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Reservoir Characterization of Pila Spi Formation (Middle–Late Eocene) in Shaqlawa and Shekhan areas, Kurdistan Region, Northern Iraq

Edris M. Pirot, Ayad N. F. Edilbi

Petroleum Geoscience Department, Faculty of Science, Soran, Iraqi-Kurdistan Region

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Corresponding Author:

Name: Edris Mohammed Pirot

E-mail: *edris.pirot@petg.soran.edu.iq*

Tel:

ABSTRACT

This study investigates reservoir quality for the Middle–Late Eocene Pila Spi Formation in Shaqlawa (Sarkand) and Gulley Keer (Shekhan) areas in Kurdistan Region of Iraq. Lithologically, the Pila Spi Formation in the studied sections is composed of limestone, dolomite, dolomitic limestone, chalky limestone, and marl. The thickness of the formation is about 102m and 200m in Sarkand and Gully Keer sections respectively. In order to evaluate the reservoir characterization of the studied formation, different techniques such as a microscopic study and core plug analysis were used. The Pila Spi Formation is characterized by several pore's types namely; vugs, moldics, channels, interparticles, fractures, boring, fenestral, and intragranulars. Several diagenetic processes were also recognized such as dolomitization, pressure solution, stylolization and dissolution. Based on the petrographic study, the lower part of the formation in Sarkand section has a porosity average of 8%, while it has an average of 21% and 17% in middle and upper parts. In Gulley Keer section, the porosity values of the formation are about 9%, 17, and 19%, in the lower, middle and upper part, respectively. The Scanning Electron Microscope (SEM) study shows almost the same porosity values, and the pore's sizes are between micropore to mesopore for the studied sections. Furthermore, the results of the core plugs analysis are roughly in agreement with optical assessments since the measured porosity values from Sarkand section are 8%, 18.5%, and 18% for lower, middle and upper parts, respectively. The porosity values of Gulley Keer section for lower, middle and upper parts of the studied section are 2.5%, 17.25%, and 22.5%, respectively. Consequently, the results revealed that the Pila Spi Formation has a good porosity except the lower part. In regards with permeability, the measured values of permeability displayed an avenge of 0.109md and 0.6698md for Sarkand and Gulley Keer respectively in which suggested fair to good permeability.

1. Introduction

The porosity of a rock is a measure of its ability to hold a fluid. Mathematically, it is the open space in a rock divided by the total rock volume (solid and space), and the permeability of a rock is a measure property of the rock to permit the passage of fluids [1]. Many studies have been conducted on the Pila Spi Formation in Iraq and its equivalent in surrounding countries. According to Wetzel in [2] the original type section of Pila Spi Formation in Iraq was sunk under the waters of the Derbendikhan dam reservoir, and therefore the supplementary type section was described at Kashati on the Barand Dagh about 10 km to the north of Darbandi Khan Town [2]. [3] studied the lithofacies, dolomitization and potentiality of the Pila Spi Formation at Taq Taq oil filed. They found that the formation was subdivided into four distinctive lithologic units, namely; dolostones, dolomitic limestones, limestones, and chalky limestone. The believe that the reservoir potentiality is greatly enhanced by secondary fracture porosity. [4] in Taq Taq oil field discovered that the Pila Spi has been charged from more than one source rock. and [5] found the porosity values of Pila Spi Formation in Taq Taq oil field range between %5 and %20. Permeability range between 0.1md and 1.0 md. However, the believe that, the reservoir potentiality is greatly enhanced by secondary fracture porosity.

Although the Pila Spi Formation acts as reservoir, rare studies have been carried out on it. The present study area is located in Kurdistan Region-Northern Iraq those areas are important to study Pila Spi Formation, because they are close to two big oil field company from Akre and Shekhan. The Sarkand section is situated about 36km to the northeast of Erbil city on the road to Sarkand village (Fig. 1). The thickness of the Pila Spi Formation in this section is approximately 62m. The second section (Gully Keer) is located about 25km to the east of Duhok city near Lalish village (Fig.1). The recorded thickness in this section is about 200m. According to the Iraqi Tectonic Division, the area is within the High Folded Zone, and regionally within the major zone of the Zagros Thrust Zone and Zagros Fold Belt (Fig. 1). This study aims to evaluate the reservoir characterization of the Pila Spi Formation using an integrated approach of petrographic image analysis (PIA) by using ImageJ that software is used to quantified porosity and Digimizer software's and core plug data analysis (porosity and permeability).

