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Title

MODELING OF THE RESVOIR (R1 BLOC OMK) OF THE HASSI MASSAOUD FILED

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اهداء

الى من كانا سندي وملاذي، والدي العزيز محمد وأمي الغالية عائشة، وإلى من لا تغيب عن بالي، فقيدة قلبي أمي حدة، رحمها الله.

إلى إخوتي الذين شاركوني الحياة بحلوها ومرها، معمر، بشير، ومسعود، وإلى أخواتي العزيزات خيرة ، جميلة، سلوى، فاطمة ، صفاء، هناء، وإلى زهرة فؤادي التي غادرتنا مبكرًا، أختي الزهرة، رحمها الله. وإلى كل أبنائهم الذين يملؤون حياتنا بهجة.

إلى فقيدتي الغالية التي تركت فراغًا لا يملؤه أحد، أختي نهال، من علمتني معنى الصبر والقوة، وإلى أمي الغالية رحمها الله ، أمي رقية. وإلى أختي الحبيبة مروة.

وإلى كل الأحباب والأصحاب الذين ساندوني ودعموني، وكانوا شموعًا تضيء دربي.والى كل اساتذتنا جزاهم الله عنا كل خير.

أهدي إليكم جميعًا ثمرة جهدي هذا، راجيًا من الله أن أكون قد وفقت في إعداد عمل ينال رضاكم ويليق بمكانتكم في قلبي.

يوسف سلطاني

إهداء

أُهدي ثمرة جهدي هذا، إلى من كانوا السند والعون، ومن غمروني بالدعاء والحب اللامحدود...

إلى منارة دربي، ونبع حناني، والديَّ العزيزين حفظهما الله ورعاهما.

إلى من شاركوني ضحكاتي ودموعي، رفاق دربي وإخوتي الأحباء.

إلى كل أستاذ ومعلم أفاض بعلمه، وأضاء لي دروب المعرفة.

وإلى كل من ساندني بكلمة طيبة، أو دعوة صادقة.

أكرم مجول

شكر وتقدير

توجبًا للفضل والعرفان، أتقدم بجزيل الشكر وعظيم الامتنان لكل من ساهم في إثراء هذا العمل البحثي، وإخراجه إلى النور.

أخص بالشكر الجزيل الأستاذة الدكتورة/ [مبروكي نصيرة]، مشرفتي الفاضلة، التي كانت نبراسًا أضاء دربي بفكرها النيّر وتوجيهاتها السديدة. إن صبرها اللامحدود، وعلمها الغزير، ودعمها المستمر كان له الأثر الأكبر في إنجاز هذه المذكرة. فلها مني أسمى آيات الشكر والتقدير.

كما أود أن أعبر عن خالص امتناني للسادة أعضاء لجنة المناقشة الكرام، الذين تفضلوا بقراءة هذا العمل، وتخصيص وقتهم الثمين لتقييمه ومناقشته. إن ملاحظاتهم القيمة ومقترحاتهم البناءة ستكون حافزًا لي للمضي قدمًا في مسيرتي العلمية والبحثية.

وختامًا، أتوجه بخالص الشكر والتقدير لجميع أساتذتي الأفاضل بقسم الجيولوجيا كل باسمه، الذين لم يدخروا جهدًا في تقديم العلم والمعرفة طوال سنوات دراستي الجامعية، فكانوا خير عون وسند.

كما اود ان اعبر عن خالص شكري الى عمال مديرية الإنتاج لسوناطراك ارارة بحاسي مسعود وعلى راسهم رئيس قسم الجيولوجيا عن تقديم يد العون وتقديم نصائح وتشجيعات نيرة وتوفير البيانات المستخدمة في هذا العمل.مع خالص التقدير والاحترام.

Abstract

Reservoir modeling R1, OMK block, Hassi Messaoud using Petrel 2018. This graduation note focuses on the integrated modeling of reservoir R1 in the OMK block of the Hassi Messaoud field, with a particular focus on the practical application of Petrel 2018 as an essential tool for the completion of all stages of modeling. The research aims to provide a comprehensive analysis of the geological and petrophysical characteristics of the reservoir, develop a simulation model that allows the estimation of oil reserves, and effectively improve future production strategies. This study focuses on:

* Mastering the use of Petrel 2018: Exploiting the integrated capabilities of the program in building accurate geological and reservoir models.

* Analysis of geological and petrophysical data in Petrel environment: import, processing and interpretation of seismic data, well records and core data directly within the program.

* Building a 3D geological model in Petrel: Creating an accurate spatial representation of the distribution of rock spikes, faults, and distribution of porous and permeable properties.

* Build a Dynamic reservoir model in Petrel: Prepare the model for reservoir simulation, calibrate it (History Matching) using historical production and pressure data, and then run different scenarios to predict future production.

* Optimal positioning of new wells and evaluation of enhanced oil recovery (EOR) techniques using Petrel: Use simulation tools in the program to test the effectiveness of different development strategies. Methodology (with focus on Petrel 2018) The study follows an integrated methodology that relies heavily on the functionality of the Petrel 2018 program at each stage:

* Import and process data in Petrel:

* Seismic data: Import 3D seismic data into Petrel and interpret it to determine reservoir horizons and faults using the software's built-in seismic interpretation tools.

* Drilling well data: Import well logs, core data, and pressure points directly into Petrel. The necessary processing and corrections of the records are then applied to ensure their accuracy.

Keywords: Cambrian R1; microfacies types; Diagenetic factures; Reservoir quality; modeling; PETREL

Résumé

Modélisation du réservoir R1, bloc OMK, Hassi Messaoud à l'aide de Petrel 2018. Cette note de fin d'études porte sur la modélisation intégrée du réservoir R1 dans le bloc OMK du champ de Hassi Messaoud, avec un accent particulier sur l'application pratique de Petrel 2018 en tant qu'outil essentiel pour la réalisation de toutes les étapes de modélisation. La recherche vise à fournir une analyse complète des caractéristiques géologiques et pétrophysiques du réservoir, à développer un modèle de simulation permettant d'estimer les réserves de pétrole et à améliorer efficacement les stratégies de production futures. Cette étude porte sur :

* Maîtriser l'utilisation de Petrel 2018 : Exploiter les capacités intégrées du programme dans la construction de modèles géologiques et de réservoirs précis. * Analyse des données géologiques et pétrophysiques en environnement Petrel : importation, traitement et interprétation des données sismiques, des enregistrements de puits et des données de base directement au sein du programme. * Construction d'un modèle géologique 3D dans Petrel : Création d'une représentation spatiale précise de la distribution des pointes rocheuses, des failles et de la distribution des propriétés poreuses et perméables. * Construire un modèle de réservoir dynamique dans Petrel : Préparez le modèle pour la simulation de réservoir, calibrez-le (History Matching) à l'aide de données historiques de production et de pression, puis exécutez différents scénarios pour prédire la production future. Positionnement optimal de nouveaux puits et évaluation des techniques de récupération assistée du pétrole (EOR) à l'aide de Petrel : Utiliser les outils de simulation du programme pour tester l'efficacité de différentes stratégies de développement. Méthodologie (avec un focus sur Petrel 2018) L'étude suit une méthodologie intégrée qui s'appuie fortement sur la fonctionnalité du programme Petrel 2018 à chaque étape : * Importer et traiter les données dans Petrel : Données sismiques : importez des données sismiques 3D dans Petrel et interprétez-les pour déterminer les horizons et les failles du réservoir à l'aide des outils d'interprétation sismique intégrés au logiciel. Données de forage de puits : importez des diagraphies de puits, des données de carottes et des points de pression directement dans Petrel. Le traitement et les corrections nécessaires des registres sont ensuite appliqués afin d'en assurer l'exactitude.

Mots-clés : Cambrien R1 ; types de microfaciès ; factures diagénétiques ; qualité des réservoirs ; modélisation ; PETREL

ملخص

نمذجة المكمن R1، كتلة OMK، حاسي مسعود باستخدام برنامج Petrel 2018

تركز مذكرة التخرج هذه على النمذجة المتكاملة للمكمن R1 في كتلة OMK بحقل حاسي مسعود، مع التركيز بشكل خاص على التطبيق العملي لبرنامج Petrel 2018 كأداة أساسية لإنجاز جميع مراحل النمذجة. يهدف البحث إلى تقديم تحليل شامل للخصائص الجيولوجية والبتروفيزيائية للمكمن، وتطوير نموذج محاكاة يسمح بتقدير الاحتياطيات النفطية، وتحسين استراتيجيات الإنتاج المستقبلية بفعالية.

تُركز هذه الدراسة على:

* إتقان استخدام برنامج Petrel 2018: استغلال القدرات المتكاملة للبرنامج في بناء نماذج جيولوجية ومكمنية دقيقة.

* تحليل البيانات الجيولوجية والبتروفيزيائية في بيئة Petrel: استيراد ومعالجة وتفسير البيانات السيزمية وسجلات الآبار والبيانات اللبية مباشرة داخل البرنامج.

* بناء نموذج جيولوجي ثلاثي الأبعاد (3D geological model) في Petrel: إنشاء تمثيل مكاني دقيق لتوزيع السحنات الصخرية، الفوالق، وتوزيع الخصائص المسامية والنفاذية.

* بناء نموذج مكمني ديناميكي (Dynamic reservoir model) في Petrel: إعداد النموذج للمحاكاة المكمنية، ومعايرته (History Matching) باستخدام بيانات الإنتاج والضغط التاريخية، ثم تشغيل سيناريوهات مختلفة للتنبؤ بالإنتاج المستقبلي.

* تحديد المواقع المثلى للآبار الجديدة وتقييم تقنيات الاستخلاص المعزز للنفط (EOR) باستخدام Petrel: استخدام أدوات المحاكاة في البرنامج لاختبار فعالية استراتيجيات التطوير المختلفة.

المنهجية المتبعة (مع التركيز على Petrel 2018)

تتبع الدراسة منهجية متكاملة تعتمد بشكل كبير على وظائف برنامج Petrel 2018 في كل مرحلة: * استيراد ومعالجة البيانات في Petrel:

* البيانات السيزمية: استيراد البيانات السيزمية ثلاثية الأبعاد (3D seismic data) إلى Petrel وتفسيرها لتحديد أفق المكمن (reservoir horizons) والفوالق (faults) باستخدام أدوات التفسير السيزمي المدمجة في البرنامج.

* بيانات آبار الحفر: استيراد سجلات الآبار الكهربائية (Well Logs) وبيانات اللب الصخري (Core Data) ونقاط الضغط (Pressure Points) مباشرة إلى Petrel. يتم بعد ذلك تطبيق المعالجة اللازمة وتصحيحات السجلات لضمان دقتها.

الكلمات المفتاحية : الكمبري R1 , أنواع السحنات الدقيقة , عوامل التصخر , جودة المكامن , النمذجة , بيترال .

Summary

Photo List

General introduction

The study of oil and gas reservoirs and understanding their behavior is critical in the oil and gas industry. By understanding the characteristics of a reservoir and how fluids flow in it, engineers can make informed decisions about optimal production strategies, accurately estimate reserves, and improve extraction efficiency. In this context, the importance of mathematical modeling of reservoirs, which provides a powerful tool for simulating complex phenomena occurring beneath the surface of the Earth.

This note focuses on the modeling of the R1 reservoir in the Hassi Messaoud field, one of the most important and largest oil fields in Algeria. This study aims to build a mathematical model of reservoir R1, which will enable us to simulate its hydrodynamic behavior and predict its future performance. The memorandum will include an analysis of the geological and petrophysical data available to the reservoir, identify the basic parameters that affect the flow of fluids, and then apply appropriate modeling techniques.

Through this modeling, we hope to gain a deeper understanding of the characteristics of reservoir R1, identify the main factors affecting its productivity, and make recommendations that may contribute to improving the management of this bioreservoir and increasing the recovery of hydrocarbons from it. The findings of this MoU will be of great value to engineers and practitioners in the oil and gas sector and will contribute to supporting strategic decision-making regarding the future of the Hassi Messaoud field.

Chapter I:Geologic setting

1. Introduction:

Hassi Messaoud is located 800 km south of Algiers, between the meridians 5°30 and 6°00 and the parallels 31°00 and 32°00N. This Hassi Messaoud field is 350km from the Algerian-Tunisian border and 80km from the city of Ouargla. (Figure 01.1) It has an area of 2000Km², at an altitude of 142m. The climate is desert with temperatures ranging from 0°C to 47°C on average. (Sonatrach document) Had been granted to the company SN REPAL (National Company of Petroleum Research in Algeria) and the company CFPA (The French Petroleum Company in Algeria) its Lambert coordinates are:

X= 790,000 - 840,000 East.

Y= 110,000 - 150,000 North.

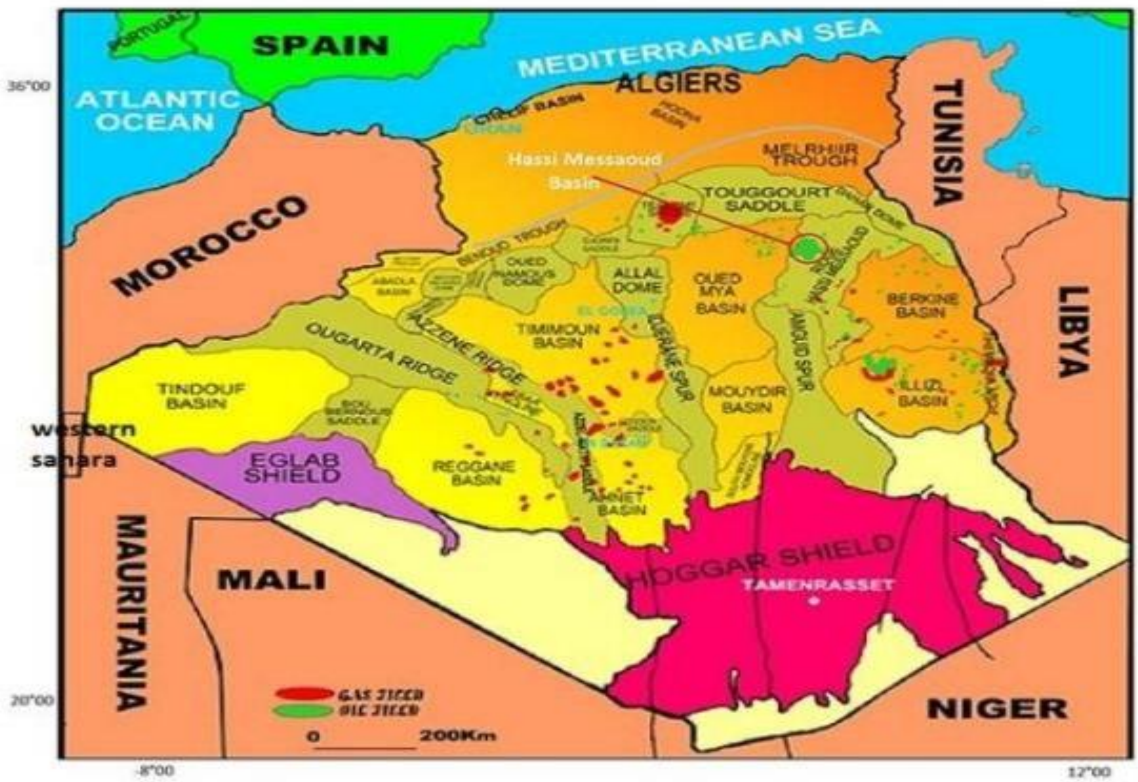

Figure 01.1: The main Algerian sedimentary basins. Hassi Messaoud Basin is surrounded by a red circle. (Sonatrach document)

2. Hassi Messoud filed :

2.1. Geological situation :

The HassiMessaoud deposit is located within the Triassic platform, on the Amguid shoal; it is geologically limited; to the north by the Djamâa-Touggourt structure, to the south by the mole of Amguid El Biod, to the east by the shoals of Dahar, Rhourde El Baguel and the depression of Ghadames and to the west by the depression of Oued -Mya. (Figure 01.2).

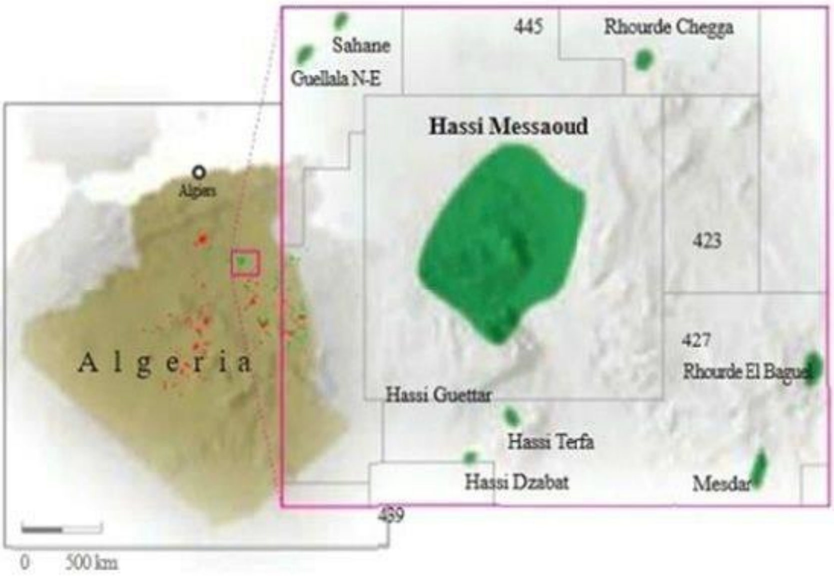

Figure 01.2: Location of the Hassi Messaoud field. (Hydrocarbon Reservoirs of Algeria, WEC 2007)

2.2. Zoning of the Hassi Messaoud field:

The evolution of the pressures of the wells according to the production allowed subdividing the deposit of Hassi Messaoud in 25 zones (Figure 01.3), said of production, of variable extension. These zones are relatively independent and correspond to a set of wells communicating with each other and not with those of the neighboring zones; they each have a specific behavior from the point of view of pressure of deposit. Wells in the same area jointly drain a well-established amount of oil into place. However, it is important to stress that the pressure factor cannot be the only criterion for characterizing areas.

2.3. Well number :

The Hassi Messaoud field is divided into two distinct parts: the North zone and the South zone (Figure 01.3), each having its own numbering established by the first detecting companies of the field. North field: includes a geographic numbering supplemented by a chronological numbering, example: Omn 63.

O: Capital letter, Ouargla permit., m: Tiny, 1600 Km2 tile, n: Tiny, square of 100 Km2

6: X-axis, and 3: Y-axis

South field: It is mainly chronological supplemented by a geographical numbering based on abscissas and ordinates of interval equal to 1,250 Km and harmonized with the lambert coordinates Ex: Md10.

