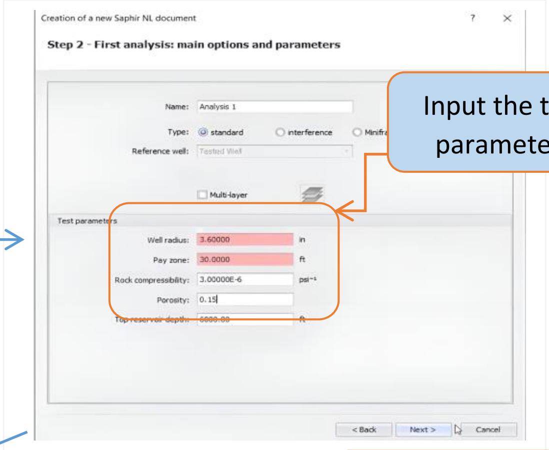
**Step 1 - Main document options**

Reference time (t=0) 6/4/2021 12:00:00 AM

Time zone (UTC+07:00) Bangkok, Hanoi, Jakarta

Longitude N/A

Latitude N/A



Input the test parameters

Creation of a new Saphir NL document

**Step 2 - First analysis: main options and parameters**

Name: Analysis 1

Type: ● standard ○ interference ○ Minifra

Reference well: Tested Well

☐ Multi-layer

Test parameters

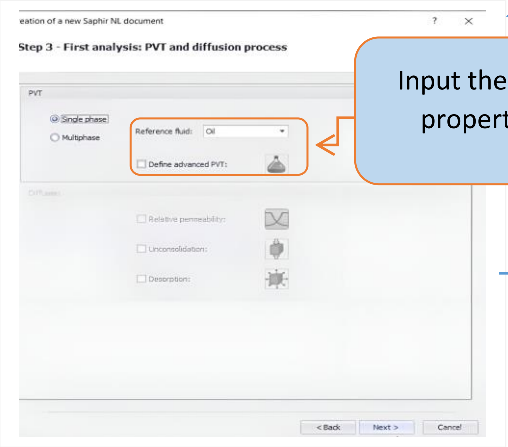
Well radius: 3.60000 in

Pay zone: 30.0000 ft

Rock compressibility: 3.00000E-6 psi⁻¹

Porosity: 0.15

Top reservoir depth: 6000.00 ft



Input the fluid properties

eation of a new Saphir NL document

**Step 3 - First analysis: PVT and diffusion process**

PVT

● Single phase

○ Multiphase

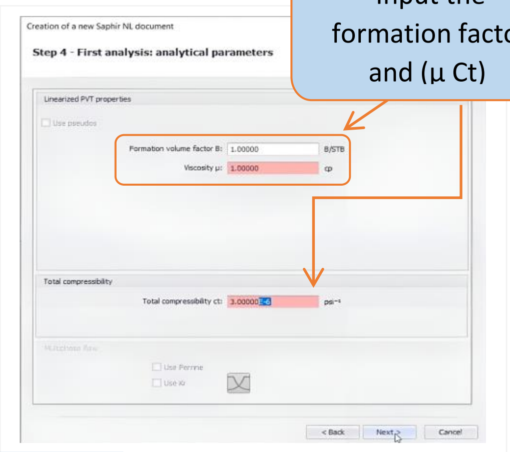
Reference fluid: Oil

☐ Define advanced PVT:

☐ Relative permeability:

☐ Unconsolidation:

☐ Desorption:



Input the formation factor and (µ Ct)

