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Petrophysical Evaluation of Cretaceous System Sediments in Amu DaryaBasin

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ABSTRACT

The Mesozoic era represents a critical period for the formation and accumulation of global hydrocarbon resources due to favorable geological and geochemical conditions. This study investigates the geological and geochemical controls on hydrocarbon generation, migration, and accumulation, with a particular focus on Cretaceous petroleum systems. The objective is to evaluate source rock quality and reservoir properties using an integrated dataset and multidisciplinary analytical approach. The methodology combines geological interpretation, geochemical characterization, and reservoir engineering analysis. Well data were utilized to assess key petrophysical properties, including porosity, permeability, and water saturation. In addition, geochemical parameters such as total organic content, organic matter type, thermal maturity, and kerogen classification were analyzed to determine hydrocarbon generation potential and maturation level. Structural and stratigraphic frameworks were also considered to evaluate migration pathways and trapping mechanisms. The results indicate that

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Cretaceous sequences are characterized by high-quality source rocks with predominantly oil-prone kerogen types and sufficient thermal maturity for effective hydrocarbon generation. Reservoir intervals exhibit favorable petrophysical characteristics, including adequate porosity and permeability, which enhance storage capacity and fluid flow efficiency. Furthermore, the presence of well-developed structural and stratigraphic traps contributes to efficient hydrocarbon accumulation and preservation. The integration of geochemical maturity indicators with reservoir quality assessment demonstrates a strong correlation between source rock richness and effective petroleum system development. Overall, the findings confirm that Cretaceous petroleum systems provide highly prospective conditions for hydrocarbon exploration. The study highlights that a combined geological and geochemical evaluation approach is essential for accurately characterizing petroleum systems and improving exploration success in sedimentary basins.

Keywords:Amu Darya,Cretaceous,GeochemistryHydrocarbon , Petrophysics.

1.**INTRODUCTION**

اَلْحَمْدُ للهِ رَبِّ العَالَمِينَ وَالصَّلاَةُ وَالسَّلَامُ عَلى سَيدِالْمُرْسَلِينَ وَعَلَى اَلِهِ وَصَحْبِهِ اَجْمَعِينَ.

Time is an important principle in the recognition and development hydrocarbon reserves, which is planned according to the geochronology table for oil and gas fields and the formation of hydrocarbon deposits, exploration and exploration according to the investigations of the time of production, generation and migration of hydrocarbons. The evolution of the crust on the face of the earth has gone through different but regular cycles of orogeny that each mobile belt was created at a specific time and represents special conditions from a historical, vital and geographical point of view (Rabbani, 2008). Similarly, oil and gas are also formed in a regular and almost consecutive cycles, which depends on the death of animals and plants, which hydrocarbon deposits are the result of the remains of these organisms. Probably, most of the organic sediments were deposited in certain conditions and time, and after millions of years, they have been converted into hydrocarbon producing materials and then into oil and gas (Rezaei, 2001).

Stratigraphy (the sequence of accumulated sediments) are an important isuse different sedimentary that describes the petroleum system and

layers. In a petroleum system, the first step from a geological point of view is to distinguish the source rock, in which geological time, the reservoir rock in which conditions and time, and From the point of view of sediment conditions and geochemical characteristics, what are the features of Posh Sang, which is important and vital for the next stages of exploration, extraction, modeling of sedimentary basins and proposing better exploitation methods.

The Mesozoic Era started from about 250 million years before today and continued until66 million years before today, and various changes in the face of the earth took place in this era and from a geographical point of view and the formation of sedimentary basins in the beginning of this era the first stages of formation and deposition of sedimentary materials have , taken place(Rabbani, 2015).

Jurassic and Cretaceous systems are a subset of the Mesozoic era, in which the deposition of organic materials and the formation of sedimentary basins took place in all three periods, but this hydrocarbon sedimentation reached its peak in the Cretaceous period, and most of the world's hydrocarbon sedimentary basins have a Cretaceous age.

About 27 % known as the main hydrocarbon areas of the world. In this article, we will evaluate Cretaceous sediments in the north of Afghanistan and try to clarify whether this is legal in different areas in small reservoirs and Is it true or not? And which conditions of the Cretaceous period can be considered effective in the deposition and burial of organic materials

Table1: Distribution of oil and gas fields according to geological life in the world(Rezaei, 2001).

No	Geological age (geochronology) in millions of years			Type of fields	Percentage of fields
	Prioud name	Start	finish		
1	Newgen	23.0	Today		18
2	Paleogene	65.5	23.0		21
3	Cretaceous	145.5	65.5	Main	27
4	jurassic	201.6	145.5		21
5	Triassic-Permo	299.0	204		6
6	Carboniferous	359	299		7
Collection					100 %

Inthe north of Afghanistan, there are two general petroleum systems that have been stabilized in most areas, and several local petroleum systems Khwaja Gugerdakwhich are the main systems in the Lower Cretaceous , and one system in the Upper Cretaceous and a joint system of the Upper Cretaceous with the Paleogene, new geochemical evaluations and sedimentary basin modeling is less done in this research, these issues are addressed in petroleum systems. It should be mentioned that in most of the researches on oil and gas in Afghanistan, the oil systems are not clearly separated and the productive layers are not clearly specified, which has caused a number of exploration and extraction problems.

One of the principles of Stratigraphic studies in order to understand petroleum systems and petrophysical properties of strata is the assessment of earth time or geochronology, in which the stratigraphy of the sequence of buried sediments, geological conditions and geochemical characteristics of the sequence of sediments are discussed (Tughyan, 2023).

