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# SUMMARY

To understand the impact of reservoir properties on recovery, it is useful to represent the degree of effect of these elements in a common way that can be compared between different reservoirs. One approach that has been used in the oil and gas industry is to codify the various elements of reservoir complexity that affect recovery using a numerical scoring system to generate a complexity index. The framework used in this project is to assign a numerical score for each of four complexity factors that typically influence oil recovery. These factors include in-situ oil viscosity, structural compartmentalization/.faulting, vertical reservoir heterogeneity and STOIIP areal density. These factors are weighted for importance and added to create an overall complexity score that relates well with oil recovery factor where recovery factor refers to the proportion of oil initially in place that is expected to be produced with the currently sanctioned development. The relationship of decreasing recovery factor with increasing complexity index holds for most types of oil and gas reservoirs/fields.

# INTRODUCTION

## BACKGROUND

The determination of recovery factors for hydrocarbon reservoirs has been a subject of interest for oil companies since the beginning of the oil industry. When a new oil/gas field has been created with a discovery well, one of the first concerns of management is an estimate of future earnings from the production of oil and/or gas from a reservoir (Craft and Hawkins, 1959).

The future earnings are based upon the barrels of recoverable oil/gas as a fraction of the size of the reservoir referred to as the recovery factor. Proven reserves of crude oil, natural gas, or natural gas liquids are estimated quantities that geologists and engineers have demonstrated with reasonable certainty to be recoverable in the future from known reservoirs under existing economic conditions.

However, there is a degree of uncertainty with regard to the extent, recoverability, and economic viability of the proven reserves. A company's financial position may depend upon the amount of reserves located, the rate at which the reserves are recovered, and the economic and engineering principles and strategies incorporated by the company to best facilitate the efficient management of the oil/gas reservoir.

A knowledge of the extent of the reserves and rates of recovery are beneficial in the sale or exchange of oil properties. The calculation of recoverable oil also serves as a guide for reservoir engineers to develop programs to improve primary recovery factors. Past attempts to develop reasonably accurate recovery factors for hydrocarbon reservoirs have depended upon the particular reservoir under consideration.

In real life applications, the existence of any property is heavily influenced by other parameters. This is to say that the existence of a property is a function of certain parameters or depends on other parameters to exist. For example; the rate at which a person sweats is as a result of the amount of heat the body is exposed to. However, these parameters do not contribute equally in magnitude to the existence of the property under study. There arises the need to assess or evaluate the effect those individual parameters have on the property. This leads us to the concept of complexity scoring.

Complexity scoring is a simple, standardized model to score various trial elements that are related to most time-consuming tasks at participating sites. This is done by assigning numbers or codes to the parameters by way of ranking them according to a person’s own preferences (scoring). These numbers or letters indicate order of quality or performance that the individual choses to assign to the various parameters.

A reservoir study that includes accurately reported values for reservoir parameters of a homogeneous nature can result in more accurate estimates for recovery factors. However, many factors have contributed to the calculation of recovery factors that have been erroneous. Data collection procedures for reservoir parameters, the accuracy of the data being measured, and the way the data is interpreted will all affect the accuracy of the recovery factors calculated.

Another critical reservoir property to consider is the heterogeneity of the reservoir. Heterogeneous reservoirs can lead to the preferential depletion of certain intervals of the reservoir and to significant rerouting of reservoir fluids. Other considerations to take into account are in-situ viscosity, Structural compartmentalization/faulting, oil saturation, oil formation volume factor, STOIIP areal density, the overall size of the reservoir, and the number of parameters used in the calculation of recovery factors.

The complexity parameter combination that had a statistically significant ability to predict recovery factor in UK North Sea fields was found to be: Oil viscosity, Vertical reservoir heterogeneity, STOIIP areal density, Structural compartmentalisation/Faulting (Wickens and Kelly, 2010).

A reservoir scoring approach that uses scoring parameters and captures both the geological and fluid complexities is to be used to re-examine the past attempts to develop meaningful correlations for recovery factors and to use the previous analysis as a guide to develop improved correlations for recovery factors by utilizing statistical and multiple linear regression models.

## AIMS AND OBJECTIVES

* + 1. **MAIN AIM**

The main aim of this project is to assess the potential recovery factor of the Jubilee Oil Field of Ghana using a correlation chart developed from the complexity scoring method.