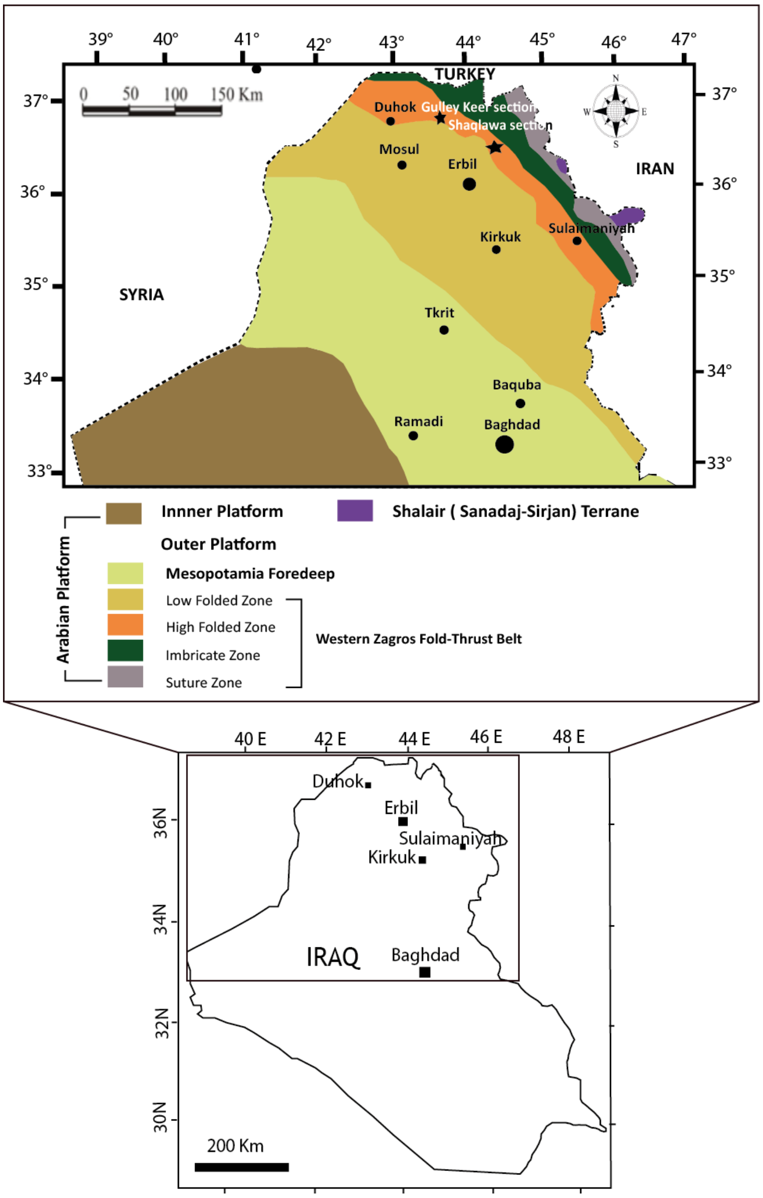

Fig. 1: Location of the studied areas [Shaqlawa area (Sarkand section) and, Shekhan area (Gulley Keer section)] on tectonic zones of Iraq (map is adapted from [6]).

2. Geological Setting

Ditmar and the Iraqi-Soviet Team [7] at the base of the Middle Eocene suggested regional unconformity. The Megasequence AP10 was divided for 2 sequences: Paleocene to Early Eocene and Middle to Late Eocene sequences. at narrow basin between a ridge located along the NE side of Balambo-Tanjero Zone and the uplifted area in the NE the Gercus Red Beds were deposited. To the SW of an emergent uplift the latter was deposited. At the end of the Mid Eocene, from the uplifted area to the basin and the NE the clastic sediments provide was filled with lagoonal carbonates of Pila Spi Formation. The High Folded Zone exists between the Derbendikhan Halabja areas near the Iranian border in the SE and extends to Zakho area, on the Turkish border in the NW (Fig. 1). The thickness of Pila Spi Formation (Middle – Late Eocene) is between (100m-200m) [2 and 8]. The lower part of the formation generally consists of vitreous and porous, hard, well bedded poorly fossiliferous limestones with sections of shell and algal. And the upper part of the Pila Spi Formation consists of bituminous and well bedded of crystalline and chalky limestone, dolomite and dolomitic limestone, white chalky limestone with chert nodules in the top of formation. According to the [2 and 8] the Pila Spi Formation generally comprises of lagoonal sediment with primary dolomite and include algae, miliolids and gastropods fauna. High Folded Zone tectonically belongs to the Unstable Shelf of Arabian platform [8]. The zone is limited to the N and NE by Imbricated Zone and to the S and SW by Low Folded Zone. In Iraqi territory, it covers a small part, about 15827 Km^2 [9]. The contact between High Folded Zone and Low Folded Zone runs parallel to the first continuous ridge of Pila Spi Formation, starting along the Iraqi-Iranian boundaries. The zone's width varies from 25 to 50km. The indication for subduction and the final closure of neo- Tethys Ocean is supplied by calc-alkaline basic and intermediate volcanic rocks of Paleocene-Eocene age which have been showed in NE Iraq (Fig. 2). These rocks formed in back arc or in island arc rifts. These volcanic rocks formed in active margin setting close to the Arabian Plate [8]. During the subduction, two pulses of uplift in Paleocene and Eocene age occurred along the NE margin of the Arabian Plate. The Pila Spi Formation has been deposited during the Middle-Late Eocene [8]. Inside Iraq, Dammam and Avanah limestone formations are correlative, as far as age, and party lithofacies are concerned, with the Pila Spi Formation. The lowermost beds of the Pila Spi Formation are younger than Dammam, and most probably of the Avanah Formation. Outside Iraq, in northeast Syria the Midyat Limestone Formation Weber [10], and in south Turkey Altinli [11] are believed to be equivalent of the Pila Spi. The Pila Spi Formation can also be correlated with the stripe of the Jahrum Formation of the east Iranian [8].