Geochronology is the science of geological time, which states when geological phenomena and processes started and ended, and it is deduced from geological studies and research that all geological events, sedimentation, formation of hydrocarbon basins, animal life, etc. Mostly have regular laws and It is continuously occurring in specific time and place conditions (Rabbani, 2018).

The five major geological eras (Archaeozoic, Proterozoic, Paleozoic, Mesozoic, and Cinozoic) are each separated in to major and important geological events that have different conditions and characteristics (Rezaei, 2001). The Mesozoic era is a period full of tension in terms of geology, tectonics and life, and fundamental changes have taken place in the face of the earth, tectonics, sedimentary basins and life, which can be referred to the development and development of continents, life and extinction of dinosaurs. This era is called the Triassic (T), Jurasic (J) and (CretaceousK) periods. It is clear that each of these periods is important from the point of view of sedimentary basins and hydrocarbon generation(Nazari & Jawhar, 2025).

In the north of Afghanistan, in some areas of the Triassic and Jurassic rich layers have been established, but the Cretaceous -periods, oil and gas period is almost universally recognized as the main layer of hydrocarbon

layers in the Amu Darya basin and its neighboring basins that have been drilled(Nazari & Jawhar, 2025).

The reason why most of Afghanistan's oil and gas fields did not achieve excellent results is the lack of access to good exploitation and geochemistry and the lack of analysis of petroleum system samples. Sedimentary basin modeling is presented.

The expansion and development of the animal and plant kingdomstook place in the Mesozoic era and the researches show that most of the sediments containing organic matter were deposited during this era and created the world's huge oil and gas reservoirs.

The Cretaceous period isT he third and last Mesozoic period, and about 27 hydrocarbon reservoirs belong to this percent of the world's largest period. The Cretaceous period is divided into two parts from the point of view of lower and upper stratigraphy and from the point of view of geochronology into two parts, old and new, which started from 145 million years ago and continued until 65 million years before today (Rabbani, 2015).

2.MATERIALS AND METHODS

This study aims to evaluate the petro physical characteristics of the Cretaceous sedimentary system within the Amu Darya sedimentary basin in northern Afghanistan, based on a descriptive–analytical approach. In the first step, the stratigraphic and geochronological framework of the area was established using data from drilled wells to determine the position of the Cretaceous sediments relative to the Triassic and Jurassic systems. Differentiation of the Lower and Upper Cretaceous horizons, identification of unconformities, and analysis of depositional environments formed the basis for recognizing reservoir sequences, source rocks, and seal formations.

In the next stage, lithological and structural investigations were conducted to identify rock types, textures, porosity levels, and diagenetic conditions. Data were collected from drilling reports, core samples, flow tests, and well log information in the Khawaja Gurgurak, Yatim Taq, Angut, Qashqari, Aq Darya, Andkhoy, and Jangal Kalan areas. This stage enabled differentiation of sandstone, carbonate, dolomitic, marl, and evaporate units, and the identification of reservoir-prone layers as well as protective seal formations(Klett & anothers, 2012).

In the main part of the study, petro physical evaluation focused on parameters such as porosity, permeability, water saturation, and net reservoir thickness. These data were extracted through core analysis, laboratory results, and interpretation of petro physical logs, and were then correlated between wells (Nazari & Jawhar, 2025). Variations in reservoir properties across the structural highs and lows of the basin were compared, and based on this, the petroleum system elements—including source rock; reservoir rock, and seal—were interpreted to scientifically assess the role of the Cretaceous sediments in the hydrocarbon potential of the Amu Darya basin(Klett & anothers, 2012).

3.RESULTS

The Cretaceous period has been important in oil and gas engineering and mineral geology in every way, and the hydrocarbon properties of this period have been evaluated from the geological and geochemical point of view in the sedimentary basins of northern Afghanistan, and the location and validity of expansionof hydrocarbons and organic materials producing oil and gas have been evaluated. In this period, it is one of the most practical problems of oil and gas engineering in the world, especially in Afghanistan, which is useful and necessary for effective exploration, extraction and exploitation.

3-1 Oil and gas deposits before Cretaceous

Triassic system: Although the Triassic sediments are very thick according to the drilled wells in the north of the country, they do not have an oil system as a whole.

In terms of lithology, Triassic sediments are mostly sandstones and siltstones, which have a good thickness. Scientists consider the reason why Triassic period sediments lack good oil reservoirs due to intense shaking and various tectonic processes.

From the geochemical and geological point of view, the sediments of productive hydrocarbon layers must have at least 15% porosity, which is one of the main petrophysical parameters of a reservoir, porosity and permeability in the rocks of the system. However, in the wells drilled in the northern part of the country and the research conducted in this case, the Triassic sediments have up to4porosity, and according to the %

scientists of this field, the Triassic sediments of Tehada are crustal sedimentary basins characterized by masses and magmatic lenses

Jurassic system: The lower and middle Jurassic strata have sandstones with a total thickness of 3000 meters, which were drilled in Khwaja Bolan, Khwaja Gugerdak and Boinghor wells and have different thicknesses of sandstone. These sediments have variable geochemical and petrophysical properties, and the porosity of the sediments11-12and % the permeability of reservoir rocks is up to 200 darcy milli (Qaim, 2019).

The petrophysical properties of the Upper Jurassic carbonate strata have been highly productive, which has been proven in the hydrocarbon deposits of Khajah Gurdak and Yatim Taq. Due to the fact that carbonate rocks have seams and fractures, the laboratory characteristics cannot state of the layer in depth. From the point of view of express the natural lithology, Jurassic Carbonate layer is divided into two parts (lower and upper) where limestone is in the lower part and dolomite in the upper part .

