Chapter 1

Introduction

1.1 General

Hydrocarbons accumulate in regions known as reservoirs within the Earth's surface. All reservoirs contain two essential components: a rock reservoir and a hydrocarbon trap. The reservoir rock is characterized by the nature and geometry of the rock (Archie, 1950). Reservoir rocks may have empty spaces or pores that can contain gas, oil, or water. The size and shape of the reservoir is governed by the sedimentary sources and atmosphere in which it was formed (Archie, 1952). Reservoirs are typically heterogeneous. The key depositional processes influence variations in the characteristics of the rock. Sedimentary rocks of clastic origin, and carbonate rocks of chemical origin are the most significant types of reservoir rocks (Nur and Wang, 1989).

Characterization of the reservoir implies extraction of the information contained in the seismic data as accurately and efficiently as possible. The elastic properties that a rock may benefit from are: porosity, incompressibility (bulk modulus (k)), rigidity (shear modulus (μ)), clay material, pore fluid, lithology and gas saturation. All these influence seismic waves that penetrate rocks (Garotta et al., 2002). Because rocks have elastic properties, in terms of elastic rock constants, the elasticity principle provides the basis for the compressional and shears waves velocities. Elasticity assures that deformation completely disappears when the stress that induces deformation is removed

(Sheriff, 1975; Sheriff and Geldart, 1995). The passing seismic waves can cause stress. The elastic properties of rock can be determined from measurements of velocity and density (ρ) (Hilterman, 2001). Biot (1956) and Gassmann (1951) equations link seismic velocities to the fluid properties and porosity of rock formation. Porosity significantly affects the seismic velocity and sometimes a velocity reduction is directly proportional to the porosity. The time-average equation is commonly used for measuring porosity from seismic velocity (Wyllie et al., 1956).

For the assessment and exploration of hydrocarbon resources, well logs and seismic data are widely used (Bahmaei and Hosseini, 2019). Well log data is the one of the most significant parameter for reservoir estimation and elucidation of reservoir parameters (Hosseini et al., 2019). The handling and analysis of well logs can be used to obtain information such as shale volume, porosity, P-wave velocity, water saturation, lithology, permeability, and production regions (Gholami and Ansari, 2017). Though well log data has higher resolution than seismic data, it correlates to a specific portion of the reservoir and errors will arise in simplifying the data to the entire reservoir in view of the complexities of the geology (Somasundaram et al., 2017). On the other hand, seismic data contains comprehensive information about fluid in the soil and conditions of rock (Maity and Aminzadeh, 2015). For example, 3D seismic data reveals the reservoir's acoustic properties covering a continuous and mathematically significant portion of the field (Van Riel, 2000; Ogiesoba, 2010). The reliability of the seismic data is less than from well log data. However, the range and reach of seismic dataset is relatively broad, covering a larger region of the field, which is its main benefit (Russell et al., 1997). A better characterization of the reservoir is provided by integrating the well log and seismic data (Hampson et al., 2001; Oliveira et al., 2005). Lateral variations in reservoir petrophysical properties can be more dependably detected by integrating this knowledge.

Reservoir characterization by seismic methods typically incorporates all available information to measure the extent of a hydrocarbon bearing reservoir's physical parameters, geometry, and flow properties. The goal is to model reservoir structure, connectivity and flow properties, such as porosity, permeability, and fluid saturations,

etc. as accurately as possible. This may involve reservoir geology experts to identify reservoir geometry and lithology, flow units and reservoir extent, fluid movement simulation and the predicted changes in reservoir properties during production process (Berkhout, 1993). The heterogeneities and complexities of the reservoir emerging from incomplete well management, insufficient resolution of geophysical data sets and problems with indirect measurements of reservoir parameters from log, seismic and output data leads to the inherent difficulty of an efficient reservoir characterization (Avseth, 2000). However, the reservoir models help to predict the probability distribution of hydrocarbon volumes more efficiently, help in geo-steering of wells to appropriate locations, and serve as inputs to the reservoir simulation (Eidsvik et al., 2004).
In this light, it is important to use the state-of-art tools and techniques for characterization of reservoirs. Therefore, in the present study, the seismic and well log data have been utilized rigorously to characterize the reservoir for two separate cases. Further the characterization has been doubly verified by state of art artificial intelligence tools.

Seismic inversion is relatively old but robust technique to extract petrophysical parameters in the subsurface. Reservoir characterization using seismic and well log data is generally performed using seismic inversion and geostatistical techniques. These techniques are routinely used by geoscientists for the interpretation of seismic reflection data to locate underlying hydrocarbonaceous and other mineral deposits within the ocean. There are several types of seismic inversion and geostatistical methods available. However, being many, they create dilemma among the application engineers and geoscientists, to choose the best one. The inversion methods are time consuming and require expertise before their application, hence use of all the methods may not be possible in the one case. To the best of the understanding, there is severe deficiency of a comparative study of this nature which could optimize the computational time and quality of results obtained from the seismic and well log data. Therefore, the present study aims at taking up this challenge to compare several seismic inversions and geostatistical methods quantitatively and qualitatively to find best and the most robust technique.
The precise objectives of the present work are enumerated below:

1.2 Objectives of present study

1. To detect the reservoir by applying various seismic inversion and geostatistical methods and techniques.

2. To carry out a comparative analysis of post-stack and pre-stack seismic inversion methods on a number of important petrophysical properties, namely, P-impedance, S-impedance, Density, Lambda-mu-rho (LMR), Elastic impedance, P-wave and S-wave velocities (V_P and V_S), and V_P/V_S ratio.

3. To investigate the influence of the conditioning on pre-stack inversion results by proper data conditioning.

4. To measure the effect of Gaussian noise using Elastic Impedance Inversion method for pre-stack data.

5. To determine the values of important petrophysical parameters, namely, porosity, density, P-wave and gamma ray from numerous geostatistical techniques for reservoir characterization.

6. To compare and analyze the performance of single attribute analysis, multi attribute analysis, probabilistic neural network and multilayer feed forward techniques on various petrophysical properties of post-stack seismic data.

1.3 Structure of thesis

The thesis is prepared as follows: In Chapter 1, an introduction about reservoir characterization and objectives of current research are discussed. Chapter 2 discusses the literature review. Chapter 3 discusses the study area and available data sets. Chapter 4 includes research methodology of the study. In this chapter, the flowchart of the methodology and various seismic inversion methods are discussed. Results are assessed and described in Chapter 5. Discussion of the results has been separately put in the Chapter 6. The conclusions and suggestions for future work have been enumerated in Chapter 7.