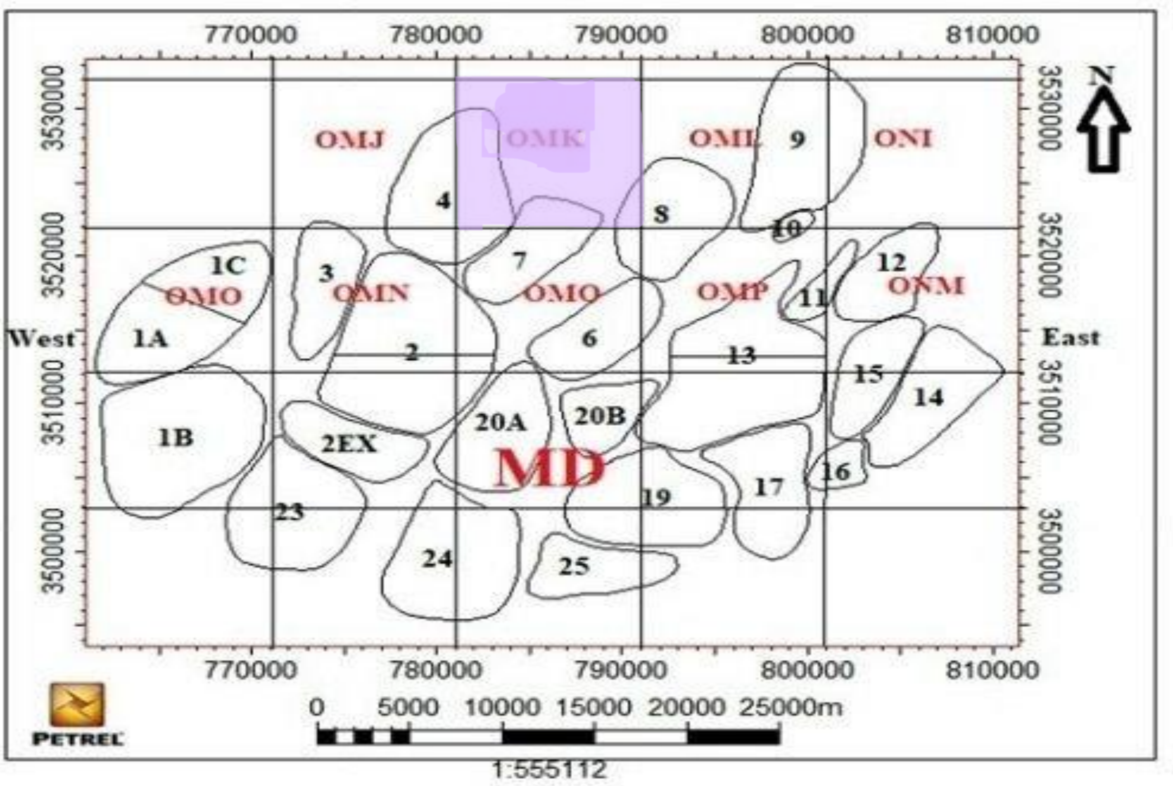

Figure 01.3: Various sectors of the Hassi Messaoud Field indicating the initial letters used for nominating the producing wells and their location concerning the entire field area.

3. Stratigrphy:

A modified generalised stratigraphic section of the Hassi Messaoud ridge (Figure 01.4), which identifies the different rock units typically found in the area, is based on the work of Balducchi and Pommier (1970), De Lapparent (1961), and Malenfer and Tillous (1963). (Djamel Boutoutaou, 2003)

3.1. Pre-Hercynian sedimentary cycle :

3. 1.1. Paleozoic :

3.1.1.1. Cambrian :

The Cambrian sediments in the Hassi Messaoud field have been divided by Malenfer and Tillous, (1963) into five major units: Zone R3, Zone R2, Zone Anisometrique (Ra), Zone Isometrique (Ri), and Zone des alterances. Among these, the Ra is the most important reservoir unit, while the Ri and R2 are considered secondary reservoirs. This information is based on multiple published sourcesby Balducchi and Pommier (1970); Bacheller and Peterson (1991); and Fennouh (1996).

The Cambrian unit R3, also known as zone R3, is a sedimentary layer consisting of highly cross-bedded, arkosic, and quartzose sandstone with a significant clay content, primarily illite. It is composed of approximately 60% quartz and 30% clay. The R3 section includes a basal conglomerate composed of pebbles to cobbles. In the Hassi Messaoud field, the thickness of the R3 section ranges from 275 meters in the south central part to 368 meters north of the field. These deposits are believed to have originated from moraines and tillites deposited during the Eco-Cambrian period and subsequently redistributed by alluvial streams.

The Cambrian unit R2, also known as zone R2, is a thick sequence of sandstones with a high clay content. These sandstones are medium to coarse-grained and contain interstitial clay and thin inter-beds of shale. The clay minerals in this zone are mainly illite with some kaolinite. Due to the presence of clays, the reservoir quality of this zone is poor, making it generally non-productive. However, in the northeastern part of the field, the upper 20 meters of this zone is included as part of the producing interval. In areas where erosion has not occurred, the thickness of this zone can reach up to 80 meters.

The Cambrian unit Ra, also known as the Zone Anisometrique, is a significant reservoir in the Hassi Messaoud field. It is characterized by a maximum total thickness of 150 meters in the western portion of the field, where it has not been affected by erosion cycles. The Ra zone is further divided into five sub-zones: Drain 4, Drain 3, Drain 2, Inter-drain, and Drain 1. These sub-zones share similar lithological characteristics, consisting mainly of highly cross-bedded, very poorly sorted, medium grained to micro-conglomeratic quartzose sandstones. Interspersed within these sandstones are irregular lenses of shaly siltstone. The composition of the Ra zone is predominantly quartz, accounting for approximately 70% of its composition. Secondary silica makes up around 14%, while clay constitutes about 8%. In some wells, the clay is primarily kaolinite. Drain 3, also known as the "Median Zone," differs from the other sub-zones in that it is finer-grained and lacks cross-bedding. It is also notable for containing abundant tubular fossils known as scolites. The primary clay mineral in Drain 3 is kaolinite. Studies by L'Homer (1967) and Beuf et al. (1971) suggest that the Ra sediments were deposited in alluvial fan and associated depositional environments. Despite variations in Drain 3, the thickness and continuity of the sub-zones remain remarkably consistent throughout the field.

The Cambrian Ri (Zone Isometrique) is a quartzitic sandstone unit that is approximately 50 meters thick. It is characterized by its homogeneous thickness, well sorted, medium-grained sandstone composition, and the presence of interbeds of shale and silstone. Throughout the section, the Ri contains numerous tubular fossils known as scolites, except for the basal meter or so which consists of winnowed debris from the underlying formation. The Ri unconformably overlies the Ra zone, and this contact is comparable to L'Homer's (1967) "Gamma Zero" marker in fieldwide correlations. While the Ri does contain hydrocarbons when present above the oil-water contact, it is not considered an important producing zone due to its poor reservoir characteristics. Despite its limited production, the top of the Ri is still considered the top of the reservoir section.

The Zone Alternances, which consists of alternating layers of quartzites, siltstones, and black shales, ranging from 25 to 40 m in thickness, is commonly regarded as the lowermost part of the Ordovician sequence according to previous researchers.

3.1.1.2. The Ordovician :

The Ordovician is a geological period that is characterized by the presence of various rock formations in the Hassi Messaoud field. These formations are eroded over a large area but are still present in the immediate vicinity of the field. Some of these formations are also found within the field boundary, particularly in the narrow grabens in the southern part of the field and the northeast sector. The Ordovician section in this area includes the following formations: El Azzel Shales Formation, Ouargla Sandstones Formation, Hamra quartzite Formation, El Atchane Sandstones Formation, and El Gassi Shales Formation. These formations vary in composition and reservoir quality, with some being fine-grained quartzite with low porosity and permeability, while others are black glauconitic, graptolitic marine shale.

3.2. Post Hercynian sedimentary cycle :

3.2.1. Mesozoic :

3.2.1.1. Triassic :

The Triassic is characterized by the deposition of sedimentary rocks that are divided into two units: the Upper Triassic and the Lower Triassic. The Upper Triassic is composed mainly of massive anhydrite and halite, while the Lower Triassic consists of a basal clastic section. The thickness of the basal unit can vary greatly due to the irregular erosion surface upon which it was deposited, with topography reaching up to 30 meters.

3.2.1.2. The Jurassic :

The Jurassic period is characterized by a thick sequence of rock layers (850 m thick), with the upper third consisting of massive dolomite. This dolomite is separated from the underlying massive salt and anhydrite unit by a thick shale section known as the Dogger Lagunar.

3.2.1.3. The Cretaceous :

The Cretaceous period is characterized by the presence of various sedimentary rocks such as anhydrite, halite, limestone, and dolomite. These rocks are found in the upper 800 meters of the Cretaceous section. Additionally, the lower Cretaceous is composed of a thick clastic unit consisting of siltstone, shale, and fine-grained sandstone, spanning a thickness of 850 meters. Within this lower unit, there is a prominent dolomite bed that is approximately 25 meters thick.

3.2.1.4. The Miocene-Pliocene :

The Miocene-Pliocene period is characterized by the presence of approximately 250 meters of sand, sandstone, and sandy shale sediments.

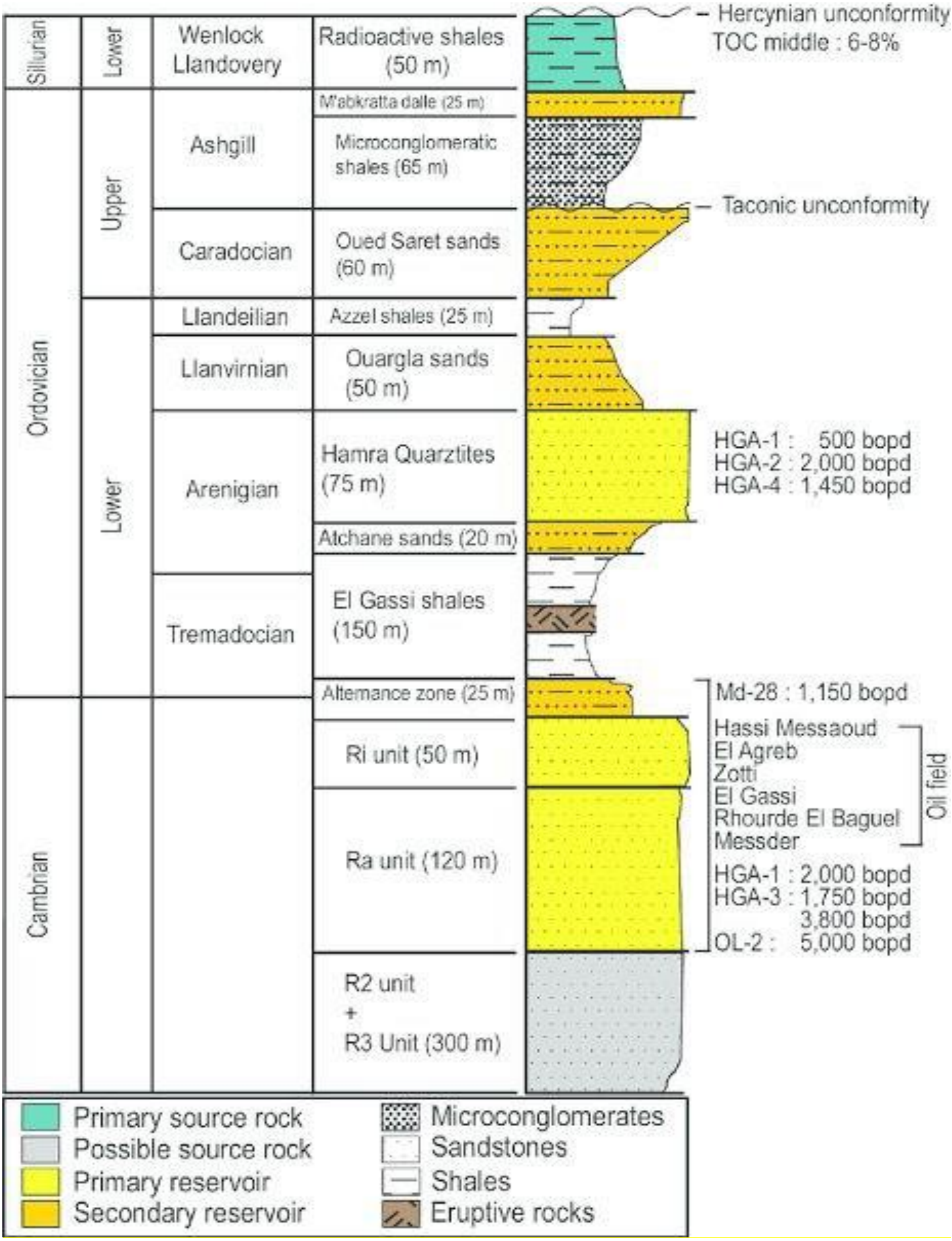

Figure 01.4: The stratigraphic column of the Paleozoic sequence in Hassi Messaoud Field, Algeria (Zerroug et al., 2007; Aïfa et al., 2014).

4. Depositional environments and diagenesis :

The depositional environments in the studied area consist of a complex system of braided river channels in the lower R3, R2, and Ra units. These units are overlain by finer sandstones with skolithos and clayey siltstone levels in the upper Ra, indicating a shallow marine environment. The marine episode continued into the Ordovician, with the deposition of fine sandstones containing skolithos and clays. The sandstones in reservoirs Ri and Ra, as well as the Hamra quartzites, often exhibit a predominance of silica, with kaolinite being the main clay mineral. Secondary silica growth is observed in fault zones and as a fill for faults and fractures. The sandstones in reservoirs R2 and R3 show a higher volume of detrital or authigenic illite compared to silica (Hydrocarbon Reservoirs of Algeria, WEC2007)

5. Structure :

The Hassi Messaoud field has a structure of an anticlinal dome, which was formed during the Hercynian orogeny. The field is extensively compartmentalized by regional fault systems and complex perpendicular and parallel systems on a smaller scale. The field is also characterized by deep narrow valleys filled with volcanic rocks, and the structural dip ranges from 4 to 10 degrees. The presence of fissures associated with the faults contributes to increased permeability and production. The volcanic rocks are mainly found in the southern part of the field (Hydrocarbon Reservoirs of Algeria, WEC2007).

6. Tectonic :

The tectonic setting of the Hassi Messaoud area in the Sahara platform has undergone significant deformation and tectonic events throughout its geological history. The majority of the Cambrian sandstones were deposited on a stable subsiding area, with a northward paleo current direction. The Hassi Messaoud structure experienced brief activity at the end of the deposition of the Ra formation, resulting in erosion of up to 50 m of that unit. The effects of the Hercynian orogeny are evident, with widespread faulting and deep erosion in the Cambrian and Ordovician rocks. The tectonic events and erosion continued during the Late Devonian through the end of the Permian period, leading to the formation of the Hassi Messaoud - El Agreb anticlinorium. The final phase of the Hercynian orogeny was followed by the deposition of Triassic sediments and the extrusion of Triassic igneous rocks. The Sahara platform gradually subsided from the pre-Late Triassic to the end of the Cretaceous, accumulating evaporite and elastic sediments. The absence of rocks from the early Tertiary suggests positive orogenic movement along the Hassi Messaoud - El Agreb high. The area has remained tectonically inactive since, with the presence of flatlying continental Miocene-Pliocene rocks. (B.Djamel, Understanding the regional migration routes and field charging history of the Oued mya — Hassi messaoud petroleum system, Algéria

7. Petroleum system :

7.1.Source rocks :

The main source rock in the Amguid - Hassi Messaoud basin is the Silurian (Figure01.5), which consists of radioactive gray-black to black clays rich in organic matter. This source rock is primarily gas-productive in the western regions, while in the eastern region, oil was generated during the late Jurassic and early Cretaceous periods. The oil generated from the Silurian source rock has contributed to significant reserves in the region, with an estimated 1.08 billion barrels of oil and 730 trillion cubic feet of gas expelled. The remaining undiscovered oil reserves in the region are estimated to be around 48 billion barrels, mainly located in the Cambro-Ordovician plays to the northwest of the Berkine and the Triassic plays in the northern and western regions of the Hassi Messaoud dome:

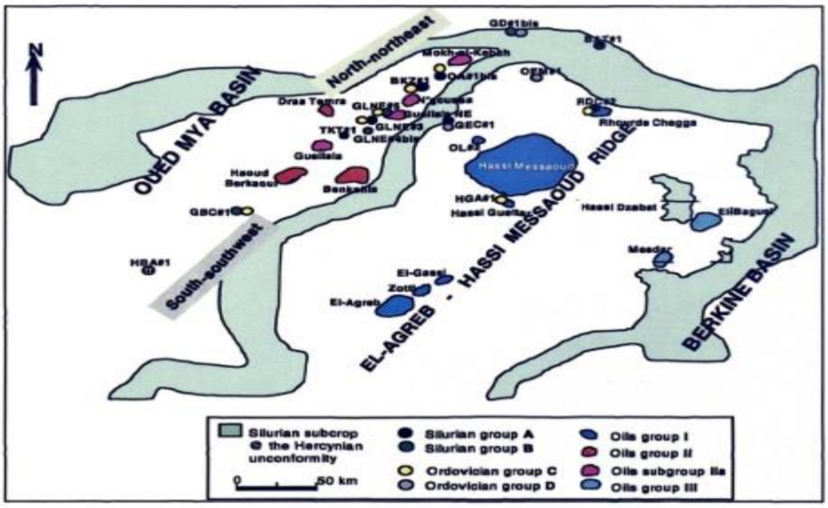

Figure 01.5: Silurian, Ordovician source rock samples and oil fields location map. (Djamel Boutoutaou, 2003)

7.2.Seal Rocks :

The Amguid – Hassi Messaoud uplift has multiple layers of rock seal that vary in age and type. The El Gassi clays cover the Cambrian reservoirs, while the Azzel clays seal the Hamra quartzites reservoir in the Ordovician. The most effective seals are the clay-evaporite deposits of the Triassic and Liassic.

7.3.Reservoirs Rocks :

The Cambro-Ordovician refers to a reservoir that has been drilled in various structures, but has only shown limited oil accumulations. However, the Hamra quartzites within the Ordovician reservoir have demonstrated significant oil impregnations, with columns of over

100m and surface areas exceeding 500 km2. Tests have indicated oil flows ranging from 6 to 14 m3/h. The unique ring shape of the Ordovician reservoir adds to its high level of interest.

The Cambrian in Hassi Messaoud and its surrounding areas is a productive reservoir in various fields. The Ri unit, which is part of the Cambrian play, serves as a transition between different facies. It is composed of medium to coarse, bioturbated sandstones. The top of the Ri reservoir is characterized by a shallow marine sandstone that exhibits abundant bioturbation. The thickness of the Ri reservoir can vary and it may also be unconformable with the reservoir Ra.

The Ordovician period is characterized by the presence of the Taconian unconformity, which separates the basal Ordovician from the Upper Ordovician. This unconformity is made up of fluvio-glacial and glacio-marine formations. The lower Ordovician is divided into two transgressive-regressive cycles, with formations that were deposited in shallow to fluviatile marine environments. The Middle Arenigian-Caradocian cycle includes a variety of rock formations and is sometimes cut off by the Taconian unconformity in certain areas (the Hamra quartzites, Ouargla sand- stones, Azzel marine clays, and the Oued Saret littoral deltaic sandstones.).

Triassic is characterized by challenges in petrographic and petrophysical characterization due to lateral discontinuity in sandstone bodies and compaction related to diagenetic phenomena. The deposits are concentrated in NE-SW oriented depressions and are marked by evaporitic formations, volcano-detritic deposits, and lagoonal deposits. The facies of the basin vary depending on the location of sedimentation and distance from input sources. The deposits are generally continental at the base and become more evaporitic towards the top.