The limestone layez (upper area) was tested in well No3of Khwaja Gugerdak area well No 4 of Yatimtaq area and well No1 of Alborz Stractur and the lower area of limestone layer was tested in Well No 3 of Khwaja Gugerdak area, Boinghor area and well No 2of KhwajaBolan. with a flow rate of As a result, a gas flow1/3million cubic meters per day was obtained from the upper area of limestone in the wells of Khajah Gordak and in other mentioned wells, and a small amount of water was observed from the lower area of the limestone layer.

layer related to upper jurassic carbonates was tested in The dolomite wells No5 of Yatimtaq and No 2Andkhoi field, gas flow was obtained from Yatimtaq well and water gushing was observed from Well No2 Andkhoi.

But the research in other wells and well number10of Khwaja Gugerdak field shows that the dolomitic part of the Jurassic carbonate layers has good productivity and gas is present in most of the wells(Klett & anothers, 2012).

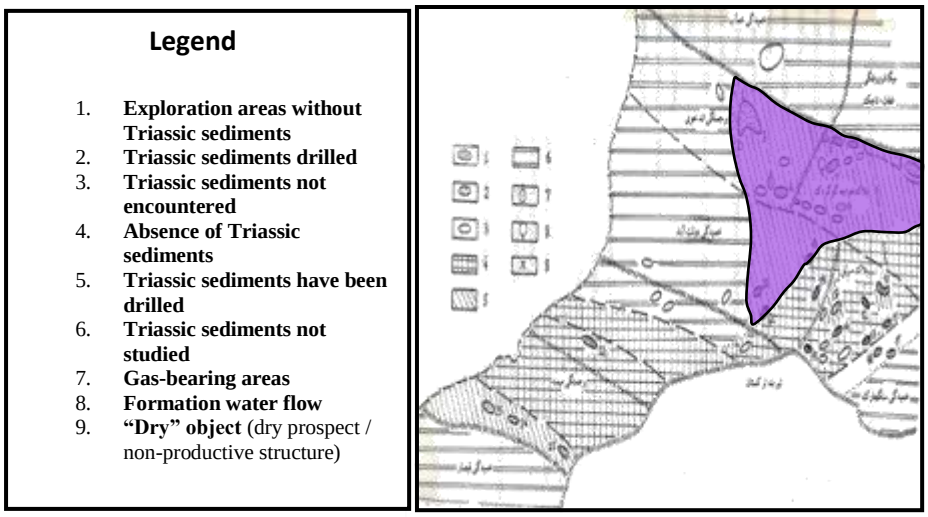


Figure 1: Schematic of the distribution areas and studied sections of Triassic sediments. :The numbers on the map: Areas 1 ,Esk -2 ,Juma -3 - ,Bashikurd4 ,Jargadaq -5 ,Yatim Taq -6 ,Bainghor -7 -Khwaja ,Gurdak 8 ,Koh Alborz -9 ,Angut -10 .Shiram -11 ,Kariz -12 ,Qezal Shiram -13 - Suzeme Qala14 ,Aqdaria -15 ,Bilangor -16 ,Sa Necharak -17 ,Arab Bai - 18 ,Gol Tipeh -19 ,Sarpol -20 ,Aqsai -21 ,Bazarkami -22 ,Khwaja Qol - 23 ,Ali Gol -24 ,Khwaja Seplan -25Jegdalak -. (Nazari, 2012).

mentioned dolomite sediments called Hesar Suit-The above(Kogitan) are known to have excellent permeability from a petrophysical point of view and are separated into two upper and lower parts: Dolomite sediments of colored jointed -the floor have good permeability and consist of clay limestones, jointed organic and oolitic fragments, and congomirate pebbles that are mostly dolomitized(Klett & anothers, 2012).

The dolomite sediments of the roof of Hesar Suite consist of small and sized crystallized dark colored clay dolomites. These sediments -medium have good permeability and the productivity of these layers has been observed in some wells such as Alborz, Boinghor and Khaja Bolan, but the petrophysical properties can vary depending on the location (Mirzad, 2012).

Gordak sediments include the uppermost part of the Jurassic strata (along with small layers of Karabil), a large thickness of salt and carbonate sulfates, and there is a possibility of the existence of local productive layers with sandstone lenses. In Gordak Suite, productive layers

containing oil, gas and water have also been seen. The lithology of these sediments are mostly dolomites, and the tests in well No10 of Khwaja Gogerdak, well No 5 of Yatimtaq, and well No2of Andkhoi show that it has poor permeability, but in the Andkhoi field well Light oil flow and been observed water in some wells have.