* + 1. **SPECIFIC OBJECTIVES**

1. To use the complexity scoring methods to assess and/or predict the potential recovery factors of oil fields.
2. To be able to evaluate how closely related recovery factors of oil fields within a common geological location are.
3. To explain and show in detail the factors required to facilitate a good potential recovery factor and hence good performance of oil fields.

## PROBLEM STATEMENT

Recovery factor is a very complex reservoir property that cannot be predicted without careful study of the various parameters that have an impact on it. The absence of just one parameter can lead to a very wrong recovery factor value. The design of a correlation to determine the recovery factors of oil fields therefore will be of benefit to companies as:

1. it would save them significant time in determining them.
2. it will allow a rapid assessment of the potential recovery performance of reservoirs.
3. it will also enable the extent of reservoir underperformance to be assessed.

## JUSTIFICATION OF THE PROJECT

The principal aim of petroleum engineering is to achieve effective and efficient data acquisition and management of reservoir production data whiles reducing significantly, time. This objective coupled with the continuous advancement in technology calls for the local industry to reorient itself to suit the demands of the current oil and gas industry. It is therefore necessary to develop a correlation that would help industry professionals in their day to day operations. The results of the project would also enable others use and further develop the approach to give more comprehensive and accurate model.

## STUDY QUESTIONS

The study intends to answer the following questions;

1. Are recovery factors the same for all oil fields in a particular locality?
2. Are recovery factors of oil fields determined by or affected by external parameters?
3. What are the possible parameters that have a direct impact on the recovery factors of oil fields?
4. Do these parameters contribute equally to the potential recovery factor of oil fields?
5. What are the intensities of those parameters on the potential recovery factors of oil fields?
6. How important are these parameters to recovery factors?

# LITERATURE REVIEW

The literature review is going to give the theoretical stance of the study, important facts about complexity scoring and the necessity of the presence of certain parameters to foster good reservoir performance or recovery factors of oil fields.

A new correlation between recovery factor and a reservoir complexity index has been developed and is demonstrated on UK and USA fields (Wickens and Kelly, 2010). The correlation allows rapid assessment of the potential recovery performance of reservoirs. Evaluation of reservoir complexity using a field scoring approach has previously been used to assess recovery factors in North Sea fields, Dromgoole (1997). However the scoring approach used was based solely on reservoir geological complexity and all nine scored parameters were subject to a high degree of subjective assessment that required expert judgement. A development of this approach by Smalley (2007) has been applied to a wider data base than the North Sea, but no details of the input parameters are available.

A reservoir scoring approach that uses six scoring parameters and captures both geological and fluid complexities has been developed by Nishikiori (2008). This approach was developed for Norwegian North Sea fields and requires less expert judgement. The correlation includes a number of key parameters such as in-situ viscosity, structural compartmentalisation, and reservoir heterogeneity.

However, unlike the existing research that had been made on complexity scoring, this project will be developed and demonstrated on a wide range of oil fields across the world instead of basing it on only a particular selected region.

## RECOVERY FACTOR

Recovery factor refers to the proportion of oil initially in place that is expected to be produced with the currently sanctioned development. Recovery factor may be affected by recovery process, reservoir complexity, well type and spacing. The recovery factor can be applied either for the whole or selected parts of the reservoir. When considering the entire reservoir, the ultimate recovery factor is defined as the relation between the ultimate recovery and the original oil in place, short OOIP:

ER - Ultimate recovery factor

NPMAX - Maximum oil produced

N - Oil initially in place

The recovery factors of oil fields are determined by a wide range of reservoir as well as fluid properties. In this study, we are going to consider four of such properties which are: In-situ oil viscosity, vertical reservoir heterogeneity, STOIIP areal density and structural compartmentalization.

## IN-SITU OIL VISCOSITY:

Viscosity is a property of fluids and slurries that indicates their resistance to flow. In-situ oil viscosity refers to the viscosity of oil as it exists in the reservoir. Viscosity of crude oil is one of the most important physical properties that influence the flow of oil through porous media and affects oil recovery factor at all stages of recovery.

There are many empirical relations that describe the viscosity of heavy oil at different temperatures. They generally provide good estimates. As the viscosity of oil decreases, its mobility increases. The oil mobility is the ratio of the effective permeability to the oil flow or its viscosity. This is given by λ0 where the oil mobility is in mD/cp, ko is the oil effective permeability in mD and μo is the oil viscosity in cp.