Creation of a new Saphir NL document

**Step 4 - First analysis: analytical parameters**

Linearized PVT properties

☐ Use pseudos

Formation volume factor B: 1.00000 B/STB

Viscosity µ: 1.00000 cp

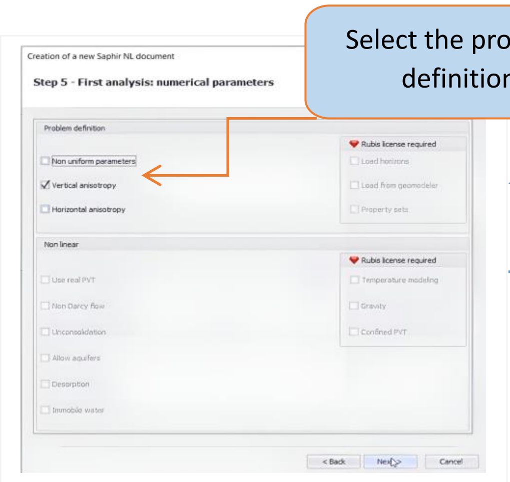
Total compressibility

Total compressibility ct: 3.00000E-6 psi⁻¹

Multiphase flow

☐ Use Perrine

☐ Use kr



Select the problem definition

Creation of a new Saphir NL document

**Step 5 - First analysis: numerical parameters**

Problem definition

☐ Non uniform parameters

☑ Vertical anisotropy

☐ Horizontal anisotropy

Rubis license required

☐ Load horizons

☐ Load from geomodeler

☐ Property sets

Non linear

☐ Use real PVT

☐ Non Darcy flow

☐ Unconsolidation

☐ Allow aquifers

☐ Desorption

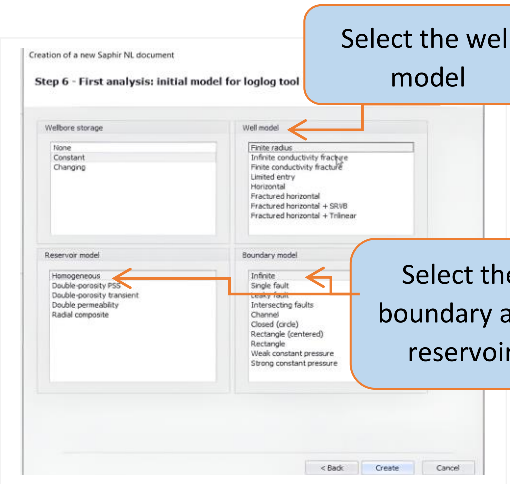
☐ Immobile water

Rubis license required

☐ Temperature modeling

☐ Gravity

☐ Confined PVT



Select the well model

Select the boundary and reservoir

Creation of a new Saphir NL document

**Step 6 - First analysis: initial model for loglog tool**

Wellbore storage

None
Constant
Changing

Well model

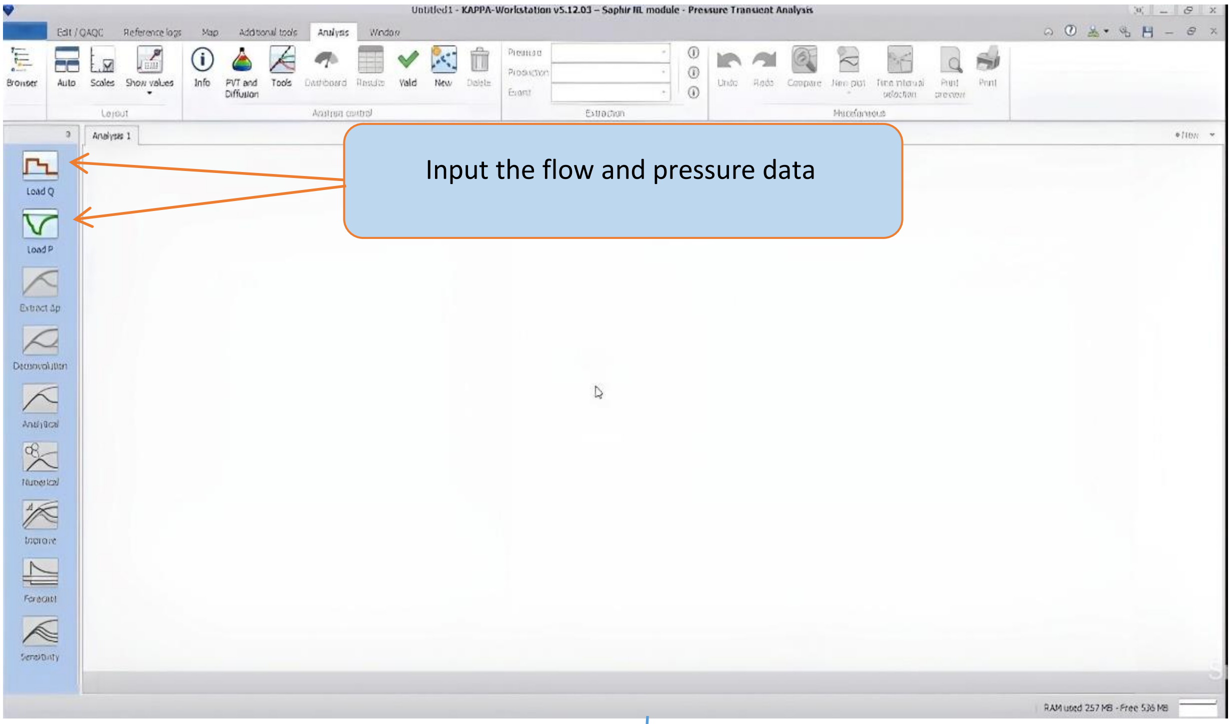
Finite radius
Infinite conductivity fracture
Finite conductivity fracture
Limited entry
Horizontal
Fractured horizontal
Fractured horizontal + SRVB
Fractured horizontal + Trilinear