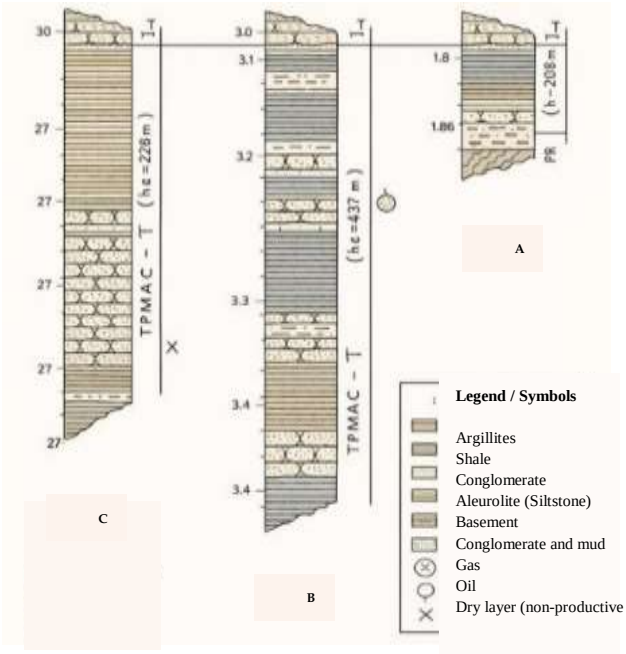


Figure2: Correlation of the sections of drilled wells in Khajah G :ogerdek, Jargadoq and Angut areas, which represent the deep sediments of the Triassic system in the Amu Darya basin, these sediments are mostly and sandstone and reach a maximum thickness of argillites 300meters, gas signs have been seen in some wells And in some wells, it is the place of migration of hydrocarbons and it is probably the source rock of oil and gas (Mirzad, 2012).

3-2 Sediments of Cretaceous system

The sediments of Cretaceous system are diverse from the lithological and petrophysical point of view in the north of the country and are important in terms of oil and gas. Because in this period of time, which covers about 80million years, various vital developments, sedimentation, tectonics, formation of new sedimentary basins, retreat and advancement of oceans

have happened on the face of the earth (Rabbani, 2018). Cretaceous sediments have a complex international and local stratigraphy, and these sediments are separated into two upper and lower parts, which are explained below.

A- These sediments in the Sediments of the lower Cretaceous system north of the country in most of the studied areas are located on top of the international -terms of geochronology Jurassic sediments and in Briacene, Velangine, Hetronine, Barimian,) stratigraphy are divided into -Karabil, Al) The above sediments are known as suites(Aptian and Albin Getrif, Barimin, Okuzbulaq, Kaligrik and Apt and Albin-Morad, Qazaltash the local nomenclature, which is also used in the neighboring countries of Afghanistan.

(From the point of view of geochronology, the sediments of the first)old Cretaceous span about46 million years. The sediments of Sweet Karabil (are mostly sandstones, carbonates, shales and)Valangian-Briacene siltstones, which occur in some areas of the Amu Darya sedimentary basin as the source rock and charge their higher layers with organic hydrocarbon Figure(materials3).

From the petrophysical point of view, the above strata and the sediments Morad suite-of Al(part of Valangin), which are mainly sandstone, mud and valorolites, have low permeability of about3darcy and porosity milli of about10-15%reservoir properties-which are almost non ,.

Velangin sediments these sediments are unconformably located above the Jurassic sediments, which is well recognized in the Qashgari, Angut and Aghdaria blocks. The aforementioned sediments consist of dense clay mud and sandstone layers. At the base of these sediments are layers of destructive, clastic and conglomerate sediments, and the thickness of these sediments in the mentioned areas ranges from90 to 106meters .

Hetronine sediments (Getrif):Hetronine strata is a familiar name for These sediments are widely spread .geologists and oil and gas engineers in the north of Afghanistan and it is known as the productive layer, which is placed on top of the underlying sediments (and consists of)Velangine colored shales with sandstone cementation are-quartz rocks. the date-sand anhydrite environment. Carbonate and alluvial layers are also -in clay observed. From the petrophysical point of view, the sediments of the

Hetronine layer have good porosity, which is due to different field characteristics, the porosity graph increases from north to south, and the porosity increases in the west side compared to the east(Klett & anothers, 2012).

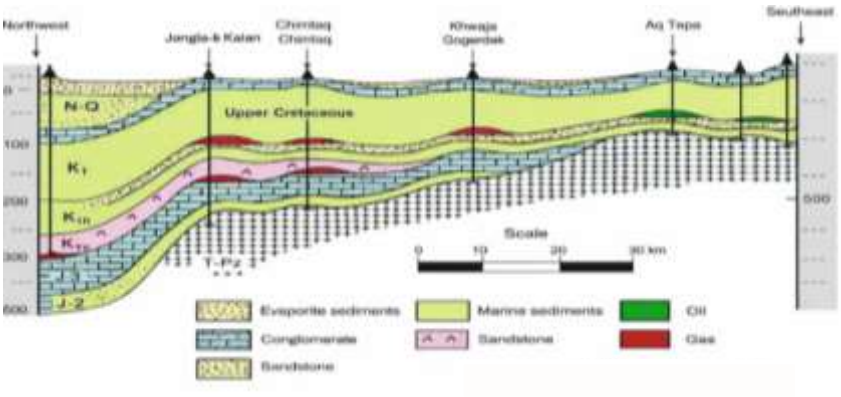


Figure3 : Cross section of Amu Darya hydrocarbon basin and the depth of studied sediments (USGS, 2018).

The porosity of Hetronin (Getrif) sediments varies according to the following rules:

Hetronine sediments are productive hydrocarbon layers that consist of alternating permeable graystones, but the existence of lenses and lenses is impermeable and reduces porosity(Qaim, 2018).

Porosity and permeability decrease with increasing depth and sediments Porosity increases from north to south, which increases by .become denser 3% ,in Jangel Kalan, in Andkhoi 12/8% in % Khwaja Gurdak, and 16/2% Also the increase of porosity towards the east is .)in Shiram block)Sarpol observed in the parts with prominences, but in the Khalm section, the porosity of the sediments of Getrif layers varies from8 to 15%.

