CHAPTER 1 OBJECTIVES, PROCEDURE AND SEISMIC ROCK PHYSICS

1.1. Objectives

Objectives of seismic reflection interpretation for hydrocarbon exploration are very varying, from regional basin to detail reservoir study. Therefore, it is difficult to define the standard objective and procedure.

The general objective of the interpretation is to provide accountable solutions from all available data and the related works can be divided into three main stages: preparation, interpretation and reporting. Focus of this book is in the data interpretation. Data preparation stage includes the preparation of the seismic data itself and gathering of all relevant information.

To do a good interpretation, seismic interpreter need to combine the knowledge on seismic interpretation, seismic data acquisition and processing, sedimentology, stratigraphy, basin evolution, well log and petrophysical analysis. The success of the interpretation also depends very much to the data availability and quality, where the two most important data are seismic and well log data.

1.2. Procedure

The procedure for seismic data interpretation can be summarized as follows (Figure 1.1):

1) Collect the main input which are the processed seismic and well data. The seismic data can be post and/or pre-stack data, depending on the purpose of the study. The most important well data are check-shot, sonic log and density log.
2) Set theobjectives and the target interval of the study The common objective is to get the following information/model for the studied interval:
    a. Time and/or depth structure
    b. Facies and/or depositional system
    c. Physical properties (porosity, sand/shale, pore-fluid saturation, etc)
3) Understand the geology of the studied interval, especially the relatedtectonic, basin evolution, structure and stratigraphy.
4) Acquire basic rock-physics knowledge to understand the relations between the physical properties of rock targets and the seismic properties.
5) Determine polarity, phase and resolution of the seismic record.
6) Tie the seismic with the well and understand the geological (lithology, thickness, porosity, pore-fluid type, vertical and lateral distribution, etc.) and geophysical (velocity, density, gamma ray/SP response, etc.) characteristics of the target.

7) When necessary do forward modeling and target response evaluation:
    a. Forward modeling to model the seismic response of a certain geological model
    b. Backward modeling to infer the geological meaning of seismic response.
8) Determine and understand the noise of the seismic data and their associated interpretation pitfalls.
9) Do geological interpretation of the seismic data to achieve the objectives. Depending on the objectives, the product of the interpretation can be the models / maps of the target structure in time and/or depth, its facies and depositional system, and physical properties.
10) When necessary use sequence seismic stratigraphy and advance methods such as seismic inversion and seismic attributes analysis to achieve the objectives.

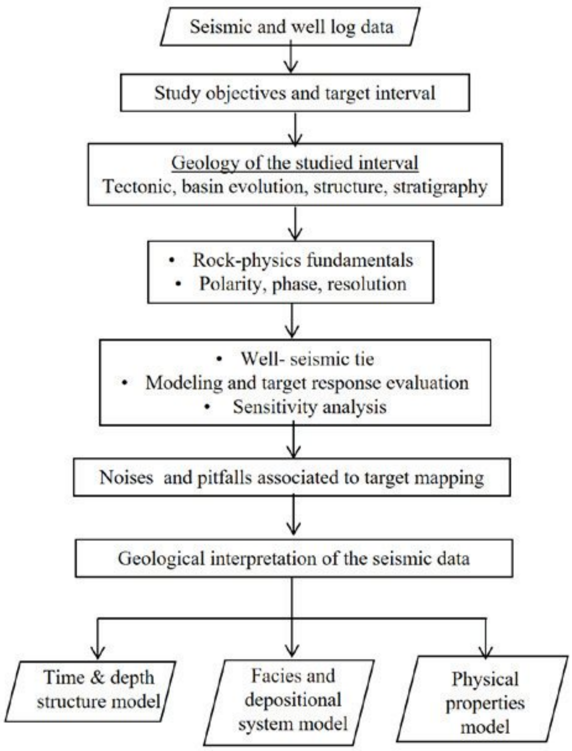

Figure 1.1 Recommended work-flow of seismic interpretation

1.3. Seismic Rock Physics Basic

In seismic rock physics analysis, knowledge of rock-physics is used to understand the relations between the physical properties of reservoir rocks and seismic properties. The common reservoir physical properties are lithology or rock type, porosity, type of pore-fluids and their saturations (Figure 1.2),while the commonly used seismic properties in interpretation are amplitude, travel-time and their derivatives such Acoustic Impedance (AI), Elastic Impedance (EI), Poisson ratio, etc.