7.4.Traps :

Exploration efforts have primarily focused on structural and mixed traps, with a particular emphasis on stratigraphic traps. Structural traps in the Middle Triassic are typically anticlinal folds that formed during different tectonic phases, either as a result of fracturing tectonics or bounded by major faults within the complex Amguid Hassi Messaoud High system. Stratigraphic traps, on the other hand, involve sandstone bodies that have been closed off by lateral wedging.

8. Lithological description of the reservoirs :

8.1.The Cambrian reservoir :

The Cambrian Ri/Ra lithology consists of a thick sequence of detritic rocks, including sandstones, quartzites, and conglomerates. The lower member, Ra, is composed of fine to coarse gray-white sandstones and compact light-gray conglomerates. The upper member, Ri, is characterized by pinkish gray sandstones of quartzite composition with a siliceous cement. The sandstone bodies and silts of reservoir Ra are discontinuous and of small lateral extent, while sandstone RI shows better continuity.

8.2.The Ordovician reservoir :

The Ordovician lithology consists of a 90-meter thick formation characterized as massive and compact. It is composed of fine to medium, locally coarse, compact hard silico-quartzite to quartzite, white to gray-white sandstone with episodes of black, silty, laminated clay. Different lithofacies have been identified, including horizontally bedded fine to very fine quartzite sandstone, obliquely bedded very fine to fine quartzite sandstone, bioturbated very fine to fine quartzite sandstone, crossbedded very fine to fine quartzite sandstone with graded bedding, very fine to fine sandstone with clay chips, clay pebbles, and clay films, and very fine to fine quartzite sandstone. The presence of ichnofacies associated with Scolithus indicates an upper shoreface, marine-type environment.

Chapter II :Working methode

1. Introduction:

Geological models can be used to perform accurate volume calculations or to test the effect of different deposit regimes against observed data.

2. Presentation of the Petrel software(Schlumberger):

Petrel is a software, which is a product of Schlumberger, that allows the user to Build a reservoir model with properties to export to a simulator. Petrel is a Windows-based software for 3D visualization, mapping and 3D modeling of the 3D tank and simulation. It was founded in 1996, and published in trade in 1998.It has become a part of the information Solutions Schlumbergere January de 2003.Trial of the Pétrel software.

3. The reservoir modeling stage :

The Petrel software, with the different modules it contains, can help us to do everything we can kind of modeling on our tank, and allow a 3D visualization or 2D (cards, cups... etc.) of the results obtained. The models carried out are:

Structural modeling:

Facie modelling:

Petro-physical modelling:

Oil-water contact modeling:

4. Create a new project and load data

Of course, a minimum of data essential to our type of modeling (we used 24 wells in OMK field), and must be loaded so that we can talk about a possible Petrel project.

OMK field well data In order to be able to model the reservoir, all the reservoir parameters must be introduced namely; The coordinates (x, y, Zs (Z ground), Zt (Z table), log depth, depth Symbol) of all the wells used to construct this model, the roofs and the walls of the existing units in each well interpreted from the logs, logs (data from the interpreted logs).

- **Fault:**

Seismic data is very important, but if it is not available, as was our case. You have to have the flaws in 3D or have them in 2D that you will need transform into 3D.

- **Horizons** :

The horizons interpreted from the seismic must be converted into a map of Depth. But due to the absence of data from the seismic maps of the region, We used the real tops of the formations in this model:

The roof of T2

- The roof of T1

– The roof of the eruptive rock
- The roof of the lower series
- The roof of the goth

5. Structural modeling:

Structural modeling is one of the most important parts of this chapter. It forms the basis for all geological modelling.

As we were unable to access the seismic data, we used only the results of the seismic interpretation and the coordinates of the networks of the faults .

- The fault networks were determined from the digitization of the map at the Triassic roof resulting from the interpretation of relatively recent seismic data, namely, a 2D seismic and a 3D seismic.
- The faults identified by the seismic interpretation have not been "loaded" into the the Petrel project and displayed as a "fault stick", i.e. flaws under the rods or strips, but they are generated as vertical faults, then they are handled.
- After that, we proceeded with the "gridding" mesh, which consists of creating the skeleton on which the model will rest. In this part, the flaws will take shape and will be taken into consideration in the skeleton of the future model. 3D Grid Concept, Simply put, a 3D grid divides a model into place in boxes. Each box is called a grid cell and will have a single type of rock, a value of porosity, a value of water saturation, etc. These are referred to as the properties of the cell. This is a simplification of the true case, but allows us to generate a representation of reality that can be used in calculations, etc.
- The pillargrid, a very important step in the realization of the of the 3D geological model. Using the fault plane, a grid is constructed composed of three layers (skeleton composed of a Top. Mid and Bottom), forming the skeleton of the model, likely to contain the different reservoir levels considered in this study.
- Horizon modeling: It is the insertion of the horizons in the 3D grid, five main limiting horizons reservoir that are interpreted from the well logs have been inserted initially to guide modeling. We have imposed as constraint for the model, the Well tops corresponding to each unity and associated flaws. They are assumed to be vertical in the absence of the seismic data. The rejection is determined automatically by the software for all the flaws, which are part of the overall framework known at the level of the study area.

6. Modeling properties :

6.1 Facie modeling :

In this section, process Deconstruction of a model facies is based on observations and with the help of ESIS. The devariogram type, Varies and azimuth for are normally designed Each facies is for Supplies. These correspond geological extremities (typically observed in a good section), and require little experimentation to create the desired effects.

Object Modeling allows users to populate a discrete facies model with different organisms of various geometries, the facies code and fraction. All geometric inputs control the shape of the body (width, thickness, etc.) are user-defined.

- ❖ **Creation of electro-facies** Due to the lack of geological data, we used electro-facies calculated at from the log results, defines as follows:
- ❖ o **Electro-facies**: This is the set of log characters that can characterize a bench and differentiate it from the formations that surround it. These facies are assigned with special equations including the loaded data previously.
- ❖ **Up-scaling** The log data of the electro-facies are "up scaled" (scaled (e.g. one-meter banks) in the static model after their loading on Petrel.
- ❖ **Data analysis Facies** distribution maps are drawn up after the geostatistical analysis of the and select an appropriate estimation method. Geostatistics, the most active area of research in the last 10 years was the year of geostatistical simulations. Simulations are necessary for any problem involving non-linear transformations of the measured variables. The estimation method used is the sequential simulation of indicators for the discrete variables, such as facies.

7. Petrophysical modeling:

Deterministic modeling, when well logs have been set to the scale to the resolution of the cells in the 3D grid. The values of each cell along the well path can be interpolated between wells in the 3D grid. The result is a grid with the property values for each cell. Up-scaling property the structural model established previously will be dressed up by the different petrophysical data. This data must first be "upscaled" then analyzed geostatistically (Sequential Gaussian simulation). Data analysis the geostatistical analysis will determine the extrapolation model to be used for the modeling. The accuracy of the resulting petrophysical model will depend on the analysis geostatistics of the corresponding data. At the end of this modeling, we will obtain a 3D simulation of the reservoir in in terms of porosity and saturation. Sequential Gaussian simulation is the method used for variables continuous such as GR, NPHI (neutron porosity), core porosity(Q), Permeability (K) of core.... etc.

8.Oil-water contact modelling:

Creating a new contact set After building a 3D Petrel grid and before performing the volume calculation, the different contacts should be defined in the process Make Contacts. Multiple contact series can be defined, and each set of contact scan contain a number of different types of Contacts. All contact sets will be stored in a folder called fluid contacts in the Petrel Models tab. All of the contacts can be created based on a constant depth value or a surface. If a surface is used as an input for contact, it must be existed in the Petrel Explorer window. Any type of surface can be used as an entrance. The user has the option to use the same contacts for all zones and segments, different contacts for each segmented /or different contacts for each area. In this model exists of oil-water contact, I interpret the contacts by displaying the wells (logs) and spikes at the depth of the contact, so we have shouted an oil-water contact file.

9.Estimation of oil in place possible

Uncertainties exist so much on certain parameters (interface, facies extension) are such that the existence of hydrocarbons in certain areas is very problematic, but cannot be definitively excluded.

In this part we will have to evaluate the hydrocarbon reserves of the OMK (lower series tank) by volumetric method.

The mathematical meaning of this method is expressed by the following formula:

$$Q_{rec} = F.\ ho.\ \Phi.\ S0.\theta.\ \rho.\ \gamma$$

Where:

Qrec : Recoverable oil reserves at ground surface conditions in tons.

F: Surface area of the oil zone in m.

h0: Average oil-bearing effective thickness of the layer in m.

Φ: Average open porosity coefficient of the reservoir layer in %.

Chapter II : Area study

1. Introduction :

in our study, we highlight on the north of Hassi Messaoud (OMK) Field which lies between Latitudes 31º 48’30.26 - 31º 53’53.52 N and Longitudes 5º 58’22.806 - 6º03’54.196 E. utilizing 24 wells for the purpose of evaluating the Cambrian reservoirs.In this part, Isopach maps were created to see the change in thickness of the cambrian reservoir.

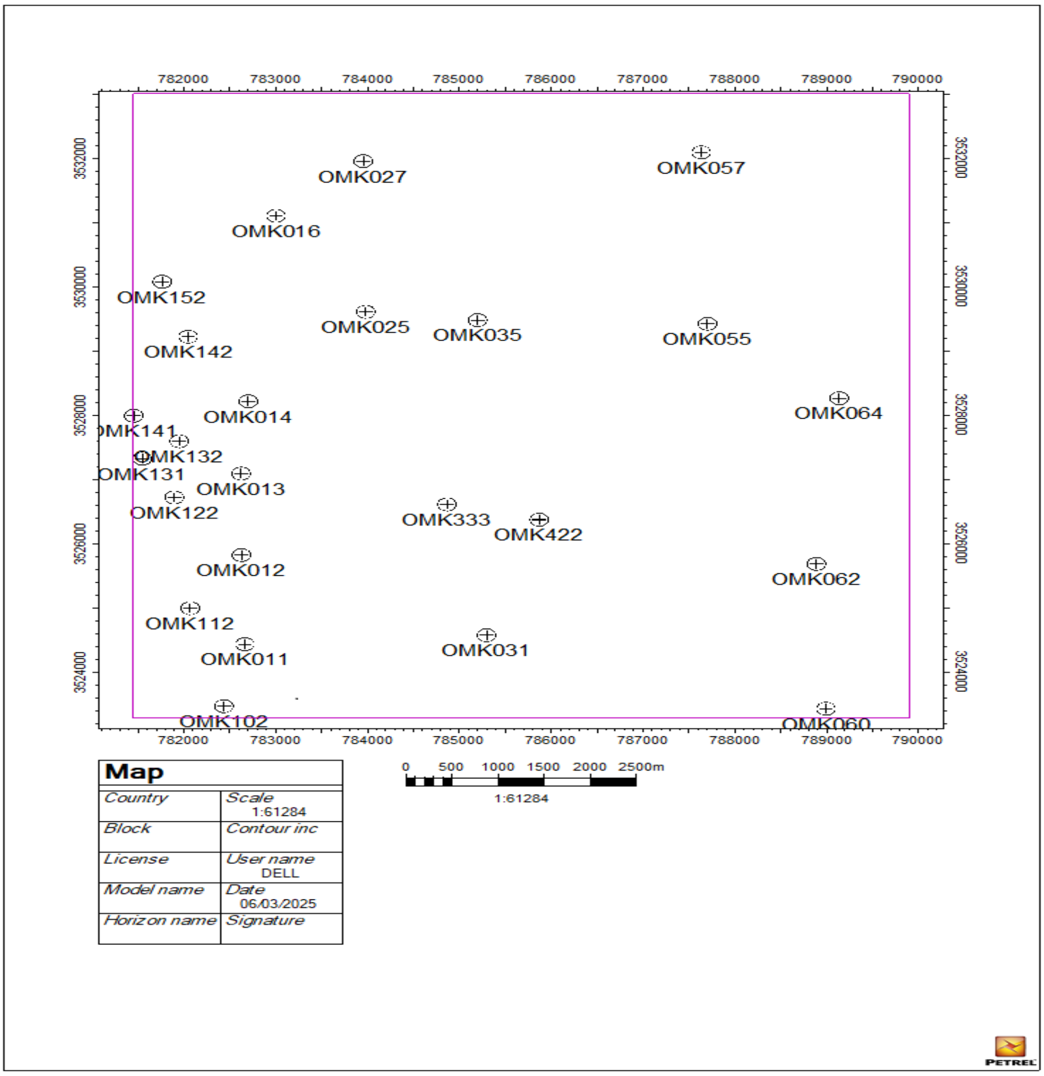

Figure.2.1 : Map showing the location of wells in the studied area

2. Isopach maps :

The isopach map shows the variation in thickness of the stratigraphic units by contour lines pass through points of equal thickness. An important of isopach map is the interpretation, which includes restoration of the original depositional edge of the stratigraphic unit. In some instances, the present day zero isopach line may represents the shore of the ancient sea, which deposited at that time (Krumbein and Sloss, 1963).

We utilised wells tops have been used for constructing the isopach maps by using a program Petrel of the studied Cambrian (R1) reservoirs shows reservoirs DH, D2, ID, D1 thickness changes. four isopach maps are constructed for DH, D2, ID, D1 reservoirs, to demonstrate the variation in the thickness of different units based on the sequence of structural changes and complex tectonic occurred in the interested area.

2.1Isopach map of DH reservoir:

Another Isopach map DH shows variable thicknesses related to complex tectonic activity during the deposition of this unit, the maximum thickness reaching DH to 90m deposits, while the minimum thickness is recorded 0 m.

We observe low thickness in the north that may be high in most of the study area and Increases in the South

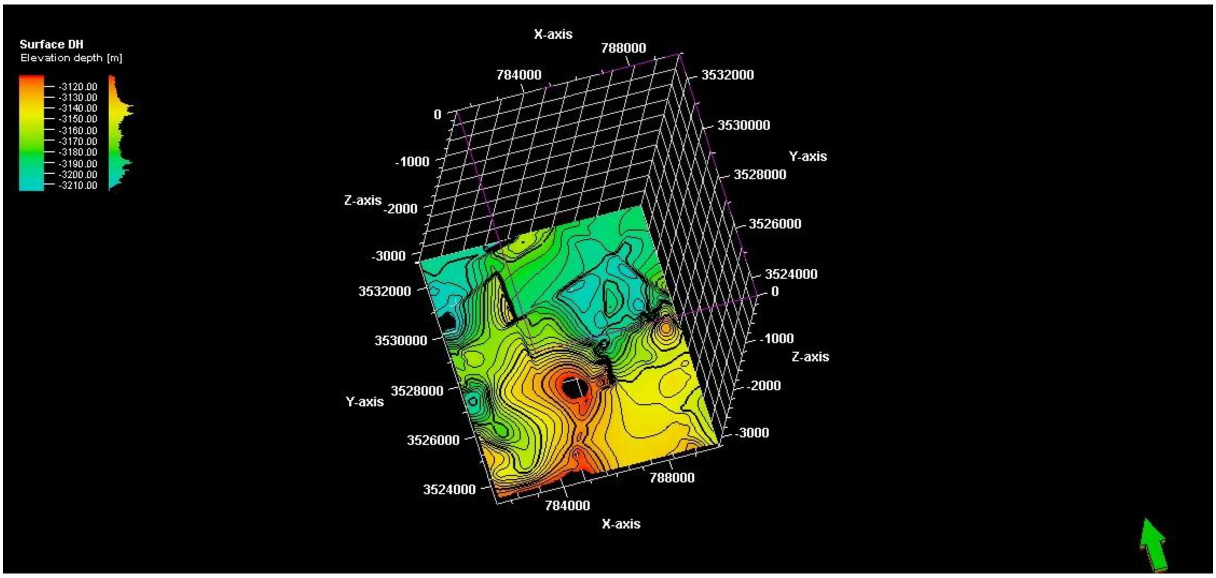

Figure 2.2: Isopach map of DH reservoir, in north of field Hassi messaoud (OMK)

2.2Isopach map of D2 reservoir :

Another Isopach map D2 shows variable thicknesses related to complex tectonic activity during the deposition of this unit, the maximum thickness reaching D2 to 55m deposits, while the minimum thickness is recorded 0 m.

We observe low thickness in the north that may be high in most of the study area and Increases in the South.

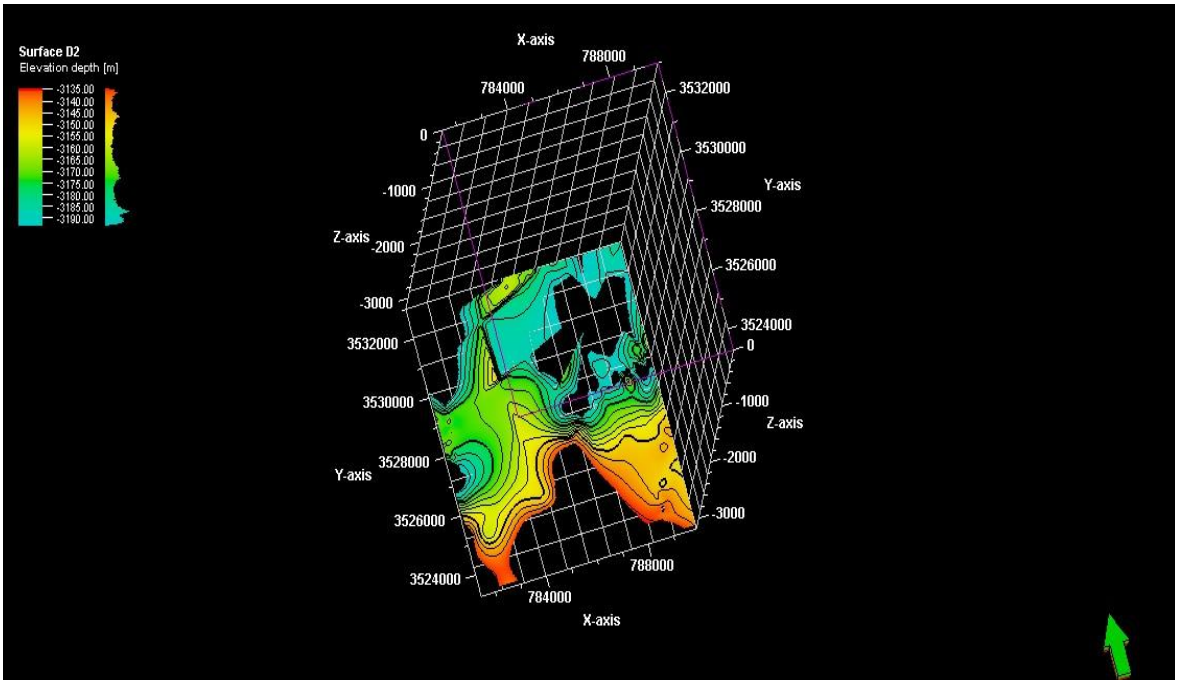

Figure 2.3: Isopach map of D2 reservoir, in north of field Hassi messaoud.(OMK)

2.3Isopach map of ID reservoir:

Another Isopach map ID shows variable thicknesses related to complex tectonic activity during the deposition of this unit, the maximum thickness reaching ID to 80 m deposits, while the minimum thickness is recorded 0 m.

We observe low thickness in the north that may be high in most of the study area and Increases in the South.

