Review Article

Complete overview of reservoir characterization in sedimentary basins

Comment [M1]: this is one of the cases of hydrocarbon traps (case of an anticlinal structure and faults). there are several types....

ABSTRACT

Evaluating the subsurface characteristics of reservoirs is an important part of hydrocarbon exploration and production in sedimentary basins. This process combines geological, geophysical, and engineering data to comprehend the subsurface geology and fluid distribution, determine reserves, and predict the fluid movement in the reservoir. The primary goal of reservoir characterization is to create a precise and dependable model of the reservoir to maximize the production procedure and reduce the associated risks of hydrocarbon exploration and production. This review examines different approach utilized for reservoir characterization in sedimentary basins, including geological, geophysical, and engineering methods. Each method's advantages and disadvantages are discussed, alongside their uses in different reservoir contexts. The importance of combining multiple lines of evidence to enhance the accuracy of the reservoir models is also examined.

Comment [M2]: briefly discussed the formation conditions

Comment [M3]: what is the best type of trap for hydrocarbons?

Keywords: Reservoir, Porosity, Permeability, Production data, Well logs, Seismic data

1. INTRODUCTION

Analyzing sedimentary basins is necessary for hydrocarbon exploration and production, and these operations are contingent upon correctly understanding the subsurface geology and fluid placement (Fig. 1). Characterizing reservoirs (Mahmood and Vaziri-Moghaddam, 2016; Chen, et al., 2019) is a vital step that combines various types of information to create a dependable model of the reservoir (Gupta and Kumar, 2020; Cao, et al., 2023; Aksel, et al., 2023). This model encompasses the geometry, composition, porosity, permeability, fluid characteristics, and fluid positioning in the reservoir (Luo et al., 2018; Nwaezeapu, et al., 2018; Zhang, 2021). To grasp the rock properties, fluid distribution, and flow capability of subsurface reservoirs, geological, geophysical, and engineering details must be integrated (Luo et al., 2018). The exactness of the reservoir model is imperative for optimizing the production plan, raising the recovery rate (Ibekwe et al., 2023), and reducing the perils connected with hydrocarbon exploration and production. This paper talks about an overview of reservoir characterization in sedimentary basins, along with its importance.

Comment [M4]: you haven't talked about the different types of reservoir rocks,!!!

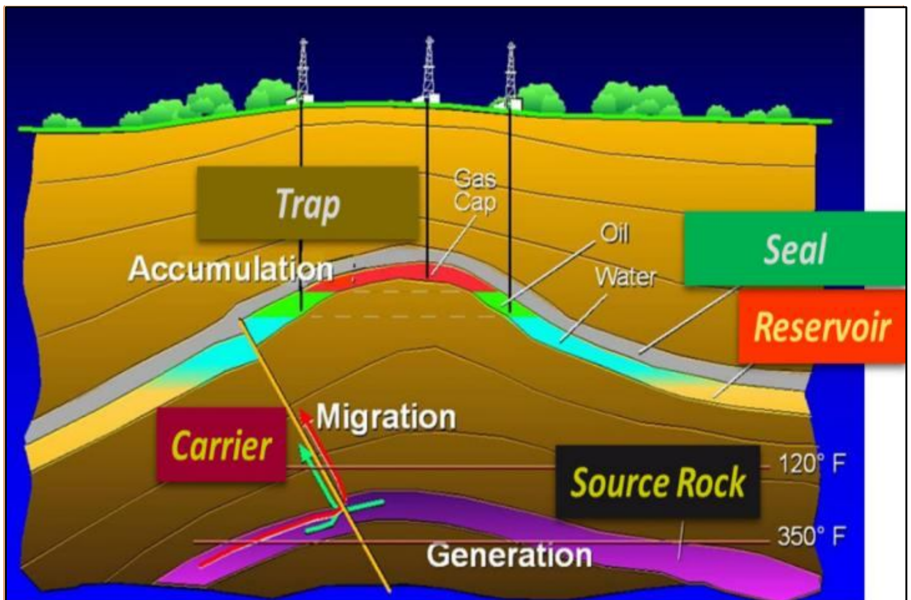
Comment [M5]: added reservoir rock typesand hydrocarbon formation conditions

