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Faculty of Science

Department of Geology

The impact of dolomitization on reservoir performance in carbonate reservoirs of the Middle East. Lessons for better reservoir management practices

Bachelor thesis

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Petroleum Engineering (B0724A330002)
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The impact of dolomitization on reservoir performance in carbonate reservoirs of the Middle East. Lessons for better reservoir management practices

Anotace:

Tato studie byla získána analýzou dostupných dat ze tří vrtů v jednom z uhlovodíkových polí na jihu Spojených arabských emirátů. Tato studie byla zaměřena na vlastnosti rezervoáru souvrství Simsima. Pro tento účel byla použita různá data, jako je gama log, neutron log, logaritmus odporu atd., stejně jako data o tenkém řezu, pórovitosti a propustnosti vypočítaná z jader. Kromě toho byly nakreslením Lorenzova plánu identifikovány různé proudové jednotky, které mají zvláštní význam ve formaci Simsima. Získané výsledky ukazují, že dolomitizace jako komplexní proces diageneze má vliv na zvýšení pórovitosti a propustnosti ve souvrství Simsima a její nadměrné zvýšení způsobuje snížení pórovitosti a snižuje kvalitu nádrže. Zkoumáním zakresleného Lorenzova pozemku je zřejmé, že hranice různých jednotek toku se shoduje s hranicí různých litologií ve souvrství Simsima, což ukazuje na přímý vliv litologie na kvalitu nádrže v tomto souvrství.

Klíčová slova: Pórovitost, propustnost, dolomitizace, Lorenzův pozemek, formace Simsima, UAE

Number of pages: 38

Number of annexes: 0

Anotation:

The present study was obtained by analyzing the available data from three wells in one of the hydrocarbon fields in the south of the United Arab Emirates. The focus of this study was on the reservoir properties of the Simsima Formation. For this purpose, various data such as gamma log, neutron log, resistivity log, etc., as well as thin section, porosity, and permeability data calculated from the cores have been used. In addition, various flow units that are of special importance in the Simsima Formation have been identified by drawing the Lorenz plot.

The obtained results show that dolomitization, as a complex diagenesis process, has an effect on the increase of porosity and permeability in the Simsima Formation, and its excessive increase causes a decrease in porosity and reduces the quality of the reservoir. By examining the drawn Lorenz plot, it is clear that the border of different flow units coincides with the border of different lithologies in the Simsima Formation, which indicates the direct effect of lithology on the reservoir quality in this Formation.

Keywords: Porosity, Permeability, Dolomitization, Lorenz Plot, Simsima Formation, UAE

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I declare that I have prepared the bachelor's thesis myself and that I have stated all the used information resources in the thesis.

In Olomouc, July 27, 2023 ……………………………………………

Sarhang Ghazi Khaleel

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Before everything, I thank God for helping me at the end of this stage of my life.

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Lastly, I would like to express my deep appreciation to my family and friends for their unwavering support, patience, and understanding throughout this academic journey. Their encouragement, belief in my abilities, and sacrifices have been instrumental in my accomplishments.

Contents

List of graphics

List of tables

List of abbreviations

SMLP	Stratigraphic Modified Lorenz Plot
CFC	Cumulative Flow Capacity
CSC	Cumulative Storage Capacity

1 Introduction

Since the initial discovery of oil in Masjid Suleiman in 1907, the Zagros Basin in southern Iran has gained recognition as a promising region for oil production, capturing global attention. As exploration efforts intensified, a significant milestone was reached in 1930 when oil was first discovered in carbonate rocks in Kirkuk, South Kurdistan, highlighting the potential of carbonates as reservoir rocks (Sorkhabi, 2010). This breakthrough spurred further interest in the study of sedimentary rocks, particularly carbonates, within the Zagros Basin and the wider Middle East.

The identification of extensive carbonate hydrocarbon reservoirs in the Zagros Basin prompted geologists and sedimentologists to focus their investigations on these sedimentary formations. These studies led to the development of various classification systems for carbonate rocks, with particular emphasis on limestones and dolostones. Dolomites and the processes of dolomitization have emerged as intriguing subjects of research within this field. Despite significant efforts, researchers have faced challenges in obtaining comprehensive and precise results, and laboratory synthesis of dolomite remains limited to specific cases.

The study of dolomites and dolomitization is of paramount importance due to their implications for reservoir quality and hydrocarbon exploration. Dolomites, composed primarily of the mineral dolomite (calcium magnesium carbonate), exhibit different properties and reservoir behavior compared to limestones. Understanding the processes that lead to dolomitization and the factors influencing the distribution and quality of dolomitic reservoirs is crucial for successful oil and gas exploration and production.

Despite ongoing research efforts, the complete and accurate understanding of dolomites and dolomitization processes is still an ongoing endeavor. Laboratories have faced challenges in reproducing the complex conditions necessary for dolomite formation, leading to limited success in synthetic dolomite production. However, researchers continue to investigate natural dolomitization occurrences and employ advanced analytical techniques to unravel the intricacies of this phenomenon.

The quest to comprehend dolomites and dolomitization processes remains an active area of research within the field of carbonate sedimentology. Future advancements in experimental techniques, combined with detailed field observations and thorough analysis of natural dolomitic reservoirs, hold the potential to shed further light on this enigmatic process and contribute to the exploration and production of hydrocarbons in the Zagros Basin and beyond.

1.1 Dolomite and dolomitization processes

Dolomite is commonly found in sedimentary environments and can form through various processes (Figure 1). Dolomite can form through several processes; for instance, forms directly from the precipitation of dolomite minerals in marine or evaporitic settings (Machel, 2004). This primary dolomite is often found in ancient dolomite rock formations (Machel, 2004). Or forms through diagenesis, which involves the alteration of pre-existing limestone or lime mud to dolomite. Secondary dolomite is the most common type and occurs through a process called dolomitization (Machel, 2004).

Dolomitization is the process by which calcium carbonate minerals, such as limestone or lime mud, are transformed into dolomite. The exact mechanisms of dolomitization are still a topic of scientific research, but several theories exist. Magnesium-rich fluids infiltrate or flow through porous limestone or lime mud, replacing the original calcium carbonate minerals with dolomite and the replacement can be partial or complete (Adams and Rhodes, 1960; Purser et al., 1994; Machel, 2004; Mansurbeg et al., 2016).

Dolomitization can also occur through the direct precipitation of dolomite minerals from magnesium-rich fluids. This process can happen in marine environments, hydrothermal settings, or even in subsurface brines (Adams and Rhodes, 1960; Mansurbeg et al., 2016; 2022). The dolomitization process is influenced by various factors The presence of magnesium-rich fluids is crucial for dolomite formation. These fluids can be derived from seawater, hydrothermal sources, or brines (Mansurbeg et al., 2016; 2022; Morad et al., 2023). Dolomitization is favored under specific temperature and pressure conditions, which vary depending on the environment and the specific dolomitization mechanism (Machel, 2004).

Dolomitization often occurs during or after the burial and diagenetic history of the rock. The availability of fluids and the duration of dolomitization can impact the extent and distribution of dolomite in the rock (Mansurbeg et al., 2016; 2022).

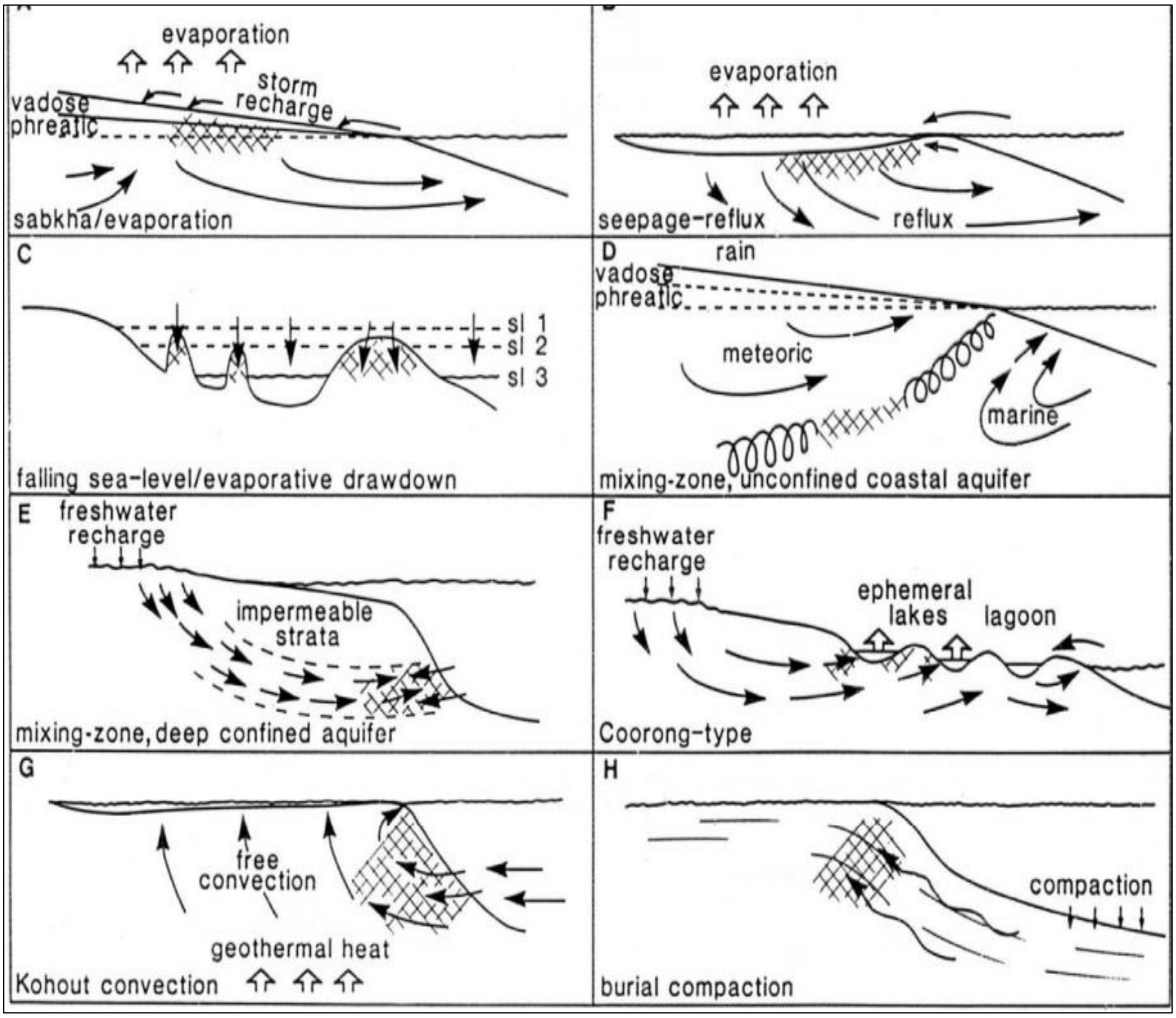

Figure 1 Different types of dolomitization model (Land, 1985).

The role of dolomites and dolomitization processes on carbonate reservoirs has always been an interesting and interesting topic among researchers in this field. Identifying the positive or negative role of dolomitization can greatly help reservoir engineers in predicting porosity and permeability and reservoir modeling (Omidpour et al., 2022).

1.2 Geological Setting and Study Area

The Simsima Formation (Late Jurassic to Early Cretaceous) is found in the Arabian Peninsula, particularly in Qatar and the United Arab Emirates, that is known for its significance in hydrocarbon exploration and production in the region (Alsharhan, 1989; Morad et al., 2023; Figure 2). The Simsima Formation is part of the larger geological framework known as the Dammam Formation. The main lithology in this formation consists of alternating layers of limestone, dolomite, and shale.