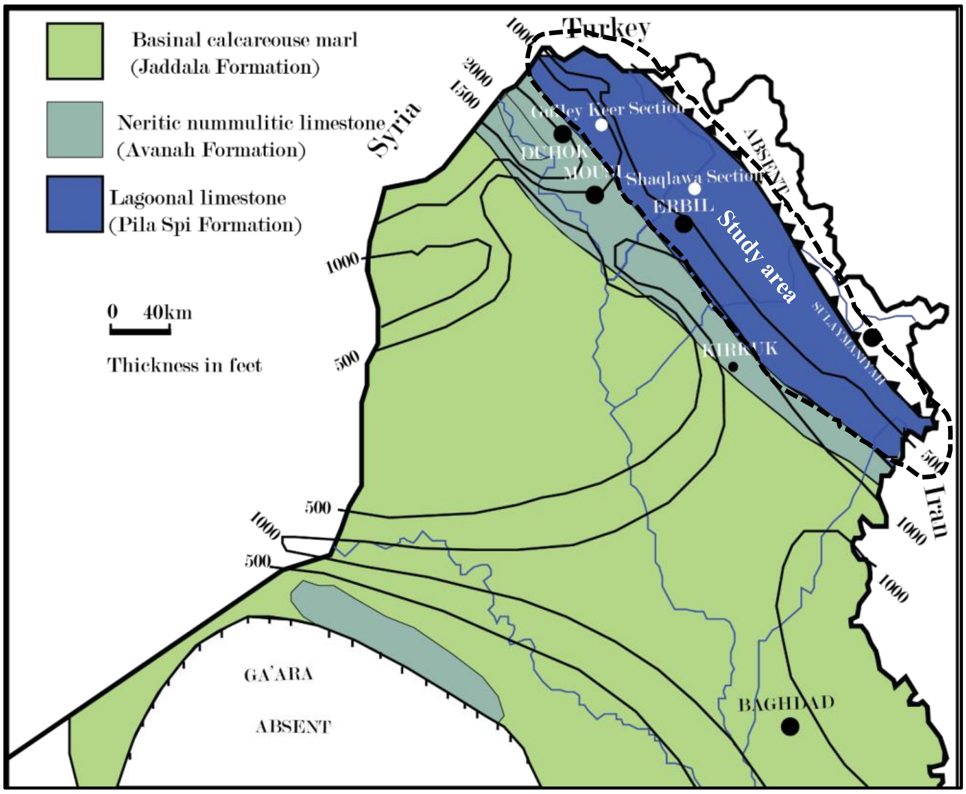

Fig. 2: Isopach facies map of the Middle-Upper Eocene showing distribution of lagoonal limestone (Pila Spi Formation), limestone (Avanah Formation), and Basinal marl (Jaddala Formation) (modified after [2]).

3. Methods and Materials

3.1. Field work and sample collection

A detailed fieldwork was carried out in order to describe the properties of selected outcrops and collecting samples. The both sections were described and logged in details. A total of 38 samples for thin sections, 6 samples for SEM analysis, and 7 core plugs were collected from studied sections The core samples were prepared in Reservoir Lab, Department of Petroleum Engineering- Soran University. In this study the Helium porosimeter methods was used for porosity measuring as follows steps, (1), in order to get plugs and core, the samples were cut into smaller parts by radial core slabbing machine. (2), a plug was taken from the prepared sample by using core plugging machine. (3), the prepared plug was put into the toluene solvent core cleaner, in order to clean the samples from the messy contents and bitumen. After the plugs were cleaned completely, the porosity was calculated by Helium Porosimeter educational series. Bulk, grain and pore volumes were estimated and porosity range was determined too and the permeability was calculated by gas permeability measurements.

3.2. Thin sections preparation: The special thin sections (impregnated by blue dyed (resin)) were prepared in special laboratory in Tehrean-Iran. Then ImageJ and Digimizer software were used to determine the size of pores and consequently the percentage of porosities.

3.3. Scanning Electron Microscope (SEM): Scanning Electron Microscopy (SEM) was used in order to identify different types of porosity and the degree of connectivity between the pores. The samples were coated by gold. Conditions standard was HV are 5kv, 12.50kv and 20 kv, a spot size of 4.5, High vacuum mode, det (ETD), and a counting time of 20 s per element for each test. SEM analysis were performed with scanning electron microscopy (SEM; QUANTA 450) coupled with energy dispersive X-ray spectroscopy (EDS; BRUKER-QUANTAX).

3.4. Petrographic Image Analysis (PIA)

The free available ImageJ software was used to estimate porosity of the studied thin sections. The process of estimation of porosity is briefly given herein: After opening ImageJ software and the JROP tool from toolbar of ImageJ was selected. JPOR would request for detect one of the images of thin sections that had been impregnated with blue epoxy, then for each image 8-bit or 16-bit were selected. Then by following the directions appearing in the toolbar in the pop-up window (Image- Adjust-Threshold) the threshold would be applied to the images of each thin sections. The aim is to threshold these various colors separately and add them together in order to measure the average porosity present in each image from each thin section. After threshold process was done for each image, porosity measurement was done by analyzing process for each thin section, in the toolbar (Analyze-Measure). To obtain a reasonable value of porosity an average of 25 images per thin section were analyzed (Fig. 3), also permeability detected under thin sections.

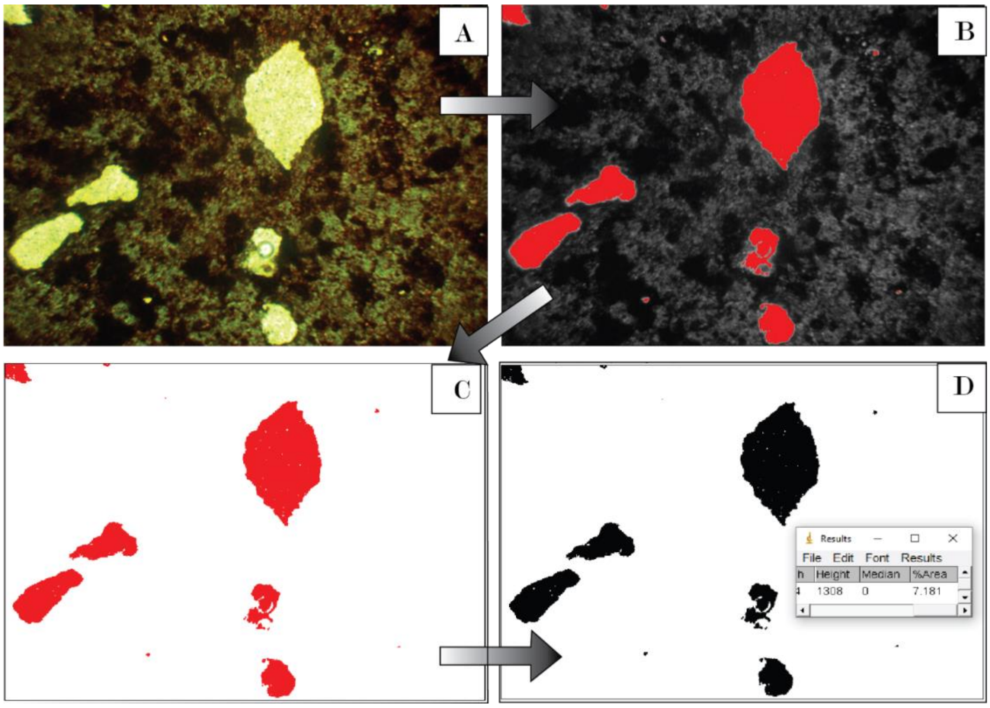

Fig. 3: Porosity measurement steps: (A) Showing thin section image impregnated with blue epoxy shows color variations of pores within micrite matrix. (B) Shows an 8-bit thresholder image consist of both pores and cemented parts. (C) Red mask during thresholding operation covering thresholder pixels and removed unwanted parts like cement and unwanted grains. (D) Binary image product of threshold operation and porous area measurement.