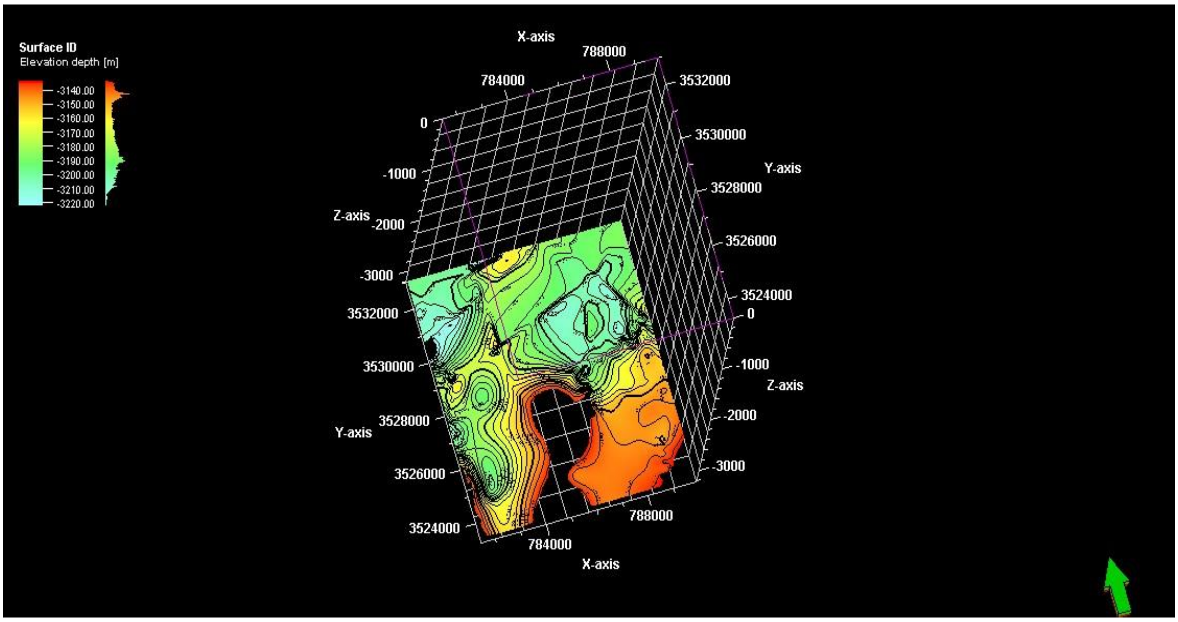

Figure 2.4: Isopach map of ID reservoir, in north of field Hassi messaoud.(OMK)

2.4Isopach map of D1 reservoir :

Another Isopach map D1 shows variable thicknesses related to complex tectonic activity during the deposition of this unit, the maximum thickness reaching D1 to 120m deposits, while the minimum thickness is recorded 0 m.

We observe low thickness in the north that may be high in most of the study area and Increases in the South.

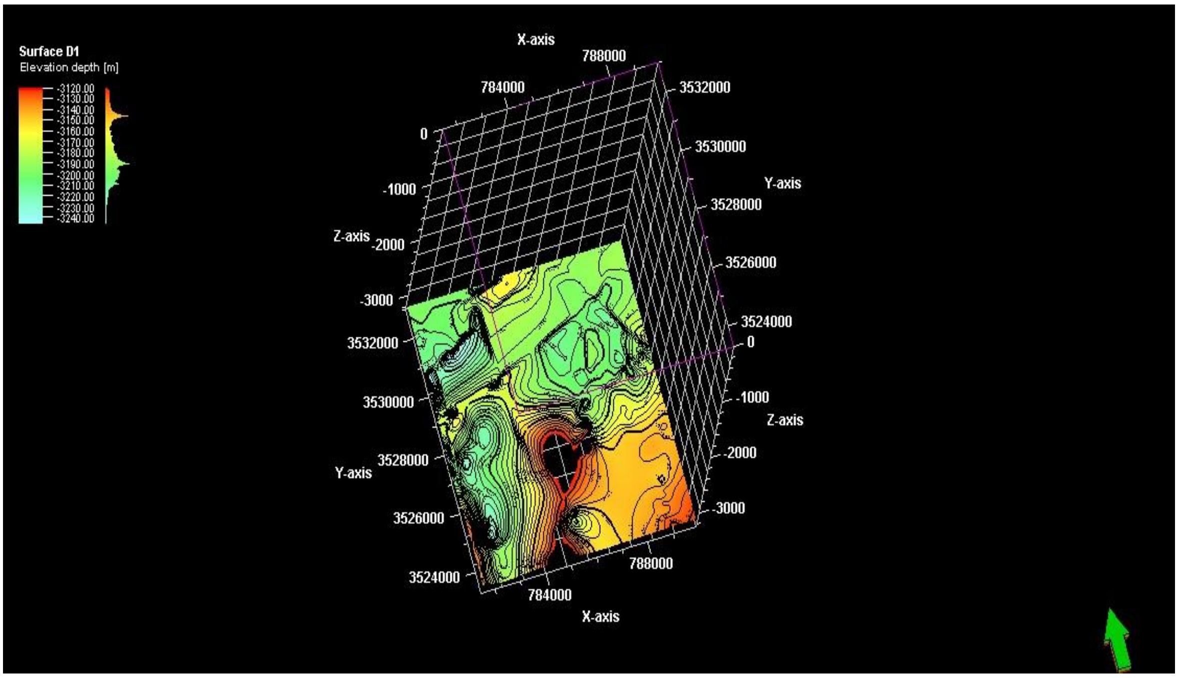

Figure 2.5: Isopach map of D1 reservoir, in north of field Hassi meassoud.(OMK)

4.Reservoir modelling

Geological models are fundamental tools for calculating precise volumes and understanding how diverse depositional environments affect our observed data. This process is a comprehensive integration of interpreted wireline logs, well tops, seismic data, and available core data. Within these 3D static reservoir models, we build in structural, stratigraphic, petrophysical, and sedimentological properties to accurately characterize the reservoir and calculate reserves. The ultimate goal is to develop a highly detailed model that faithfully represents vertical and lateral heterogeneity at the well level, serving as a critical resource for determining reservoir quality and enabling effective reservoir management.

The accuracy of any reservoir model hinges on the quantity and quality of the available data, the condition of the input data, and the caliber of the geological, geophysical, and petrophysical interpretations. Consequently, reservoir modeling has become a standard and essential practice for petroleum companies in their reservoir management efforts and economic decision-making.

Petrel, a Schlumberger software product, is a prominent tool in this field. It allows users to construct a reservoir model and export its properties to a simulator. Petrel is a Windows-based software offering 3D visualization, mapping, 3D reservoir modeling, and simulation capabilities. It was founded in 1996, commercially published in 1998, and became part of Schlumberger Solutions in January 2003.

In our specific approach, we've carried out three distinct types of modeling for the R1 reservoir, based on various study parameters discussed in earlier chapters:

- Structural modelling
- Facies modelling
- Petrophysical modelling

4.1 Structural Modeling

This text introduces structural modeling as a foundational and critical component within the geological modeling process. It highlights its position as the initial step in building 3D models.

4.1.1 Faults Model

Seismic data is incredibly important, but if it's unavailable—as in our situation—it becomes critical to either acquire fault data in 3D directly or transform 2D fault data into 3D. These faults must then be seamlessly integrated into the geological model, as they lay the groundwork for generating the essential 3D grid.

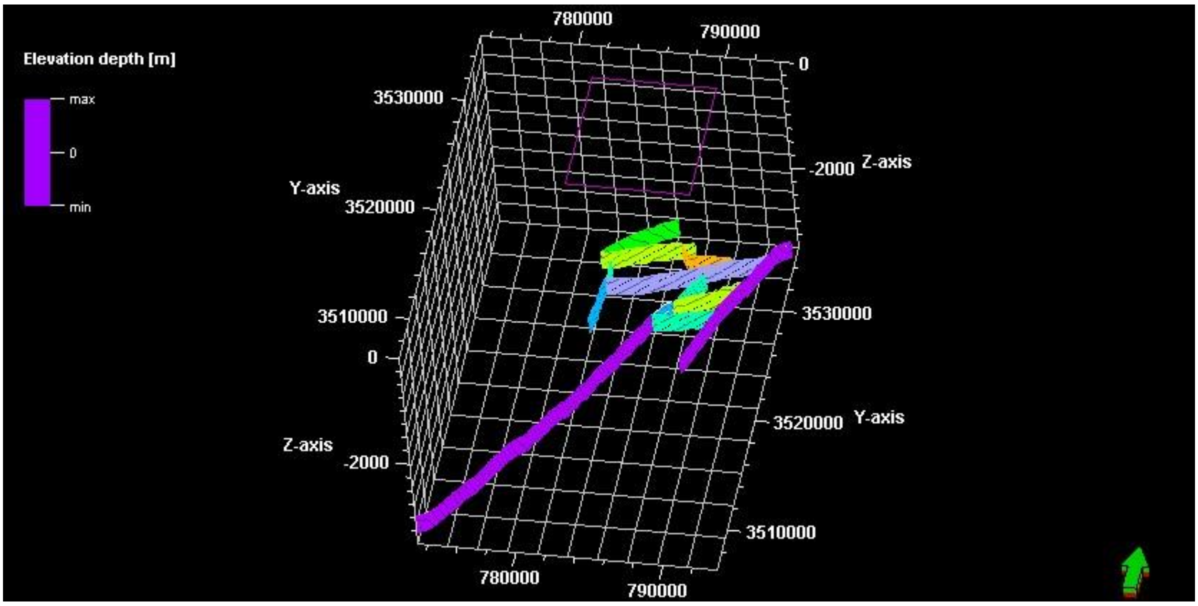

Figure 2.6 : Faults model in 3D in north of field Hassi meassoud (OMK)

4.1.2 Pillar gridding

He Pillar grid is a crucial step in building the 3D model. We use the fault planes from the fault model as the foundation for generating this 3D grid. This grid is structured with three layers—a Top, Mid, and Bottom—forming the model's essential skeleton. For the Hassi Messaoud R1 reservoir study, we adopted a grid scale of 50m x 50m. This specific scale was chosen because of the significant heterogeneity observed within the Hassi Messaoud reservoir.

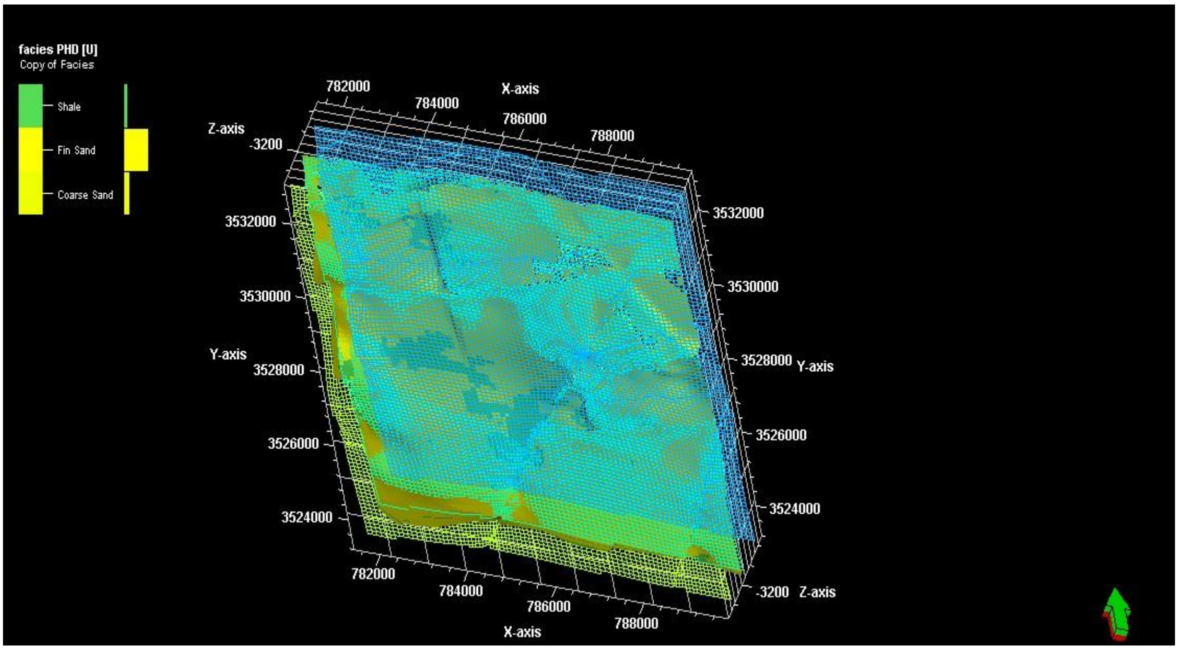

Figure 2.7: Pillar gridding (X Y) in 3D in north of field Hassi meassoud (OMK)

4.1.3 Make horizons

his phase involves inserting horizons into the 3D grid. We included four main horizons—DH,D2,ID,D1,—which define the reservoir's boundaries within the model. After this, we created the layers within these zones, with each layer representing 5m in our study.

As constraints for the model, we used the well tops (the depths where specific geological formations are encountered in wells) corresponding to each drainage point, along with their associated faults. It's important to note that, due to the absence of seismic data, these faults are assumed to be vertical.

The overall process of stratigraphic subdivision is broken down into three distinct steps:

4.1.3.1Horizon Creation Process

This step involves integrating the input surfaces directly into the 3D grid. These surfaces can come from various sources, such as seismic data, well tops, interpretations of seismic lines, or any other point or line data that defines a geological surface. In our specific study, given the data we had available, we primarily used surfaces derived from well tops.

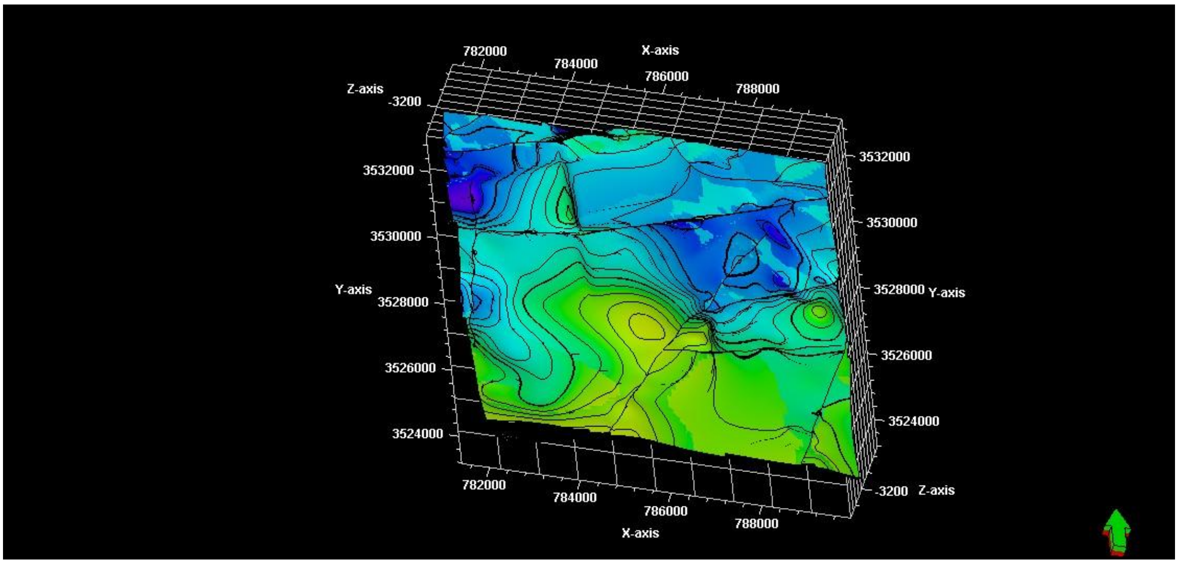

Figure 2.8: Horizon model in 3D in north of field Hassi meassoud (OMK)

4.1.3.2Zone Creation Process

We also insert additional horizons into the 3D grid. We do this by stacking isochores either above or below the horizons that were previously put into the model.

4.1.3.3Layering

The concluding step involves generating the fine-scale layering, which is crucial for subsequent property modeling (such as Facies and Petrophysical modeling). These layers precisely define the top and bottom boundaries of each cell within the 3D Grid. In our study, a 5m layer scale (also referred to as Z-gridding) was utilized.

The overarching structural model is a result of integrating three distinct operations: fault modeling, pillar gridding, and vertical layering. These are all combined into a single, cohesive three-dimensional grid data model. This integrated structural model serves as the fundamental framework for the entire study area, providing the basis from which all other geological models will be developed.

By generating structural cross-sections from this 3D model in various directions across the study sector, we can clearly visualize the lateral extent and thickness variations of the reservoir zones (DH,D2,ID,D1,), along with the influence of faults. A significant observation is that in the northeastern part of the study area, these reservoir zones have been eroded by the Hercynian unconformity. Conversely, the reservoir zones in the western part remain relatively intact.

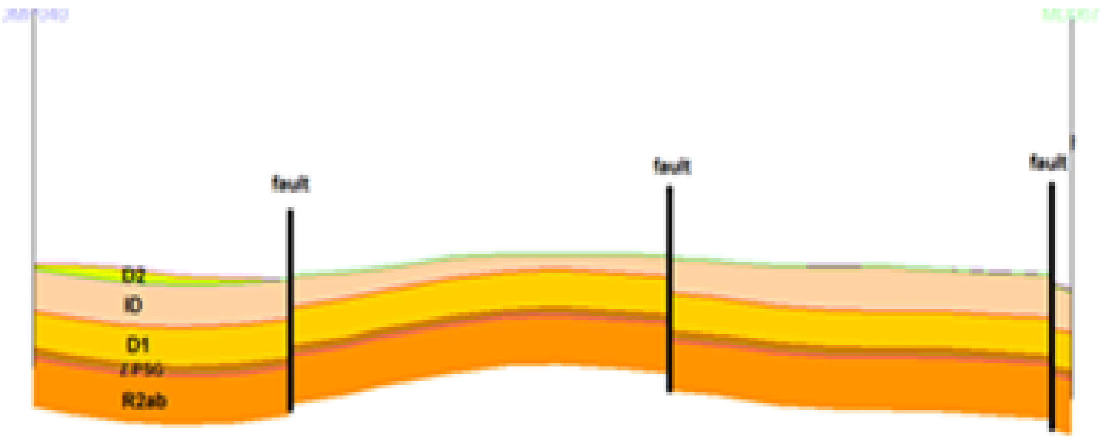

Figure2.9: Structural cross sample in the area of interest.

4.1.3.4 Horizon surface DH :

A) **Properties Facies PHD :**

The model shows a three-dimensional model of a subsurface "horizon", a characteristic stratified surface in rock formations. Color contrast (green and yellow) indicates differences in depth or rocky characteristics (facies - facies) of this horizon. The numbers on the axes determine the geographical coordinates of the studied area. In general, this model gives a visual visualization of subsurface geological structures and is an essential tool in the exploration of oil, gas and other underground resources.