This formation is characterized by thick, carbonate-rich layers that are commonly fossiliferous, containing various marine organisms such as bivalves, gastropods, and corals (Alsharhan, 1989; Morad et al., 2023; Figure 3). The Simsima Formation is an important hydrocarbon reservoir in the Persian Gulf region. It contains significant oil and gas reserves, particularly in Qatar and the United Arab Emirates (Alsharhan, 1989). The carbonate rocks of the Simsima Formation provide excellent reservoir properties, such as high porosity and permeability, which are conducive to the accumulation and flow of hydrocarbons (Alsharhan, 1989).

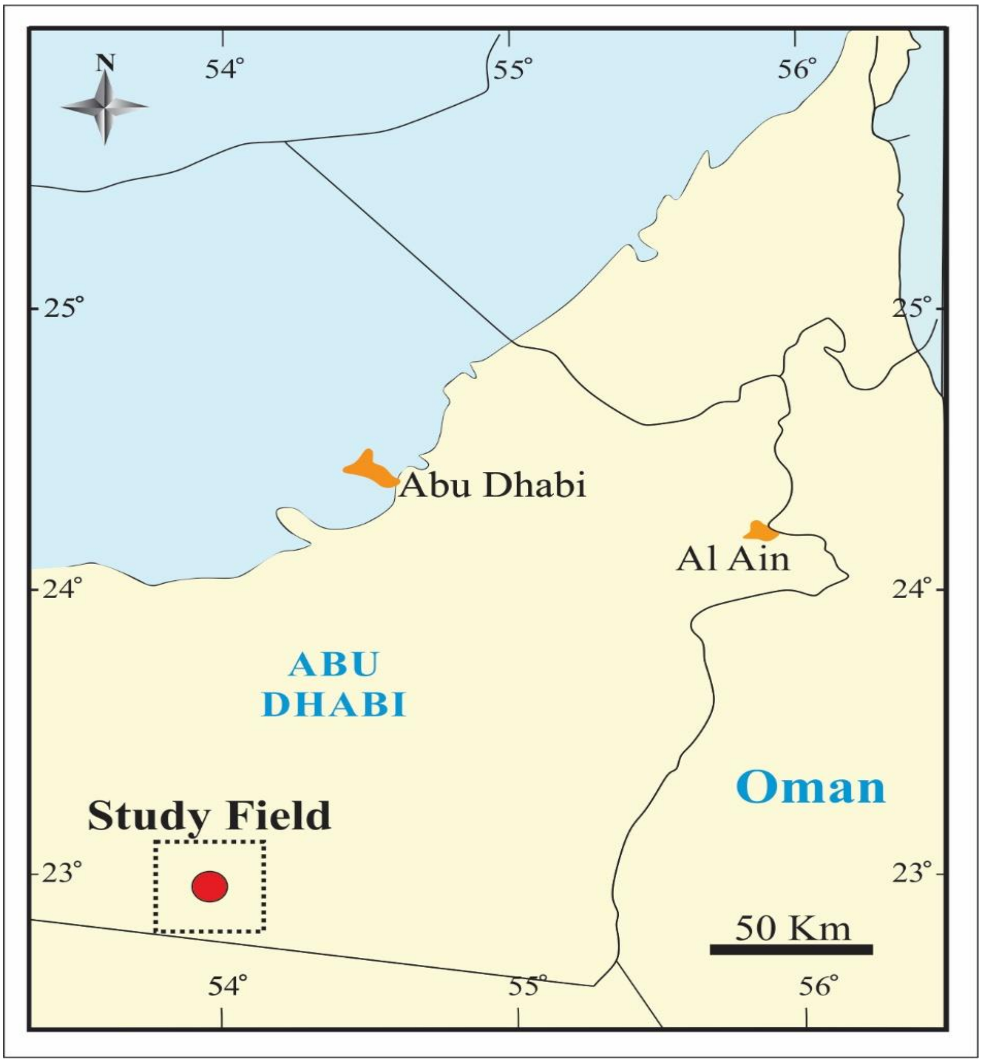

Figure 2 Location map showing Abu Dhabi and the study field in a black box and red point (Morad et al., 2023).

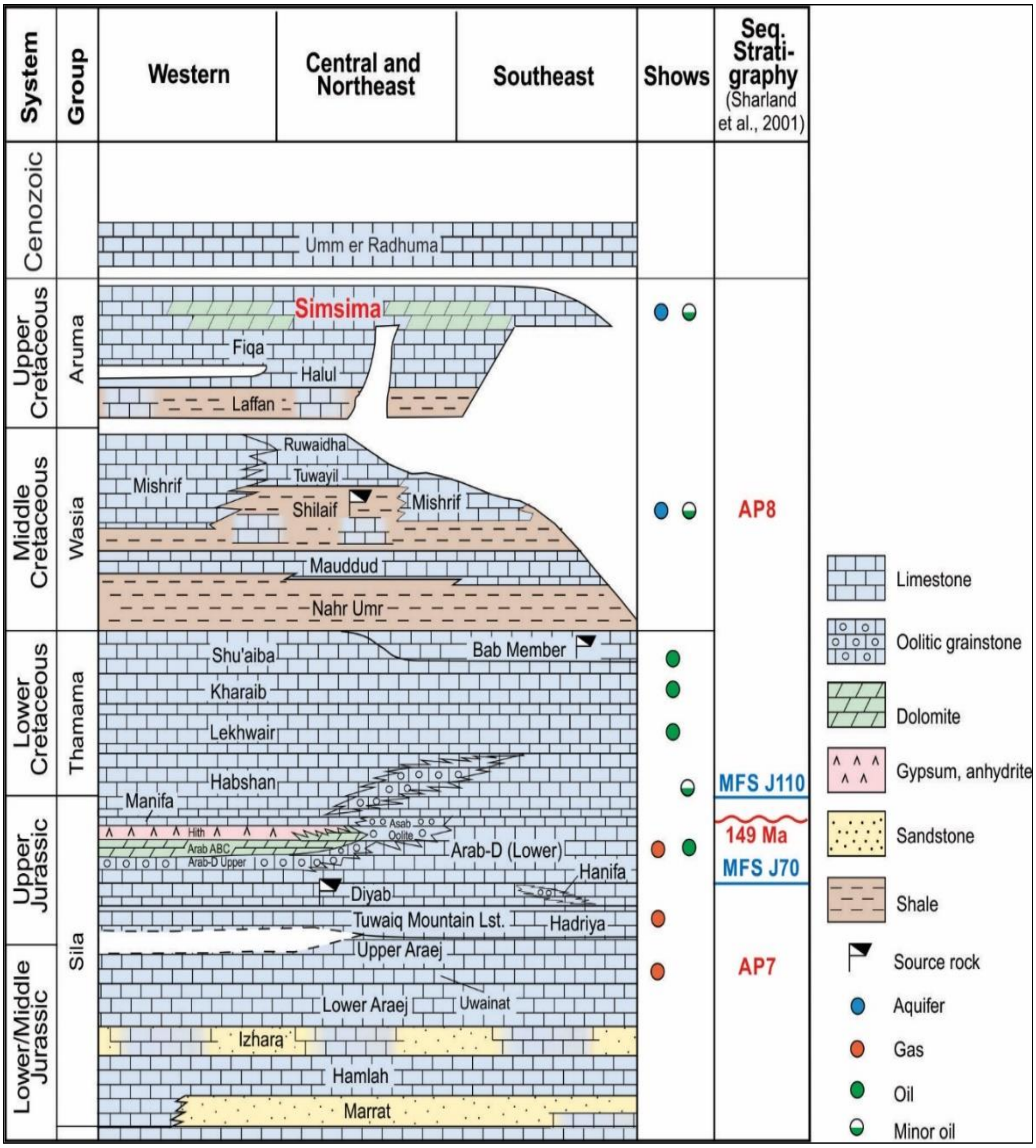

Figure 3 Stratigraphic column of the UAE (Morad et al., 2023).

The hydrocarbon reservoirs within the Simsima Formation are typically trapped within structural and stratigraphic features. Structural traps can include anticlines, faulted structures, or reef complexes, while stratigraphic traps result from variations in rock properties, such as changes in porosity or permeability (Figure 4). Understanding the structural and stratigraphic characteristics of the Simsima Formation is crucial for successful hydrocarbon exploration and production.

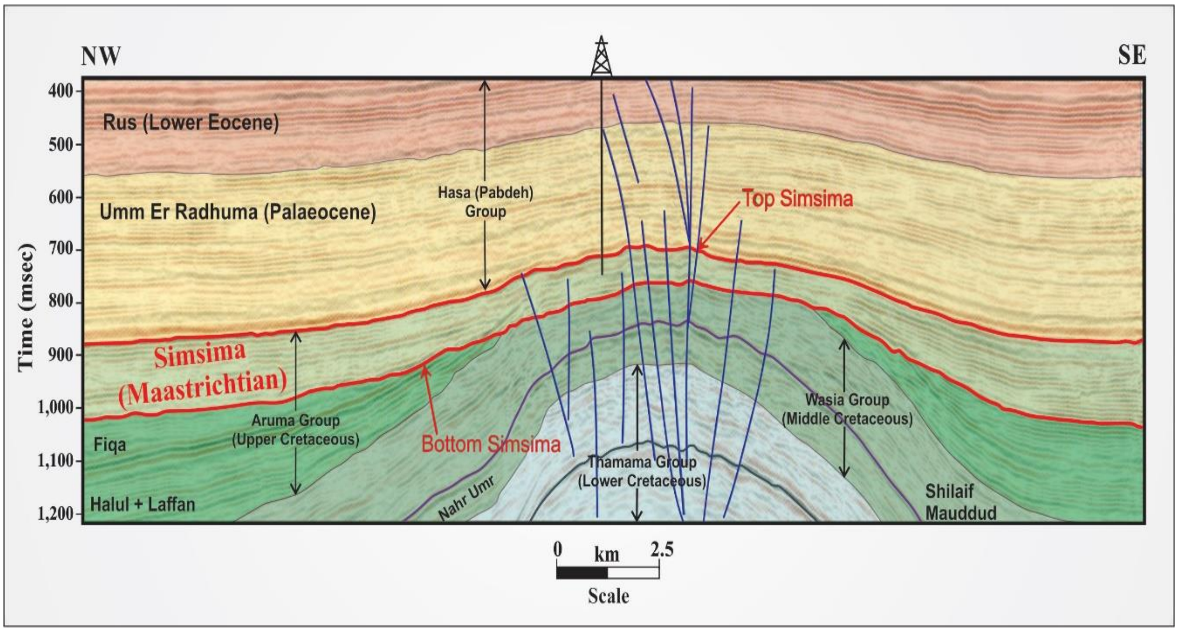

Figure 4 The location of the Simsima Formation in the studied anticline (Morad et al., 2023).

1.3 Dolomitization Model in Simsima Formation

The study of carbonate rocks of the Simsima Formation has shown that no dolomitic process alone can be the main cause of dolomitization in the Sesame Formation. Morad et al. (2023) have proposed a seepage reflux model for the dolomitization of Simsima Formation. According to this model, the dolomitization process took place within peritidal and shoal carbonate deposits, with the highest occurrence observed in the highstand systems tracts (HST). This dolomitization was driven by the presence of penesaline brines, which formed as a result of the recurrent tidal-evaporative pumping or reflux of seawater during periods of marine regression (Figure 5A-D; Morad et al., 2023).