3.5. Core plug Sample Preparations

In order to get plug cores, the samples were cut into smaller parts by radial core slabbing machine. Then the plugs were taken from the prepared samples by using core plugging machine. The prepared plugs were put into the toluene solvent core cleaner, in order to clean the samples from the bitumen. After the plugs were cleaned completely, the porosity and permeability were measured by helium porosimeter and perimeter, respectively. The core making steps and properties are: (A) Core plugging machine (Model CP-01) for cutting the taken samples and getting core sample by the properties of drilling depth up to 4.5” and bit rotation speed range between 150 to 2450 RPM. (B) Extracted cutting horizontal core plug from the rock sample taken from different parts of Pila Spi Formation from Sarkand and Gulley Keer sections. (C) The trim saw (Model: TS-01) was used to prepare the standard core plugs with core diameter between (1-1.5”), and core length (up to 5”).

3.6. Porosity and Permeability measurements steps

The steps of porosity and permeability measurements are: (A) The dynamic displacement solvent cleaning for bitumen extracting from all samples taken from both sections. (B) 300mll of Toluene solvent used for extracted bitumen from each sample. (C) The core samples put into the Soxhlet extractor instrument used for cleaning core samples. (D) Heater used for rising heat of Toluene solvent for and the researcher putted at 25^°. (E) The helium porosimeter (Model: P H e P-01) instrument that is used for porosity determination by the property’s porosity range between 1-40%, max pressure 10BAR, core diameter (up to 1.5’’), and core length (up to 3.5’’). (F) The gas permeability (Model: M P-02) instrument that is used for permeability determination by the property’s permeability range between 1-500md, max inlet pressure: 8BAR, max confining pressure: 10BAR, core diameter (up to 1.5’’), and core length (up to 3.5’’). (G) The ready core plugs for analysis from both Shaqlawa and Gulley Keer sections.

4. Results and Discussion

Petrographic image analysis (PIA) is a common tool for studying and measuring the porosity shape, size, and estimating the porosity values [12]and [13]. Pila Spi Formation comprises different distinct lithologies from the both sections generally are limestone, dolomite, dolomitic limestone, chalky limestone, marl, and marly limestone characterized by characterized by rich in bitumen’s within intercrystalline and micropores and rich in bitumen seepage from the middle and upper parts of Gulley Keer section, all have discrete petrophysical and diagenetic characteristics. Dolomitization and dissolution which are part of diagenetic process have largely increased the secondary porosity of intercrystalline, moldic and vuggy pore spaces in dolomitic, dolomitic limestone and chalky limestone. Therefore, this may suggest that the diagenetic process such as dolomitization and stylolite development is the prime controlling factor for the development of pore space (Figs. 4K, 4L). The field observation and microscopic study reveal that the majority of the pore spaces are filled either partially or completely with bitumen especially in Gulley Keer section. This feature can be considered as evidence for good reservoir quality of formation that indicate presented of hydrocarbon within those reservoirs. As mentioned earlier different techniques are used for assessment of the porosity. The common type pores in Sarkand section include intraparticle, intercrystalline, moldic, fractures, vugs, and micro-vugs (Figs. 4A, 4B, 4C, 4D, and 4F). The estimated porosity values of the Sarkand section that obtained from ImageJ software range between 1% to 42%. The values of lower part range between 6% to 12% with an average of 8%. the estimated porosity values from middle part they are in range 1% to 42% with an average of 21%. In the upper part the estimated values are in range 11% to 27% with an average of 17% (Table 1). Also, the common type of pores in Gulley Keer section include intaparticle, intercrystalline, moldic, microfractures, interparticle, vugs, and micro-vugs, channel, boring, and permeability (fracture) occurred by dissolution or diagenetic effect on the formation (Figs. 4A, 4B, 4C, 4D, 4E, 4F, 4G, 4H, and 4I). The estimated porosity values of this section range between 3% to 44%. The values of lower part range between 3% to 13% with an average of 9%. The estimated porosity values for middle part are in range 3% to 30% with an average of 17%. For the upper part, these values are in range 6% to 44% with an average of 19% (Table 2). The study of porosity by using Scanning Electron Microscope (SEM) shows the nearly the same porosity values and types of porosity that achieved from PIA (Figs. 5A and 5B).

Table 1: The porosity types and values of the Pila Spi Formation from Sarkand section in Shaqlawa area

Parts of formation	Samples	Porosity Types	Porosity %
	SA24,N.R	Microfracture and Intercrystalline	13%
	SA23,P.R	Intercrystalline and Micofracture	11%
	SA22,P.R	Microfracture and Intercrystalline	13%
Upper Part	SA21,N.R	Microfracture and Moldic	27%
	SA20,N.R	Vugs and Moldic	18%
	Average		**17%**
	SA17,P.R	Moldic and Vugs	15%
	SA16,N.R	Vugs and Intercrystalline	17%
	SA14,P.R	Vugs, Moldic, and Intraparticle	16%
Middle Part	SA12,N.R	Microvugs and Fenestral	1%
	SA11,P.R	Moldic, Vugs, and Dissolution	17%
	SA19,P.R	Microfracture, Vugs, and Dissolution	42%
	Average		**21%**
	SA7,N.R	Vugs, Moldic, and Intercrystalline	7%
	SA6,P.R	Fracture and Moldic	12%
Lower Part	SA4,P.R	Vugs and Moldic	6%
	SA1,N.R	Vugs and Moldic	8%
	Average		**8%**

Abbreviations Key: SA: Sarkand, GK: Gulley Keer, P.P.L: Plane polarized light, B.R: Blue Resin, and N.R: Normal Resin.