After the viscosity of oil is reduced and the mobility is increased, the displacement of oil by another fluid becomes easier. In fact, the oil may even drain by gravity to bottom layers if the viscosity reaches small values. The higher the in-situ viscosity value of the oil the lower its flow and hence a lower recovery. The converse is equally true.

## STRUCTURAL COMPARTMENTALISATION/FAULTING

This is the segregation of a petroleum accumulation formation into a number of individual fluid/pressure compartments (Jolley et al). Thus, reservoir compartmentalisation impacts the volume of moveable (produceable) oil that might be connected to any given well drilled in a field, which restricts the volume of reserves that can be ‘booked’(reserved in advance) for that field.

Structural Compartmentalization is caused by barriers to fluid flow. A reservoir may be laterally compartmentalized by faults that generate seals and/or lateral variations in reservoir quality.

To understand the impact of reservoir compartmentalization on recovery, it is useful to represent the degree of compartmentalization in a common way that can be compared between different reservoirs. One approach that has been used in the oil and gas industry is to codify the various elements of reservoir complexity that affect recovery using a numerical scoring system to generate a complexity index. This approach grew out of the initial work of Dromgoole & Speers (1997).

The relationship of decreasing recovery factor with increasing complexity index holds for most types of oil reservoirs. The complexity factors incorporated into the complexity index specifically relate to structural compartmentalisation factor. There is a clear inverse relationship between the compartmentalisation score and recovery factor. A statistical analysis of a much larger database indicates that 35% of the total variation in recovery factor can be accounted for by the degree of reservoir compartmentalization.  
Reservoir/structural compartmentalization is caused by sealing faults or depositional discontinuities and can have an adverse effect on oil or gas recovery factors by reducing the efficiency of drainage (connectedness to a producing well) and sweep (between injectors and producers).

The more compartmentalized an oil field is, the lower the fluid flow and subsequently, the lower the recovery factor.

## VERTICAL RESERVOIR HETEROGENEITY

Reservoir heterogeneity refers to the non-uniformity in the structural arrangements of a petroleum bearing formation. The existence of different sand formations each with different permeability characteristics is an example. As a result of different geological processes, there exist different layers in a reservoir. The layers vary in rock type, porosity, permeability and others. The movement of fluids varies from rock to rock.

In a typical reservoir formation, the ratio of the maximum permeability value to the minimum permeability value is known as the vertical reservoir heterogeneity (kmax / kmin ). The movement of oil is faster in the more permeable layers compared to the others. Likewise, the movement of oil is slower in the less permeable layers compared to the others. The lower the vertical reservoir heterogeneity, the higher the recovery factor due to higher oil flow. The converse also holds.

## STOIIP AREAL DENSITY:

This refers to stock tank oil initially in place areal density. The STOIIP areal density as used in this concept is the amount of oil volume per unit of area. It has the unit Sm3/km2 (standard cubic metre per square kilometer). This parameter greatly affects recovery factors of oil, in that higher values presents a higher value of recovering more oil deposits and vice versa.

# PROPOSED RESEARCH METHODOLOGY

## DATA ACQUISITION

In this project, oil fields across the globe whose data can be gotten will be selected globally. These data will further be grouped according to regions in terms of continents. When these oil fields are selected, their geological and fluid properties that are under study in this project (oil viscosity, vertical reservoir heterogeneity, STOIIP areal density) will be recorded and then scored using a scoring approach defined below.

## COMPLEXITY INDEX APPROACH

The complexity parameter combination that will be used to assess potential Recovery Factors of oil fields in this study are:

* Oil viscosity
* Vertical reservoir heterogeneity
* STOIIP areal density
* Structural cornpartmentalisation/Faulting

The scoring approach to be used is as follows:

A value of 1 to 5 will be assigned (scored) to the various parameters in order of their decreasing effects on recovery factor. That is, an assigned value of 1 to a particular parameter will show a higher influence of that parameter on the recovery factor. The trend decreases from 1 to 5 with a score of 5 bearing the lowest effect on the recovery factor.