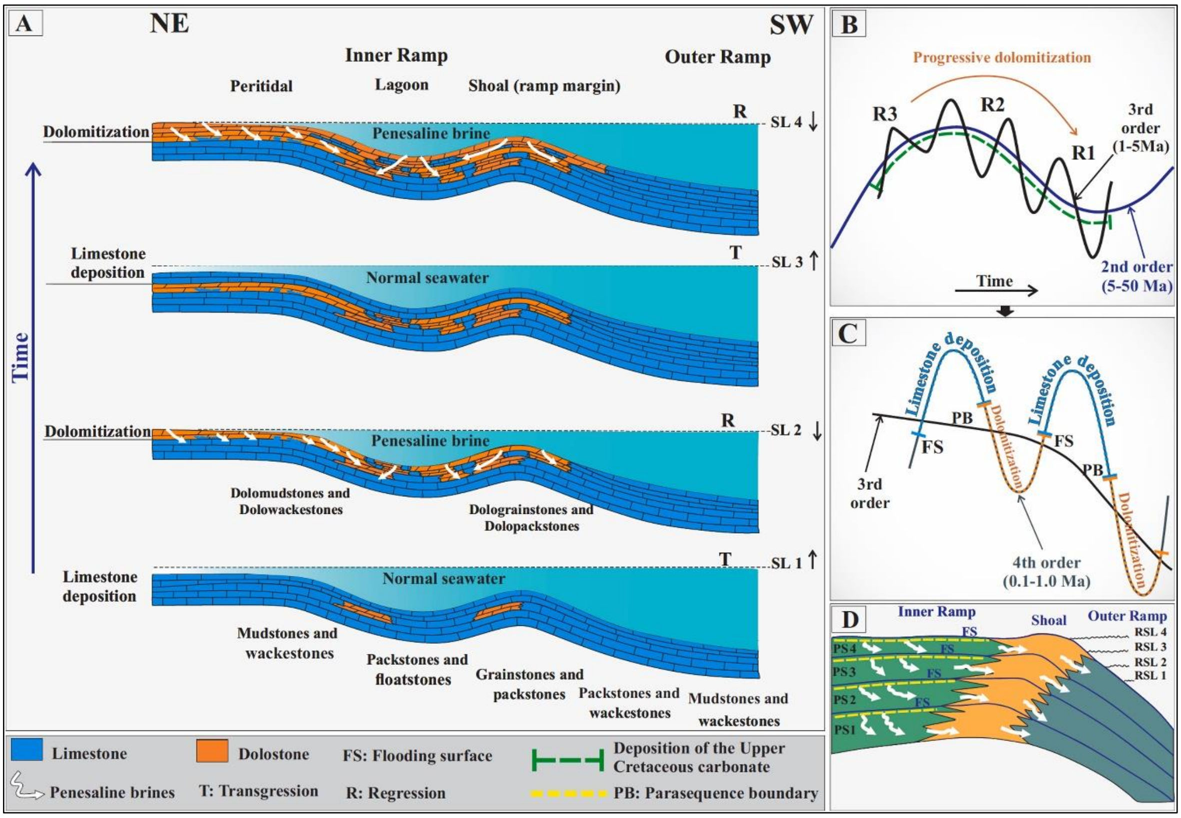

Figure 5 A –D Dolomitization model for Simsima Formation (Morad et al., 2023).

1.4 Aim and purpose of the study

The Simsima Formation, located in the Persian Gulf region, has garnered extensive attention and investment in exploration and production activities (Alsharhan, 1989). Its rich petroleum resources have been a focal point, with numerous oil and gas fields discovered within this formation, making significant contributions to the petroleum industry of Qatar and the United Arab Emirates. The exploration endeavors have involved employing seismic surveys, drilling exploration wells, and conducting reservoir characterization studies, all aimed at optimizing hydrocarbon recovery.

However, the exploration and production of the Simsima Formation are not without challenges. Its geological characteristics present hurdles that need to be addressed. The complex nature of carbonate reservoirs within the formation, including variations in porosity and permeability, pose significant obstacles (Alsharhan, 1989; Morad et al., 2023). Additionally, diagenetic alterations occurring over time can impact the quality of the reservoir. These challenges necessitate meticulous geological and reservoir studies to thoroughly evaluate and develop the hydrocarbon resources within the Simsima Formation.

To overcome these challenges and effectively exploit the hydrocarbon potential, a comprehensive understanding of the formation's geological complexities and reservoir properties is essential. Detailed investigations and analyses are required to delineate the reservoir's porosity, permeability, and diagenetic history. By leveraging advanced geological and reservoir characterization techniques, the industry can gain valuable insights into the depositional environment, reservoir architecture, and fluid flow patterns within the Simsima Formation. Such knowledge will guide the development strategies and enhance the efficiency of hydrocarbon recovery processes.

Given the significance of the Simsima Formation as a valuable hydrocarbon reservoir, ongoing research and technological advancements continue to drive advancements in exploration and production techniques. The petroleum industry's persistent efforts and dedication to understanding the formation's complexities are pivotal in unlocking its full hydrocarbon potential and ensuring sustainable resource exploitation.

The most important goals of this study are to investigate the reservoir properties and the most important effect of dolomitization on reservoir quality changes in the Simsima Formation in one of the hydrocarbon fields in the south of the United Arab Emirates (Figure 2).

2 Literature Review

Hallsworth, C (1999) insured that the name "dolomite" refers to both the sedimentary rock that contains the mineral calcium magnesium carbonate (CaMg(CO3)2) as well as the mineral itself. Déodat Gratet de Dolomieu (1750–1801), a French naturalist and geologist, first characterized the rock dolomite in 1791 after observing exposures in the northern Italian Dolomite Alps. Dolomitic limestone is a type of limestone that has had some of its original structure replaced by dolomite. It is referred to as magnesian limestone in older American geology literature. Dolomite can have a wide range of structural, textural, and chemical properties and appears to originate in a variety of environments. There may be more than one way for dolomite to form, according to some academics, who have said that "there are dolomites and dolomites." Since the majority of the minerals in the rock record differ greatly from modern dolomite, experts believe that the environments and mechanisms involved in the dolomite formation.

Gregg, J (2015) Published that although the rock was given this name initially, it is occasionally called dolostone to prevent confusion. The mineral is white when pure, however, impurity residues can alter its color to a variety of hues, including pink, yellow, brown, and gray. Dolomite is a mineral that produces curved, frequently twinned crystals, however,r it is typically found in large form. It forms a trigonal-rhombohedral crystal structure. Dolomite is the name given to a sedimentary rock that contains the mineral calcium magnesium carbonate (CaMg(CO3)2) as its main component. The word "dolostone" is sometimes used for the rock even though the original name was "dolostone." The mineral is white when pure, but impurities can tint it pink, yellow, brown, or gray, among other colors. Dolomite is a mineral that often occurs in large form, but it can also form curved crystals that are frequently twinned. The trigonal-rhombohedral system is where it crystallizes.

Morrow, D (1982) thought that, dolomite frequently substitutes ferrous iron for some of the magnesium, and a complete series between dolomite and ankerite [CaFe(CO3)2] is quite probable to exist. Manganese can also replace magnesium, but usually only to a little level and almost often only in conjunction with iron. Other cations that are known to substitute, albeit in very small amounts, for calcium and magnesium in the structure of dolomite are barium, lead, and zinc. Dolostones have been found to contain almost all of the natural elements in at least trace amounts. Uncertainty surrounds which of these genuinely exist in the dolomite; others may exist in other mineral components of the examined rocks.

Barber, D and Eedder, R (1985) simply agreed that the dolomite structure is similar to the calcite structure, except every other cation layer has magnesium ions instead of calcium ions. As a result, it is possible to imagine the ideal dolomite structure as consisting of layers of calcium, CO3, magnesium, another layer of CO3, and so on. However, unlike calcites, dolomites may also show order-disorder correlations, as was mentioned for the potassium feldspars. This happens because some of the cation layers' purity may not be as high as it should be; for example, some "calcium layers" may also contain magnesium and some "magnesium layers" may also contain some calcium. Holocene dolomites—those developed during the past 11,700 years—with less-than-ideal dolomite structures are usually referred to as protodolomites.

Caetano H. (2017) argued tha, dolomitization a process involved in the formation of carbonate rocks, may or may not considerably improve the sediments' reservoir quality. In this respect, Abu Dhabi, United Arab Emirates' onshore oil field's Upper Cretaceous reservoir was the subject of a diagenesis investigation. The report goes into detail about dolomitization related to facies and its particular impact on improving reservoir quality. The study's framework is based on 850 thin sections that have undergone extensive petrographic analysis and description, the isotopic compositions (C, O, Sr) of chosen samples, and fluid inclusion microthermometry of dolomite that was generated in upper and middle reservoir units. In the middle reservoir unit, the study found that dolomitization of shoal grainstones and packstones produced coarse crystalline dolomite, which significantly increased reservoir porosity and permeability. In contrast, dolomitization of pretidal mudstones and wackestones produced microcrystalline dolomite, which had no effect on the permeability of the upper reservoir unit and only slightly increased the micro-porosity. Eo- and mesodiagenesis (Th = ca 65-90° C; salinity = 15-21 wt% NaCl) produced dolomite. Pretidal mudstone dolomitization is thought to have taken place in an evaporative environment, but packstones and grainstones of bioclastic shoal and subtidal sediments may have undergone deepage reflux mechanisms. As a result, dolomitization trend maps for the middle and upper reservoir units were created. The facies model was then constructed using these dolomitization trend maps as constraints in order to respect the diagenetic overprint. In both the upper and middle reservoir units, a blind test using an integrated facies model showed strong predictability in terms of reservoir quality distribution and production behavior. As a result, field development strategies can be improved with the right placement of wells into the reservoir.

Sajed, and Glover (2020) agreed that, carbonate rocks' porosity and pore microstructure's form are both impacted by the geochemical process of dolomitization. It is thought to be one of several diagenetic processes that affect the main matrix of carbonate rock to eventually determine the reservoir quality of the carbonate formation. Calcite (CaCO3) is replaced wholly or partially by dolomite (CaMg(CO3)2) during the diagenetic process known as "dolomitization.". By replacing it, the rock's volume is reduced by around 12.3%, improving the rock's overall porosity. Due to the dolomitization of the susceptible groundmass (aragonite or high Mg-calcite), partial dolomitization typically results in a mimetic texture, leaving the stable mineralized grains that preserve the fundamental fabric of the rock. Early and late dolomitization are additional categories for dolomitization. Early dolomitization is frequently inhibited by the presence of associated minerals (such as calcite and anhydride) in tidal flat environments. In contrast, late diagenetic dolomitization increases the percentage of dolomite and thereby increases the porosity of the rocks in the absence of compaction and cementation processes.

Lawrence, J (2015) also published that dolomitization can change the petrophysical characteristics of carbonate rocks by increasing or decreasing their heterogeneity. Following cementing and compaction, the dolomitization-induced improvement in reservoir characteristics may be diminished, or it may be further enhanced by fracturing. The pore network of the rock may be partially or completely blocked by cementation as early or late diagenesis, which lowers pore connectivity and, as a result, lowers permeability and raises electrical resistivity. Cementation also plays a significant role in controlling the reservoir quality of dolomite units. This study characterized three forms of cement: dolomite cement, calcite cement used to plug certain cracks, and anhydride cement related to reflux dolomitization in the Butmah Formation.

Ibrahem, Y. et al. (2021) informed that Dolomites and/or dolomitic rocks are significant from a geological and sedimentary perspective as potential hydrocarbon reservoirs.

Because of this, they have drawn the attention of numerous researchers worldwide, particularly in topics pertaining to their origins, mechanisms, and environments of deposition. The carbonate rocks often undergo dolomitization processes soon after they are deposited, and they are also growing during the various stages of burial diagenesis. In general, dolomitization processes result in the partial or total erosion of the host limestone rocks' native dispositional texture. The Mg-rich, dolomitizing fluids have marine, hydrothermal, evaporative seepage reflux, and local limestone dissolution as their sources. Porosity ratings in dolomite reservoirs are often higher than those in limestone.