Table 2: The porosity types and values of the Pila Spi Formation from Gulley Keer section, Shekhan area

Parts of Formation	Sample	Porosity Type	Porosity %
	GK39, N.R	Vugs and Moldic	6%
	GK38, P.R	Moldic and Vugs	15%
Upper Part	GK37, P.R	Moldic and Vugs	20%
	GK34, N.R	Vugs and Microfracture	12%
	GK31, P.R	Cavern	44%
	Average		**19%**
	GK27, P.R	Microfracture and Vugs	5%
	GK26, P.R	Vugs and Intercrystalline	5%
	GK24, N.R	Vugs and Moldic	30%
	GK23, P.R	Moldic and Intraparticle	7%
	GK22, N.R	Intraparticle, Vugs, and Moldic	7%
	GK21, P.R	Intraparticle, Vugs, Moldic, and Fracture	10%
Middle Part	GK18, P.R	Intercrystalline	3%
	GK16, N.R	Vugs and Boring	27%
	GK15, P.R	Vugs and Intercrystalline	11%
	GK13, N.R	Vugs	4%
	GK11, N.R	Vugs and Moldic	10%
	GK8, N.R	Vugs and Fenestral	3%
	Average		**17**
	GK9, P.R	Vugs, Intercrystalline, Fenestral and Moldic	3%
	GK6, N.R	Vugs and Moldic	9%
Lower Part	GK5, P.R	Vugs, Intercrystalline, and Moldic	6%
	GK3, N.R	Vugs, Fenestral and Intercrystalline	4%
	GK2, P.R	Channel, Moldic, Fracture, and Intercrystalline	13%
	Average		**9%**

