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The Impact of Formation Water Salinity on the Formation Resistivity Factor

Neima A. M. Alshareef *
Department of Petroleum Engineering, Faculty of Engineering, University of Benghazi, Libya.
**Corresponding author:* neima.alshareef@uob.edu.ly

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Abstract:
The objective of this study is to develop a new empirical correlation to determine the formation resistivity factor (Fr) as a function of porosity, similar to approaches adopted in previous research. In addition, the study examines the effect of formation-water salinity on the resistivity factor.
Core samples from three different oil fields in Libya's Sirte Basin were selected for analysis. A portion of the laboratory measurements was conducted at the Libyan Petroleum Institute (LPI) in Tripoli, Libya. Several empirical correlations were formulated to quantify the influence of salinity on the formation resistivity factor. Among these, the best-fit correlation demonstrated the highest correlation coefficient, providing the most accurate representation of salinity's impact on Fr.

Keywords: Formation Resistivity Factor, Formation Water Salinity, Porosity, Empirical Correlation, Sirte Basin, Core Analysis.

أثر ملوحة مياه التكوين وعامل مقاومية التكوين في المكامن

نعيمة عبدربه معزب الشريف *
قسم الهندسة النفطية، كلية الهندسة، جامعة بنغازي، ليبيا.

الملخص
هدف هذه الدراسة هو تطوير علاقة تجريبية جديدة لتحديد عامل مقاومية التكوين (Fr) بوصفه دالّة في المسامية، وذلك على نحو مماثل للأساليب المتبعة في الدراسات السابقة. كما تتناول الدراسة تأثير ملوحة مياه التكوين على عامل المقاومية.

تم اختيار عينات لبّية من ثلاثة حقول نفطية مختلفة في حوض سرت بليبيا لإجراء التحليل. وقد أُجري جزء من القياسات المخبرية في معهد النفط الليبي (LPI) في طرابلس، ليبيا. كما جرى تطوير عدة علاقات تجريبية لقياس تأثير الملوحة على عامل مقاومية التكوين. ومن بين هذه العلاقات، كانت العلاقة الأفضل ملاءمة هي تلك التي حققت أعلى معامل ارتباط، ما يجعلها الأكثر دقة في تمثيل تأثير الملوحة على قيمة Fr.

الكلمات المفتاحية: ملوحة مياه التكوين، معامل مقاومية التكوين، المسامية، العلاقات التجريبية، حوض سرت، تحليل العينات اللبّية.

1- introduction
Electrical resistivity has long been recognized as one of the most fundamental petrophysical properties used in evaluating hydrocarbon-bearing formations. It provides essential information about pore structure, fluid saturation, and reservoir quality, thereby forming the basis for interpreting well logs and guiding reservoir

engineering decisions. The resistivity of reservoir rocks is controlled primarily by the properties of the pore-filling fluids—most notably, the salinity of the formation water—alongside porosity, pore geometry, lithology, wettability, temperature, and in-situ stress conditions. Because hydrocarbons act as electrical insulators while brine serves as a conductive medium, understanding the interplay between rock texture and fluid characteristics is crucial for accurately determining water saturation and assessing producible reserves.

The formation resistivity factor (Fr), defined as the ratio of the resistivity of a rock fully saturated with brine (Ro) to the resistivity of the brine alone (Rw), serves as a key parameter in this context. Archie's pioneering work (1942) established a quantitative relation between Fr, porosity, and cementation factor, forming the theoretical foundation for modern formation evaluation. Since then, numerous studies have investigated how variations in pore geometry, sorting, grain shape, cementation, and interstitial fluid chemistry influence electrical conductivity in reservoir rocks. Researchers such as Pirson, Keller, Calhoun, and Amyx et al. expanded the physical and empirical understanding of resistivity behavior, demonstrating that the conduction of electric current occurs exclusively through the interconnected water-filled pore network. Consequently, any factor that modifies the salinity, ionic concentration, or distribution of formation water can affect measured resistivity values and, by extension, the derived petrophysical parameters.

Among the factors influencing resistivity, formation water salinity has received increasing attention, particularly in reservoirs where salinity varies spatially or vertically due to hydrodynamic processes, stratification, or diagenetic alterations. Higher salinity typically enhances brine conductivity, reducing Rw and thereby altering the resistivity response of the rock–fluid system. However, this relationship is not always linear or straightforward, especially under different confining pressures and degrees of grain sorting. Rock texture can modify the tortuosity and connectivity of pore pathways, affecting the degree to which salinity influences electrical conduction. As such, empirical correlations that incorporate salinity effects—beyond porosity alone—are essential for improving the accuracy of formation evaluation models.

Despite the extensive research in this field, gaps remain in understanding how salinity interacts with rock fabric parameters under realistic reservoir conditions. This is particularly relevant for Libyan reservoirs, where significant variability in formation water salinity is observed across different fields in the Sirte Basin. Developing reliable empirical correlations tailored to such geological settings can enhance the precision of water saturation calculations and improve hydrocarbon quantification.