2.IMPORTANCE OF RESERVOIR CHARACTERISATION

It is critical for successful hydrocarbon exploration and production in sedimentary basins to understand reservoir characteristics (Al-Lawati, 2014; Li and Li, 2016; Alzayer and Al-Dhamin 2019; Li et al., 2021; Oguadinma et al, 2021). This includes information on porosity,

Comment [M6]: I think the depth of the reservoir is very important for the realization as well as for the production permeability, fluid saturation, rock types, and the environmental conditions of deposition. This is required to realise the potential of hydrocarbon reservoirs (Oguadinma et al., 2016), as well as to devise effective strategies for drilling, completion, and production. Not only is it necessary to detect reservoirs, but the characterisation of them is important for managing the associated risks and uncertainties (Ibekwe et al., 2023; Oguadinma et al., 2023;). By combining seismic, well log, and core data, engineers can construct more accurate geological models and make intelligent choices regarding reservoir development, such as well spacing, artificial lift, and water injection.

Comment [M7]: cited some examples of the risks



Comment [M8]: change temperature units to celsius

Fig. 1.A sedimentary basin showing the five elements of a petroleum systems which includes reservoir (Craig and Quagliaroli, 2020)

Comment [M9]: Modified Figure 1
The figure must show the lithologic facies of the rocks (reservoirs, covers and substratum)

Comment [M10]: the figure only shows the 2 types of traps (anticline structure and faults)!!!,

Comment [M11]: The fault is reverse!!!
Added «F» next to the fault, yellow line

3. METHODS OF RESERVOIR CHARACTERISATION

Analysing reservoirs is an intricate task that necessitates the combination of numerous kinds of information and practices (Fig. 2). Some of the most widely-used approaches for characterization include geological methods which involve interpreting data that is located on the surface and underneath it to recognize the stratigraphic and structural arrangement of the sedimentary basin (Ozkan and Raghavan, 2014; Luo et al., 2018; Jammes and Bellahsen, 2019; DeGroot and Laubach, 2019; Zhang, 2021; Oguadinma et al., 2023). One such technique is mapping the surface which entails identifying and plotting geological components such as outcrops, faults, and folds to grasp the structural make-up of the sedimentary basin (Oguadinma et al., 2014). The information collected from surface mapping can be used to modify subsurface models and advance the accuracy of the reservoir assessment. Some of the most popular methods for reservoir characterization are the ones listed below.

Comment [M12]: the structural has distinct roles: 1- positive role for trapping and 2- negative role if the hydrocarbons are flush with the surface

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3.1 Geological methods

3.1.1 Well logging

Using geological methodologies, it is possible to comprehend the sedimentary basin's structural and stratigraphic framework by interpreting surface and subsurface data (Corbett and Davidson 1993). These techniques consist of:
Surface mapping **-** Surface mapping entails locating and mapping geological features including outcrops, faults, and folds in order to comprehend the sedimentary basin's structural architecture (Oguadinma et al., 2014; Okoro et al., 2020). Surface mapping data can be utilized to limit subsurface models and increase the precision of reservoir characterisation.

3.1.2 Core analysis

Requires the extraction of rock samples from the subsurface during the drilling procedure, and it is essential for validating the well log data and for constructing precise geological and reservoir models (Amaefule, et al., 1993). It also provides knowledge about the properties of the reservoir rocks, such as porosity, permeability, grain size, and mineralogy (Amaefule, et al., 1993).

3.1.3 Fluid samples analysis

Samples of fluids can be acquired from wells and cores, which gives insight into the nature, composition, and characteristics of the hydrocarbons and other liquids held within the reservoir.