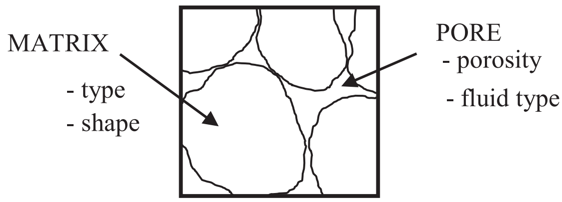

Figure 1.2 Rock physics model of a reservoir rock

The relations of reservoir physical properties with the seismic properties can be better understood by applying forward or backward modeling. Empirically, the magnitude (how big and small) of seismic amplitude is proportional to the reflected energy recorded by the receiver (Figure 1.3). The ratio of reflected energy and the incidence energy on normal incidence angle is:

$$E_{(reflected)} / E_{(incidence)} \approx R^2 \quad (1.1)$$

$$R = (Z_{lower} - Z_{upper}) / (Z_{lower} + Z_{upper}) \quad (1.2)$$

$$Z = \rho_{sat} \, . \, V_{p\ sat} \quad (1.3)$$

where
- E = seismic energy
- Z = Acoustic Impedance (AI)
- Z_{upper} = upper rock AI
- Z_{lower} = lower rock AI
- R = reflection coefficient
- ρ_{sat} = density of saturated rock
- $V_{p\ sat}$ = P-wave velocity of saturated rock

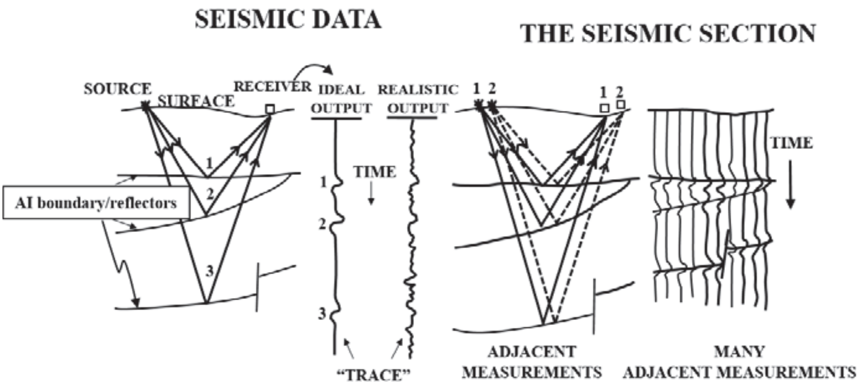

Figure 1.3 Simplified model showing the relation of seismic wave propagation, seismic trace and seismic section.

Equations 1.1 to 1.3 show that AI is the most important elastic property which control the magnitude of amplitude. Since AI is dependent to density and Vp, then the ability to calculate density and Vp is very important in seismic modeling and interpretation.

Density of saturated rocks can be computed using the following equation:

$$\rho_{sat} = \rho_m(1-\phi) + \rho_f \phi \qquad (1.4)$$

$$\rho_{sat} = \rho_m(1-\phi) + \rho_w S_w \phi + \rho_{hc}(1-S_w)\phi \qquad (1.5)$$

where ρ_m = density of rock-matrix
ρ_w = density of water filling the rock pores
ρ_{hc} = density of hydrocarbon fillingthe rock pores
Φ = total porosity of saturated rock
S_w = water saturation

Exercise 1.1

A sand reservoir has properties as described below. Compute the saturated rock density for two cases : oil-filled and gas-filled, with degree of S_w 100%, 80%, 60%, 40%, 20% and 0%. Plot the saturated rock density of oil and gas cases in vertical axis and degree of water saturation in horizontal axis. For each problem compute the density sensitivity S_d (%) = (ρ_1- ρ_2) /ρ_1 x 100% for case ρ_1 for S_w = 100% and ρ_2 for S_w = 0%.

From questions a to c below draw conclusion which rock physical properties give the biggest effect on density of reservoir rocks

a. *Matrix density 2.7 g/cc, oil density 0.8 g/cc, gas density 0.001 g/cc and porosity 20%.*

b. *Matrix density 2.2 g/cc, oil density 0.8 g/cc, gas density 0.001 g/cc and porosity 20%.*

c. *Matrix density 2.7 g/cc, oil density 0.2 g/cc, gas density 0.001 g/cc and porosity 20%.*