They strongly advise conducting geochemical analyses during future development or exploration as these data are required, along with petrographic observation, to understand the dolomitization mechanism. In general, it is very difficult to predict the origin and the source of the dolomitizing fluids, as well as the enrichment of Mg2+ and indicative information of refluxing dolomites. They advise concentrating on the interaction between dolomitization and fracture since they improve the quality of dolostone reservoirs since the stylolitic fractures and finely crystalline dolomitic stringers appear to increase porosity inside the dolomitized zone of the Judea Formation.

According to Xiao, Y (2013), it could be said, in many carbonate reservoirs, the geographical distribution of dolomite presence—and in particular, the diagenetic transitions between limestone and dolomite—is a key indicator of reservoir quality. The most famous and numerous specimens are from the Middle East, specifically the Jurassic Ghawar field in Saudi Arabia. Dolomite can act as a reservoir or as a baffle or flow barrier, depending on the original depositional texture, style of dolomitization, and presence of anhydrite cement. High permeability dolomites, often known as "Super K" dolomites, with multi-darcy permeability that periodically occur in thin zones (sometimes less than 5 ft), are essential to the performance of each well and the overall reservoir. Dolomites that are longitudinally continuous and low permeability, or "tight," can also significantly affect the subsurface flow and, consequently, reservoir management techniques.

Analogues of outcrops can be studied in order to get insight into the distribution and connectivity of sedimentary bodies. The subject of many outcrop research has been dolomitized carbonates. There are, however, not many models that particularly address the transitions between limestone and dolomite and/or characterize the connection of dolomite bodies in projected dolomitization. The significant exceptions are outcrop-based investigations that identified dolomite fronts linked to geothermal circulation and ascending hydrothermal fluids, respectively.

Yang, L. et al. (2020) informed that because of their established deposits, carbonate reservoirs are widespread around the world and essential for oil and gas exploration. It is crucial to comprehend the impact of diagenesis on the evolution of reservoir porosity as it is one of the main factors affecting reservoir quality. However, carbonate reservoirs are typically formed with complicated cracks/pores during diagenesis, which makes reservoir prediction challenging and hinders the development of oil and gas exploration. The basis for increasing oil and gas exploration efficiency is the establishment and evolution of reservoir porosity, which is the subject of carbonate reservoir research. Reservoir porosity evolution in carbonate reservoirs is primarily caused by the dissolution and precipitation of carbonate minerals, like dolomitization.

Dolomite is the most significant carbonate reservoir, and it has drawn a lot of interest. Numerous new problems have emerged as a result of the ongoing research and discoveries of oil and gas in deeply buried dolomite formations. How dolomitization impacts reservoir porosity during distinct sedimentation-diagenesis processes is a crucial question. However, due to the majority of prior research focusing on qualitative testing and analysis of dolomitization, which lacked a systematic description of carbonate minerals under various burial conditions throughout the entire diagenetic process, this has not received much attention. A number of one- and two-dimensional numerical models were built using the deep strata of the Tarim Basin in Northwestern China under diverse diagenetic circumstances.

(2015) Wang, G. Informed that, due to the scientific relevance in sedimentary geology and commercial significance as possible hydrocarbon reservoirs, dolomites have drawn extensive research on their beginnings, either on the dolomitization environments or dolomitizing fluids. Dolostones frequently have more porosity than nearby limestones, especially in deep burial conditions. Dolostones' origin of porosity, however, is still up for debate. While in replacement, dolostones porosity is basically diagenetic origin, either formation during or after the dolomitization process, in carbonate systems, porosity in limestone is related to both primary sedimentary textures and subsequent diagenesis. Porosity in dolostones is typically thought to be genetically linked to the dolomitization process, which involves repeated cycles of dissolving a precursor carbonate and precipitating dolomite.

The porosity in replacement dolostones can be separated into two primary groups based on the development timing of the porosity relative to the dolomitization process: syndolomitization origin and postdolomitization origin. Dolomite was mostly created during the first two stages of dolomitization (stages I and II) by replacing volume for volume while maintaining or slightly decreasing porosity due to the addition of an external source. In stage II, only a few intercrystalline holes were created. During the advanced stage of dolomitization, remaining microcrystalline calcite or micritized grains were selectively dissolved to create intercrystalline and vuggy holes. (stage III).

3 Methodology

In this bachelor's thesis, log and core data related to the Simsima Formation in three wells of one of the hydrocarbon fields in the south of the United Arab Emirates have been used. Data from various types of logs, such as gamma-ray logs, Density logs, Neutron Porosity Logs, and resistivity logs, have been analyzed.

The density Log measures the bulk density of the formation by utilizing a density logging tool that is lowered into the wellbore. The tool emits gamma rays, and based on the attenuation or reduction in the intensity of these gamma rays as they pass through the formation, the density of the rocks can be determined (Asquith et al., 2004).

Neutron Porosity Log is a type of well log used in the field of petrophysics to measure the porosity of rocks surrounding a borehole in oil and gas exploration and production. It provides information about the presence and amount of fluids within the formation (Asquith et al., 2004).

The Neutron Porosity Log measures the hydrogen content or hydrogen index of the rocks by utilizing a neutron logging tool that emits neutrons into the formation and measures their interactions with the formation's nuclei (Asquith et al., 2004). This Log provides a porosity measurement typically expressed as a fraction or percentage. It represents the volume of pore space within the rock, which can contain fluids. Porosity values range from 0 (no porosity) to 1 or 100% (complete porosity) (Asquith et al., 2004).

The resistivity log is a well log used in the field of petrophysics to measure the electrical resistivity of rocks surrounding a borehole in oil and gas exploration and production. It provides valuable information about the rock's ability to conduct electricity, which is related to its composition, porosity, fluid content, and other petrophysical properties (Asquith et al., 2004). The resistivity log operates on the principle that different rocks have varying electrical conductivity. The logging tool measures the resistance to electrical current flow through the rocks. This resistance is influenced by factors such as the presence of conductive fluids, mineralogy, porosity, and saturation (Asquith et al., 2004).

In addition, to log data, porosity and permeability data obtained from cores in the laboratory have been used. Moreover, the thin sections prepared from the cores were also used for microscopic and petrological studies.

For further analysis of the reservoir properties in different units of the Simsima Formation, the Lorenz method has been used. The proposed way to assess the minimum number of flow units in a reservoir is to make use of the Stratigraphic Modified Lorenz Plot (SMLP) technique (Gunter et al., 1997). To compute the SMLP, continuous (foot-by-foot) core porosity and permeability and the respective k/ϕ ratio are arranged in stratigraphic order. Subsequently, the products of k*h and ϕ*h are calculated, the partial sums are computed, and, subsequently, a normalization to 100% is carried out.

The next step is then to plot both values ϕ*h and k*h on a single well with enough petrophysical information. In the last step, the following formulas are used to calculate storage capacity and flow capacity (Gunter et al., 1997).

ϕ: Porosity (%)

h: Depth (ft)

K: Permeability

$$\textbf{Storage Capacity} = \frac{\emptyset_n \times h_n}{\sum \emptyset_n \times h_n} \quad \text{..... Equation (1)}$$

$$\textbf{Flow capacity} = \frac{k_n \times h_n}{\sum k_n \times h_n} \quad \text{..... Equation (2)}$$

4 Results and discussion

4.1 Results

In well number 1, according to core data from X282 ft to X355 ft depth, the ratio of limestone to dolostone is lower. At this depth, the porosity fluctuates between 1% and 35%. And according to that, the permeability varies between 0.01 mD and 990 mD (Table 1; Figure 6). Further, at a depth of X355 to X464 ft, limestone is more than dolostone, and the porosity is reported between 10% and 42%, and the permeability varies between 1 mD and 10000 mD at this depth. The average porosity and permeability can be considered as 30% and 800 mD, respectively (Table 1; Figure 6). In the same manner, with the increase in depth from X464 to X528 ft, the increase in the ratio of dolostone to limestone is evident. In this depth, porosity is reported between 1% and 30% of the studied samples. The average permeability at this depth can be said to be 20%. Due to the changes in porosity at these depths and naturally, there have been changes in permeability, which were between 0.01 and 100 mD, and an average of 10 mD can be considered for the samples in this range. Likewise, between X528 ft and X620 ft in well number 1, the ratio of limestone to dolostone in the Simsima Formation increases, and in some parts between these two depths, the ratio of limestone and dolostone can be considered equal. Between these two depths, the porosity fluctuates from 33% to 2% and its average can be considered as 20%. On the other hand, the permeability between these depths was considered to be 0.01 to 10 mD (Table 1; Figure 6).

Table 1 Porosity, permeability, and lithology data related to the main zones of the Simsima Formation in well No. 1

Depth (ft)	Maine lithology	Porosity (%)	Permeability (mD.)
X282-X355	80% dolostone	1-30 Ave. 20	0.01-990 Ave. 100
X355-X464	90% limestone	10-42 Ave. 30	1-10000 Ave. 800
X464-X528	95% dolostone	1-30 Ave. 20	0.01-100 Ave. 10

X582-X620	more limestone and some place is equal	2-32 Ave. 20	0.01- 100 Ave. 10

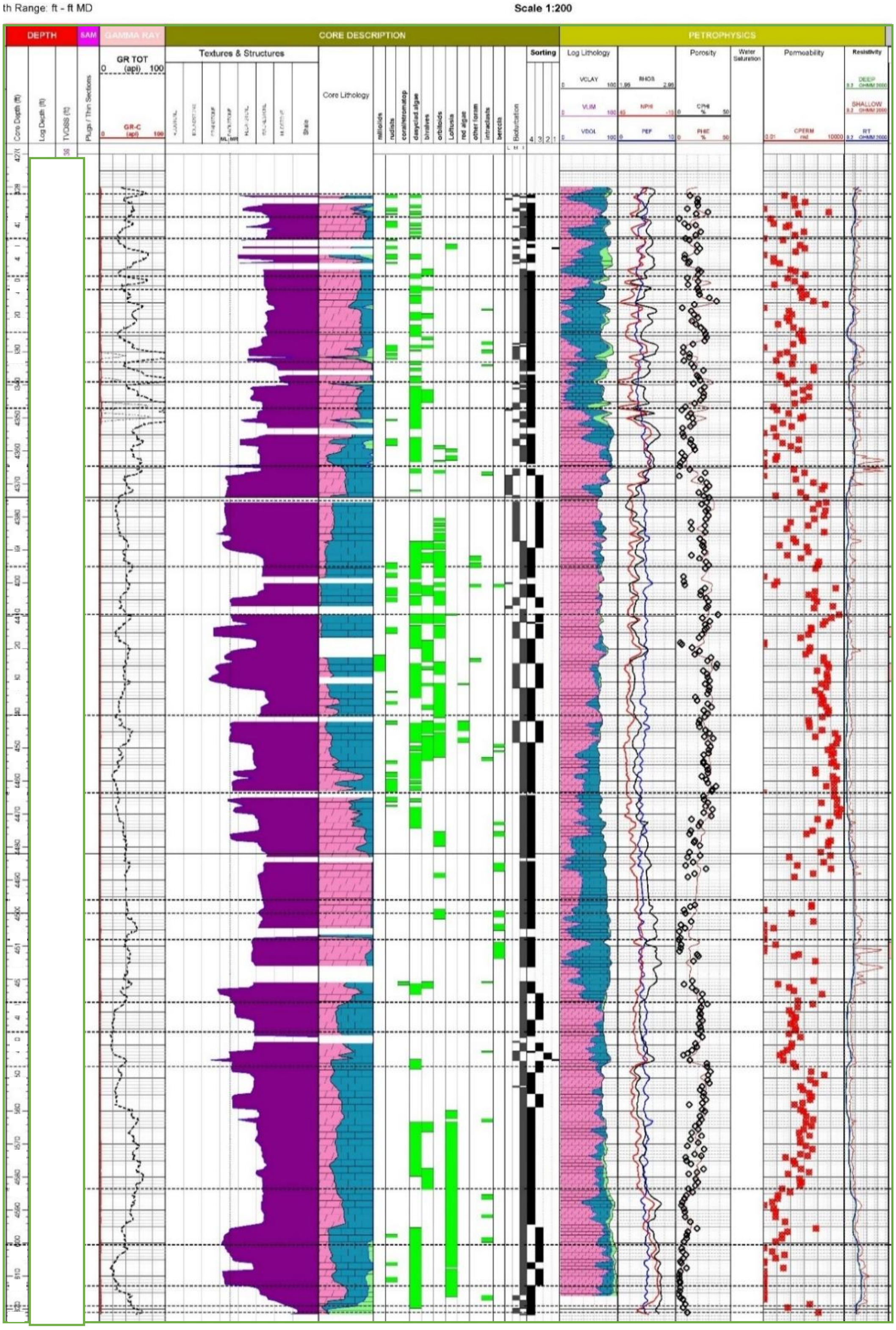

Figure 6 Available data from well number 1

In well number 2, the lithology of the Simsima Formation primarily comprises shale and dolostone. Notably, over 90% of the limestones present in this particular field have undergone dolomitization, resulting in a relatively low percentage of unaltered limestone. The porosity ratio within this well exhibits significant variation, ranging from 2% to 25%. On average, the porosity is estimated to be around 15%.