Hetronine In the sediments of layers, the permeability is variable, which is603mD in the Alborz Structure 706 mD in the Shiram block, .which are porous sandstones, but in Jangel Kalan in well No3most of , the above sediments are impermeable (Haqbin, 2021).

The effective thickness of sandstones in Sheberghan area and Boinghor GeologicalStructure reaches up to100meters, in Alborz Structure Shiram Block and Andkhovi, this thickness is up to60meters, which is

related to the reduction of hetronine deposits and the increase of flowering in the section. This thickness has been reduced to25meters in the Jangel Kalan area. Permeability in sandstone (in the lower part) varies from100 to600milli darcies in most cases (Wadud, 2014).

Open porosity in these sediments is on average14/4%and effective porosity is about8%and this porosity is almost good for oil and gas reservoirs. The open porosity in the sandstones of the upper part is about 10%on average, which in case of pressure difference, the permeability decreases and even becomes impermeable (Wadud, 2014).

In the upper parts of the Getrif layer (in higher buildings such as Khaja Bolan, Shiram, Alborz, etc.) reservoir properties (porosity and permeability) improve and have good hydrocarbon capacity. According to the above, all Hetronin sandstone layers can be described as good oil Andkhoi and)and gas reservoirs. The sandstones of the depressed areas Jangal Kalan) have reservoirs with good capacity.

Barimin sediments These sediments consist of thin and anhydrite mudstones that have good characteristics of stone cover. Barymine sediments)locally known as barium(have low porosity and permeability, which prevent the escape of hydrocarbons from depth to higher layers (Jawhar, 2022).

In some areas of Amu Darya basin, there are barium deposits with thin layers of10 to 15of limestone and dolomite with fossils meters consisting barimine(which have reservoir properties and have been observed as hydrocarbon productive layers).

The sediments of the Barimin layer are about40meters thick, which are mostly condensed and anhydrite clay muds, and it has the good properties of protecting rock in terms of thickness. This thickness varies in the drilled wells of the Amu Darya basin and reaches up to100meters (Klett & anothers, 2012).

Opt sediments -:Apt sediments (local name)country in the north of the have a wide spread, but they have been less studied from a geochemical point of view. These sediments have been studied in13points of Amu Darya Basin, and the petrophysical properties of these sediments are evaluated as average porosity and permeability, and they form hydrocarbon reservoir layers (Qaim, 2019).

Aptin sediments in the lower consist of alternating sandstones, carbonates)limestone and gypsum(and marls, which also have a small amount of mud and seamed siltstones.

the Opt sediments, there are clayey sandstones and In the upper part of limestone)with a thickness of up to20meters(, and the sandstone layers are evaluated as productive and have a thickness of8 to 27meters in Khaja Bolan and varies from12 to 20 meters in points 5 and 7of Khaja Gurdak. which this thickness decreases to ,6meters in Andkhoi and to zero in Jangal Kalan. According to the above, the average reservoir properties in these layers can be considered.

These sediments are divided into three smaller layers _-:Albin sediments with the local name Alpe Nazar according to their lithological and petrophysical properties, and each part has different properties. The bottom layer consisting of gray clays and sandstones has dense carbonate layers, the sandstones are up to15meters thick in the northern ridge of the country and are completely lost in Andkhoi and up to6meters in Yatim Taq, Khajah Gurdak and Khalm and in the chimney areas and Qara Batur is up to24meters thick. The upper layers consist of limestone, condensed marl, mudstone and sandstone(Klett & anothers, 2012).

The porosity of sandstones in the Lower Albin sediments is about15% but the permeability of these sediments is very low and is about2 the Albin millidarcy. According to the flow of oil and gas obtained from sediments, it can be said that the middle layers have excellent hydrocarbon properties, which consist of rock Rigi is limestone with a thin layer of clay. The thickness of these sediments is reduced in Shiram areas, but the thickness of clay layers increases.

Although temporary hydrocarbon flows have been obtained in Yatimtaq, Khaja Bolan and Jangal Kalan wells, and also in Angut, the flow of oil from this layer has been obtained, which was more than30tons per day, but it was stopped later.

thickness of these sediments in Angut area is about The240meters. In general, it can be said that the middle layers of the Albinian strata have productive graystones and have moderate petrophysical properties (Klett & anothers, 2012).

Table 2: Petroleum System and Key Hydrocarbon Potential Properties of the Lower Cretaceous (Neocomian) Sediments in the Amu Darya Basin

No.	Stratigraphic Unit / Suite / Formation	Local Name	Petroleum System Role	Exploration & Economic Significance	Fluid Type and Relative Occurrence	Reservoir Quality
1	Upper Al-Morad (K1v) – Clays and Aleurolites	Upper Al-Morad	Seal (Cap Rock)	Key role in preserving hydrocarbon accumulations	No porosity and permeability; no fluid content	Non-reservoir; excellent sealing quality
2	Lower Barremian (K1br), Okuzbulak Suite, Unit XIII	Lower Barremian	Secondary (Associated) Reservoir	Moderate importance; complementary role in petroleum system	Oil and gas in hydrodynamic connection with Getrif	Moderate quality; continuous with Getrif unit
3	Hauterivian (K1h), Qazaltash Suite, Unit XIV (= Getrif)	Getrif / Qazaltash	Main Reservoir	Highly significant; 11 hydrocarbon fields discovered	Oil, gas, and gas-condensate; largest known accumulations	Good to very good quality; multi-layered reservoirs
4	Valanginian (K1v), Karabil–Al-Morad Unit (XIVa)	Karabil–Al-Morad	Local/Secondary Reservoir (Migration Pathway)	Moderate exploration potential	Formation water with dissolved gas; minor hydrocarbon accumulations	Moderate quality; limited lateral extent
5	Neocomian Complex (K1n)	Lower Cretaceous (Tabashir)	Complete Petroleum System	One of the most important petroleum systems in northern	Oil, gas, and condensate (stratigraphic and structural traps)	Sandstone reservoirs with shale seals