Therefore, this study aims to investigate the impact of formation water salinity on the formation resistivity factor using core samples from three Libyan oil fields. Laboratory measurements were conducted under controlled conditions, and empirical correlations were developed to quantify the relationship between salinity, confining pressure, sorting, and Fr. The results contribute to refining formation evaluation techniques and offer a practical tool for reservoir characterization in high-salinity environments.

2- Literature Review

Understanding the **formation resistivity factor (Fr)** and its relationship to rock and fluid properties has long been a central focus in petrophysical and reservoir characterization studies. Early foundational work in this field established the physical and empirical bases upon which modern interpretation techniques are still built.

The **electrical behavior of reservoir rocks** was first comprehensively analyzed by **Pirson (1963)** [1], who demonstrated that resistivity is not only a function of the intrinsic properties of the rock but is also strongly influenced by **formation water salinity, porosity, and hydrocarbon saturation**. Pirson explained that as the hydrocarbon saturation increases, overall resistivity tends to decrease, primarily because hydrocarbons act as electrical insulators, thus impeding ionic conduction through the pore fluids. His work underscored that factors such as **pore geometry, rock composition, temperature, and formation stress** significantly modify the resistivity response, making it an indispensable diagnostic tool in evaluating reservoir characteristics.

A landmark contribution to the field came from **Archie (1942)** [2], who introduced a quantitative relationship—later termed *Archie's Law*—linking resistivity to porosity and water saturation. He defined the formation resistivity factor as the ratio between the resistivity of a rock fully saturated with formation water (Ro) and that of the water itself (Rw), expressed as

$$\boldsymbol{Fr = \frac{Ro}{Rw} = a\,\phi^{-m}}$$

where $a$is the tortuosity constant and $m$the cementation exponent. Archie's equation became the cornerstone of modern petrophysics, providing a theoretical framework for determining water saturation and estimating hydrocarbon volumes in the subsurface.

Subsequent investigations expanded upon Archie's conceptual model. **Keller (1953)** [3] explored the **effect of wettability** on the resistivity of sands and found that the distribution and relative position of the conductive fluid within the pore system alter the electrical characteristics of the rock. His findings emphasized that rock–fluid interactions, such as surface wetting behavior, can substantially influence the measured resistivity and, consequently, the calculated water saturation.

Further theoretical developments were made by **Amyx, Bass, and Whiting (1960)** [4], who examined the **geometrical and physical parameters controlling ionic flow** in porous media. They introduced expressions that accounted for the cross-sectional area and tortuosity of current paths, highlighting that conduction in reservoir rocks occurs exclusively through the interconnected pore network. Their analytical approach formed the physical basis for interpreting laboratory measurements of core resistivity.
In a complementary effort, **Calhoun (1960)** [5] elaborated on the influence of **porosity on current conduction**. He reasoned that the ability of a rock to transmit electric current is proportional to the fraction of the pore volume containing conductive water. In formations with partial hydrocarbon saturation, current flow diminishes proportionally to the reduction in water-filled porosity, illustrating a direct link between porosity and resistivity.
Empirical formulations soon followed to refine the quantitative understanding of this relationship. The **Schlumberger (1972)** [6] model established an empirical expression relating porosity to the formation resistivity factor, commonly expressed as $Fr = 0.81/\phi^2$. This relationship became a practical reference in **well-log interpretation manuals**. Similarly, **Zaafran (1975)** [7] developed an alternative empirical model derived from sandstone core measurements, expressed as $Fr = 1.48/\phi^{1.66}$, which demonstrated improved applicability to **specific lithological conditions** such as fine-grained or well-cemented sands.
Expanding upon the influence of textural properties, **Atkins and Smith (1961)** [8] investigated the **significance of particle shape** and cementation on the resistivity–porosity relationship. Through laboratory experiments, they concluded that the porosity exponent (m) varies with the **grain shape, overburden pressure, and cementation degree**, indicating that m is not a constant but rather a parameter dependent on rock fabric. Their findings also revealed that particle angularity and compaction alter the tortuosity of conduction pathways, thus affecting the resistivity factor.
As petrophysical models advanced, **Pérez Rosales et al. (2000)** [9] introduced a **new formulation for fractured porous media**, arguing that traditional Archie-type relationships are inadequate for representing electrical behavior in fractured formations. They proposed a modified model based on physical reasoning and empirical fitting, which better accounted for the complex geometry and discontinuities of fractured reservoirs.
Later, **Hamada and Al-Awad (2000)** [10] examined the **influence of water saturation exponent (n)** on hydrocarbon evaluation. They found that this parameter exerts a significant effect on the calculation of water saturation, particularly under varying wettability and clay content conditions. Their study revealed that assuming constant tortuosity and cementation factors while varying *n* produces more accurate predictions of water saturation across heterogeneous samples.
Finally, **Tabibi and Emadi (2003)** [11] emphasized that the **cementation factor** plays a critical role in determining pore structure characteristics and, consequently, water saturation. Their analysis indicated that variations in pore connectivity and the volume fraction of water-filled pores directly influence the computed resistivity, highlighting the necessity of integrating cementation effects into saturation calculations.