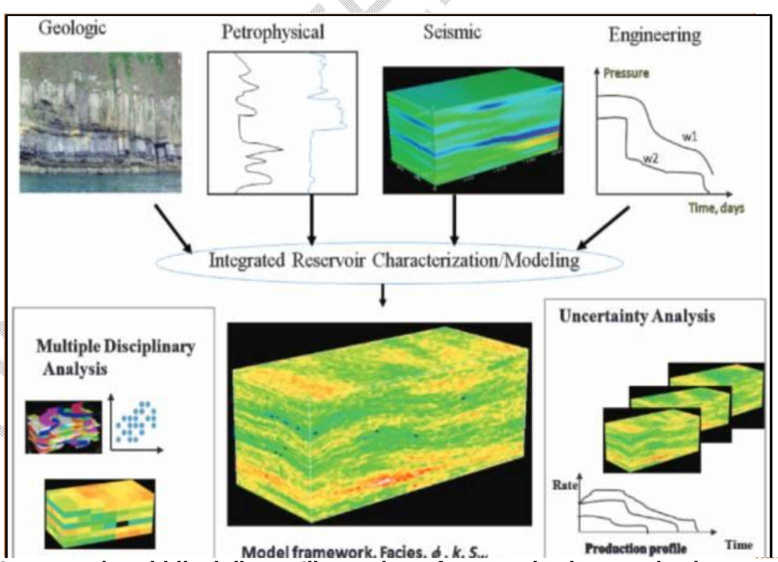

Fig. 2. Integrated multidisciplinary Illustration of reservoir characterization approach (Yu et al., 2011)

3.1.4 Numeric modeling

Comment [M14]: also the proposed mapping of the subsurface is of essential importance

Comment [M15]: rock samples for the purpose of a petrological study

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Numerical models are employed to simulate the flow pattern of hydrocarbons and other fluids in the reservoir. These models use the geological and petrophysical information to anticipate the output of the reservoir under a variety of circumstances.

Comment [M19]: example for circumstances

3.2. Geophysical methods

Physical properties of the underground stone layers are evaluated and interpreted using remote sensing techniques which are known as geophysical methods (Corbett and Davidson 1993). These methods include:

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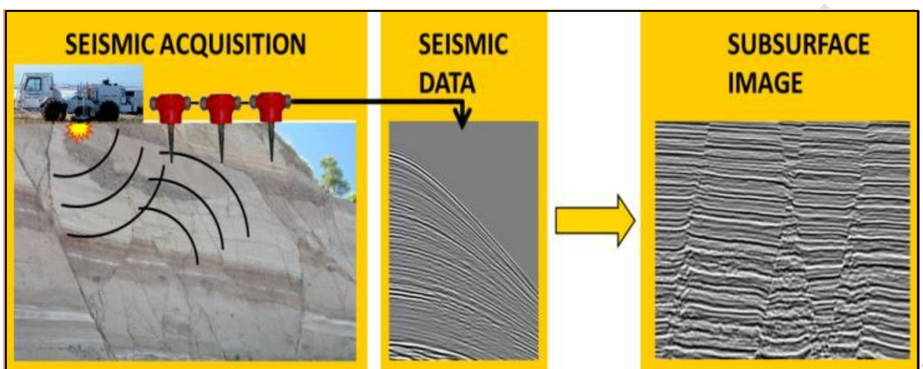

Fig. 3. Process of subsurface data collection from seismic acquisition to subsurface image (Craig and Quagliaroli, 2020)

Comment [M23]: Sorry, it's not a figure (poorly presented) !!!!!! Moved figure 4 down