B- Sediments of the upper Cretaceous system: The sediments of the upper part of the Cretaceous system are also divided into smaller stages, which are described below from bottom to top:

These sediments have two layers of limestone with -:Sinman sediments the top of Sinman sediments there are small layers of sand stones, in interesting hydrocarbon sands called tagarine, and its thickness varies from 20 to 40meters in Khajah Gurdak and the maximum thickness of the layer Tagarin is fruitful in the building of Yatimtaq and Angut The other limestone , which is -graystone is limestone with thin layers of sandstone located in Sinman carpet and its thickness is about12meters .

From the point of view of porosity and permeability, these sediments have average properties, in some wells, water flow and in some wells, such as Yatam Taq, gas and condensate flow have been obtained (Ulmishek, G. F. (2004).

These sediments are known by the local -Turonin sediments:-Sinonin names of Sinon and Turon and have two productive grayzones that are about10Santon sediments -meters thick, which are related to Kaniac located at an interval of 450meters. It has moderate porosity and permeability and gas flow has been observed.

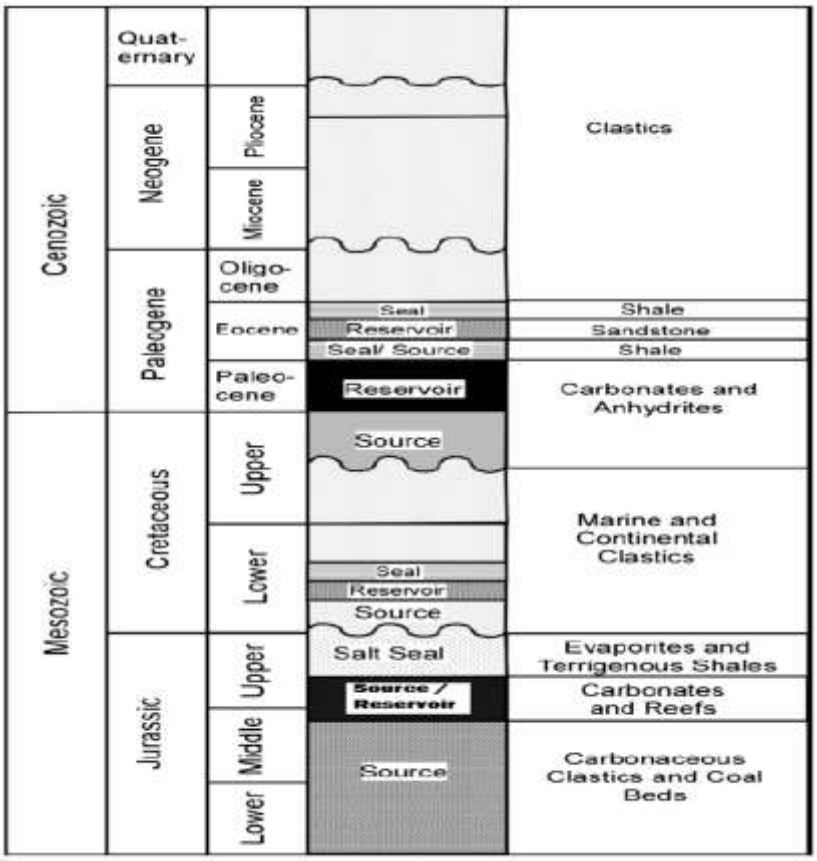
Table 3. Comparison of Petrophysical Properties of Aptian (Unit XII) and Lower Albian (Unit XIa) Sediments, Amu Darya Basin

No.	Petrophysical Properties	Aptian (Unit XII)	Lower Albian (Unit XIa)
1	Main Lithology	Feldspathic sandstone, aleurolite, limestone with thin layers	Sandy limestone, sandstone, clay
2	Color	Gray to reddish	Gray
3	Cement Type	Carbonate and clay	Carbonate–clay
4	Total Porosity	10–27.7%	10–23.8%
5	Effective (Open) Porosity	11–17%	10–21%
6	Permeability	2.5–395 mD (average: 50–100 mD)	3.9–120 mD (maximum: 236 mD)
7	Oil Saturation	65–74%	61–74%
8	Gas Saturation	Up to 64%	Up to 64%
9	Formation Thickness	10–94 m	10–25 m
10	Net Pay Thickness	5.7–15.6 m	3.0–13.8 m
11	Bulk Density	2.01–2.36 g/cm³	Similar
12	Carbonate Content	4.7–22%	Variable
13	Reservoir Quality	Excellent to very good	Moderate to good
14	Fluid Type	Oil, gas, CO_2	Light oil, gas, minor condensate
15	Reservoir Continuity	High	Limited and more discontinuous

The other gray zone is related to the limestone of the lower sediments of Santon, where the gas flow was found at a depth of348meters in Yatim and in the interval of ,Taq1709 .meters at point No 1of Jangal Kalan, these sediments were also seen and the gas flow was found, and after the fields of Yatim Taq in the south The thickness of these sediments decreases and eventually disappears. (British Geological Survey 2011).