Archie defined the formation resistivity factor Fr as (Archie , 1942)

$$\boldsymbol{F_r = \frac{R_o}{R_w}},$$

where Rw is the resistivity of the water and Ro is the resistivity of a deposit that is completely saturated with water. Unity will be subordinated to Ro. The fluid distribution inside the rock space was significantly influenced by the wettability (Keller, 1953). The electric behaviour of fluid-filled sandstone would also change if the conducting fluid's relative position with regard to the rock surface were altered. the formation resistivity factor,

$$\mathbf{F_r = a\ Ø^{-m}} \quad (1.1)$$

has theoretical roots in some of the early well log and core analysis textbooks and literature. The formation resistivity factor's basic definition is where almost all documented derivations begin.

$$\mathbf{F_r = R_o / R_w} \quad \mathbf{(1.2)}$$

where Rw is the resistivity of the conductive fluid and Ro is the resistivity of the porous media that is 100% saturated with it.

For the conduction of ions via the model, each derivation necessitates a simplified model of the porous media that uses geometric shapes of pores, pore throats, and bulk volume that are simply characterised in terms of length and cross-sectional area.

Here is a broad derivation that is comparable to [Amyx et al., 1960]. For many materials, resistivity (R) is defined as

(1.3)

$$R = \frac{rA}{L}$$

Where r = resistance of the material.
A = the cross-sectional area perpendicular to ionic flow.
L = Length of the ionic flow path.

Using a cube of salt water, the resistance of the cube could be defined as

$$\mathbf{r_w = R_w\, L/A} \quad \textbf{(1.4)}$$

where L and A stand for the water cube's dimensions. There would be less volume available for water in a cube of porous media with the same dimensions as a cube of water. The part of the cube that is thought to be an insulator is the matrix. Only the pore space has the ability to conduct ionic flow.

Thus, an apparent flow path (La) and apparent cross-sectional area (Aa) are employed. The cube's resistivity is

$$\mathbf{r_2 = R_w\, L_a/Aa} \quad \textbf{(1.5)}$$

By definition the resistivity of the cube of core saturated with water is

$$\mathbf{R_o = r_2\, A/L} \quad \textbf{(1.6)}$$

Substituting the last two equations yields :

$$\mathbf{R_o = R_w\, L_a\, A/AaL} \quad \textbf{(1.7)}$$

Using this definition of R_o in the F_r equation result in :

$$F_r = \frac{L_a / L}{Aa / A} \quad (1.8)$$

In other words, the ratio of the apparent flow channel to the cube's length to the apparent cross-sectional area to the cube's cross-sectional area. The tortuosity factor, represented by the symbol a, is the ratio of the lengths, which is proportional to tortuosity. It is assumed that the porosity of the porous media (ØA) multiplied by the real area equals the apparent cross-sectional area. Applying this definition results in

$$\mathbf{F_r = a/Ø} \quad \textbf{(1.9)}$$

Porosity has no power as such m can be seen as one.

2.2 formation resistivity factor ,Fr and porosity :

It makes sense that porosity plays a significant role in regulating the flow of electric current as clean sedimentary rocks conduct electricity due to the salinity of the water that is contained in their pores .

A formation with 20% connate water saturation and 80% oil saturation, for example, should transmit no more than 20% of the current that would be transmitted if the entire bulk volume conducted to the same degree as the water. This is an initial approximation of the current conductance, which should be no greater than that represented by the fractional porosity [Calhoun, 1960].

$$\mathbf{F_r} = \frac{1}{Ø} \quad (1.10)$$

- **[Shlumberege**,1994] According to well-surviving organisations, the relationship between porosity and (Fr) is reported as:

$$F_r = \frac{0.81}{\emptyset^2} \quad (1.11)$$

- **[Zaafran et al**. 1960] . found that the formation resistivity factor may well correlated to the porosity and introduce this equation based on the better sandstone samples .

$$F_r = \frac{a}{\emptyset^m} \quad (1.12)$$

- **[Atkins, ER. Et al.** ,1961] concluede from results of laboratory tests that the value of porosity exponent or shape factor in Archie equation is determined by the profile of particles in the structure, and affected only by particle shape .This factor can be changed by overburden pressure, solution , overgrowth and cementation of individual grains.

there general equation is written as :

$$F_r = \frac{1.48}{\emptyset^{1.66}} \quad (1.13)$$

Can be useful to a given composition just when values of a, and m , have been well-known for the particular structure.

Also they reported that monographs may be used to obtained porosity when formation resistivity factor is identified.

It shape of sand , clay content and clay particle shape as determined by the clay type are known or can be predictable , and estimation the correlation between formation resistivity factor and porosity in well logging problems can be found .

- **[Perez Rosales , C. et al.,**2002] .

revealed a novel way to calculate the fracture porous media's formation resistivity factor. They attempted to fit the investigative data to an Archie-type equation.

They demonstrated that finding a compatible partner is impossible.

They showed that it is impossible to get a good match .