The nature of porosity in this well has a considerable impact on its permeability characteristics, which vary at different depths. The permeability ratio fluctuates between 0.01 and 10,000 millidarcies (mD). Taking into account the overall range, the average permeability in this well is approximately 100 mD (as depicted in Table 2 and Figure 7). These findings highlight the heterogeneity of porosity and permeability within the Simsima Formation in well number 2. Such variations have implications for fluid flow and the extraction of hydrocarbons from the reservoir. Understanding the spatial distribution of porosity and permeability, as well as their relationship with lithology and dolomitization, is crucial for effective reservoir characterization and optimizing hydrocarbon recovery strategies in this field.

Table 2 Porosity, permeability, and lithology data related to the main zone of the Simsima Formation in well No. 2

Depth (ft)	**Maine lithology**	**Porosity (%)**	**Permeability (mD.)**
X624-X946	Dolostone and shale	2- 25 Ave. 15	0.01-10000 Ave. 100

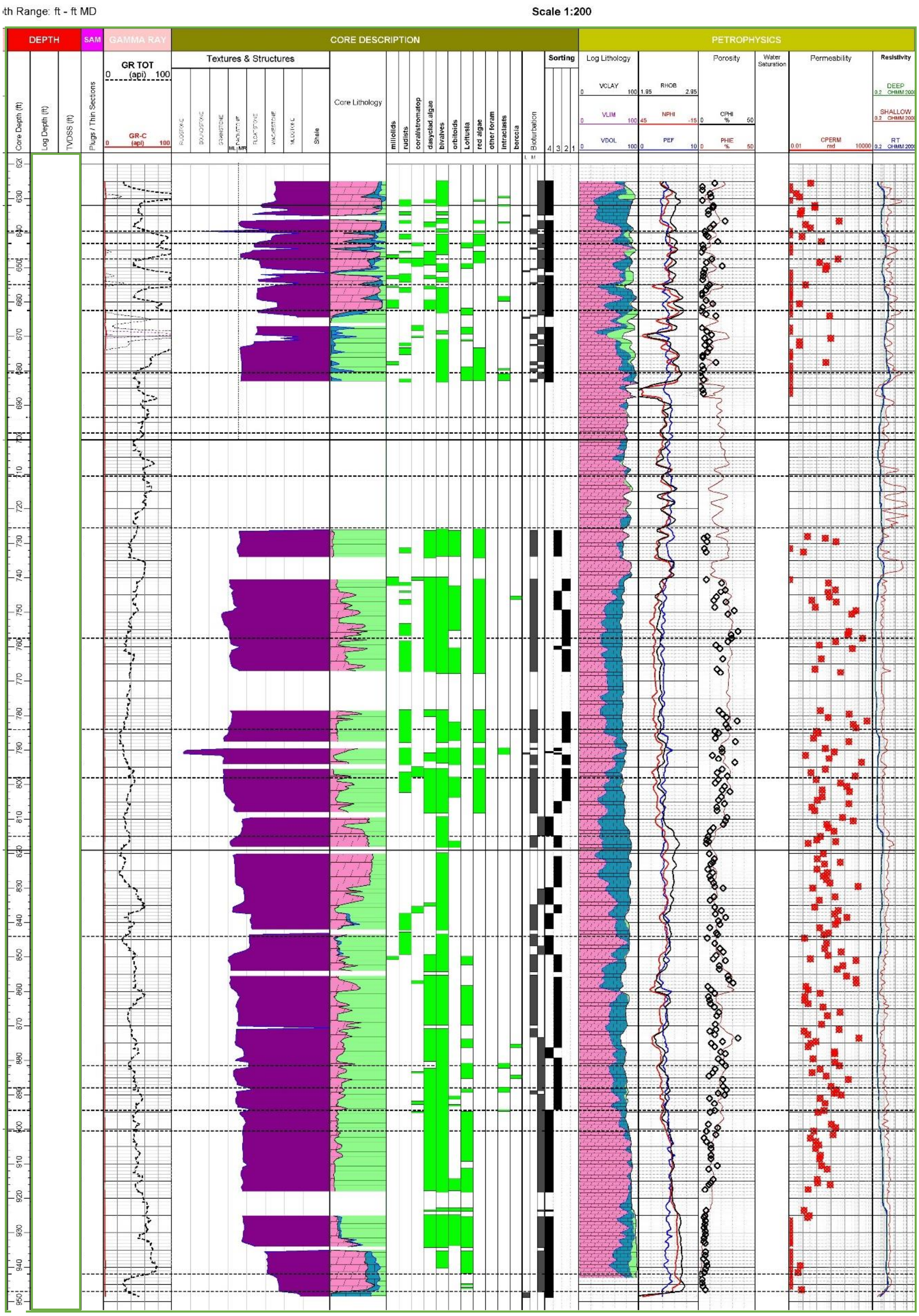

Figure 7 Available data from well number 2

In well No. 3, the lithology of the Simsima Formation is mostly dolostone from X114 ft to X222 ft depth, and more than 90% of limestone is dolomitized. The porosity between these depths varies between 1% and 30%, and the average porosity can be considered to be 15%. Also, with changes in porosity, the permeability in this depth is variable and varies between 0.01 and 100 mD, and it can be considered as an average of 10 mD (Table 3; Figure 8). Further, from a depth of X222 ft to X270 ft, the lithology of the Simsima Formation was limestone and the percentage of dolostone is very low. The percentage of porosity in this depth fluctuates between 10 and 38%, and the average is 20% as well as, the permeability in this depth varies from 0.1 to 1000 mD and the average permeability is 100 mD (Table 3; Figure 8). In the same manner, from the depth of X275 ft to X298 ft, the lithology of the Simsima Formation is more than dolostone, the porosity in these depths is 10 to 39%, and the average is 30%. The permeability between these depths is 100 to 10,000 mD and the average is 1000 mD. At the end of the Simsime Formation in well number 3 and from the depth of X298 ft to X438 ft, the lithology of the Simsima Formation is limestone and the percentage of dolomitization at this depth is low. The porosity in this depth was 10 to 30% and the average was 25%. Also, permeability in these depths is between 0.01 and 1000 mD and the average is 1000 mD (Table 3; Figure 8).

Table 3 Porosity, permeability, and lithology data related to the main zones of the Simsima Formation in well No.3.

Depth (ft)	**Maine lithology**	**Porosity (%)**	**Permeability (mD.)**
X114-X222	Dolostone	1-30 Ave. 15	0.01-100 Ave. 10
X222-X270	Limestone	10-38 Ave. 20%	0.1-10000 Ave. 100
X275-X298	Dolostone	10-39 ave. 30%	100-10000 Ave. 1000
X298-X438	Limestone	10-30 Ave. 25	0.01-1000 Ave. 100

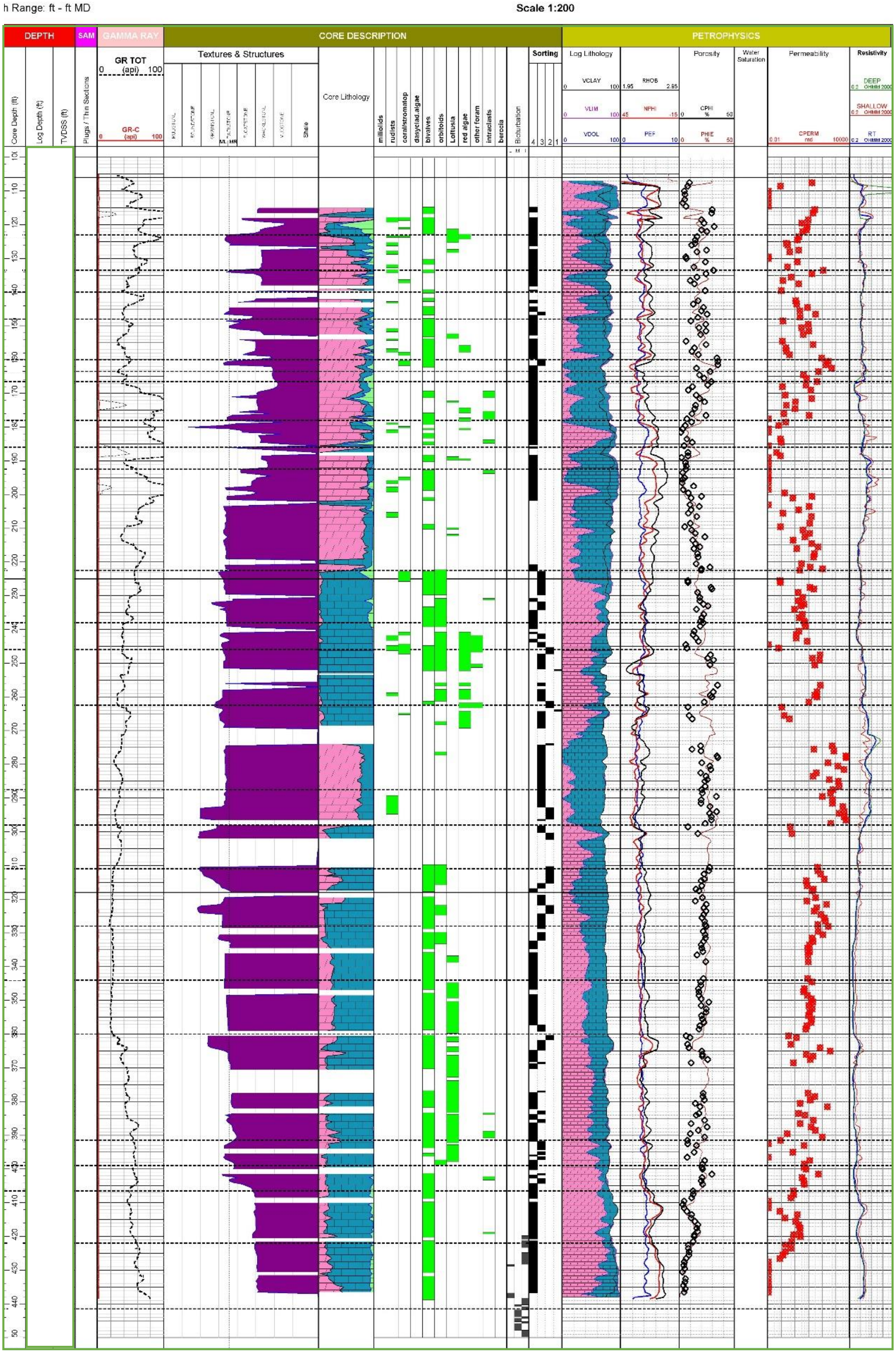

Figure 8 Available data from well number 3

Microscopic images of Simsima Formation samples collected from well-core samples show the difference in dolomitization in different degrees (Figure 9). Thus that in some parts of this formation, extensive dolomitization is observed, while in some other parts, the percentage of dolomitization is more limited.