These sediments are -Upper Campanian and Maastrichtian sediments: Maastrichtian, which in some parts -known by the local name Campanian are580meters thick and have sandstones and quartz sands, which have excellent reservoir properties from the point of view of petrophysical properties and are among the best hydrocarbon reservoirs in the north. It is considered a country (Azizi, 2016).

The porosity obtained from Upper Campanian and Maastrichtian sandstone samples in Kariz varies up to19%and the permeability of these sediments is about200millidarcy. These sediments have good basins, but there . petrophysical properties in the Amu Darya and Marghab Sharif-e-are very few or none in Mazar (Qaim, 2016).



Petroleum system and hydrocarbon deposits of Amu Darya basin in the north of the country (Wadud, 2014).

3-3 Paleogene sediments-Common Cretaceous

The sediments of the upper Cretaceous Maastrichtian -Ghori Suite: and are known by the local name)Datin(the lower layers of the Paleogene bearing layers of Afghanistan are related to -Ghori Suite, most of the coal these sediments, and the lithology of these sediments consists of dense and jointed dolomitized carbonates (Azizi, 2016).

dolomite and anhydrite, these sediments have ,It is composed of clay, marl been drilled in all the wells in the north of the country and have different thicknesses, which is up to300 meters in Angut and up to 500meters around in Qashgari (Jawhar & Nazari, 2025).

Dat and Pliocene (In a part of the past researches, the lower Paleogene and Aghjar)Bukhara Suite(sediments named Bukhara Formation Formation were studied, and these sediments were observed in the border and ,areas of the northern part of the country with the northern neighbors in the oil and gas wells of the mentioned countries as lime. Bukhara sweet is known to exist in the northern parts of the Afghan Tajik and Amu Darya basin sediments (Qaim, 2019).

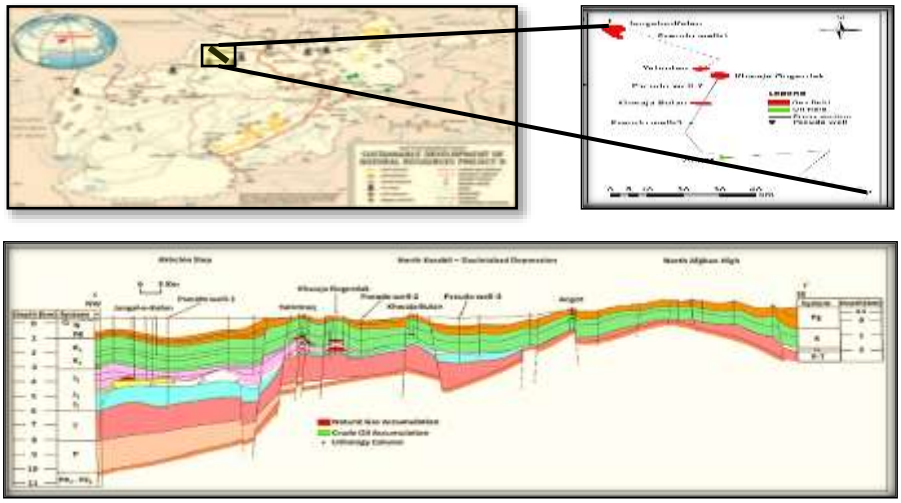


Figure3: Transverse sections of Permian (Triassic, Jurassic,)Paleozoic Cretaceous, Paleogene, Neogene and Quaternary sediments, which are shown with the thickness and depth limits of the drilled wells, the correlation of these sections shows that the sediments of the Cretaceous period It has a special importance for oil and gas, and it is mostly gas rich in the areas of Jangal Kalan to Khajah Gurdak, and in the areas of the northern Tahdab ridge and Shiram Sarpol block in Khajah Angut, Qashgari and Aqdaria fields (Fooshanji, 2021).

4. DISCUSSION

The results of this study demonstrate that the Cretaceous system sediments of the Amu Darya Basin in northern Afghanistan play a significant, though spatially variable, role in the regional petroleum system. Integration of stratigraphic, lithological, and petrophysical analyses provides a clearer understanding of how reservoir quality, seal efficiency, and hydrocarbon potential are controlled by both depositional and post-depositional factors.

Stratigraphic and Depositional Controls: The stratigraphic framework established from well data shows that the Cretaceous succession is positioned between older Triassic–Jurassic units and younger formations, with several unconformities marking changes in sedimentary regimes. These discontinuities likely influenced hydrocarbon migration pathways and compartmentalization. Variations between Lower and Upper Cretaceous units indicate shifts in depositional environments from more clastic-dominated settings to carbonate and evaporitic conditions, which directly affected reservoir heterogeneity.

Although the thickness of Cretaceous sediments in the Afghan sector of the Amu Darya Basin is generally, lower than in neighboring northern countries, their stratigraphic continuity and favorable lithofacies associations allow for the development of effective petroleum system elements within limited vertical intervals.

Lithological and Diagenetic Influence on Reservoir Quality: Lithological evaluation shows that reservoir intervals are mainly associated with sandstones and carbonates, with dolomitization locally enhancing secondary porosity. The presence of marls and evaporites provides competent sealing units, supporting the formation of stratigraphic and structural traps. Diagenetic processes such as compaction, cementation, and dissolution have had contrasting effects: while cementation locally reduced permeability, dissolution and dolomitization improved pore connectivity in some intervals.

Structural features and fracture systems observed in cores and well logs further contribute to permeability enhancement, especially in tighter carbonate units. These factors explain why even relatively thin Cretaceous units can retain commercial hydrocarbon accumulations.