Based on the physical consideration, they developed a new model and came up with the following formula :

$$F_r = \frac{1}{1-(1-\emptyset)^{0.78}} \quad (1.14)$$

- **[Hamada.G.M. et al.,**1996]. Concluded that the water saturation exponent has very big effect on water saturation calculation by two techniques conventional and 3-D technique by supposition fixed values of shape factor and tortuosity factor and change the water saturation exponent.

Also saturation exponent is exaggerated by many factors such as wettability and clay that encourage oil wet distinctiveness .

Where the water saturation exponent depends on the distribution of the conducting phase in the core sample and for on wettability .

- **[Tabibi and Emadi**,2003] . determined that the cementation factor affects pore space and the quantity of water saturation (the ratio of the volume of water entering pores to the total pore volume), which in turn affects the water saturation calculation .

Objective of the paper

To look into how the formation resistivity factor is affected by the salinity of the formation water.

Experimental Measurements:

Laboratory measurements methods were applied on core samples were selected from three different oil fields in Sirte Basin located in Libya.some of these measurements were conducted in(LPI Tripoli – Libya) laboratories . 12 sandstone core samples were selected from three fields had porosities between (0.19 %-0.30 %) ,(degree of sorting 100%,80%,60%,40%) ,
[(NaCl 0.3%) Fr between 6.51-3.15],[(NaCl 1%) Fr between 13.06-5.80],
[(NaCl 5%)Fr between 18.55-5.64].

Results :-

It is shown that the increasing of the formation water salinity causes an increase in the formation resistivity factor as illustrated in fig.(1.1) through (1.2).

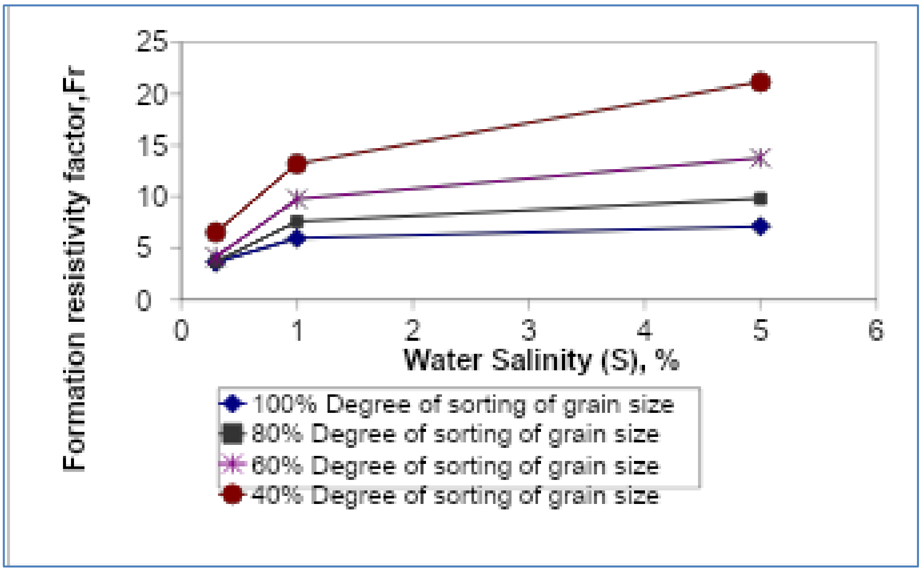

Figure 1: Effect of formation water salinity on the formation resistivity factor (Fr).

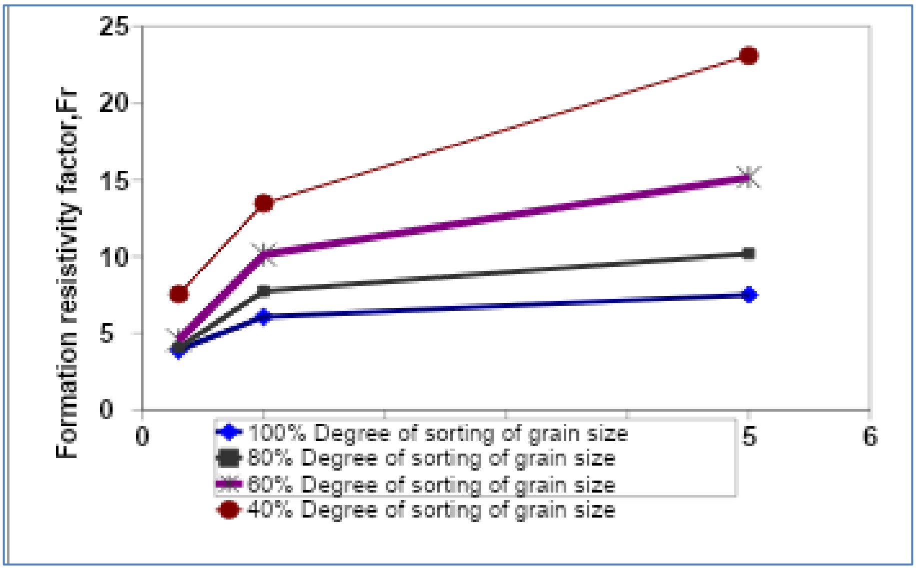

Figure 2: Relationship between salinity and brine resistivity (Rw)

This is explained as follows : the increase of the amount of NaCl in the formation water cause an increase in the ability of transformation of the electric current causing an increase in the electric conductivity of brine (R_w) ,which means a decrease in water resistivity (R_w).