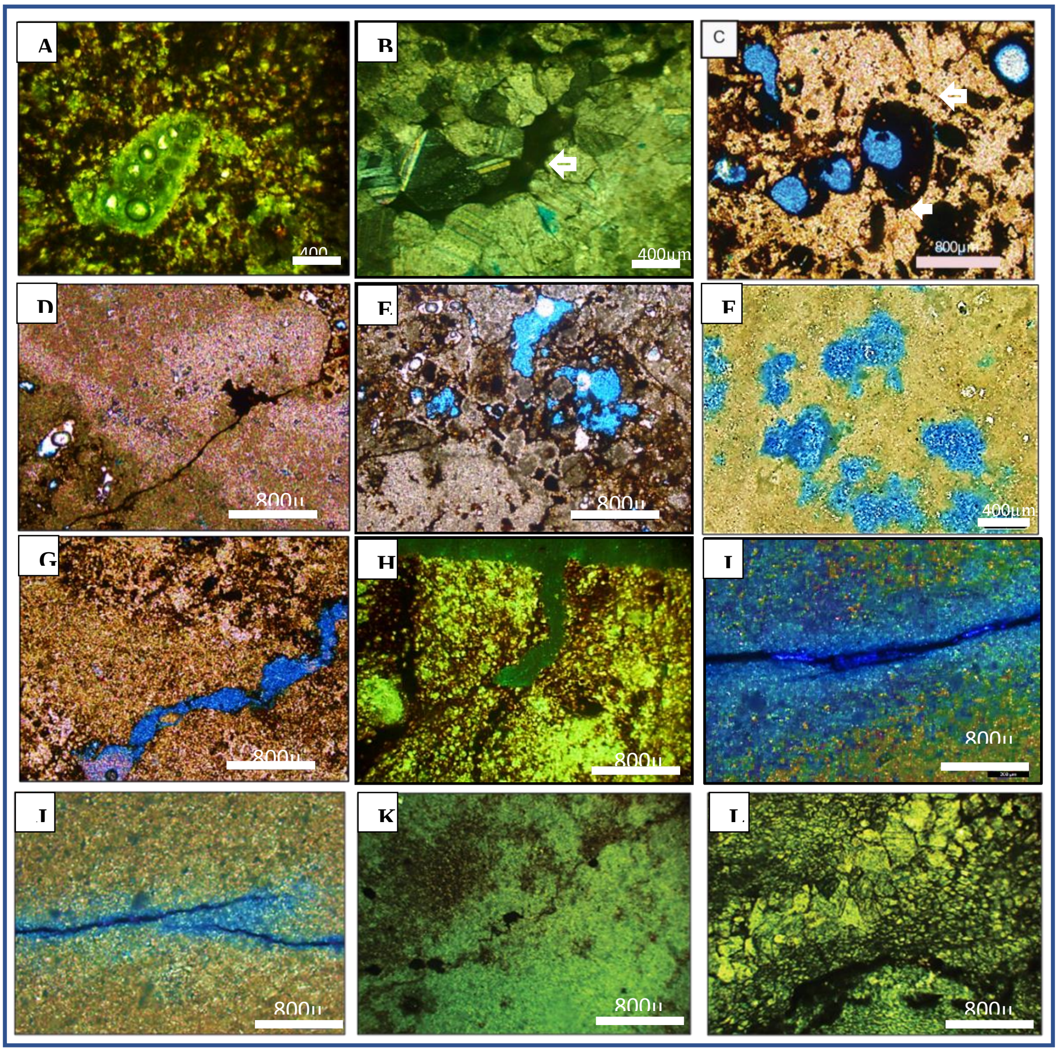

Fig. 4: Thin section photos for porosity types from Pila Spi Formation. (A) Intraparticle porosity of skeletal grain formed by leaching of soft parts with skeleton. P.P.L (4X), GK. 11, N.R. (B) The intercystalline porosity within collected mosaic crystals of blocky cement (arrow) P.P.L (4X), SA.23, B.R. (C) Moldic porosity formed by partly leaching of some grains, partly filed by bitumen from the upper part of Pila Spi Formation P.P.L (4X), GK. 38, B.R. (D) Microfracture porosity occur along the fracture by leaching or dissolution within micrite matrix filled with bitumen P.P.L (4X), GK. 21, B.R. (E) Interparticle porosity between skeletal particles (middle part) Gulley Keer section P.P.L (4X), GK. 21, B.R. (F) Vuggy porosity as a result of solution processes within a dissolved micrite matrix P.P.L (4X), SA. 14, B.R. (G) Channel porosity with fine microsparite P.P.L (4X), GK. 38, B.R. (H) Boring porosity within dolomite X.P.L (4X), GK. 13, B.R. (I and J) The interconnected and dissolution parts make a good way to fluids flow within micrite matrix P.P.L (4X), SA. 6, B.R. (K) The irregular stylolite type with high and low amplitudes and filled with bitumen from the middle part of Pila Spi Formation from Gulley Keer section P.P.L (4X). (L) Coarse crystalline dolomitization, upper part of the formation from Sarkand section P.P.L (4X).

Abbreviations: Key*: SA: Sarkand, GK: Gulley Keer, P.P.L: Plane polarized light, B.R: Blue Resin, and N.R: Normal Resin.*

The pore size varies within depositional rock fabric, owing to groups of crystal and grain size. Pores size can be regarded as mesopore which are divided into small pore size (between 1/16mm to ½mm) and large pore size (between ½mm to 4mm), and mega-pore that are divided into small pore size (between 4mm to 32mm) and large pore size (between 32mm to 256mm) [14]. Depend on the digimizer software, the pores size from Sarkand section can be classified as micropore to mesopore (large) since the pore area from the lower part are between 0.173-0.237 mm^2, the middle part between 0.026-0.161 mm^2, and the upper part between 0.11-0.312 mm^2. In regard with Gulley Keer section, the predicted porosity size range between micropore- mesopore (large), the pore area from the lower part is between 0.028-0.24 mm^2, the middle part porosity area between 0.031-0.61 mm^2, and from the upper part the porosity area is between 0.061-0.125 mm^2 (Figs. 5E and 5F). Also, porosity values determined by using SEM images show almost the same results that obtained from thin section studies (Table 3 and Figs. 5C and 5D).

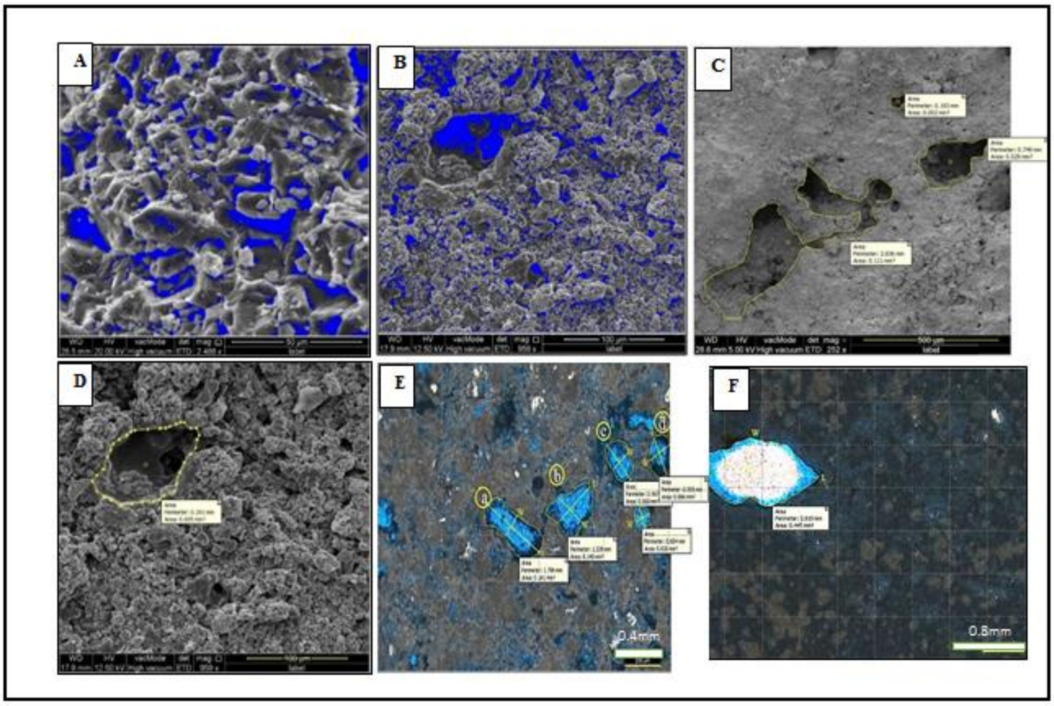

Fig. 5: SEM photograph of some studied thin sections. (A) Intercrystalline and micro-vugs porosity, the value of porosity is 12%. (B) The moldic porosity with a value of 13% (C) The vugs porous, the pore size ranges between Micropore-Mesopore. (D) The vugs porosity, pore size is in range Micropore-Mesopore (Large). (E) The pores size is Mesopore (Small) P.P.L, (4X), B.R. (F) The pores size is Micropore-Mesopore P.P.L, (4X), B.R.