1 > 2 > 3 > 4 > 5

Decreasing effect of parameter score on recovery factor

### STRUCTURAL COMPARTMENTALISATION/FAULTING SCORING SYSTEM

Unlike the scoring systems for oil viscosity, reservoir heterogeneity and STOIIP areal density the structural compartmentalisation/faulting does not follow a well laid down scoring system. As such, description of a particular oil field will be used in defining and assigning a score to the structural compartmentalisation/faulting. The more compartmentalized an oil field is, the lower the free flow of oil and hence the lower the recovery factor. Excellent scores (a score of 1) will be assigned to oil fields with least compartmentalization/faulting. This scoring trend will be reduced as the compartmentalization/faulting increases. The least score (a score of 5) will be assigned to highly compartmentalised oil fields.

### VERTICAL RESERVOIR HETEROGENEITY SCORING SYSTEM

The table below shows how the scoring will be done for reservoir heterogeneity:

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| **SCORE** | **RANGE** | **REASON** | **EFFECT ON RECOVERY FACTOR** |
| 1 | 1-10 | The formation is homogeneous or has a low vertical heterogeneity. This permits a high oil flow through the formation | EXCELLENT |
| 2 | 101-102 | The vertical heterogeneity increases slightly, causing a decrease in oil flow through the formation | VERY GOOD |
| 3 | 102-103 | The vertical heterogeneity continues to increase marginally, further decreasing oil flow through the formation | GOOD |
| 4 | 103-104 | The vertical heterogeneity is high resulting in a low flow of oil through the formation | FAIR |
| 5 | >104 | The vertical heterogeneity is very high resulting in a very low flow of oil through the formation | POOR |

### IN-SITU OIL VISCOSITY SCORING SYSTEM

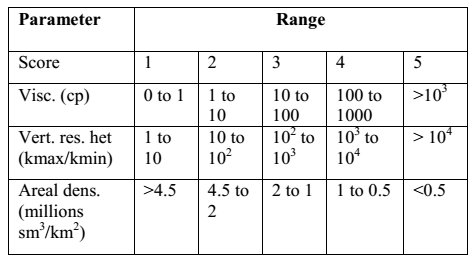
Viscosity is the most important parameter for oil production as this determines the ability of a fluid to flow. The higher the oil viscosity, the lower the ability of the oil to flow with ease and subsequently the lower the recovery factor. The selected approach for the oil viscosity scoring is from 1-5 for each factor of ten increase in oil viscosity. In scoring with respect to viscosity, the value 0-1cp will be scored as 1, value 1-10cp as 2, the value 10-100cp as 3, 100-1000cp as 4, value greater than 1000cp as 5.

### STOIIP AREAL DENSITY SCORING SYSTEM

Under STOIIP areal density the higher the value, the greater the recovery factor and vice versa. Values greater than 4.5 million sm3/km2 as scored as 1, values ranging from 4.5-2 million sm3/km2 as 2, values ranging from 2-1 million sm3/km2 as 3, values ranging 1-0.5 million sm3/km2 as 4 and those values less than 0.5 million sm3/km2 as 5.

### SUMMARY OF SCORING APPROACH

The table below summarises the scoring approaches selected to be used in this study:



### DEVELOPING RECOVERY FACTOR SCORE

The scoring systems above are then combined to give a Recovery factor score (a sum of the individual parameter score). This score parameter is formed as a weighted combination of the four score schemes. A weighted factor of two on the oil viscosity score is added to a factor of two on the structural compartmentalization/ faulting score, together with the vertical heterogeneity score and the STOIIP areal density score to obtain the final score. Correlations would be obtained after plotting recovery factor against recovery factor score. This correlation would be used in predicting potential recovery factors of various oil fields.

# EXPECTED RESULTS

When a low recovery factor score value is obtained from an oil field, the unknown recovery factor will be expected to be high. On the other hand, when a high recovery factor score is obtained from a field, a low recovery factor is expected to be evaluated.

The recovery factors that will be determined from oil fields with unknown recovery factors are expected to be an accurate or close to accurate estimate of the real recovery factor of that field.

After scoring and obtaining the recovery factors of known oil fields, it is expected to be similar to the recovery factors of those known fields.

# CONCLUSION

Based on the complexity scoring approach, we intend to develop a correlation of different parameters to score oil fields. Through the scoring of these oil fields, the recovery factors of other fields can be predicted.

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