Also increasing the water salinity causes an increase in the formation conductively and a decrease in the formation resistivity (R_o) . but due to the presence of the rock grains the decrease in (R_o) will be with a low rate compare by that of (R_w). resulting in an increase in (F_r) by increase salinity .

Also fig.(1.2) through fig.(1.3) were plotted on log-log papers to predict the empirical correlations that show the effect of salinity on the formation resistivity factor as shown in fig. (1.4) through fig. (1.6).

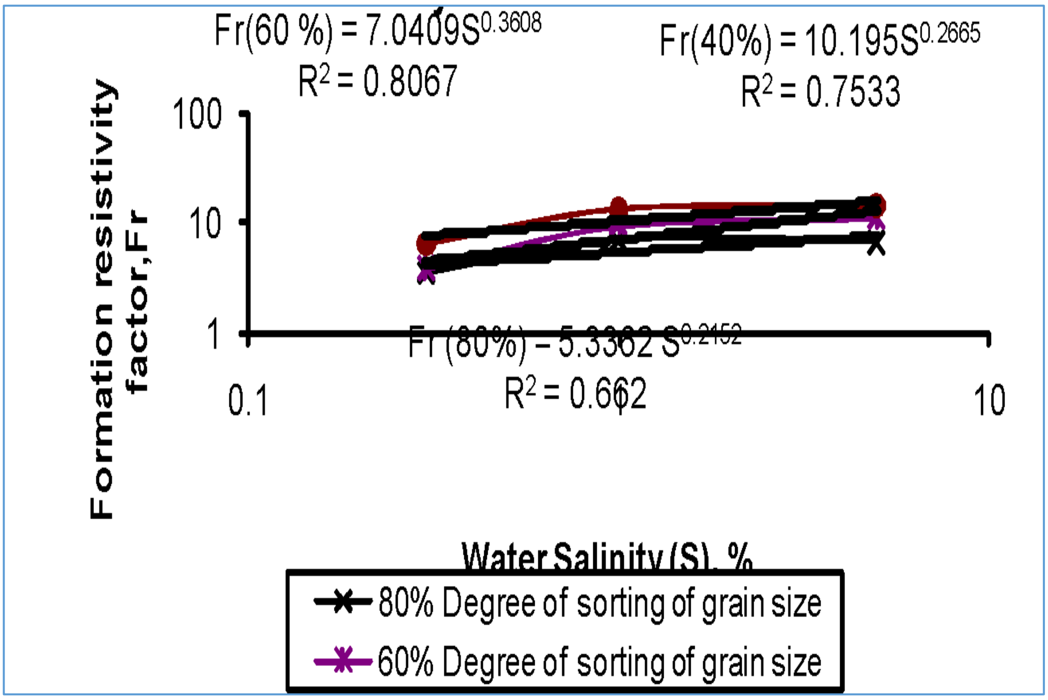

Figure 3: Variation of rock resistivity (Ro) with increasing salinity.