Table 3: The porosity values of the Pila Spi Formation that were determined using the Leica Microscope and Scanning Electron Microscope (SEM)

Sections	Parts	Sample No.	Porosity by Leica Microscope	Porosity by SEM
Sarkand	Upper part	SA22	13%	12%
	Lower part	SA7	7%	8%
Gulley Keer	Upper part	GK38	15%	17%
	Middle to Upper part	GK34	12%	13%
	Lower to Middle part	GK11	10%	9%
	Lower part	GK3	4%	5%

4.1. Cement type and its effect on porosity

Cementation take places by a chemical deposition of calcium carbonate$(CaCo_3)_2$ and/or by solution inside or between grains or in cracks process from saturated solutions, these processes leading to growth of calcite cement in these cavities or porous [15]. In this study, three types of cements are found. The first common type is the granular cement. This type of cement consists of anhedral to subhedral structure, generally >10-60 µm [16]. Granular cement is the most common type in the studied samples of the Pila Spi Formation especially the lower and upper parts of Sarkand section and the middle part of Gulley Keer section (Fig. 6A). The second common type is the blocky cement which refer to a mosaic crystal in which the individuals in all direction have the same diameter) [17]. This type of cement is found in the middle and upper parts of the formation in Sarkand section within the molds and fractures of previously dissolved skeletal grains, and observed in the lower part of Pila Spi Formation in Gulley Keer section (Fig. 6B). The third uncommon type of cement is the drusy cement that consists of calcite crystals in the structure or shape of anhedral to subhedral, it is usually greater than >10 µm, the crystal sizes increase from pore walls to center of cavities or porous [17]. The drusy cement was observed in the lower part of the Pila Spi Formation from Gulley Keer section (Fig. 6C).

As shown in (Table 4), the porosity decreased by cementation and showing how cementation directly affects porosity in the carbonate rocks especially in the lower part of the Pila Spi Formation, where high values of cementation effect on the rocks often produce lower porosity measurements.

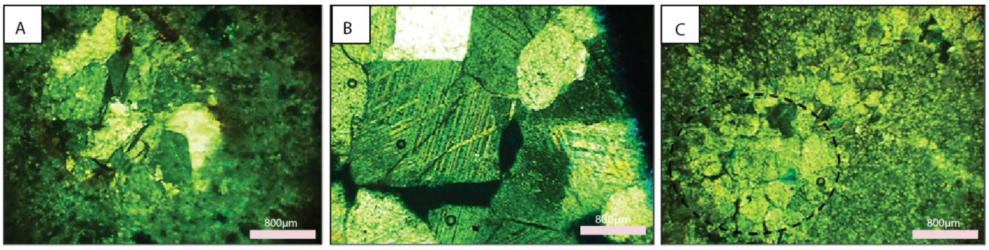

Fig. 6: The Cement types from different parts of Pila Spi Formation from Sarkand and Gulley Keer sections. (A) Granular cement from the lower part of formation from Sarkand section P.P.L (4X), SA.6, B.R. (B) Blocky cement filled the molds of previously dissolved skeletal grains from the upper part of Pila Spi Formation from Sarkand section P.P.L (4X), SA.23, B.R. (C) The drusy cement in the lower part of Pila Spi Formation from Gulley Keer section P.P.L (4X), GK.5, B.R

Table 4: The values of porosities for both cases of pores with and without cement for different thin sections images from different parts of Pila Spi Formation

Sections	Sample No.	Total porosity (with cement) %	Effective porosity %
	28SA6	15%	12%
Sarkand	15SA6	13%	6%
	9SA17	8.2%	6%
	10SA17	1.74%	1.71%
	12GK37	19%	15%
Gulley Ker	4GK37	22.5%	19%
	3GK5	4.6%	3.3%
	4GK5	2.1%	1.7%

4.2. Direct methods of measurement of porosity and permeability

The direct method of measurement of porosity and permeability in the laboratory is one of the most reliable methods. As shown in (Table 5), in Sarkand section, the core plug analysis reveals that the porosity values are 8%,18.5%, and 18% for the lower, middle, and upper part respectively. In Gulley Keer section, the porosity values are 2.5%, 19%, 17.25%, and 22.5% from lower to upper part. Similar to the estimated values of porosity using ImageJ processing, the measured values of the middle and upper parts show good porosity except lower part (Tables 5 and 6). The lower part of Pila Spi Formation seems to be affected by cementation.

In regards with permeability, the values of permeability ranges between o.0487md to 0.8209md, with an average of 0.0487md, 0.0md, and 0.17md for lower, middle, and upper parts of formation from Sarkand section, and 0.3087, 0.8043, 0.8209, and 0.7455md for lower, middle, and upper parts from Gulley Keer (Table 5). The permeability values suggest poor to fair permeability for analyzed samples ((Table 6).

As shown in (Table 7 and Fig. 7), the formation can be regarded as poor to good reservoir expect one sample that has very low permeability.

Table 5: The porosity and permeability values which are determined by porosimeter and permeameter instrument

Core Samples	Core Porosity (%)	Core Permeability (md)
GKC4	22.5%	0.7455md
GKC3	17.25%	0.8209md
GKC2	19%	0.8043md
GKC1	2.5%	0.3087md
SAC3	18%	0.17md
SAC2	18.5%	0.0 md
SAC1	8.0%	0.0487md

Table 6: Porosity and Permeability as indicator of reservoir quality[1]

Porosity (%)	Reservoir quality
0-5	Negligible
5-10	Poor
10-15	Fair
15-20	Good
20-25	Very good
permeability (Millidarcy)	
<1.0-15	Poor to fair
15-50	Moderate
50-250	Good
250-1000	Very good
>1000	Excellent

Table 7: The Porosities values which are determined by porosimeter instruments and permeability values determined by permeameter instrument for Pila Spi Formation from Sarkand and Gulley Keer sections.