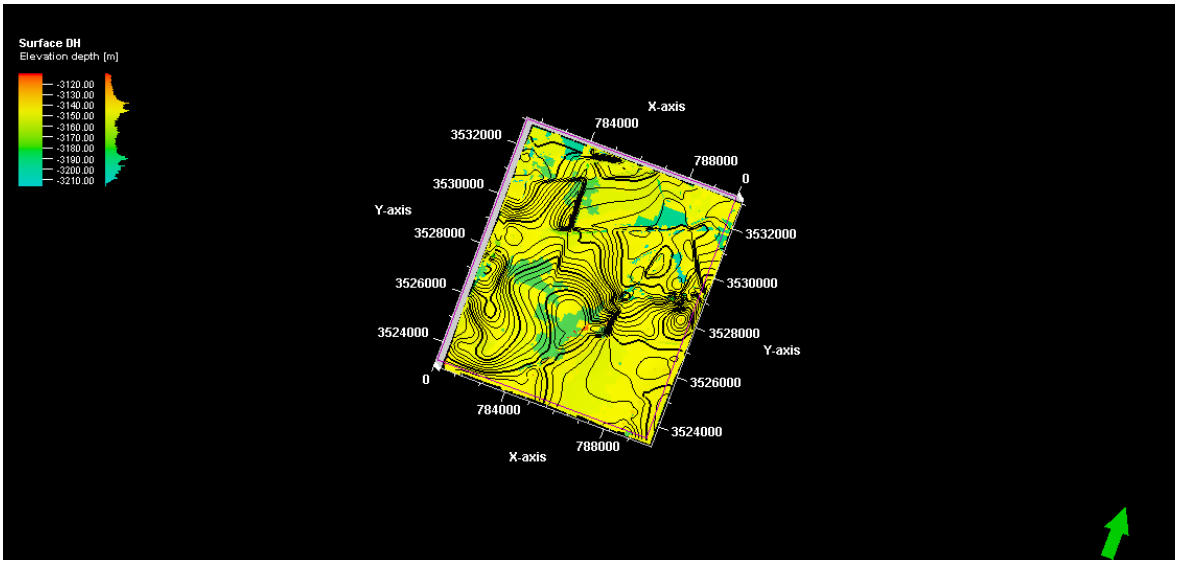

Figure3.1 : Horizon Model in 3D in surface DH of facies

b) Properties VCL :

The model shows a three-dimensional geological model of the distribution of the clay ratio (VCL) over the surface of a given underground layer.

* Warm colors (red/yellow): indicate a lower clay content, which means cleaner and better rock for reserve (e.g. hydrocarbon-bearing sand).

* Cold colors (blue/violet): Indicates a higher clay ratio, which means more clay rocks (such as insulating or non-quality clay rocks).

* The model illustrates how rock quality changes across the geological surface, and helps geologists identify potential reserve areas and understand subsurface geological structures (e.g., folds and faults).

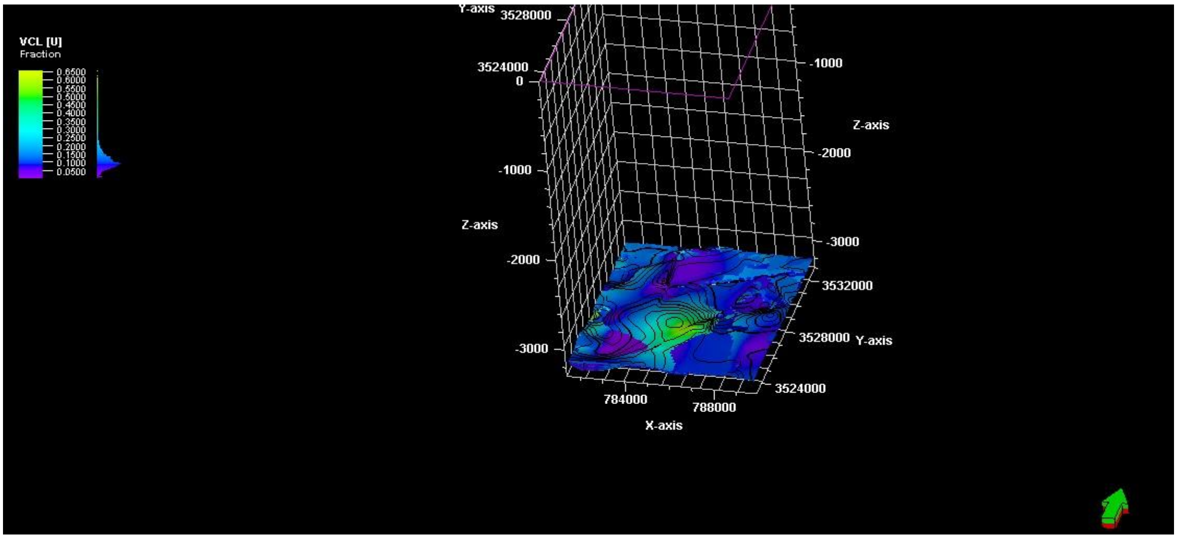

Figure3.2 : Horizon Model in 3D In surface DH of VCL

c) **Properties CPORH :**

The model represents a three-dimensional scientific analysis of a "horizon" beneath the surface, based on seismic data converted to depth. It shows structural structures such as folds (convexities and concaves) and is used to identify potential traps for resources (e.g. oil and gas). It is based on quantitative foundations (time-depth conversion, interpolation) and extracts structural properties (slope, curvature). This analysis is necessary for drilling planning and resource estimation, taking into account the challenges associated with data accuracy.

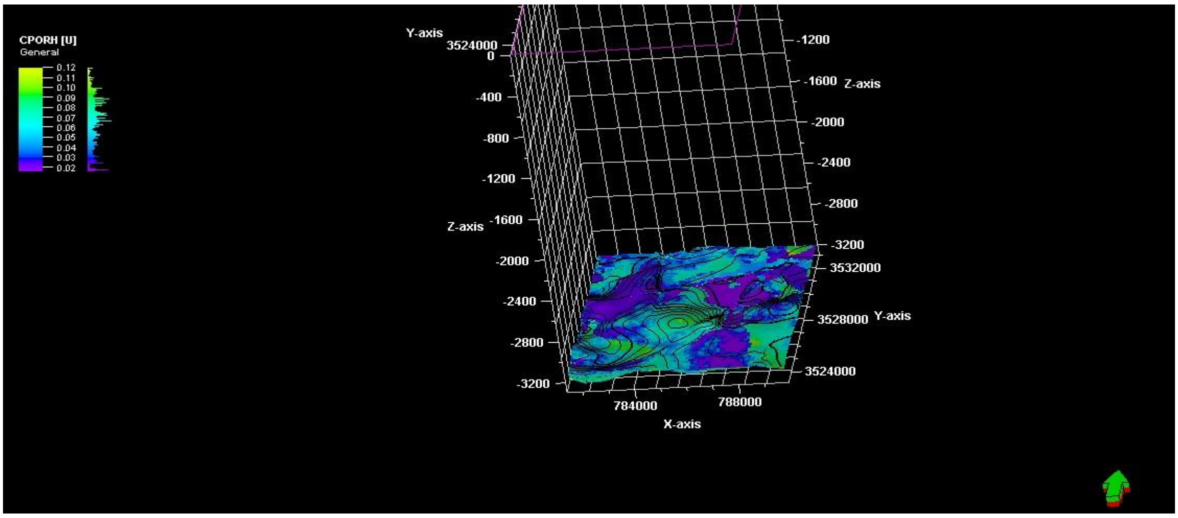

Figure3.3 : Horizon Model in 3D In surface DH of CPORH

d) **Properties Permeability CKH :**

Permeability is a measure of a rock's ability to allow liquids (such as oil, gas, water) to flow through its continuous pores and fractures. The higher the permeability, the easier and faster the fluid flows.

* Spatial distribution of permeability: The model shows a large variation in the trans-horizon distribution DH:

* High Permeability zones: appear in red, orange and yellow. These areas are most important from a production perspective, as hydrocarbons can be efficiently extracted. These areas may indicate well-sorted sand channels, fractured carbonates, or well-developed secondary porosity.

* Low Permeability Zones: Appear in purple and dark blue. These areas hinder fluid movement and may be unproductive or produced at very low rates. They may represent rocks with poor porosity (tight rocks), clay areas (shaly intervals), or rocks with porous and unconnected porous areas. It shows structural structures such

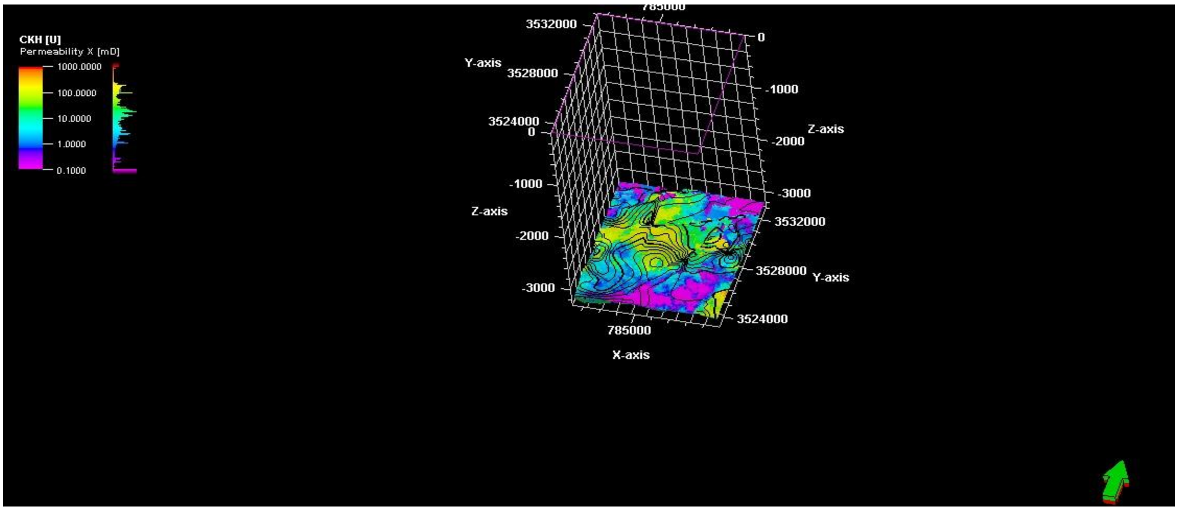

Figure3.4 : Horizon Model in 3D In surface DH of Permeabiliy

e) Properties porosity effective PHIE :

The model shows a three-dimensional model of an underground rock layer. The colors represent the "effective porosity" of the rock: red/yellow for high porosity (better for oil/gas storage), blue/violet for low porosity (less stored). This model helps in determining the best places to drill and explore for underground resources.

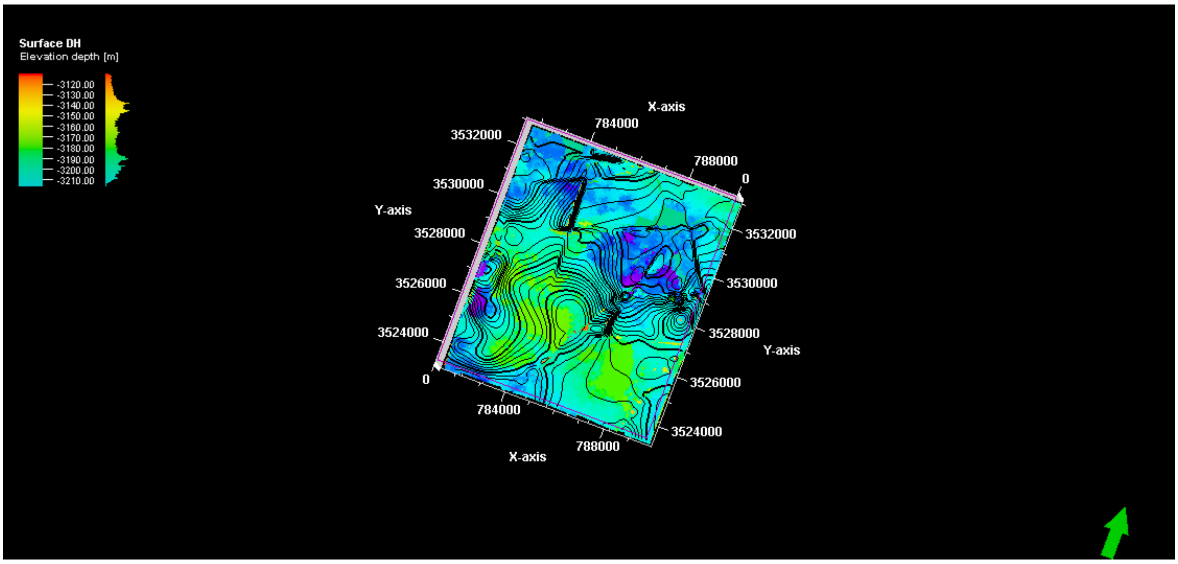

Figure3.5 : Horizon Model in 3D In surface DH of Porosity effective PHIE

f) Properties water saturation SW :

The three-dimensional horizon model and the water saturation (DH) surface of the R1 reservoir in Hassi Messaoud:

* Dark blue: indicates areas of very high water saturation (too much water). These areas are often below the oil-water contact (OWC) level.

* Yellow/Orange: Refers to areas of low water saturation (low water), often areas where oil or gas is above water.

* Helps determine the level of water-oil contact (OWC), which is crucial for estimating the size of hydrocarbon reserves. Areas with very low water saturation are the main targets of production.

* This combination helps determine the best well locations and avoid drilling wells in areas with high volumes of water.

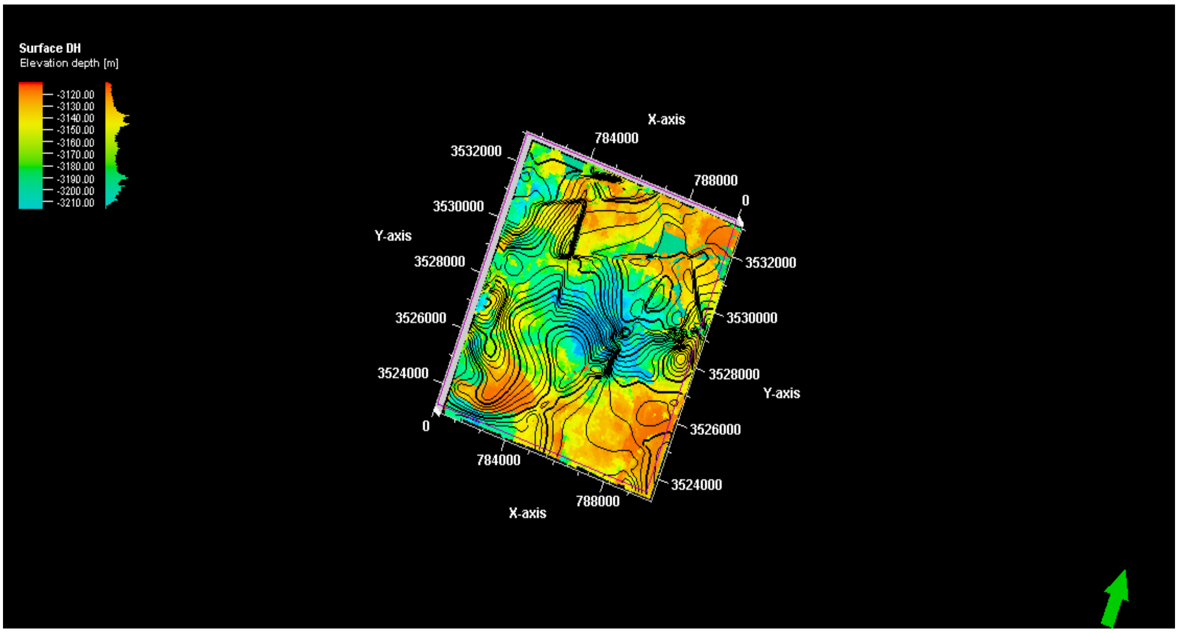

Figure3.6 : Horizon Model in 3D In surface DH of water saturation

4.1.3.5 Horizon surface D2 :

a) **Properties Facies PHD :**

The three-dimensional model of a single geological horizon (Surface D2). This horizon represents a boundary surface within the rock formation.

* Navy blue/violet: represents the deepest points on the horizon (more negative, around -3220 m and below).

* Light blue: slightly deeper areas.

* Green: medium-depth areas (about -3200 to -3195 m).

* Yellow/yellowish green: represents the elevated areas on the horizon (less negative, around -3190 m). In petroleum geology, these elevations are the preferred aggregation places for hydrocarbons (oil and gas) because of their lower density. They migrate upwards through porous rocks and gather at the highest structural point under impermeable rock cover.

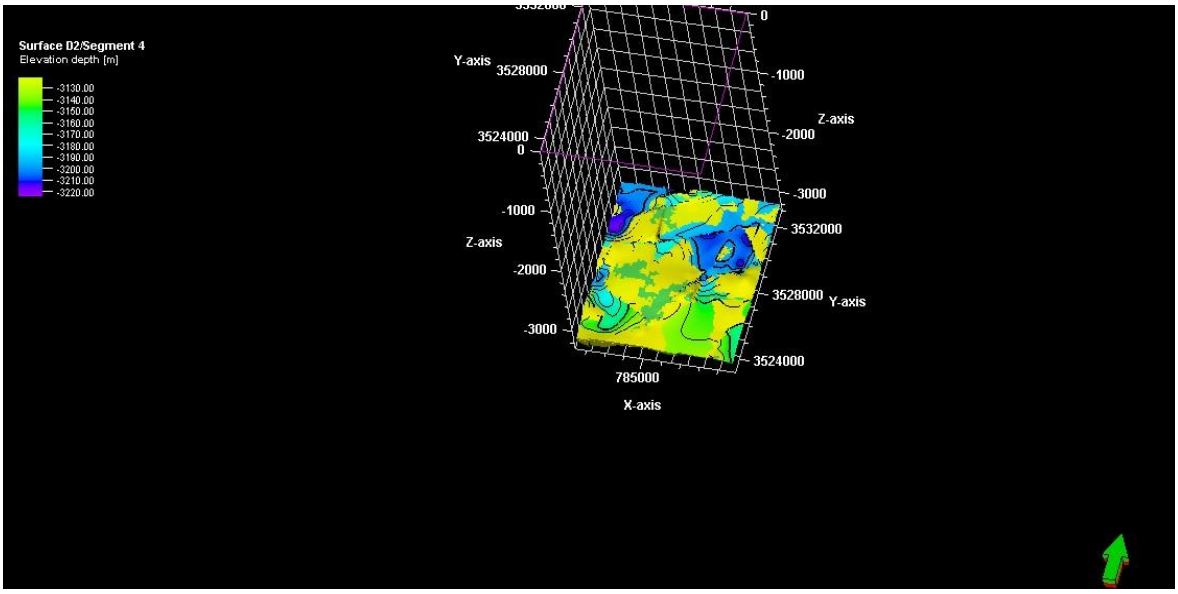

Figure 3.7 : Horizon Model in 3D In surface D2 of facies

b) Properties VCL :

The model shows advanced analysis of underground data, most likely in geology or petroleum exploration. The three-dimensional view illustrates a "horizon model" that represents the distribution of "clay volume" (VCL) within this horizon. This type of visualization is necessary to understand the characteristics of subsurface rock formations, which have important applications in resource exploration (oil and gas).