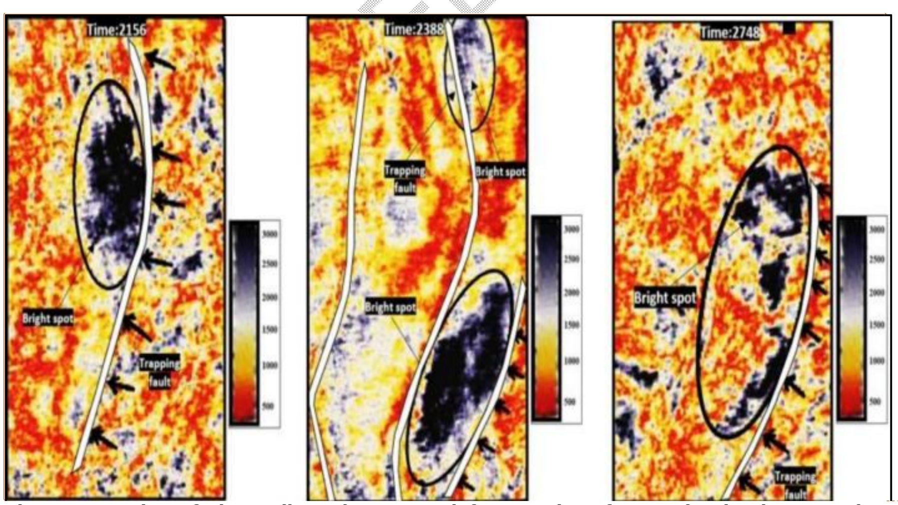

Fig. 4: Results of time slices interpreted from subsurface seismic data. It shows hydrocarbon reserve in form of bright spot and also shows some structural configuration (Ibekwe et al., 2023)

3.2.1 Seismic survey

To picture the subsurface geology, seismic surveys generate and detect sound waves (Craig and Quagliaroli, 2020; Fig. 3). Seismic data can be used to evaluate reserves, forecast fluid flow behavior in the reservoir, and offer precise information about the structural and stratigraphic framework of the sedimentary basin.

The most important instrument for subsurface imaging is seismic data analysis, which offers details on the lithology, fluid distribution, and subsurface structures (Aniwetalu, et al, 2018; Kelechi et al., 2023; Fig. 4). In order to determine the position and shape of hydrocarbon reservoirs, it is utilized to create 3D models of the subsurface.

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3.2.2 Gravity and magnetic surveys

In order to map the subsurface geology, gravity and magnetic surveys measure changes in the Earth's gravitational and magnetic fields. These techniques can be used to locate structures and lithologies that are not evident on seismic data as well as to learn about the thickness, density, and magnetic susceptibility of the rocks (Barest, et al., 2004; Wang and Hsieh, 2019).

Comment [M27]: and provoded information on the lithology

3.3.Engineering methods

In order to calculate reserves and forecast fluid flow behavior, engineering methods measure and evaluate production data from the reservoir (Ribeiro and Ximenes, 2016). These techniques consist of

3.3.1 Production data analysis

To assess reserves and forecast fluid flow behavior, production data analysis entails the interpretation of production rates and pressure data from the reservoir (Joshua et al., 2022; Fig. 5). This technique can be utilized to optimize the production strategy and can provide information about the reservoir performance, including well productivity, drainage area, and fluid characteristics (Ribeiro and Ximenes, 2016).

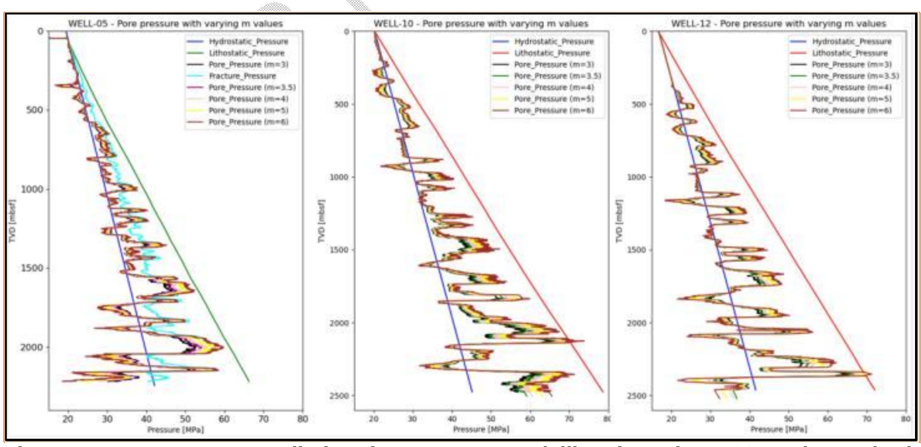

Fig. 5. Pore pressure prediction from Eaton modelling based on ∆t sonic method (Joshua et al., 2022)

Comment [M28]: Figure 5 is not visible and not readable (modified and enlarge the writing)

3.3.2 Well testing

In order to calculate reserves and forecast fluid flow behavior, well testing measures pressure and flow rate data from the reservoir. It can be used to optimize the completion and stimulation approach by providing extensive information about the reservoir's attributes, such as permeability, skin factor, and wellbore storage (Amaefule, et al., 1993).