Core Sample	Core Porosity (%)	Core Permeability (md)
GKC4	22.5%	0.7455md
GKC3	17.25%	0.8209md
GKC2	19%	0.8043md
GKC1	2.5%	0.3087md
SAC3	18%	0.17md
SAC2	18.5%	0md
SAC1	8%	0.0487md

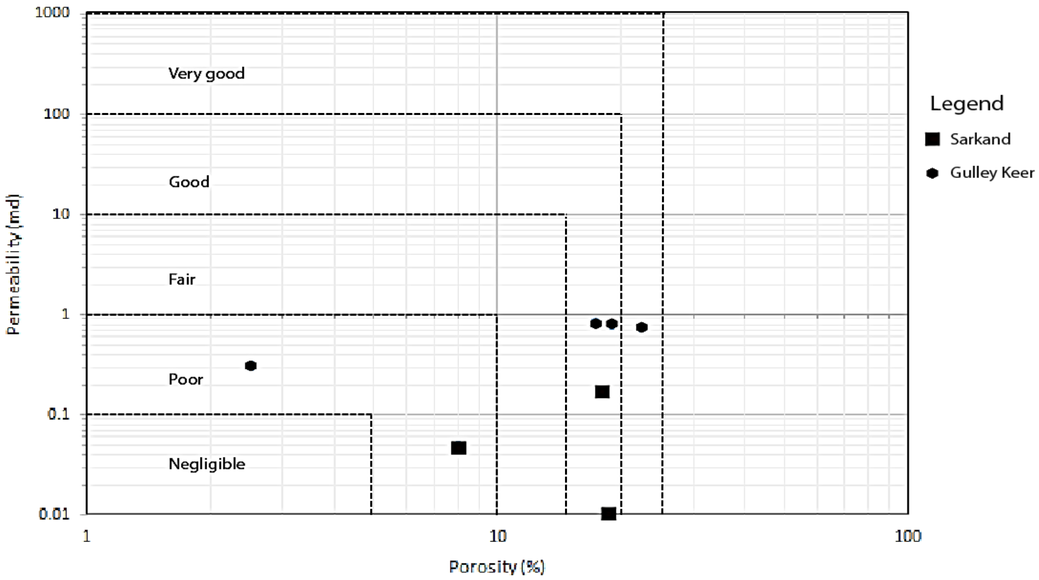

Fig. 7: Cross plot showing porosity vs permeability of Pila Spi samples of the Pila Spi Formation in studied sections. Cross-plot is drawn based on qualitative description of porosity and permeability proposed by [1], [18], and [19].

6. Conclusions

Pila Spi Formation comprises different distinct lithologies from the both sections generally are dolomitic limestone, chalky limestone, marl, limestone, marly limestone, and dolomite, characterized by characterized by rich in bitumen seepage and rich in bitumen's within intercrystalline and micropores from the middle and upper parts of Gulley Keer section, Generally, the cementation cause reduction in porosity and permeability by filling the molds and fractures porous of previously dissolved skeletal grains, especially the effect of cementation is observed in lower and middle parts of formation in Sarkand section and also in lower and middle parts of formation in Gulley Keer section. The petrographic image analysis (PIA) of the thin sections indicate that the carbonate of the Pila Spi is characterized by several types of pores including vugs, fractures, moldic, intercrystalline, boring, micro-vugs, and cavernous in which pores' size are recognized as micropore to mesopore (large). In terms of reservoir quality new things about this study that, the porosity and permeability values display good reservoir quality except lower part of formation in which it is regarded as poor reservoir quality.

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توصيف مكامن تكوين البلاسبي (العصر الأيوسيني الأوسط المتأخر) في منطقتي شقلاوة و الشيخان، إقليم كردستان، شمال العراق

ادريس محمد بيروت[1] اياد نوري فقي[2]
قسم علوم البترو ليوم جيوساينس، جامعة سوران، اربيل، العراق

الملخص

تتناول هذه الدراسة جودة الخزني لتكوين البلاسبي الأيوسين المتوسط المتأخر في مناطق شقلاوة (سركند) وكلي كير (شيخان) في إقليم كردستان العراق. من الناحية الصخارية و في المقاطع المدروسة, يتألف تكوين البلاسبي من الحجر الجيري والدولومايت والحجر الجيري الدولوميتي والحجر الجيري الطباشيري والصلصال. سمك التكوين تتراوح حوالي 62 متر في مقطع سركند بينما تكون 200 مترا في مقطع كلي كير. في هذه الدراسة تم استخدام تقنيات مختلفة مثل الدراسة المجهرية وتحليل المكونات الأساسية لغرض تقييم الصفات المكمنية للتكوين. تتميز التكوين بوجود عدة أنواع من المسامية وهي:مسامية الفجواة و القوالب و القنوات و بين الحبيبات والكسور والحفر و الاشباك و داخل الحبيبات. تم التعرف أيضًا على العديد من عمليات التحويرية مثل الدلمتة و محاليل الضغط , الستايلولايت و االاذابة.أعتمادا على دراسة البتروغرافية، تبين بأن التكوين في مقطع سركند ذات متوسط المسامية وتبلغ 8٪ في الجزء السفلي و21٪ في الجزء الاوسط و 17٪ في الجزء العليا من التكوين.كما هي الحال في المقطع كلي كير, بحيث تتراوح نسبة المسامي فيها 9٪ و 17 و 19٪ في الجزء السفلي والوسطى والعليا على التوالي. أظهرت دراسة المجهر الإلكتروني (SEM) تشابه كبيرفي قيم المسامية مقارنة بنتائج دراسته بالشرائح الرقيقة و تبين أحجام المسامات بين المسام الدقيقة إلى منوسطة الاحجام في المقاطع المدروسة. أضافة الى ذلك ، تتوافق نتائج تحليل المقابس الأساسية تقريبًا مع التقييم البصري نظرًا لأن قيم المسامية المقاسة من مقطع ساركند هي 8٪ و 18.5٪ و 18٪ للجزء السفلي والمتوسط والعلوي على التوالي. بينما قيم المسامية لالتكوين في مقطع كلي كير للجزء السفلي والأوسط والعلوي هي 2.5٪ و 17.25٪ و 22.5٪ على التوالي. وبالتالي ، أضهرت النتائج أن التكوين بلاسبي تتمتع بمسامية جيدة باستثناء الجزء السفلي. فيما يتعلق بالنفاذية ، تُظهر القيم المقاسة للنفاذية انتقامًا قدره md0.109 و md0.6698 لمقطعي ساركند و كلي كير على التوالي مما يشير إلى نفاذية واطيئة إلى جيدة.