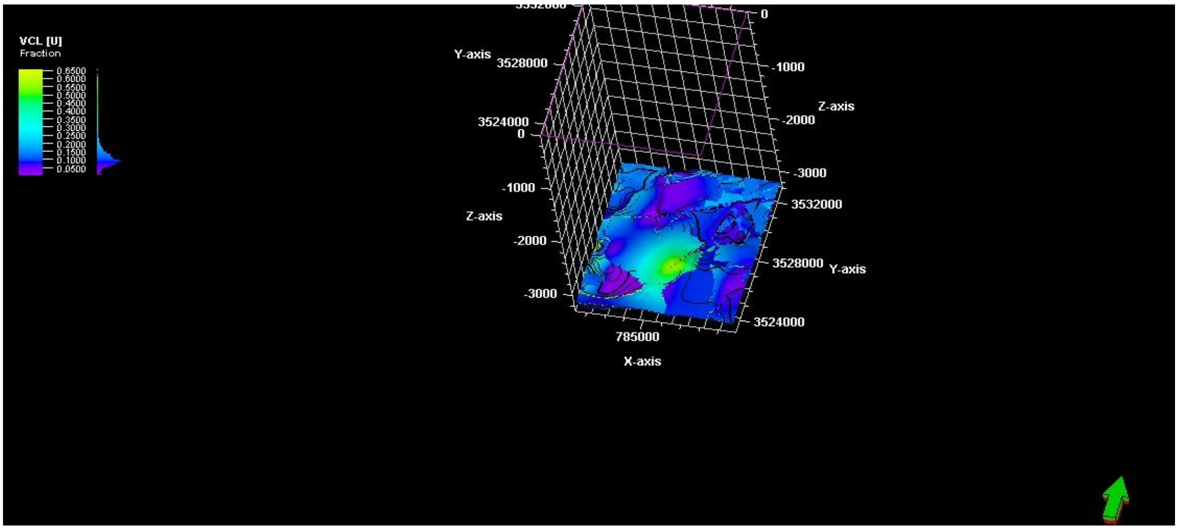

Figure3.8 : Horizon Model in 3D In surface D2 of VCL

c) Properties CPORH :

The image shows a visualization of a subsurface geological horizon (D2) and the distribution of a property called CPORH within it. Changing colors indicate heterogeneity in this property across the horizon. Due to the common use of these models in the oil and gas industry, CPORH is likely to refer to porosity or a related petrophysical property critical to understanding fluid flow and resource potential in a reservoir. The three-dimensional representation allows a thorough understanding of how this property changes spatially within the Earth's interior.

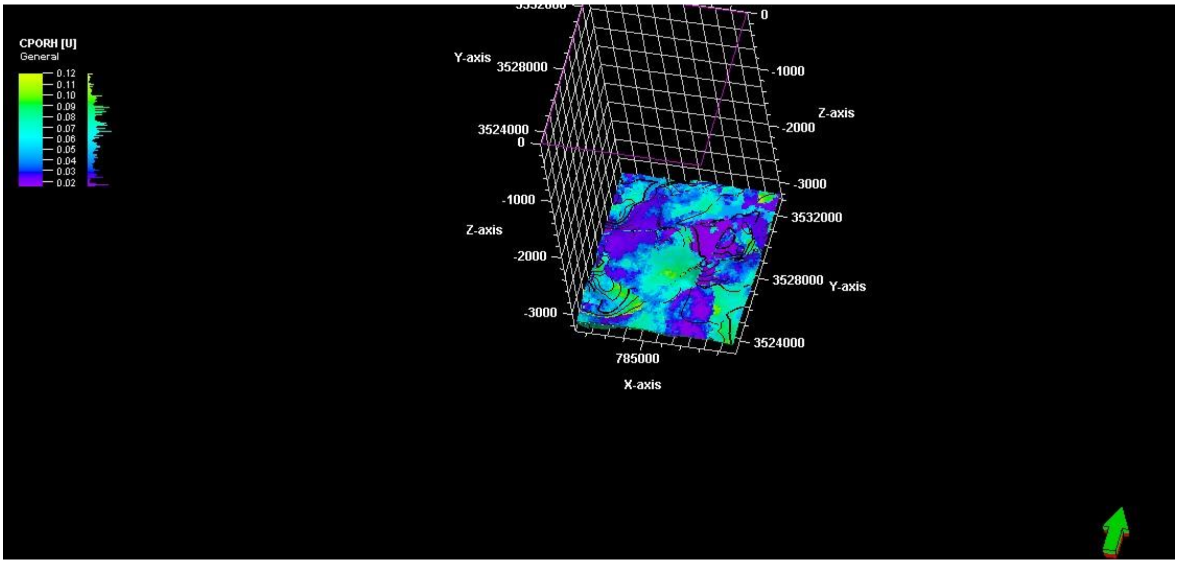

Figure 3.9 : Horizon Model in 3D In surface D2 of CPORH

d) Properties Permeability CKH:

The model shows a large variation in permeability values within layer D2. This variation is very normal in geological formations and is due to several factors:

* Change in rock type (Lithology): There may be areas with sandy rocks (or other porous rocks) with high permeability, and other areas with clay or shales or fine-grained rocks with low permeability.

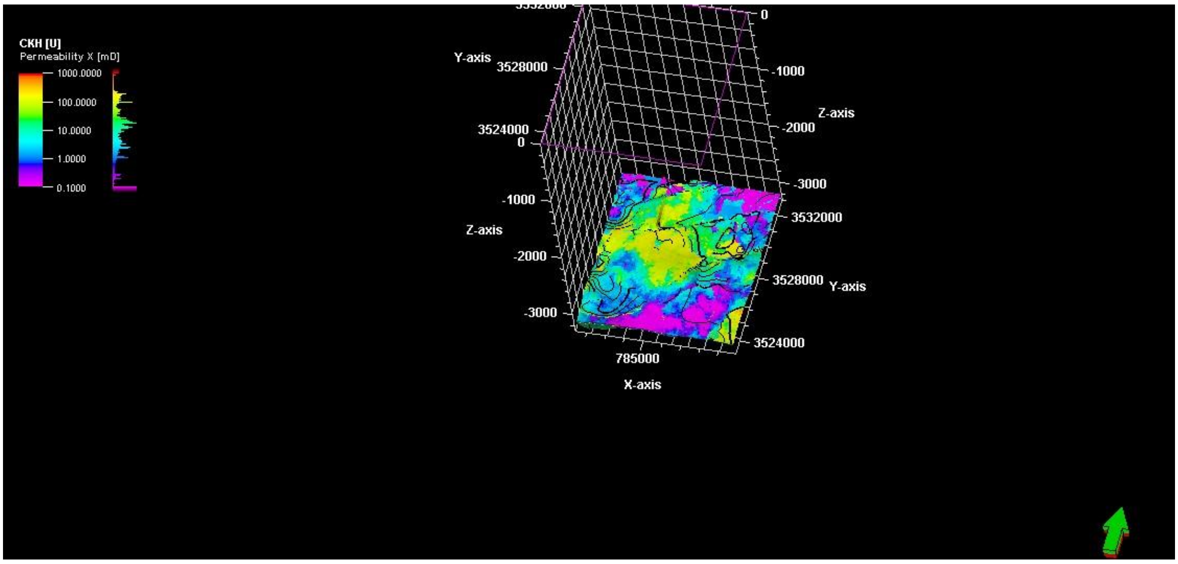

Figure 4.1 : Horizon Model in 3D In surface D2 of Permeability CKH

e) Properties Porosity effective PHIE :

Spatial distribution of porosity: The most prominent feature is the contrast of colors on the "surface D2" within the 3D grid. This color contrast refers to the spatial contrast of effective porosity across this specific geological horizon.

* High porosity vs. low porosity areas:

* Areas depicted in light blue/turquoise (depending on the color strip, likely correspond to higher values on the scale) indicate areas with higher effective porosity. These areas will be more permeable and therefore more suitable for fluid collection and flow.

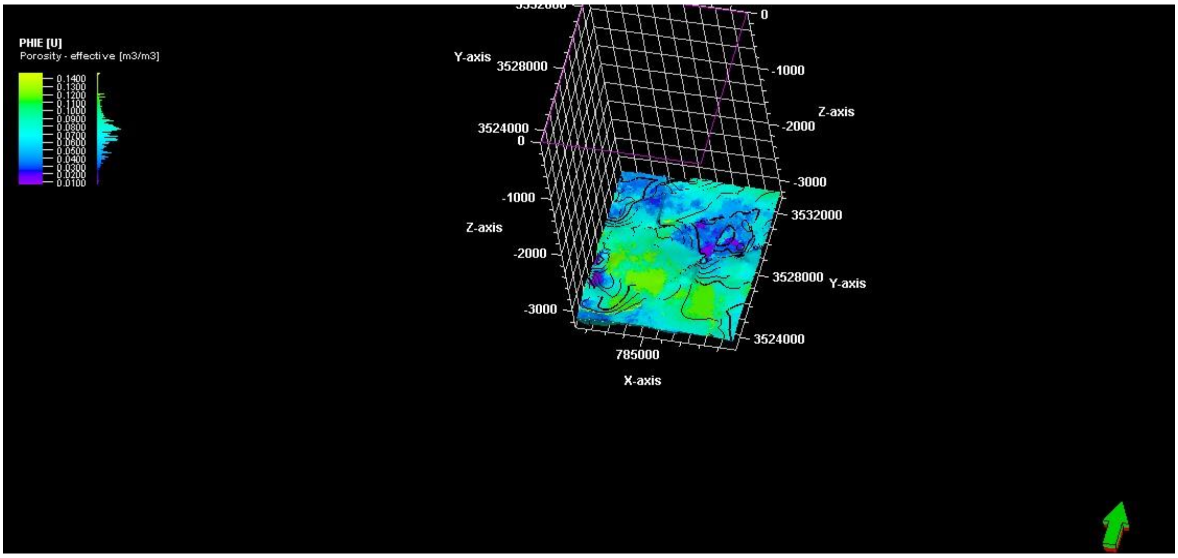

Figure 4.2 : Horizon Model in 3D In surface D2 of Porosity effective PHIE

f) Properties water saturation SW:

Based on the color distribution of water saturation on the surface of D2, the following can be concluded:

* Potential hydrocarbon zones: Areas that appear red, brown, or light yellow (where SW values are low) are the areas most likely to contain hydrocarbons (oil or gas). These areas seem to be concentrated at the top of the model (at relatively lower depths).

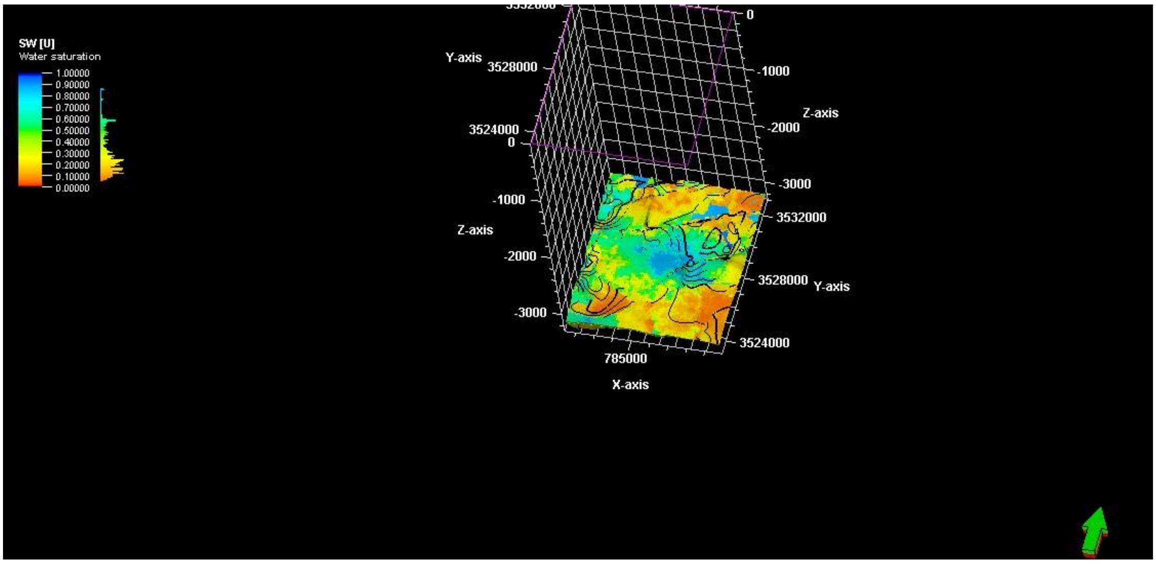

Figure 4.3 : Horizon Model in 3D In surface D2 of water saturation SW

4.1.3.6 Horizon surface ID:

a) Properties facies:

The image shows a three-dimensional geological model that shows:

* Types of rocks (factions): such as clay and sand of both types (fine and coarse), which indicate different underground sedimentation environments. These types are important for identifying oil/gas aquifers or groundwater.

* One of the stratigraphic surfaces (horizon): It is the wavy yellow surface that shows the depth and extension of a certain layer underground.

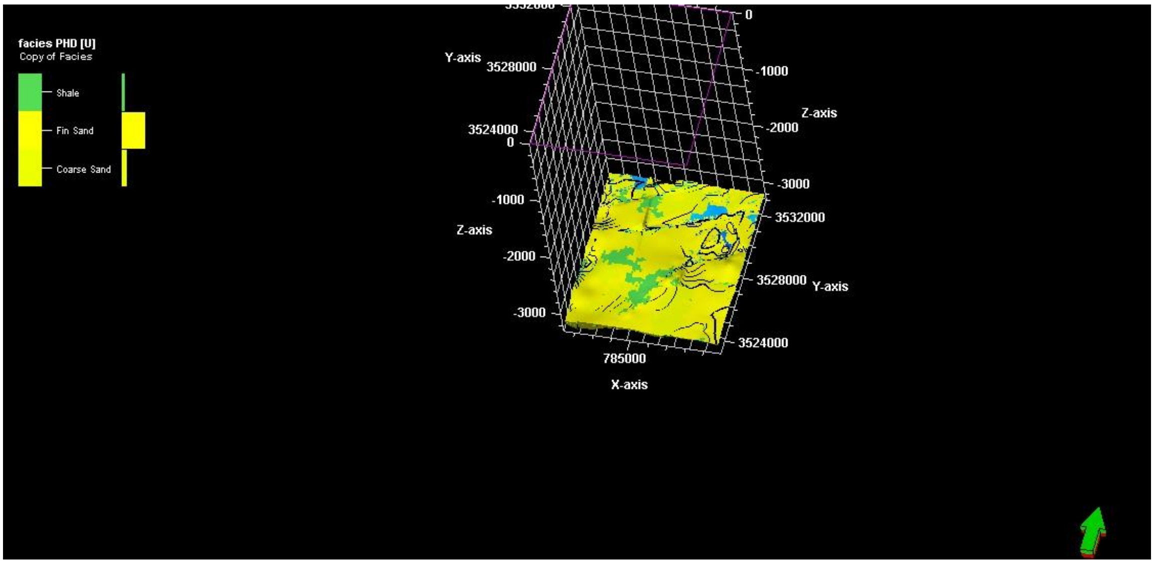

Figure 4.4 : Horizon Model in 3D In surface ID of Facies PHD

b) Properties VCL :

Surface map of VCL: The represented three-dimensional horizon is colored according to the values of VCL. We see that there is a large variation in VCL values across the surface, showing areas with low VCL values (blue/purple), areas with medium VCL values (green), and areas with high VCL values (pink/magenta).

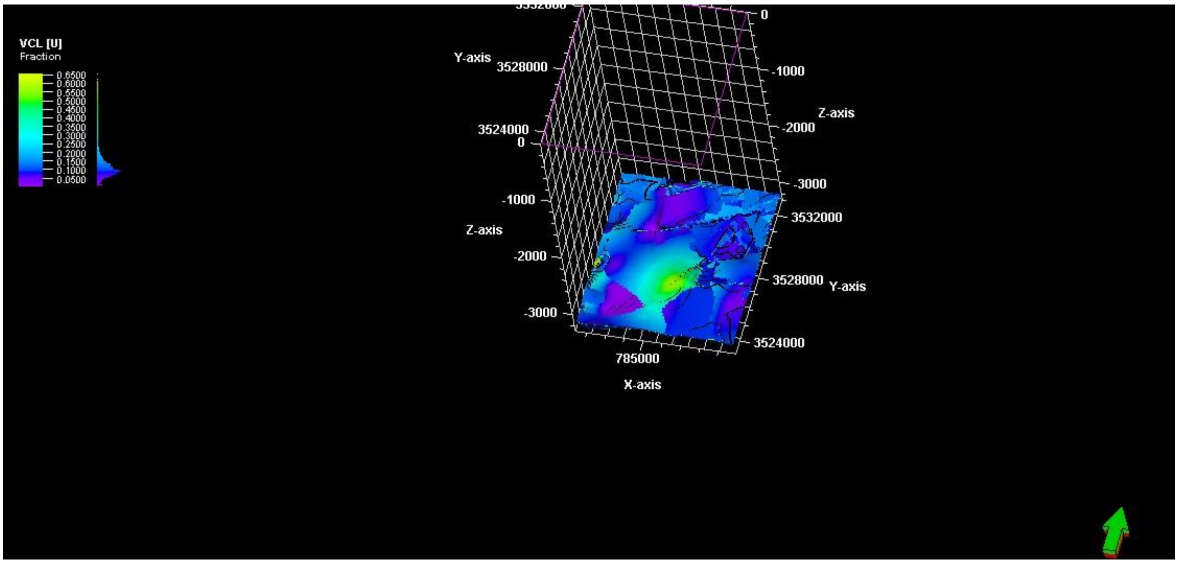

Figure 4.5 : Horizon Model in 3D In surface ID of VCL

c) Properties CPORH :

The model in 3D in surface ID of CPORH, Changing colors on the surface of the horizon indicate a heterogeneous distribution of the CPORH attribute. This means that porosity (if it is indeed porous) is not uniform across this geological layer.

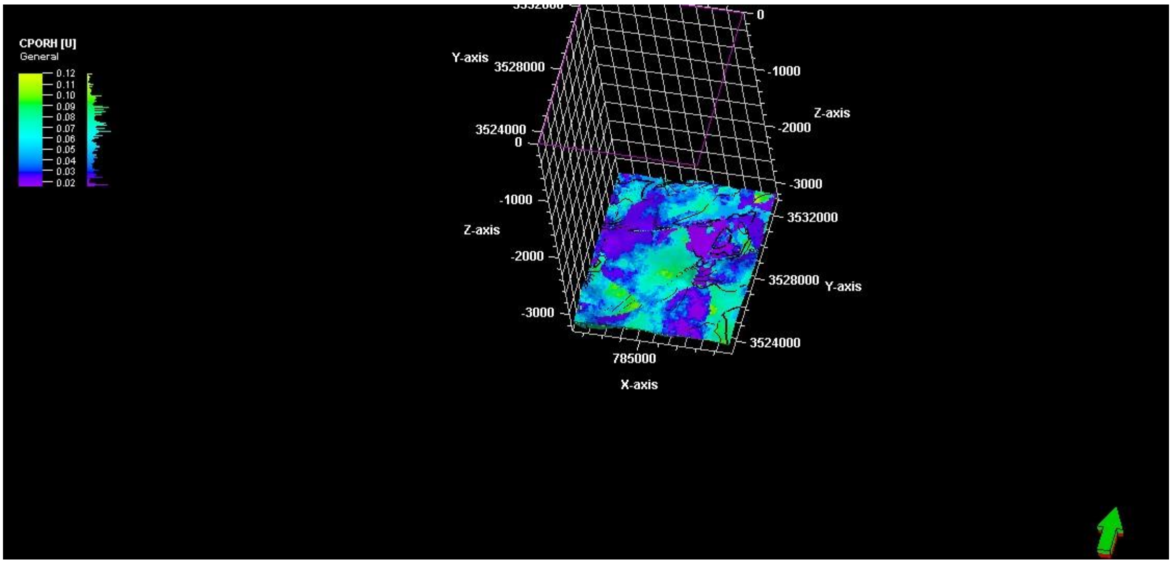

Figure 4.6 : Horizon Model in 3D In surface ID of CPORH

d) Properties Permeability CKH:

The image shows a 3D model of the surface of Geological ID :

* Different colors on the surface represent different permeability values. There is a color scale on the left side of the image that shows the extent of transmittance:

* Red/Light Yellow: Indicates very high permeability values (up to 1000,000 md). These areas with high permeability are preferred pathways for fluid flow (e.g. oil, gas, groundwater).