Petrophysical Characteristics and Reservoir Performance: Petrophysical analysis confirms that porosity and permeability are the key parameters controlling reservoir performance. Core and log data show that, despite limited thickness, certain intervals exhibit favorable porosity and hydrocarbon saturation. Water saturation values and net reservoir thickness vary between structural highs and lows, suggesting that structural position strongly influences fluid distribution.

The relatively good hydrocarbon saturation and signs of adequate thermal maturity indicate that source rock intervals within or below the Cretaceous succession have generated sufficient hydrocarbons, and that migration into available reservoirs has been effective. This supports the interpretation of an operational petroleum system in the basin.

System Integration and Exploration Implications: One of the key findings of this research is the importance of integrating geological, petrophysical, and modeling stages in resource development. The study highlights that incomplete linkage between exploration, evaluation, and production stages can lead to underutilization of hydrocarbon resources. By contrast, detailed petrophysical evaluation, followed by two- and three-dimensional modeling, provides a realistic image of subsurface reservoirs and reduces geological uncertainty.

The results suggest that future exploration strategies in the Afghan sector of the Amu Darya Basin should focus on:

Detailed petrophysical characterization of thin but high-quality Cretaceous reservoirs

Identification of diagenetically enhanced zones

Structural highs with improved hydrocarbon saturation

Integrated basin modeling to better predict reservoir distribution

Although Afghanistan's hydrocarbon reserves are relatively limited compared to major producing countries, the study demonstrates that scientifically guided evaluation can maximize recovery from existing resources. Even modest reservoir intervals, when properly characterized and managed, can contribute significantly to national energy development.

5.CONCLUSION

Petrophysical research in the hydrocarbon fields of the Amu Darya basin is very important and valuable because Afghanistan's oil and gas reserves are very small compared to the countries that have oil and gas, so these valuable underground reserves should be carefully and using modern knowledge. exploited to extract maximum hydrocarbons.

The petrophysical properties of oil system sediments, which include parent rock source rock), reservoir rock and cover rock, are important because the more we measure and identify the characteristics of oil and gas reservoirs, the better systems and methods You can choose to explore.It should be remembered that the process of using underground resources (oil, gas, water and various mines) is a set of different processes that are carried out together with integration and coordination and through

several stages, and this coordination is one of the successes and necessities of resource exploitation. it is normal. If there is no coordination and sequence between the stages of knowledge and geology of the region to the exploration and extraction of mining areas, none of the processes will be carried out successfully.

Unfortunately, in the extraction and exploitation of oil and gas wells and most mines of solid useful materials in our country, there is less sequence of exploration to extraction and most of the processes remain incomplete, useless and incomplete.

In order to better advance the exploration and extraction affairs, it is necessary to carry out petrophysical investigations and evaluation of reservoir properties in oil and gas reservoirs in the first step, and then interpret various modeling based on the results of the above evaluations, -dimensional and three-and based on those models, to the models Two dimensional obtained, to obtain the status, conditions and characteristics of the underground reservoirs.

The petrophysical properties of the rocks of the oil and gas column have provided us with a real picture of the underground hydrocarbon bed, which clarifies the reality of the reservoir compared to our perception and shows the hydrocarbon systems more clearly. Cretaceous sediments have good petrophysical properties, and porosity and permeability are the most important of these properties. However, in the Amu Darya basin, most of theCretaceous sediments are thin and have less reservoirs compared to the northern neighboring countries, but the same amount has good saturation and thermal maturity properties. which was clearly explained rich area-in the above tables in each oil.

Recommendations: Considering the spatial variability and relatively limited thickness of Cretaceous reservoirs in the Amu Darya Basin, it is strongly recommended that future studies focus on more detailed and systematic sampling across different structural zones. Increasing the density of sampling points, especially in underexplored areas such as Jangal Kalan, Andkhoy, and marginal basin zones, will significantly improve the accuracy of reservoir characterization and reduce geological uncertainty. Improving the quality of sample identification and classification is another critical requirement. Advanced petrographic

analysis, including thin section studies, scanning electron microscopy (SEM), and X-ray diffraction (XRD), should be applied to better distinguish lithological variations, diagenetic alterations, and pore system evolution. Accurate identification of rock types and mineral composition will enhance the understanding of reservoir heterogeneity and hydrocarbon storage capacity.

The study highlights the importance of expanded laboratory investigations to refine petrophysical and geochemical interpretations. It is recommended that comprehensive laboratory measurements, including porosity, permeability, capillary pressure, fluid saturation, and geochemical parameters (TOC, Rock-Eval pyrolysis, kerogen typing), be conducted on a larger number of core and cutting samples. Such analyses will provide more reliable input data for reservoir modeling and resource estimation. In addition to laboratory work, intensive field (surface and subsurface) investigations should be carried out. Field studies, including outcrop analysis, structural mapping and sedimentological logging, can provide valuable analogs for subsurface interpretation. Integration of field data with well logs and seismic data will improve the understanding of depositional environments, structural controls, and reservoir continuity.

Finally, it is recommended to adopt a fully integrated and multidisciplinary approach combining geology, geochemistry, petrophysics, and reservoir engineering. The use of advanced 2D and 3D reservoir modeling, basin modeling, and simulation techniques should be expanded to better predict hydrocarbon distribution and optimize exploration strategies. Strengthening coordination between exploration, evaluation, and production stages will ensure more efficient utilization of Afghanistan's limited hydrocarbon resources and enhance long-term energy development.

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