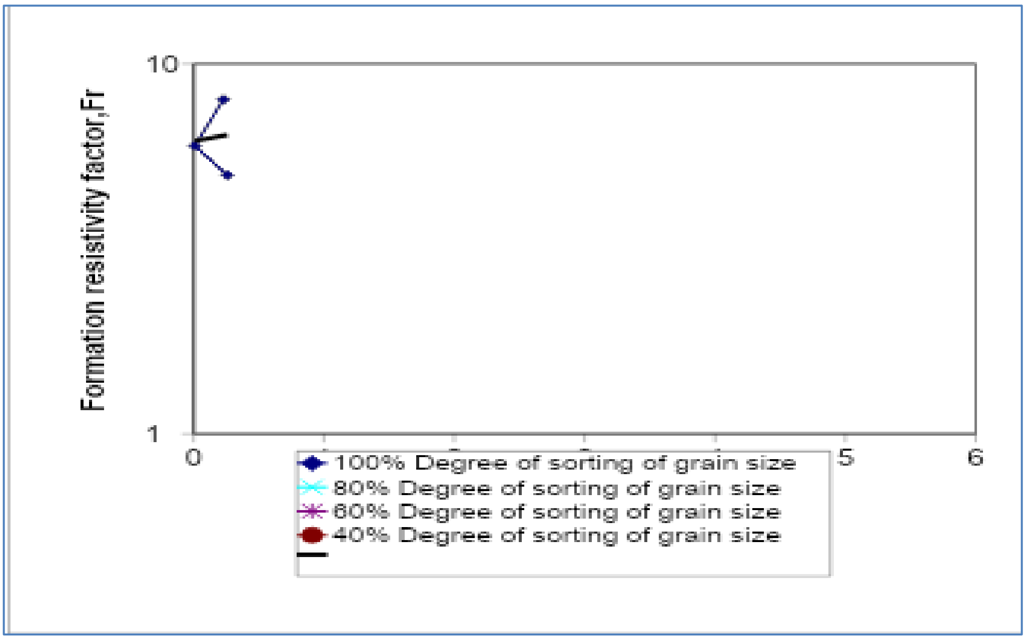

Figure 4: Log–log plot showing empirical correlation between salinity and Fr

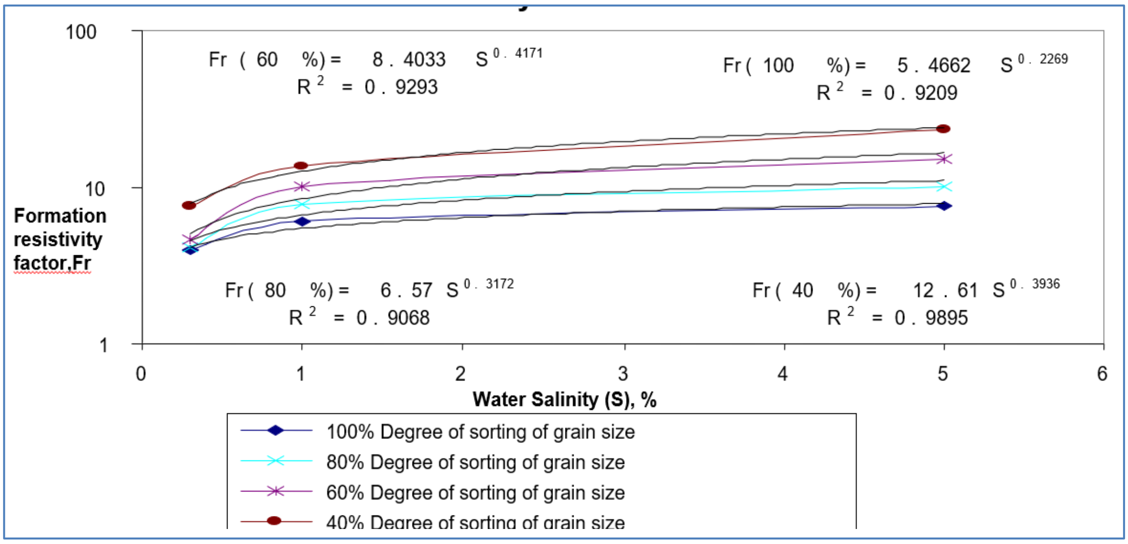

Figure 5: Effect of grain-size sorting on the formation resistivity factor at **5000Psi**

Table (1.1) displays the correlations that were obtained for the various levels of water salinity formation.

Table (1). effect of formation water salinity on Formation resistivity factor.

Confined pressure (C)	Degree of Sorting	Correlations
3000 psi.	80% 60% 40%	F_r=5.3362$S^{0.2152}$ (1.1) F_r =7.040$S^{0.3608}$ (1.2) F_r =10.195$S^{0.2665}$ (1.3)
4000 psi.	100%. 80% 60% 40%	F_r =5.1873$S^{0.2328}$ (1.4) F_r =7.758$S^{0.4166}$ (1.5) F_r =6.1858$S^{0.3393}$ (1.6) F_r =11.538$S^{0.4118}$ (1.7)
5000 psi.	100%. 80% 60% 40%	F_r =5.4662$S^{0.2269}$ (1.8) F_r =6.57$S^{0.3172}$ (1.9) F_r =8.4033$S^{0.4171}$ (1.10) F_r =12.61$S^{0.3936}$ (1.11)

Similarly, data of table (1.1) were used to obtain a general formula for the formation resistivity factor (F_r) as a function of water salinity (S) taking into consideration effect of confined pressure and degree sorting of the grain size. The general formula is given as :

$$\mathbf{F_r = a\ S^{-b}}$$

Where (a) & (b) are constants obtained from figure (1.7) and figure (1.8). as shown before these two figures were plotted by the aid of correlations obtained and mentioned in the table (1.1).

Knowing each of the degree of sorting and confined pressure, we can determine constants (a) & (b) from figure (1.7) and figure (1.8) then using the general equation $\mathbf{F_r = a\ S^b}$ you can find (F_r) as a function of the water salinity (S).