Comment [M29]: calculate the capacity of the reserve and frorecast ....

4. RESERVOIR CHARACTERIZATION CHALLENGES

Because sedimentary basins are complicated and diverse, characterization of reservoirs is a difficult undertaking (Ozkan and Raghavan, 2014; Luo et al., 2018; Zhang, 2021). Even with the enormous advancements achieved in this area, engineers still have a lot of difficulties adequately describing reservoirs (Luo et al., 2018; Zhang, 2021). Data quality, heterogeneity, non-uniqueness, and uncertainty with sedimentary basin reservoir characterization are some of the difficulties.

Comment [M30]: added (structure, form, dimension, depth, etc.)

4.1. Data quality

The location, accessibility, and depth of the reservoir all have an impact on the type and amount of data that can be used to characterize the reservoir. The data is frequently lacking or imperfect, which can cause uncertainty and mistakes in the geological models. It's also possible that the data is of poor quality, which makes it challenging to comprehend or combine with other data types. For instance, low signal-to-noise ratios or resolution in seismic data may make it challenging to detect underlying features or distinguish between various rock types. The petrophysical characteristics of the rocks may be unknown because to artifacts or gaps in well logs. Additionally, it can be challenging to create reliable geological models since data from many sources may be inaccurate or conflicting.

4.2. Heterogeneity

Sedimentary basins are extremely heterogeneous, with varied fluid distribution, complicated geological formations, and rock characteristics. It may be challenging to create precise geological models and forecast the behavior of fluid flow in the reservoir due to this heterogeneity. The porosities, permeabilities, and lithologies of the reservoir rocks may vary significantly depending on depth or location. With changes in fluid characteristics, saturation, and motility, fluid distribution can also be complicated. It can be challenging to create representative models for the entire reservoir and to extrapolate data from one location to another due to heterogeneity.

Comment [M31]: and distinct rock ...

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4.3.Non-uniqueness

Reservoir characterization is frequently impacted by non-uniqueness, which refers to the ability of different geological models to accurately fit the same data. This might happen as a result of the sedimentary basin's complexity and heterogeneity, as well as the scarcity of data. Non-uniqueness can cause predictions of reservoir behavior to be imprecise since different models may yield inconsistent results. In order to validate their projections, reservoir engineers must carefully assess the model's underlying assumptions and unknowns.

4.4. Uncertainty

A significant obstacle to reservoir characterization is uncertainty, which can compromise the models' dependability and accuracy. A number of factors, such as data quality, heterogeneity, non-uniqueness, and modelling assumptions, can cause uncertainty. For instance, the fluid distribution and flow behavior predictions may be affected by the uncertainty in the petrophysical characteristics of the rocks. The boundary conditions, well performance, and production history are only a few examples of the parameters and

Comment [M33]: heterogeneity of what?

assumptions that are employed in numerical models that can introduce uncertainty. The sources of uncertainty must be carefully considered by reservoir engineers, and their effects on forecasts of reservoir behavior must be quantified.

4. CONCLUSION

Characterizing reservoirs is a crucial step in the discovery and extraction of hydrocarbons in sedimentary basins. Techniques from geology, geophysics, and engineering are utilized to characterize reservoirs. These techniques offer supplementary data on the underlying geology and fluid distribution, and they can be used to calculate reserves and forecast how fluids will flow in a reservoir. It can be challenging to create precise geological models and predict the flow behavior of fluids in the reservoir due to issues with data quality, heterogeneity, non-uniqueness, and uncertainty. To create accurate models, reservoir engineers must carefully assess the data at hand and incorporate a variety of supporting evidence. In a bid to assess the effects of various assumptions and parameters, they must also quantify the uncertainties and do sensitivity studies.

By combining various sources of data and employing cutting-edge technology and methodology, such as high-resolution seismic imaging, advanced well logging techniques, and machine learning algorithms, it is possible to increase the accuracy of reservoir models, characterize reservoirs more accurately, and mitigate challenges.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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