* Green/Light Blue: Indicates average permeability values.

* Purple/Navy Blue: Indicates very low permeability values (up to 0.1000 md). These areas are considered obstacles to fluid flow, indicating rocks with poor permeability.

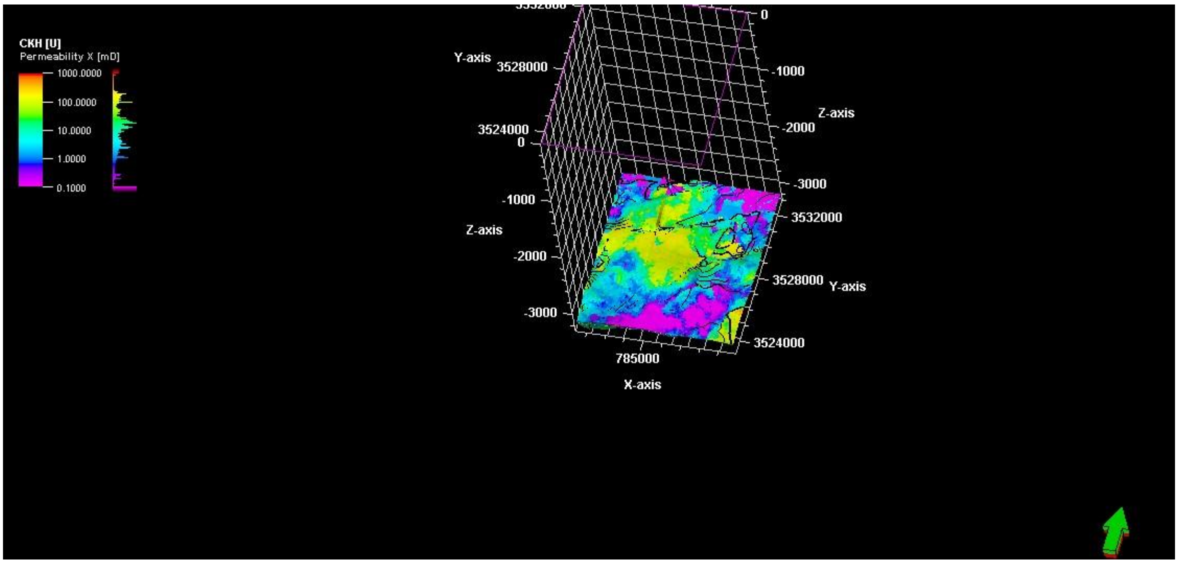

Figure 4.7 : Horizon Model in 3D In surface ID of Permeability CKH

e) Properties Porosity effective:

Effective porosity is a portion of the total volume of rock occupied by pores connected to each other, which allow liquids (such as oil, gas, water) to pass through. It differs from "total porosity" which encompasses all pores, including non-contact or isolated pores (such as very fine pores in clay that retain associated water).

We note that the effective porosity is greater in the southern section of the OMK up to 0,1400 m3.

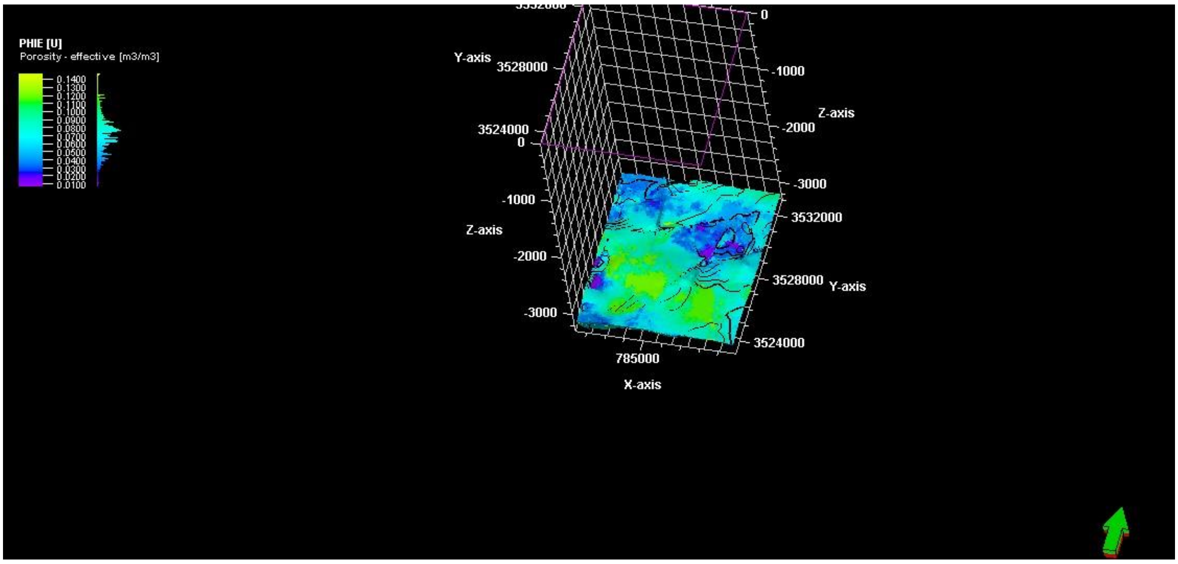

Figure 4.8 : Horizon Model in 3D In surface ID of Porosity effective PHIE

f) Properties water saturation SW:

Structure-related fluid distribution: The model clearly shows that the distribution of water saturation is not random but is related to the geological structure (or topography) of this horizon. The deeper regions (which lean towards the lower right part of the pattern) have higher water saturation, while the higher regions (which lean towards the upper left) have lower water saturation, which corresponds to the principle of fluid differentiation in the tank (water at the bottom, oil/gas at the top).

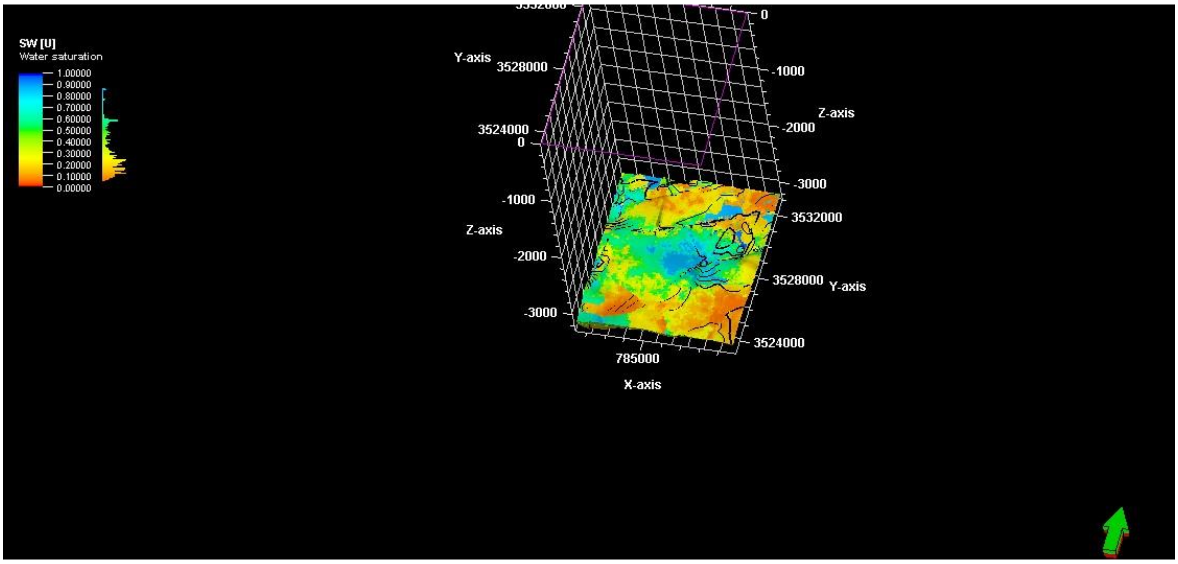

Figure 4.9 : Horizon Model in 3D In surface ID of water saturation SW

4.1.3.7 Horizon surface D1:

a) Properties Facies PHD :

3D Model: This model represents the distribution of rock species (facies) under the surface in a given area. The X and Y axes determine the horizontal position, while the Z axis represents the depth (where negative numbers indicate greater depths below the surface).

* Facies Types: On the left of the screen, the green and yellow columns show the existing facings:

* Shale (laminar clay): Usually fine-grained rock, refers to a low-energy deposition environment (such as a deep seabed or lake).

* Fin Sand (fine sand): refers to an environment with slightly higher energy than clay, and may be associated with shores or delta systems.

* Coarse Sand (coarse sand): Denotes a high-energy deposition environment.

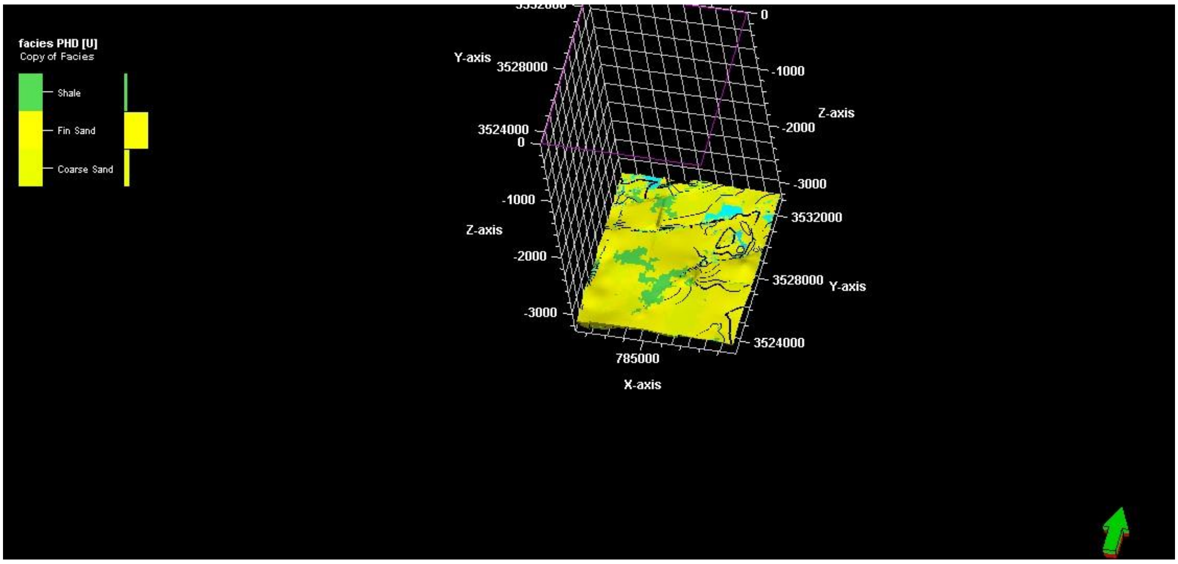

Figure 5.1 : Horizon Model in 3D In surface D1 of Facies PHD

b) Properties VCL :

Geological feature "VCL [U]" and Color Scale: On the left side, there is a color scale showing "VCL [U]" values ranging from 0.0500 (dark purple) to 0.6500 (red). The light blue and violet area on the surface within the grid shows the spatial distribution of this value.

* Low VCL values (violet/dark blue): Indicates low clay content. This is usually preferred in reservoir rocks (such as sandstone) because lower clay content means higher porosity and permeability, facilitating the flow of liquids (oil, gas, water).

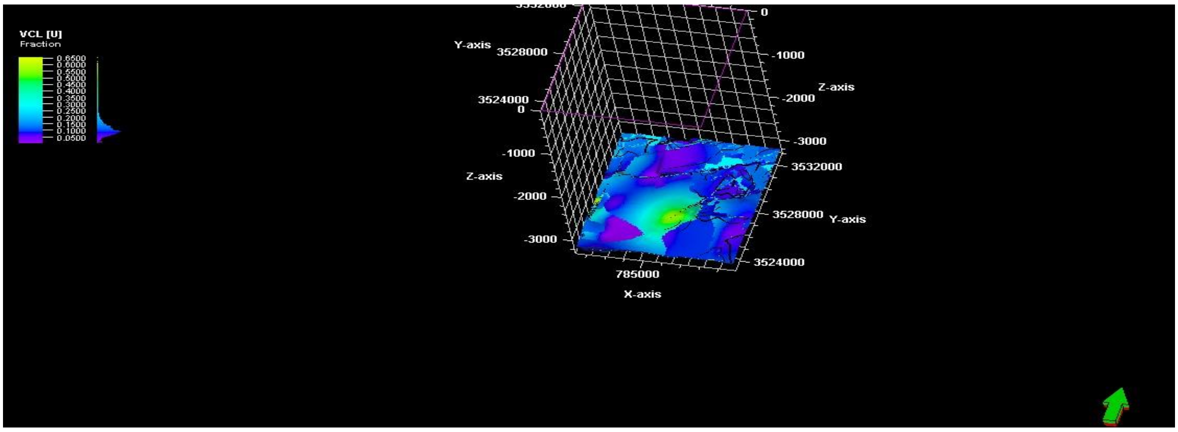

Figure 5.2 : Horizon Model in 3D In surface D1 of VCL

c) Properties CPORH :

The picture can be interpreted geologically as follows:

* Representation of a reservoir or fluid-carrying layer: This model represents part of an underground reservoir rock, whose properties are modeled by geologists and petrophysicists. The "CPORH" feature is a critical factor in understanding the ability of this reservoir to absorb and store hydrocarbons or groundwater.

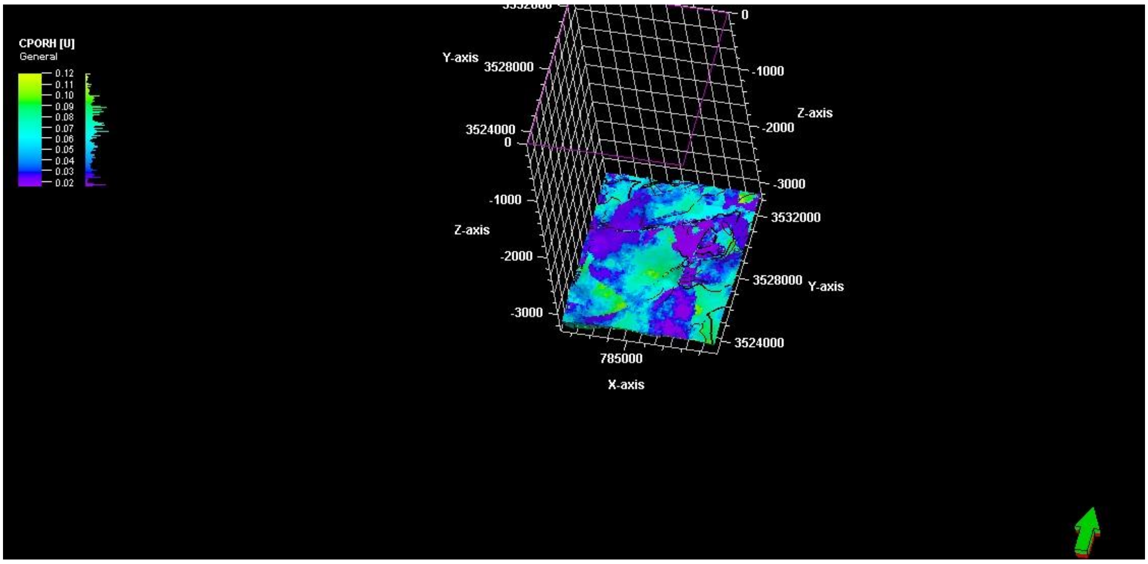

Figure 5.3 : Horizon Model in 3D In surface D1 of CPORH

d) Properties Permebility CKH :

The model shows that the permeability is not homogeneous across the surface D1. There is a great variation in their distribution.

* We observe the presence of "pockets" or areas with high permeability (red and yellow colors) surrounded by areas with lower permeability (green, blue, violet colors).

* This variation in permeability is normal and expected in geological formations, and is caused by factors such as:

* Sediment sedimentation: Different sediment types and grain size during sedimentation.

* Rock formation: the presence of different types of rocks (such as sandstone, shell, limestone) that differ in their porosity and permeability.

* Tectonic and post-deposition processes: Fractures can increase permeability, while compression or transformation processes may reduce it.

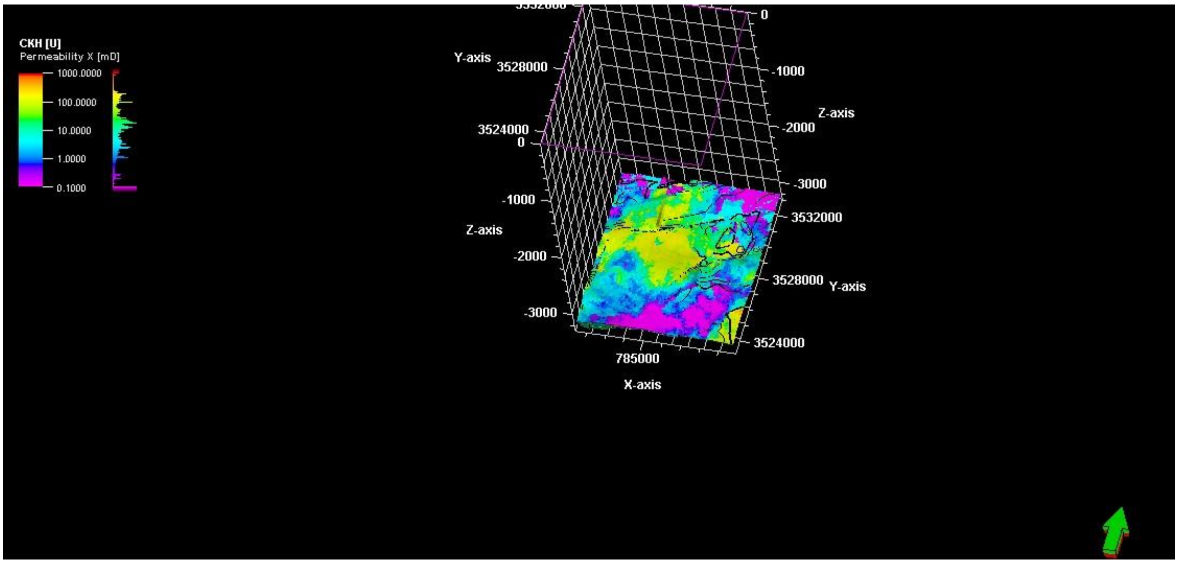

Figure 5.4 : Horizon Model in 3D In surface D1 of Permeability CKH

e) Proprties Porosity effective PHIE :

Effective Porosity: The part of the total porosity in which the pores are connected to each other, allowing fluids to flow through the rock. This is the most important type of reservoir assessment.

* The unit used in the image is [m3/m3] or simply a decimal value (no unit) representing the ratio of pores to total volume, where 0.100 means 10%.