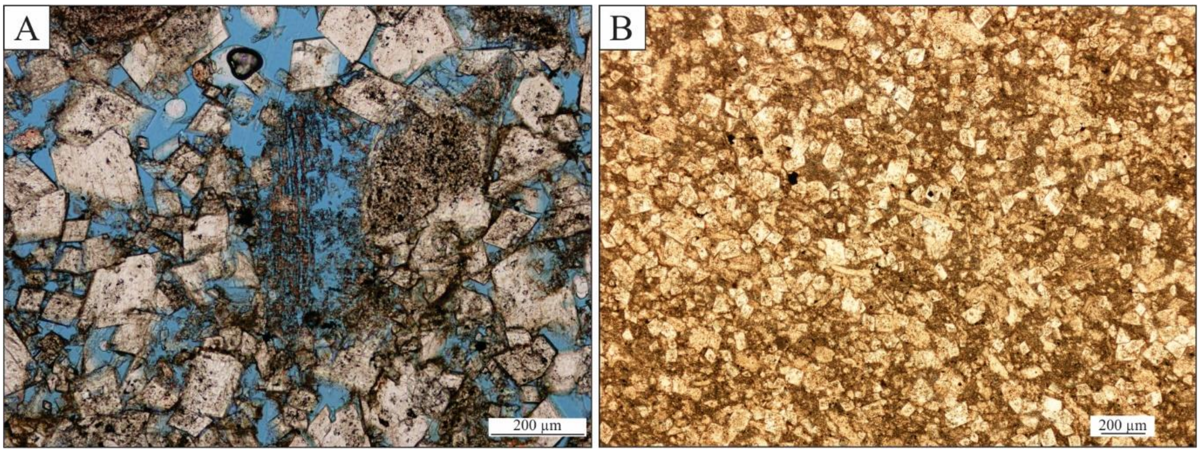

Figure 9 Microscope images prepared from core samples of Simsima Formation. (A) Limited dolomitization of limestone, which has increased porosity and permeability. (B)The high percentage of dolomitization has reduced the porosity and permeability in the reservoir rock.

Using the existing data of porosity, permeability, and depth from the studied wells and using special formulas mentioned in the methodology chapter, the ratio of storage capacity and flow capacity has been calculated for the samples of three wells (Tables 4, 5, and 6).

Table 4 The results obtained from calculations for storage capacity and flow capacity of well No. 1

H (Ft)	**Q (%)**	**K (mD)**	**k/q**	**q*h**	**k*h**	**cum1**	**cum2**	**Storage capacity**	**Flow capacity**
290	8	0.1	0.0125	2320	29	2320	29	0.57	0.001
292	10	0.9	0.09	2920	262.8	5240	291.8	1.29	0.01
295	12	0.7	0.058	3540	206.5	8780	498.3	2.17	0.01
310	20	10	0.5	6200	3100	14980	3598.3	3.70	0.12
311	20	9.5	0.475	6220	2954.5	21200	6552.8	5.24	0.23

H (Ft)	Q (%)	K (mD)	k/q	q*h	k*h	cum1	cum2	Storage capacity	Flow capacity
318	18	1	0.055	5724	318	26924	6870.8	6.65	0.24
322	18	1	0.055	5796	322	32720	39590.8	8.09	1.39
324	28	9.8	0.35	9072	3175.2	41792	42766	10.33	1.51
333	9	0.1	0.011	2997	33.3	44789	42799.3	11.07	1.51
334	15	1.3	0.086	5010	434.2	49799	43233.5	12.31	1.52
336	18	1.6	0.088	6048	537.6	55847	43771.1	13.80	1.54
339	15	0.9	0.06	5085	305.1	60932	44076.2	15.06	1.55
342	15	1	0.066	5130	342	66062	44418.2	16.33	1.56
347	5	0.1	0.02	1735	34.7	67797	44452.9	16.76	1.56
376	30	100	3.333	11280	37600	79077	82052.9	19.55	2.89
395	30	100	3.333	11850	39500	90927	121552.9	22.48	4.29
400	27	80	2.962	10800	32000	105697	153592.6	26.13	5.42
402	27	90	3.333	10854	36180	116551	189772.6	28.81	6.70
404	25	40	1.6	10100	16160	126651	205932.6	31.31	7.27
406	25	50	2	10150	20300	136801	226232.6	33.82	7.98
410	30	1000	33.33	12300	410000	149101	636232.6	36.86	22.46
412	25	500	20	10300	206000	159401	801832.6	39.41	28.31
414	25	400	16	10350	165600	169751	967432.6	41.97	34.15
425	39	990	25.384	16575	420750	186326	1388182.6	46.07	49.01
428	25	300	12	10700	128400	197026	1516582.6	48.71	53.54
440	28	980	35	12320	431200	209346	1947782.6	51.76	68.77
444	23	40	1.739	10212	17760	219558	1965542.6	54.28	69.40
446	28	98	3.5	12488	43708	232046	2009250.6	57.37	70.94
450	29	980	33.793	13050	441000	245096	2450250.6	60.60	86.51
456	30	40	1.333	13680	18240	258776	2468490.6	63.98	87.15
476	14	80	5.714	6664	38080	265440	2506570.6	65.63	88.50
480	10	110	11	4800	52800	270240	2559370.6	66.82	90.36
485	12	1	0.083	5820	485	276060	2559855.6	68.25	90.38
488	18	90	5	8784	43920	284844	2603775.6	70.43	91.93
489	12	13	1.083	5868	6357	290712	2610132.6	71.88	92.16
490	12	15	1.25	5880	7350	296592	2617482.6	73.33	92.42
496	18	60	3.333	8928	29760	305520	2647242.6	75.54	93.47
500	9	1	0.111	4500	500	310020	2647742.6	76.65	93.48
508	5	0.05	0.01	2540	25.4	312560	2647768	77.28	93.48
510	5	0.05	0.01	2550	25.5	315110	2647793.5	77.91	93.49
512	7	0.06	0.008	3584	30.72	318694	2647824.22	78.80	93.49
536	20	60	3	10720	32160	329414	2679984.22	81.45	94.62
550	30	60	2	16500	33000	345914	2712984.22	85.53	95.79
555	25	40	1.6	13875	22200	359789	2735184.22	88.96	96.57
560	28	90	3.214	15680	50400	375469	2785584.22	92.83	98.35
570	20	80	4	11400	45600	386869	2831184.22	95.65	99.96
575	10	0.98	0.098	5750	563.5	392619	2831747.72	97.08	99.98
584	12	0.6	0.05	7008	350.4	399627	2832098.12	98.81	99.99

H (Ft)	**Q (%)**	**K (mD)**	**k/q**	**q*h**	**k*h**	**cum1**	**cum2**	**Storage capacity**	**Flow capacity**
600	8	0.09	0.011	4800	54	404427	2832152.12	100	100

Table 5 The results obtained from calculations for storage capacity and flow capacity of well No. 2**.**

H (ft)	Q (%)	K (mD)	K/Q	Q*H	K*H	Cum1	Cum2	Storage Capacity	Flow Capacity
625	15	0.56	0.037	9375	350	9375	350	4.89	1.18
626	4	0.05	0.012	2504	31.3	11879	381.3	6.19	1.29
628	11	0.09	0.008	6908	56.52	18787	437.82	9.80	1.48
630	5	0.05	0.01	3150	31.5	21937	469.32	11.44	1.59
632	14	0.9	0.064	8848	568.8	30785	1038.12	16.05	3.51
634	14	0.9	0.064	8876	570.6	39661	1608.72	20.68	5.45
640	8	0.05	0.006	5120	32	44781	1640.72	23.36	5.55
642	10	0.1	0.01	6420	64.2	51201	1704.92	26.70	5.77
645	5	0.05	0.01	3225	32.25	54426	1737.17	28.39	5.88
655	10	0.1	0.01	6550	65.5	60976	1802.67	31.80	6.10
660	10	0.05	0.005	6600	33	67576	1835.67	35.25	6.22
662	5	0.04	0.008	3310	26.48	70886	1862.15	36.97	6.31
758	25	20	0.8	18950	15160	89836	17022.15	46.86	57.68
815	10	4	0.4	8150	3260	97986	20282.15	51.11	68.73
816	10	1	0.1	8160	816	106146	21098.15	55.37	71.49
820	10	5	0.5	8200	4100	114346	25198.15	59.64	85.39
822	15	1	0.066	12330	822	126676	26020.15	66.08	88.17
824	10	1	0.1	8240	824	134916	26844.15	70.37	90.96
826	8	0.9	0.112	6608	743.4	141524	27587.55	73.82	93.48
828	12	1	0.083	9936	828	151460	28415.55	79.01	96.29
830	11	1	0.090	9130	830	160590	29245.55	83.77	99.10
935	5	0.04	0.008	4675	37.4	165265	29282.95	86.21	99.23
942	10	0.1	0.01	9420	94.2	174685	29377.15	91.12	99.55
944	8	0.09	0.011	7552	84.96	182237	29462.11	95.06	99.83
946	10	0.05	0.005	9460	47.3	191697	29509.41	100	100

Table 6 The results obtained from calculations for storage capacity and flow capacity of well No. 3

H (ft)	**Q (%)**	**K (mD)**	**k/q**	**q*h**	**k*h**	**cum1**	**cum2**	**Storege capacity**	**Flow capacity**
134	14	0.5	0.035	1876	67	1876	67	0.59	0.0008
140	24	1	0.041	3360	140	5236	207	1.66	0.002
142	20	1	0.05	2840	142	8076	349	2.57	0.004
148	19	30	1.578	2812	4440	10888	4789	3.46	0.060
150	10	0.1	0.01	1500	15	12388	4804	3.94	0.061
152	18	5	0.277	2736	760	15124	5564	4.81	0.070
154	15	8	0.533	2310	1232	17434	6796	5.55	0.086
156	12	0.5	0.041	1872	78	19306	6874	6.14	0.087
158	14	0.9	0.064	2212	142.2	21518	7016.2	6.85	0.08
160	33	100	3.030	5280	16000	26798	23016.2	8.53	0.29
162	33	300	9.090	5346	48600	32144	71616.2	10.23	0.91
164	29	90	3.103	4756	14760	36900	86376.2	11.75	1.09
166	30	95	3.166	4980	15770	41880	102146.2	13.33	1.29
170	15	0.8	0.053	2550	136	44430	102282.2	14.15	1.29
176	30	9	0.3	5280	1584	49710	103866.2	15.83	1.32
178	10	0.7	0.07	1780	124.6	51490	103990.8	16.40	1.32
190	10	0.1	0.01	1900	19	53390	104009.8	17.00	1.32
192	8	0.05	0.006	1536	9.6	54926	104019.4	17.49	1.32
195	8	0.05	0.006	1560	9.75	56486	104029.15	17.99	1.32
197	9	0.05	0.005	1773	9.85	58259	104039	18.55	1.32
204	22	1	0.045	4488	204	62747	104243	19.98	1.32
209	10	0.1	0.01	2090	20.9	64837	104263.9	20.65	1.32
210	10	0.1	0.01	2100	21	66937	104284.9	21.32	1.32
212	13	10	0.769	2756	2120	69693	106404.9	22.19	1.35
214	15	1	0.066	3210	214	72903	106618.9	23.22	1.35
216	20	30	1.5	4320	6480	77223	113098.9	24.59	1.43
220	20	1	0.05	4400	220	81623	113318.9	25.99	1.44
224	10	0.1	0.01	2240	22.4	83863	113341.3	26.71	1.44
225	10	0.1	0.01	2250	22.5	86113	113363.8	27.42	1.44
226	10	0.1	0.01	2260	22.6	88373	113386.4	28.14	1.44
238	30	90	3	7140	21420	95513	134806.4	30.42	1.71
240	30	80	2.666	7200	19200	102713	154006.4	32.71	1.95
242	31	100	3.225	7502	24200	110215	178206.4	35.10	2.26
245	10	0.1	0.01	2450	24.5	112665	178230.9	35.88	2.26
246	10	0.1	0.01	2460	24.6	115125	178255.5	36.66	2.26
247	30	90	3	7410	22230	122535	200485.5	39.02	2.54
249	29	70	2.41	7221	17430	129756	217915.5	41.32	2.76
250	30	90	3	7500	22500	137256	240415.5	43.71	3.05
252	35	100	2.857	8820	25200	146076	265615.5	46.52	3.37
254	32	80	2.5	8128	20320	154204	285935.5	49.11	3.63