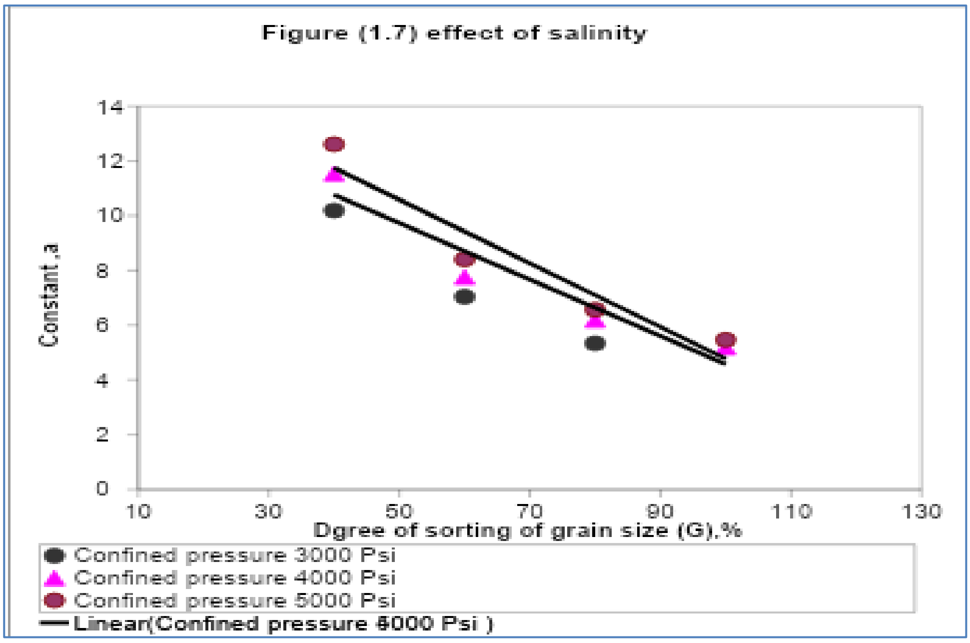

Figure 6: Effect of Grain-Size Sorting on the Empirical Constant (a) Under Different Confining Pressures

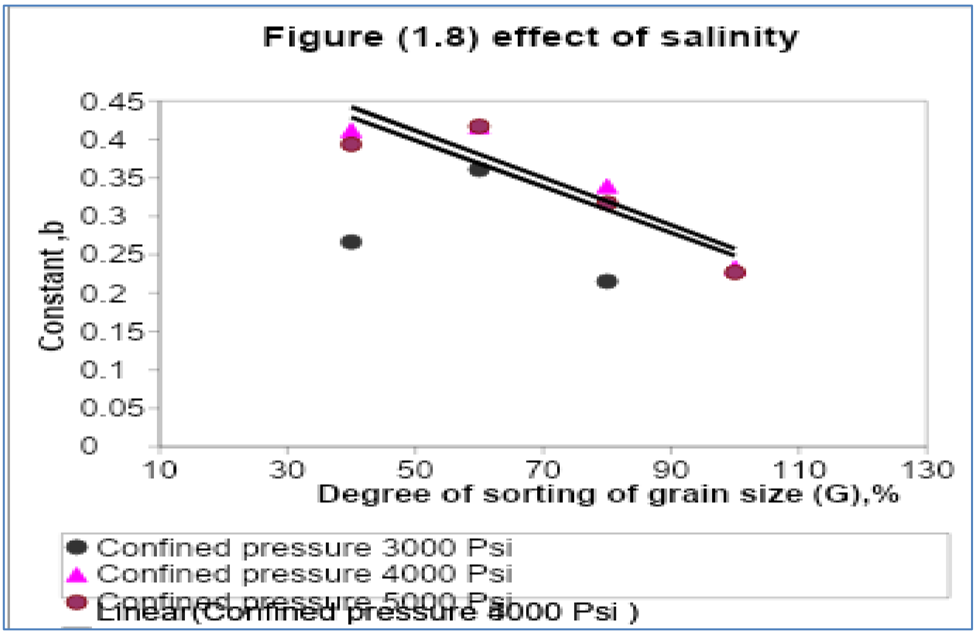

Figure 7: Effect of Grain-Size Sorting on the Empirical Constant (b) Under Different Confining Pressures

Discussion of Results

The results obtained from this study clearly demonstrate that **formation water salinity exerts a significant influence on the formation resistivity factor (Fr)** of reservoir rocks. Laboratory experiments conducted on sandstone core samples collected from three oil fields in the Sirte Basin revealed a consistent pattern: **as salinity increases, the formation resistivity factor also increases**. This behavior aligns with the theoretical expectations derived from **Archie's Law (Archie, 1942)** [2] and subsequent empirical correlations proposed by **Pirson (1963)** [1] and **Calhoun (1960)** [5], which emphasize the dependence of electrical conductivity on both porosity and the ionic concentration of the pore fluid.

Effect of Increasing Salinity

The data showed that increasing the concentration of sodium chloride (NaCl) from **0.3% to 5%** caused a notable increase in Fr values across all samples, irrespective of the degree of sorting or confining pressure. This can be explained by the fact that as salinity increases, the **ionic concentration of the formation water rises**, enhancing the brine's ability to conduct electric current. This enhancement leads to **higher brine conductivity (lower Rw)**.

However, because the rock matrix itself acts as an insulator, the overall decrease in the resistivity of the rock (Ro) is less pronounced than the decrease in Rw. Consequently, the ratio $Fr = \frac{Ro}{Rw}$ increases with salinity.
This finding is consistent with the theoretical model proposed by **Hamada and Al-Awad (2000)** [10], who indicated that **the resistivity factor is sensitive to variations in the conductive phase distribution** and fluid properties. Similarly, **Tabibi and Emadi (2003)** [11] emphasized that changes in the composition and continuity of the water phase—such as those induced by salinity—affect the resistivity response due to their influence on pore connectivity and cementation.