* Red/yellow (0.1400 - 0.1300): represents the highest values of effective porosity, i.e. these areas contain the largest proportion of continuous spaces capable of storing liquids.

* Green (approx. 0.0800 - 0.0600): represents average porous values.

* Purple/dark blue (0.0100): Represents the lowest values of effective porosity, indicating that these areas have few spaces or that voids are not well connected.

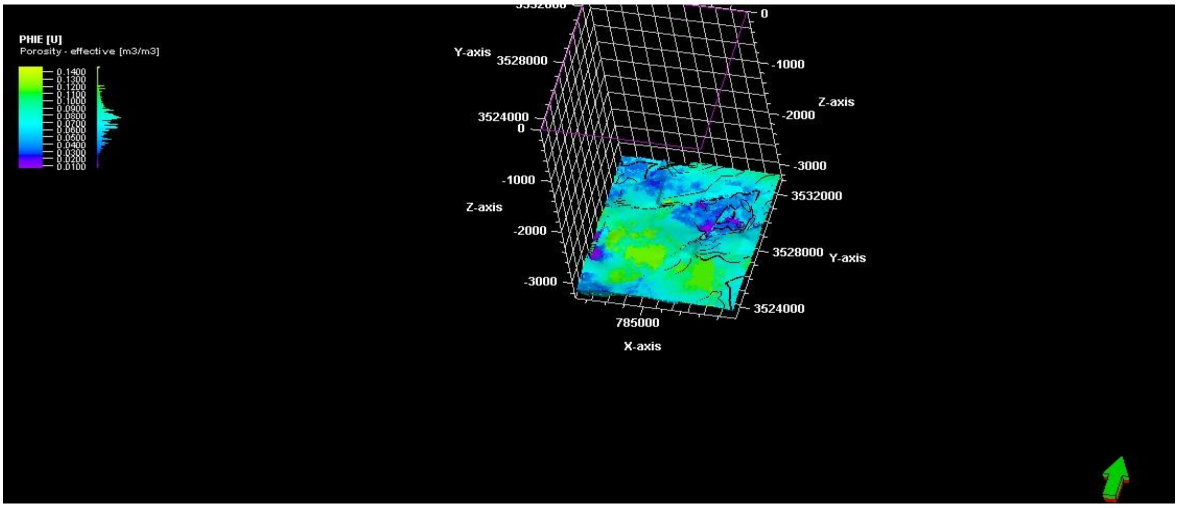

Figure 5.5 : Horizon Model in 3D In surface D1 of Porosity effective PHIE

f) Properties water saturation SW:

Distribution of water saturation in the model:

* Light and dark blue parts appear at the bottom and sides of the model, indicating an area with high water saturation in the deep and lower parts of the reservoir.

* Green, yellow and orange colors appear in the upper and middle parts of the model, indicating areas with low water saturation. These areas are most likely to contain oil or gas in a hydrocarbon reservoir.

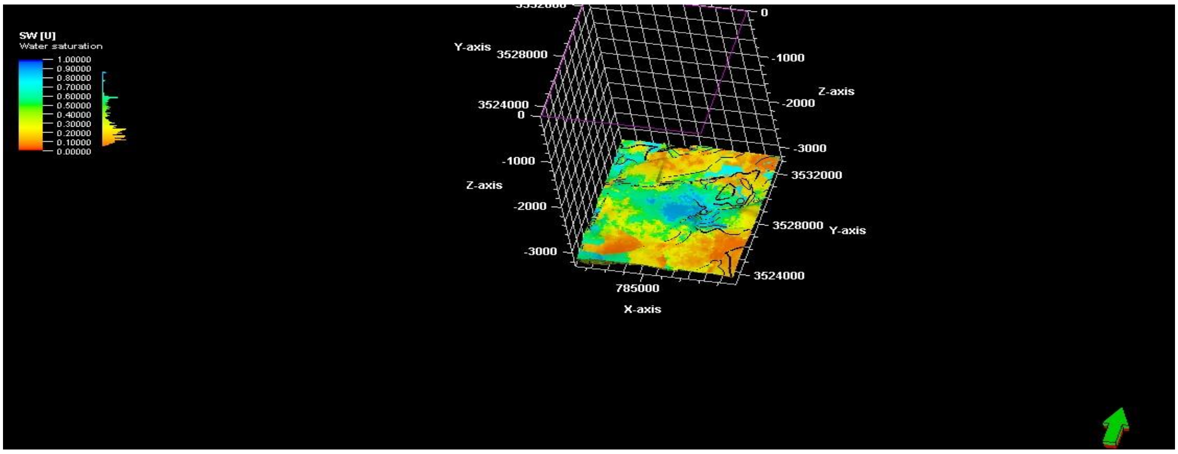

Figure 5.6 : Horizon Model in 3D In surface D1 of water saturation

4.2The modeling of facies

This section focuses on modeling facies, specifically how we build a basic facies model. This model is built using data from Seismic Inversion Section (SIS) observations and acoustic impedance (AI).

Key Facies Parameters For each facies, we provide the variogram type, its range, and azimuth. These parameters are carefully chosen to reflect extreme geological conditions, typically those observed in high-quality geological sections. This design minimizes the need for extensive trial and error to achieve the desired modeling effects.

Enhancing Models with Object Modeling Our Object Modeling feature empowers users to populate a discrete facies model with various simulated organisms. You can define their geometries (like width and thickness), assign a specific facies code, and set their fraction within the model. All geometric inputs that control the body shape are entirely user-defined, offering flexible customization.

4.2.1 Data analysis

Facies distribution maps are generated after performing a geostatistical analysis of the available data and choosing an appropriate estimation method. Over the last two decades, geostatistical simulations have been the most active area of research within geostatistics.

These simulations are vital for any problem involving non-linear transformations of measured variables. When dealing with discrete variables, such as facies, the estimation method used is sequential indicator simulation.

4.2.2 Creation of electrofacies

For lack of geological data, we used electrofacies calculated from the log and microfacies results, defined as follows:

4.2.2.1Electrofacies

This refers to the suite of well-log characteristics that uniquely define a specific geological layer, or "bench," distinguishing it from the surrounding formations.

These facies are then characterized using specialized equations that incorporate pre-existing data.

4.2.2.2 Scaling of facies (Up-scaling)

Once electrofacies log data is loaded into Petrel, it undergoes an "up-scaling" process. This means we convert the detailed log measurements into a geologically relevant scale, such as one-meter thick rock units.

This up-scaling is crucial for building the static model, as it involves creating defined geological bodies within the model, each assigned its specific facies.

In Petrel, the up-scaling of petrophysical properties works like this:

- Porosity is up-scaled by simply calculating a straight average of the porosity values for each layer.
- Permeability is up-scaled using a more nuanced approach, combining both arithmetic and harmonic averages to get an accurate representation.

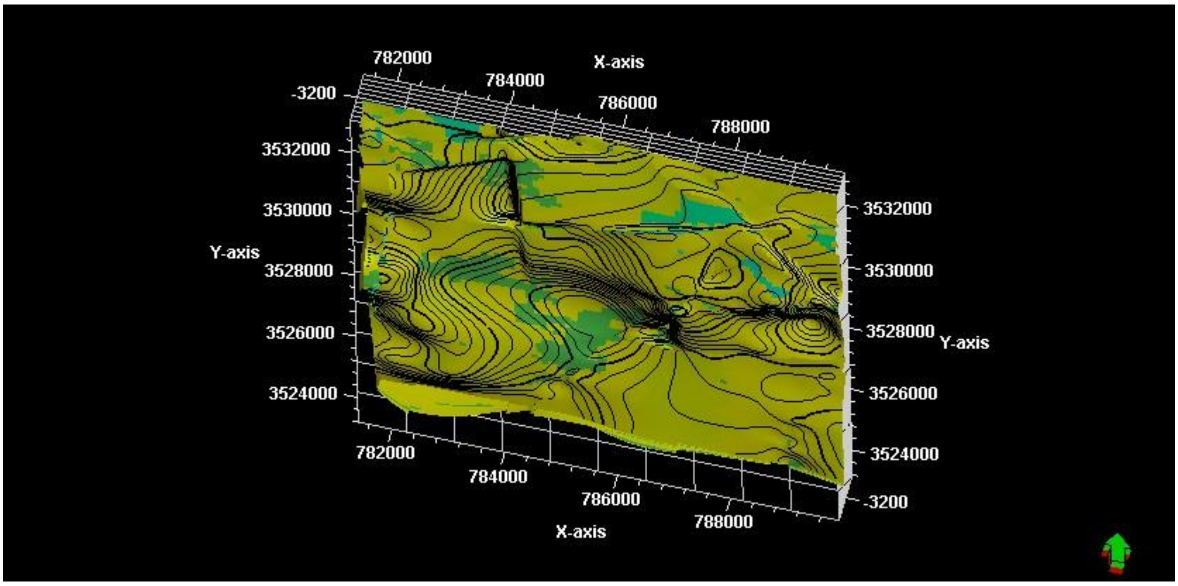

Figure 5.7 : Model in 3D in surface DH of facies (omk)

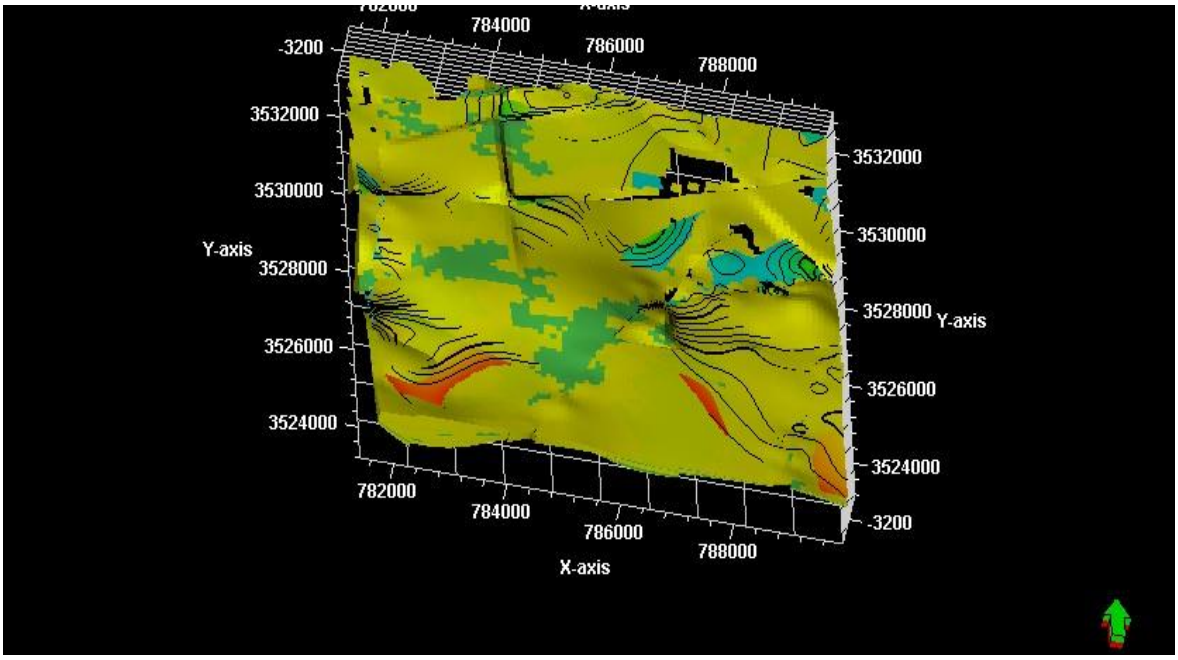

Figure 5.8 :Model in 3D in surface D2 of facies (omk)

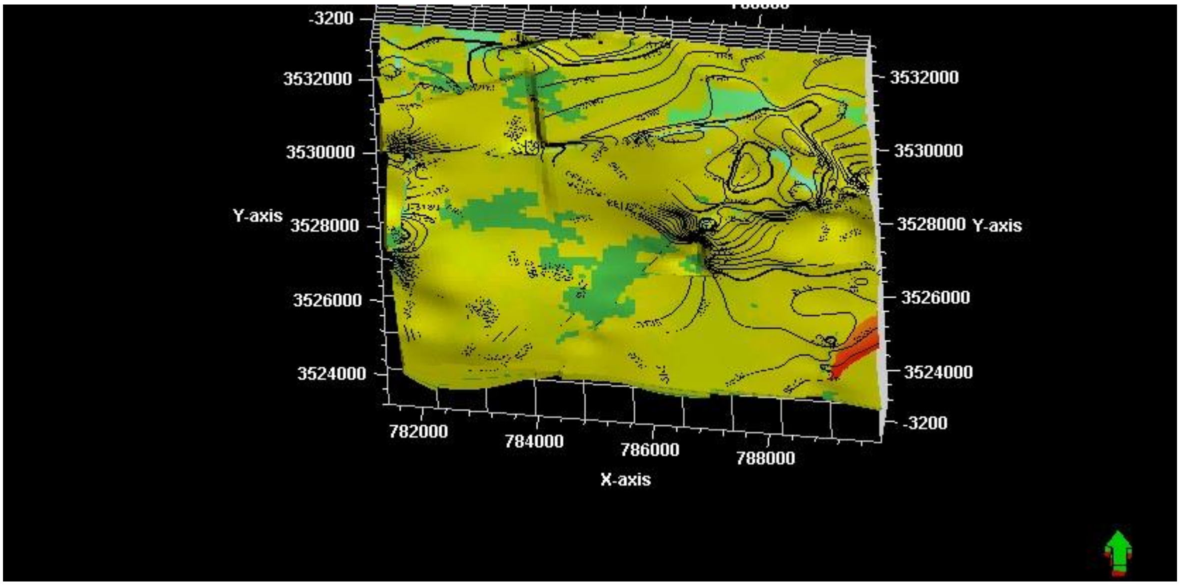

Figure 5.9 : Model in 3D in surface ID of facies (omk)

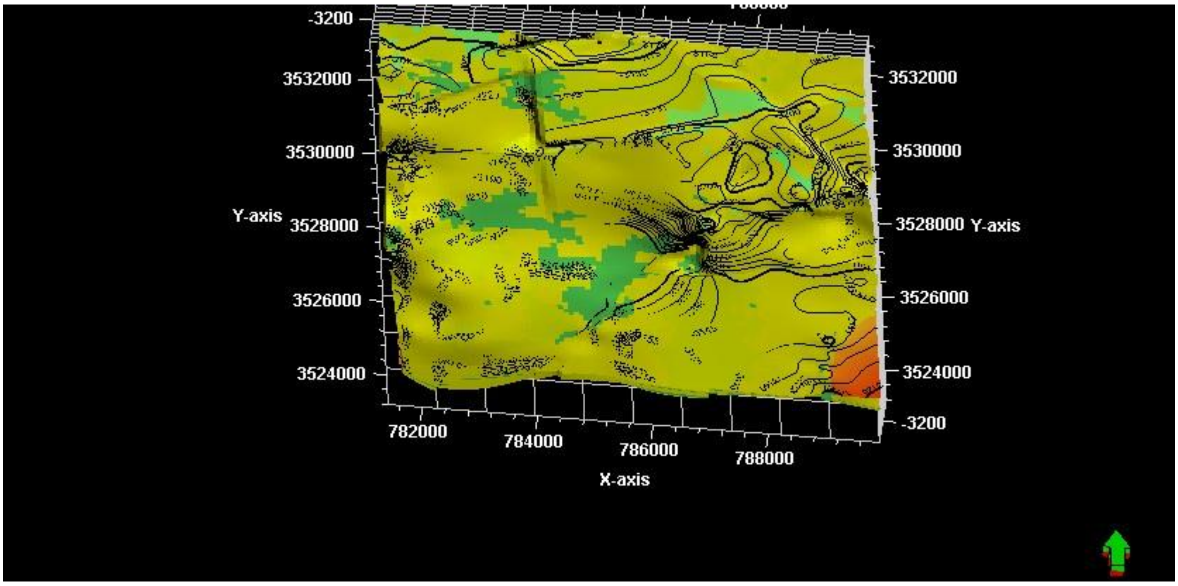

Figure 6.1: Model in 3D in surface D1 of facies (omk)

4.3Petrophysical modeling

When we talk about deterministic modeling, it involves scaling well log data to match the resolution of the 3D grid cells. This means that once the well log values are adjusted to this scale, the property values for each cell along the well path can be smoothly interpolated between the wells within the 3D grid. The end result is a complete grid, with every cell populated by its corresponding property value.

4.3.1 Scaling the property (Up-scaling)

We'll be populating the previously created structural model with various petrophysical data. First, this data needs to be "upscaled" (or re-scaled), and then we'll perform a geostatistical analysis on it.

4.3.2 Data analysis

Geostatistical analysis is crucial for determining the right extrapolation model for our reservoir modeling. The accuracy of the final petrophysical model hinges entirely on how well this geostatistical analysis is performed on the relevant data. Ultimately, this modeling process will yield a 3D simulation of the reservoir, providing insights into both porosity and saturation.

For continuous variables like Gamma Ray (GR), Neutron Porosity (NPHI), Core porosity (Q), and Core permeability (K), we'll use Sequential Gaussian simulation.

in our petrophysical modeling, permeability was the central focus. This is because, in the study area, porosity remains relatively constant, at around 14%. In stark contrast, permeability shows significant variation, ranging from 0.1 md to 1000 md.

5.Discussion

The integrated geological model and the Production Department's model reveal the following:

The productive reservoir, situated at a depth of 3240 meters, is primarily composed of Cambrian sandstone. This sandstone has an average thickness of 300 meters and consists of R1 production layers and R2 production layers, arranged from bottom to top. The primary mechanism driving HMD production is natural depletion.

While the D2 class exhibits unfavorable petrophysical properties, the critical classes—D2, ID, and D1—are remarkably heterogeneous. These classes are characterized by an average porosity of 14% and permeability ranging widely from 0.1 to 1000 mD.

The vast extent of the HMD field, combined with fault barriers and lateral facies variations, has led to erratic reservoir quality throughout the area. Consequently, the field has been divided into numerous distinct domains. The heterogeneity of the Hassi Messaoud (HMD) field is further complicated by two important factors: local complications arising from fracturing and erosion, and the deterioration of reservoir quality caused by diagenesis influenced by tectonic activity.

General Conclusions

General Conclusions

This study culminates the efforts made in modeling the R1 reservoir in the Hassi Messaoud OMK field, providing a detailed and reliable view of its geological and petrophysical properties. Modeling, based on the latest technology and the most accurate data available, has allowed us to construct a three-dimensional representation that accurately reflects the distribution of porosity and permeability, and describes the behavior of fluids within the reservoir.

The results obtained confirmed the pivotal role of geological and reservoir modeling in improving the overall understanding of hydrocarbon reservoirs. This in-depth understanding is the cornerstone of making informed strategic decisions about field development, improving the efficiency of drilling and production operations, and optimizing the location of future wells.

This memorandum forms a solid foundation for future research, as it can be built upon to incorporate more dynamic data (such as production data and well tests) into the model to increase its predictive accuracy.

It also opens up prospects for exploring advanced production scenarios, including enhanced oil recovery technologies, with the aim of maximizing the economic value of the reservoir and ensuring sustainable production.

We hope that this study will contribute to the enhancement of scientific and applied knowledge in the field of reservoir engineering, and will provide effective support to Algeria's efforts to exploit its natural resources efficiently and effectively.

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