H (ft)	Q (%)	K (mD)	k/q	q*h	k*h	cum1	cum2	Storege capacity	Flow capacity
260	30	80	2.666	7800	20800	162004	306735.5	51.60	3.89
262	25	10	0.4	6550	2620	168554	309355.5	53.68	3.93
263	10	0.1	0.01	2630	26.3	171184	309381.8	54.52	3.93
274	10	1000	100	2740	274000	173924	583381.8	55.39	7.41
276	20	1000	50	5520	276000	179444	859381.8	57.15	10.92
278	35	5000	142.85	9730	1390000	189174	2249381.8	60.25	28.58
280	30	1000	33.33	8400	280000	197574	2529381.8	62.93	32.14
282	20	100	5	5640	28200	203214	2557581.8	64.7	32.50
284	20	100	5	5680	28400	208894	2585981.8	66.53	32.86
286	20	500	25	5720	143000	214614	2728981.8	68.35	34.68
288	20	1000	50	5760	288000	220374	3016981.8	70.19	38.34
290	30	8000	266.66	8700	2320000	229074	5336981.8	72.96	67.82
291	33	7000	212.121	9603	2037000	238677	7373981.8	76.02	93.71
333	18	10	0.555	5994	3330	244671	7377311.8	77.93	93.75
338	10	50	5	3380	16900	248051	7394211.8	79.00	93.97
340	10	10	1	3400	3400	251451	7397611.8	80.09	94.01
345	14	100	7.142	4830	34500	256281	7432111.8	81.62	94.45
346	18	100	5.555	6228	34600	262509	7466711.8	83.61	94.89
350	20	200	10	7000	70000	269509	7536711.8	85.84	95.78
350	20	100	5	7000	35000	276509	7571711.8	88.07	96.22
360	22	300	13.636	7920	108000	284429	7679711.8	90.59	97.59
362	20	500	25	7240	181000	291669	7860711.8	92.90	99.89
396	20	8	0.4	7920	3168	299589	7863879.8	95.42	99.93
398	22	10	0.454	8756	3980	304653	7867859.8	97.03	99.99
422	12	0.9	0.075	5064	379.8	309717	7868239.6	98.64	99.99
424	10	0.9	0.09	4240	381.6	313957	7868621.2	100	100

4.2 Discussion

The dolomitization process can have significant implications for porosity and permeability in rock formations. In other words, dolomitization can have both positive and negative effects on porosity (Sun, 1995; Omidpour et al., 2022). In some cases, the dolomitization process can enhance or preserve the existing porosity of the rock (Sun, 1995; Omidpour et al., 2022). This occurs when dolomite crystals precipitate within existing pore spaces, resulting in a network of intercrystalline porosity (Omidpour et al., 2022). As a result, the overall porosity may remain relatively high or even increase due to dolomitization. On the other hand, dolomitization can also lead to a reduction in porosity. This can occur when dolomite crystals grow in the pore spaces, filling them and reducing the overall pore volume (Omidpour et al., 2022). This process is known as dolomite cementation, and it can decrease the porosity of the rock.

Dolomitization can sometimes enhance the permeability of the rock (Tavakoli, 2021). This occurs when dolomite crystals selectively replace less permeable carbonate minerals, creating interconnected pore networks that facilitate fluid flow. The dolomite crystals may exhibit higher permeability compared to the original carbonate minerals, thus increasing the overall permeability of the rock (Tavakoli, 2021; Morad et al., 2023). On the contrary, dolomitization can also lead to a reduction in permeability. Dolomite cementation can occlude pore spaces and restrict fluid flow pathways, decreasing the permeability of the rock. Additionally, the growth of dolomite crystals can cause the rock to become more compact, reducing the interconnectivity of the pores and further limiting permeability (Tavakoli, 2021).

This is very important that we must be careful the effect of dolomitization on porosity and permeability depends on various factors, including the extent and type of dolomitization, the original rock composition, the distribution and texture of dolomite crystals, and the diagenetic history of the formation (Omidpour et al., 2022). Understanding these factors and their interplay is crucial in assessing reservoir quality, fluid flow characteristics, and the overall productivity of hydrocarbon reservoirs associated with dolomitized rocks. For this reason, in order to identify the role of dolomitization on the increase or decrease of porosity and permeability, it is necessary to study different and relatively complex factors.

Through careful examination and analysis of the available log and core data obtained from three wells, we have discovered a noteworthy relationship between lithology changes and corresponding variations in porosity and permeability within the samples from the Simsima Formation. This relationship is highlighted in Figures 6, 7, and 8.

The observed changes indicate the existence of a complex association between the degree of dolomitization in the Simsima Formation and the levels of porosity and permeability within this reservoir. Specifically, in the case of well number one, as the dolomitization percentage increases and the reservoir rock approaches full dolomitization, the porosity and permeability values demonstrate a decrease (refer to Table 1 and Figure 6). Conversely, when the reservoir rock of the Simsima Formation experiences partial dolomitization, without surpassing a certain threshold (as depicted in Figure 9), the porosity and permeability percentages exhibit remarkably high values.

These findings suggest that the dolomitization process has a significant impact on the characteristics of the reservoir rock. When the dolomitization is extensive, resulting in the conversion of a substantial portion of the rock matrix to dolomite, the porosity and permeability tend to be lower. This can be attributed to the replacement of more porous and permeable rock components by dolomite, which is typically less porous and has lower permeability.

On the other hand, when the dolomitization is partial and confined within certain limits, the porosity and permeability values remain considerably high. In such cases, the dolomitization process affects only a portion of the rock matrix, leaving other components intact. This can preserve or even enhance the porosity and permeability characteristics of the reservoir rock.

These observations emphasize the importance of understanding the dolomitization process and its effects on the subsurface formations. By recognizing the intricate relationship between dolomitization percentages and porosity-permeability variations, we gain valuable insights into the behavior and potential of the Simsima Formation as a reservoir. This knowledge aids in making informed decisions regarding reservoir management, exploration strategies, and optimizing hydrocarbon recovery from this geological unit.

5.1 Lorenz method

The Lorenz technique was initially developed by Lorenz in 1905 to assess wealth distribution within populations. In the field of petroleum sciences, this technique was adapted as the stratigraphic modified Lorenz plot (SMLP) by Schmalz and Rahme in 1950. The SMLP involves plotting cumulative flow capacity (CFC) against cumulative storage capacity (CSC). To calculate CFC, the permeability of each sample is multiplied by its distance to the next sample, while CSC is determined in a similar way using porosity data. Both CFC and CSC values are normalized to 100% in the SMLP. To draw meaningful conclusions, it is important to gather sufficient data within a reasonable distance (Chekani and Kharrat, 2009; Tavakoli, 2018; Mohsin et al., 2023). One of the applications of the Lorenz plot is to identify different zones with different storage and flow capabilities in carbonate reservoirs.

The benefit of incorporating storage capacity and flow capacity in a reservoir characterization analysis using the Lorenz plot or a similar approach would be to gain insights into the distribution patterns of these reservoir properties (Riazi, 2018). By analyzing the Lorenz curve or a similar representation, you may be able to identify regions or zones with higher storage capacity (indicating areas with larger volumes of hydrocarbons or fluids) and areas with higher flow capacity (indicating better connectivity and permeability for fluid flow).

These insights can aid in decision-making for reservoir development, well placement, production optimization, and resource estimation (Mahjour et al., 2016). Understanding the spatial distribution of storage and flow capacity can guide operators in targeting areas with higher potential for hydrocarbon accumulation and more favorable fluid flow characteristics, leading to improved reservoir management and production performance (Mahjour et al., 2016; Mohsin et al., 2023).

Interpreting a Lorenz plot in the context of reservoir characterization involves analyzing the distribution patterns of a specific reservoir property or parameter (Tavakoli, 2018; Yarmohammadi et al., 2022). Steeper initial slopes on the Lorenz curve indicate areas of the reservoir with higher concentrations of the property being analyzed (Yarmohammadi et al., 2022; Mohsin et al., 2023). These zones represent areas of potential high reservoir quality and may correspond to regions with better porosity, permeability, or fluid saturation. They can be targeted for enhanced production or focused exploration efforts. Flat or less steep sections on the Lorenz curve may suggest reservoir areas with lower concentrations of the property. These zones might be bypassed during development or indicate areas with less favorable reservoir characteristics. Investigating these areas could uncover untapped potential or reveal geological or engineering challenges.

A steep initial slope on the Lorenz curve followed by a plateau or flatter section suggests the presence of well-connected flow channels within the reservoir. These channels represent preferential flow paths for hydrocarbons or fluids and can guide decisions regarding well placement, hydraulic fracturing, or infill drilling locations (Gunter et al., 1997).

If the Lorenz curve exhibits multiple inflection points or has a jagged pattern, it indicates compartmentalization within the reservoir (Mohsin et al., 2023). This means the reservoir is divided into distinct compartments with limited fluid communication. Identifying these compartments helps in understanding fluid flow patterns and optimizing production strategies (Mahjour et al., 2016).

Sudden changes, sharp inflection points, or irregular patterns in the Lorenz curve may indicate geological features such as faults, lithological changes, or reservoir boundaries. These areas may require specific attention during reservoir modeling, simulation, or field development to account for variations in reservoir properties and fluid flow characteristics (Gunter et al., 1997; Riazi, 2018).

In Figure 10, a Lorenz diagram is drawn using the available data from well number 1. The analysis of this diagram shows that there are basically three main flow units, as depicted from the three-line gradients. The Upper part of the reservoir (red line), consists of a unit with low flow capacity (only 10%). The middle part of the reservoir (black line), provides 70% of the flow capacity. The Lower part of the reservoir (yellow line), provides 10% of the total flow capacity. Comparing these three zones, the middle black line is the best zone for fluid flow in well No. 1 due to its high slope. two main inflection points can be identified in the plot of well number one. These inflection points are aligned with the lithological changes in the reservoir. It seems that the changes in lithology that have caused changes in porosity and permeability are the main reason for the creation of these different zones and inflection points.