Influence of Confining Pressure and Sorting

The results summarized in Table (1.1) indicate that both **confining pressure** and **degree of grain sorting** play a secondary but noticeable role in controlling the resistivity factor. For each salinity level, increasing confining pressure from **3000 psi to 5000 psi** slightly altered the Fr values, which is attributed to the **reduction in pore volume and increased tortuosity** under stress conditions. Poorly sorted samples (40–60%) displayed higher resistivity factors compared to well-sorted samples (80–100%), confirming that irregular pore structures and reduced connectivity increase the tortuous path of electric current, as also noted by **Atkins and Smith (1961)** [8].
The empirical equations derived in this study (Fr = a S^b) for various combinations of confining pressure and sorting degree provide quantitative evidence that both parameters influence the constants a and b. Specifically, a and b tend to increase with decreasing sorting quality and higher pressure, highlighting the **nonlinear dependence** of electrical behavior on rock texture and mechanical compaction.

Comparison with Previous Models

When compared with established correlations—such as those of **Schlumberger (1972)** [6] and **Zaafran (1975)** [7]—the experimental results from this study show similar trends but indicate slightly higher Fr values at corresponding porosities. This deviation can be attributed to differences in **salinity levels**, **mineral composition**, and **experimental pressure conditions**. The findings of **Pérez Rosales et al. (2000)** [9], who introduced a modified model for fractured porous media, further support the idea that **structural heterogeneity and fluid properties must be incorporated** into resistivity-porosity relationships to achieve realistic field applications.

Interpretation of the Empirical Correlation

The general empirical correlation proposed in this research, $Fr = aS^b$, effectively captures the **functional dependence of Fr on salinity** while accounting for pressure and sorting variations. The values of the constants a and b, determined graphically from Figures (1.7) and (1.8), exhibit systematic trends that can be used to predict formation resistivity factors for given formation conditions. This correlation provides a practical predictive tool that extends the applicability of classical Archie-type equations to **high-salinity environments**, where conventional models often underestimate Fr.

Implications for Reservoir Evaluation

The observed increase in the formation resistivity factor with salinity has direct implications for **petrophysical interpretation and hydrocarbon saturation estimation**. Traditional resistivity logging techniques often assume constant formation water resistivity; however, the present findings show that **ignoring salinity variations may lead to inaccurate water saturation calculations**, especially in reservoirs with fluctuating formation water compositions. Incorporating salinity-dependent correlations into log interpretation workflows enhances the accuracy of **saturation models, permeability predictions, and reservoir quality assessments**.

Overall Discussion

In summary, the results validate the theoretical postulates of earlier studies while offering new empirical insight specific to **Libyan sandstone formations**. The observed trends affirm that **formation resistivity is a multifactorial property** influenced by both **rock texture** (porosity, sorting, cementation) and **fluid characteristics** (salinity, wettability). The positive correlation between salinity and Fr emphasizes the need for **localized calibration of resistivity models** in reservoir analysis. The derived empirical relationships therefore serve as a reliable framework for predicting resistivity behavior under varying geological and geochemical conditions.

Conclusion:-

This study has demonstrated that **formation water salinity exerts a pronounced and systematic influence on the formation resistivity factor (Fr)** of reservoir rocks. Through controlled laboratory measurements on sandstone core samples from three oil fields in the **Sirte Basin, Libya**, it was established that increasing salinity leads to an increase in the formation resistivity factor. This relationship arises because higher salt concentrations enhance the electrical conductivity of the formation water (reducing Rw), while the resistivity of the rock matrix (Ro) decreases at a much slower rate, thereby increasing the overall ratio $Fr = Ro/Rw$.
The experimental results confirmed that **grain sorting and confining pressure** also contribute to the variation in Fr. Poorly sorted samples exhibited higher resistivity factors due to increased tortuosity and reduced pore connectivity, while higher confining pressures slightly increased Fr by compressing the pore structure. These findings are consistent with the theoretical frameworks established by **Archie (1942)** and subsequent refinements

by **Atkins and Smith (1961)** and **Hamada and Al-Awad (2000)**, which collectively emphasize the influence of pore geometry, cementation, and fluid distribution on electrical behavior.

An **empirical correlation** of the form $Fr = aS^b$was derived to express the quantitative relationship between salinity (S) and the formation resistivity factor, with the constants *a* and *b* depending on the degree of sorting and confining pressure. This correlation provides a practical predictive model for reservoir characterization and can be integrated into formation evaluation workflows to improve the accuracy of **water saturation and hydrocarbon estimation** in high-salinity environments.

In conclusion, the research confirms that **salinity, rock texture, and stress conditions must be jointly considered** when interpreting resistivity data from well logs or laboratory analyses. The proposed correlation enhances the predictive capability of classical Archie-type models and contributes to more reliable reservoir evaluation under variable salinity conditions, particularly in Libyan sandstone formations.

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Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflict of interest.