Reservoir model

Homogeneous
Double-porosity PSS
Double-porosity transient
Double permeability
Radial composite

Boundary model

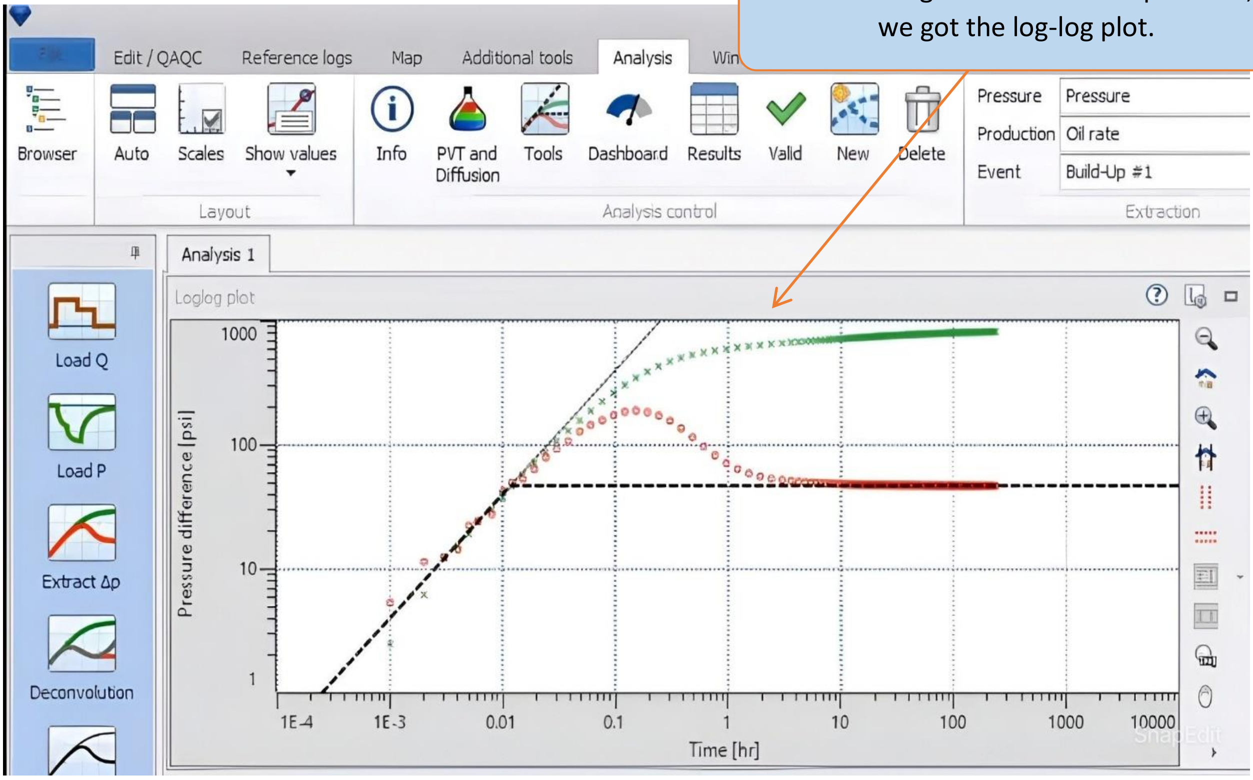
Infinite
Single fault
Leaky fault
Intersecting faults
Channel
Closed (circle)
Rectangle (centered)
Rectangle
Weak constant pressure
Strong constant pressure



Untitled1 - KAPPA-Workstation v5.12.03 – Saphir NL module - Pressure Transient Analysis

Input the flow and pressure data

After loading the flow and the pressure, we got the log-log plot.



Pressure: Pressure
Production: Oil rate
Event: Build-Up #1

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