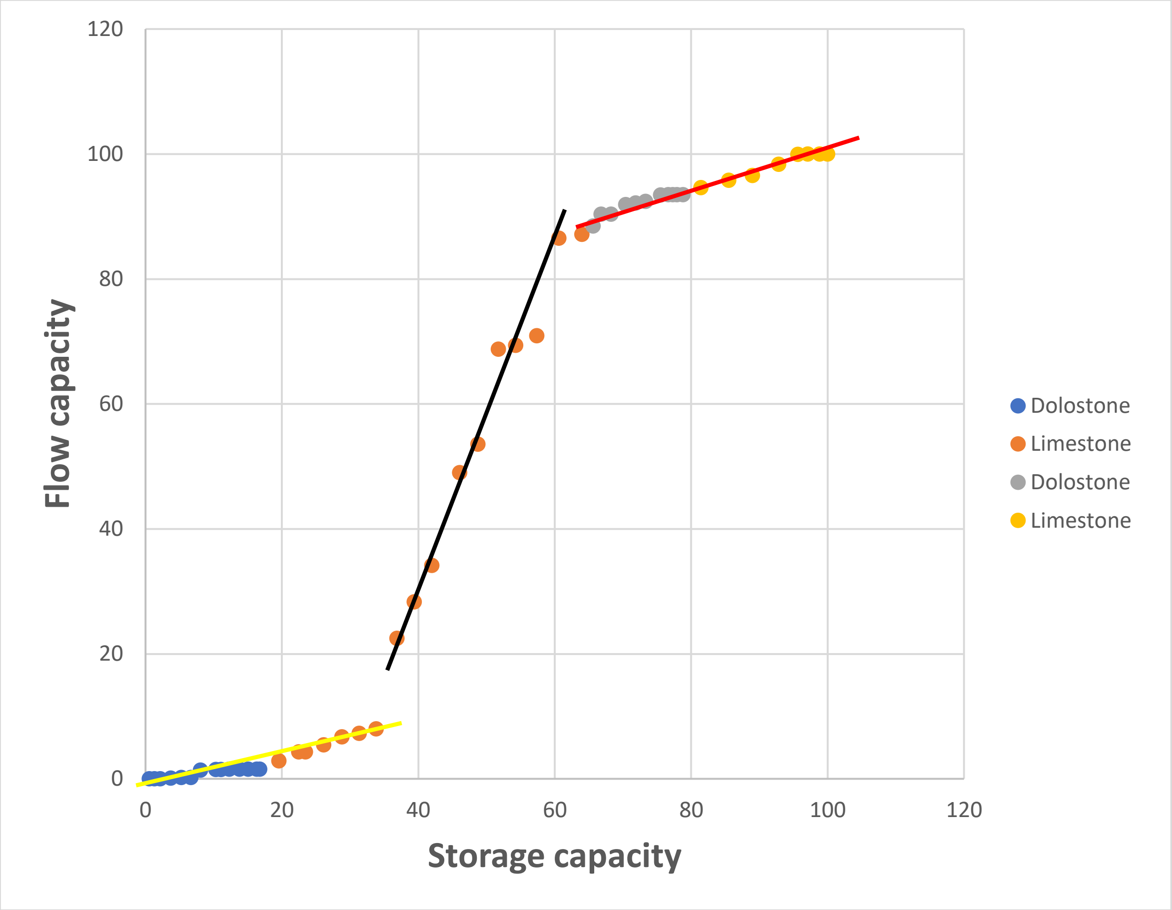

Figure 10 Stratigraphic modified Lorenz plot for well No. 1 data.

In well No. 2, where the Simsima Formation is mainly composed of dolostone and a very small percentage of the remaining limestone, Lorenz's plot shows that there are four main flow units. that the best quality can be considered for the middle flow unit (yellow line) (due to its high slope) in the Lorenz plot drawn for the samples of this well, it is clear that there are no very sharp inflection points in this diagram and the boundary between the flow units It is slower, the main reason for which can be the uniformity of the lithology of Simsima Formation in this well (Figure 11).

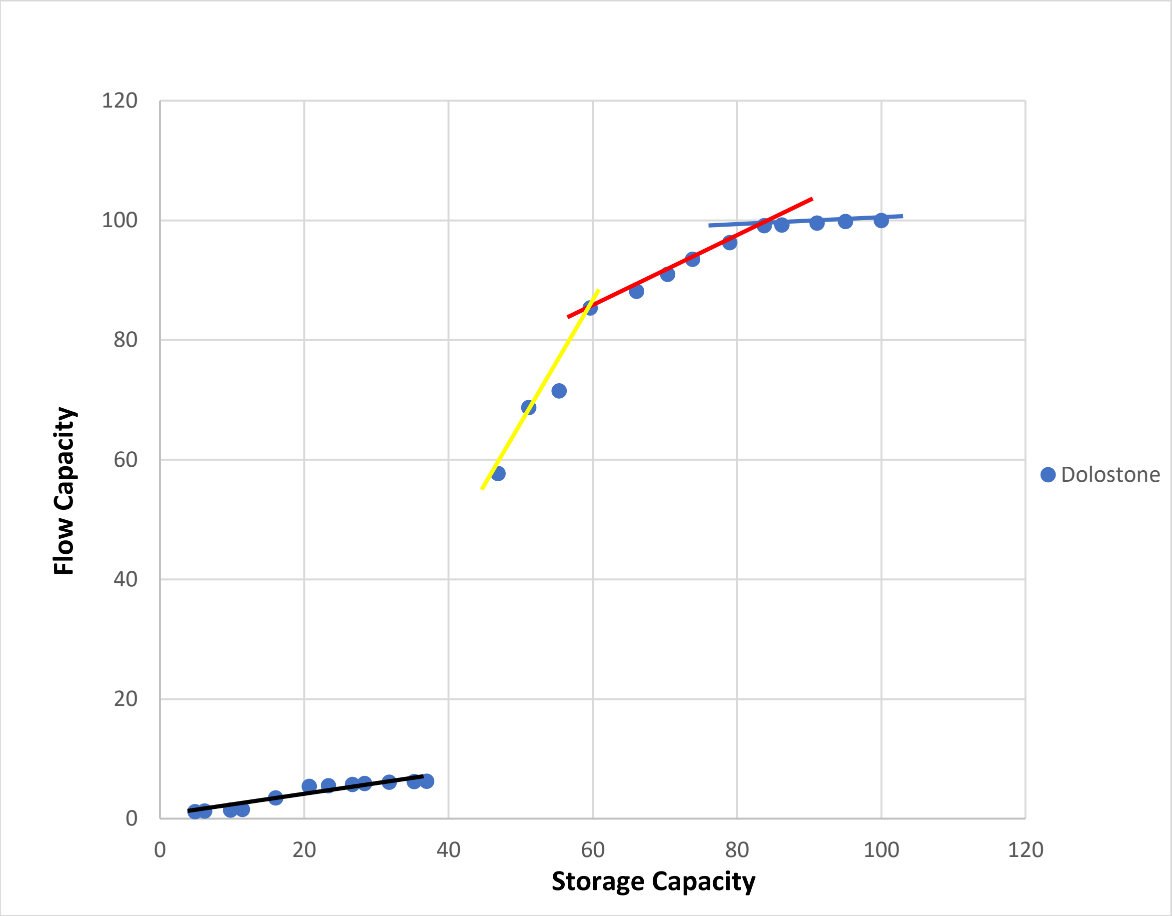

Figure 11 Stratigraphic modified Lorenz plot for well No. 2 data.

Lorenz plot was drawn for well number 3 by using available data. As shown in Figure 12, five main flow units have been identified for this well. In terms of quality, the middle flow units (blue and green lines) are better than other units. There are four main inflection points in the Lorenz diagram drawn for this well, which seem to have been created due to the effect of dolomitization and the difference in the amount of dolomitization in the reservoir rocks of the Simsima Formation (Figure 12).

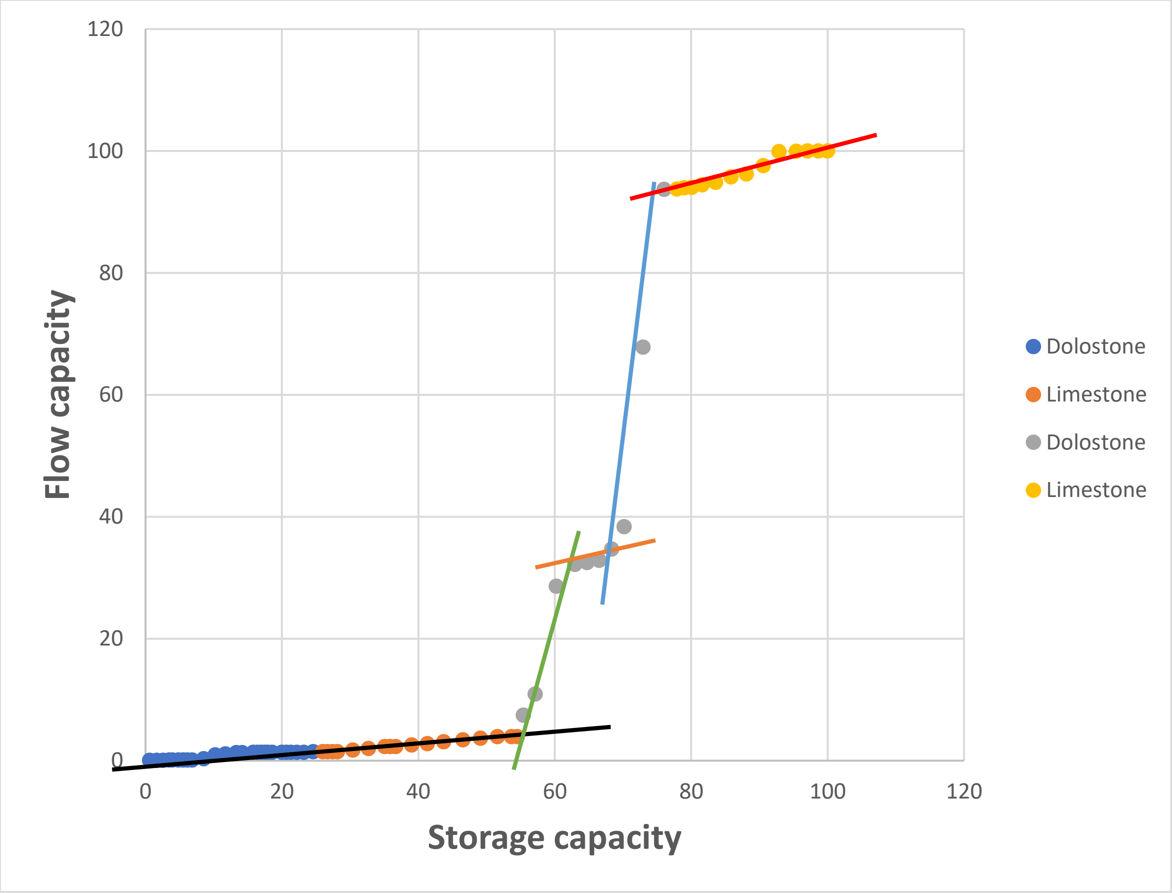

Figure 12 Stratigraphic modified Lorenz plot for well No. 3 data.

6 Conclusions

The main purpose of this study is to investigate the effect of dolomitization on the quality of the reservoir properties of the Simsima Formation. The data of this research was collected from three wells in one of the hydrocarbon fields in the south of the United Arab Emirates. The analysis of this data shows that secondary dolomitization, which is a complex process of diagenesis in carbonate rocks, can have a different effect on hydrocarbon reservoirs. In other words, the effect of the dolomitization process cannot be simply considered positive or negative because various factors can change the effect of dolomitization on the reservoir. For instance, the ratio of dolomitization is one of the most important factors. By examining the samples of the Simsima Formation in three studied wells, it is clear that the percentage of dolomitization has an inverse relationship with the reservoir quality. In other words, it can be said that dolomitization up to a certain level increases the quality of the reservoir in the Simsima Formation, and if the dolomitization exceeds a certain limit, it causes a severe decrease in the quality of the reservoir. In addition, in this study, the most important flow units in the Simsima Formation have been identified by drawing the Lorenz plot. The important point in the identification of flow units is that the boundary of these units almost coincides with the boundaries of lithology change. In other words, lithological changes are one of the most important factors controlling reservoir quality.

In general, it can be said that in the Simsima Formation, the zones that are composed of 80% limestone and 20% dolostone have the best reservoir quality. And on the contrary, the zones that consist of more than 90% of dolostone and the percentage of limestone in them is much less are the worst reservoir zones in the Simsima Formation.

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