Depositional sequence interpretation using seismic and well data of offshore Central Sumatra Basin

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Abstract. Offshore Central Sumatra Basin is an integral part of Central Sumatra Basin known for producing hydrocarbon basins. The derivation of stratigraphic study of seismic and well data is intended to improve accuracy of geological interpretation. Sequence stratigraphy studies have a significant role in exploratory studies to determine which depositional sequence can be inferred as hydrocarbon reservoir and its correlation in petroleum system. This study aims to identify biogenic gas sequential interpretation using seismic and well data of offshore Central Sumatra Basin. The procedure to analyze sequence stratigraphy is to identify stratigraphy surface markers using GR log, then map these markers to the seismic section that has been tied with good data to determine the distribution of each stratigraphy sequence. This study area has five depositional sequences, which are predominantly formed in marine depositional environments. Potential source rock in this area is at DS-1 which has a lacustrine depositional environment with euxinic conditions. The euxinic shale at the upper TST-1 deposit could be a source rock with hydrocarbon migration through faults. Biogenic gas reservoir potential is in Petani Formation (DS-5). Shale in MFS-5 and HST-5 could be a hydrocarbon trap, whereas LST-5 and TST-5 sandstone deposits can be a reservoir.

Keywords: biogenic gas, depositional sequence, offshore Central Sumatra Basin, sequence stratigraphy

1. Introduction

One of the largest hydrocarbon contributor basins in Indonesia is the Central Sumatra Basin. The Central Sumatra Basin is part of Sundaland, located in the back arc on the Sumatra Island. The Sumatra Island formed in the accretion zone by several part of the continental plate and micro oceanic plate. The bedrock of Central Sumatra Basin was formed in Pre-Tertiary period, whereas the structure and stratigraphy were formed in Pre-Tertiary period to present. The stratigraphy units of the Central Sumatra Basin consist of Pematang Formation, Sihapas Group, Petani Formation and Minas Formation. The success of hydrocarbon exploration depends on understanding the subsurface geology of exploration fields [1]. Sequence stratigraphy studies have a significant role in exploratory studies to determine the continuity of petroleum system [2]. Sedimentary deposits from Pematang Formation to Petani Formation are predominantly formed in marine depositional environments (Figure 1a) [3]. To understand marine sedimentary basin, the application of sequence stratigraphy will be carried out by observing geographic control and correlation of global sea-level change patterns [4]. This method will determine which depositional sequence can be inferred as hydrocarbon reservoir and its correlation in petroleum system.
2. Materials and Methods

The study area is located in Central Sumatra Basin, between Pedang Island and Sumatra Island (Figure 1b). The data used in this study are one 2D seismic line and GR log from a well located near the seismic line. The procedure to analyze sequence stratigraphy in this study is identification of stratigraphic surface markers using GR logs, then mapping these markers into the seismic line that has been tied with well data to determine the distribution of each stratigraphic sequence in the study area [5].

2.1 Identification of Stratigraphic Surface Markers

Depositional sequence consist of several system tract that form one sediment deposition cycle. Each system tract is bounded by different stratigraphy surface depending on sediment deposition factors. The size and phase of global sea level will affect accommodation rate and sediment supply in sediment deposition process. These different factors will result in different parasequence set of each system tract. Parasequence set, which is based on accommodation rate and sediment supply, are elaborated three classifications, namely progradation, aggradation and retrogradation [6]. Progradation is deposited when sediment supply is greater than accommodation rate. Aggradation is deposited when sediment supply and accommodation rate are same, whereas retrogradation is deposited when accommodation rate is greater than sediment supply.

System tract is classified into three, namely is Lowstand System Tract (LST), Transgressive System Tract (TST) and Highstand System Tract (HST) [7]. Based on the depositional environment, LST consist of three depositional environment, namely slopes basin fans, basin floor fans and prograding wedge. LST deposit has an aggradation and progradation parasequence set. LST deposited over the stratigraphy surface, namely Sequence Boundary (SB) and bounded by stratigraphic surface, namely Maximum Regression Surface (MRS). TST deposited over the MRS and bounded by stratigraphic surface, namely Maximum Flooding Surface (MFS) with retrogradation parasequence set, whereas HST deposited over the MSF and bounded by next SB. The HST deposit is estimated to be formed when the tide reaches the maximum global sea level and then recedes with the regression phase. That results in HST deposit having aggradation and progradation parasequence set. A simple conceptual model of depositional sequence is described in Figure 2.
Simple stratigraphic sequence analysis model is based on GR log characteristics in determining stratigraphic surface [9]. The GR log pattern has a basic concept that characterizes changes in sediment deposition energy that affects grain size and the parasequence set. The primary forms are divided into five characteristics, namely cylindrical, funnel, bell, symmetrical and serrated (Figure 3). Cylindrical shape is characterized by sharp boundaries at the upper and bottom sequence boundaries, which consistent GR log reading indicates consistent or uniform lithology relatively. GR values decrease upward from maximum value consistently, indicating a decrease of shale content in coarsening upward trend, which obtains thick sediments from rapid deposition in the funnel shape. GR values increase upward consistently from minimum value, indicating the increase of shale content in fining upward trend in the bell shape. Symmetrical shape is formed as gradual cleaning upward trend which changes from its maximum value with dirtying uptrend of similar grain size without sharp breaks. Serrated/irregular shape is characterized as fluctuated GR reading with high and low values over very short vertical interval of well profile, which indicates laminated beds of sand and shale [10].

Figure 3. Stratigraphic surface markers identification based on GR log motifs [9, 10].
2.2 Integrating Well and Seismic Data
Integrating well and seismic data is carried out to determine the distribution of each stratigraphy sequence in this study area. The stratigraphic sequence markers were integrated with a seismic line using check shot data. The check shot data showed the variation in depth with time.

3. Result and Discussion
The component of the depositional sequence consists of stratigraphic surface markers, system tract and parasequence set that has been interpreted in the study area (Figure 4). There are five depositional sequences (DS) from Pematang to Petani Formation. DS-1 consists of LST-1, TST-1 and HST-1 system tract deposited at Eocene-Oligocene period. DS-1 was formed when there was regional expansion in Southeast Asia because of a collision of southern margin Indian Plate and Asia Continental Plate [11]. This expansion resulted in the horst and graben. DS-1 formed in a lacustrine deposition environment with euxinic conditions, which have little global sea level influence. It can be seen from the LST-1 deposit thickness, which is about 188 ft thicker than TST-1 and HST-1 deposits which indicates that the sediment supply in DS-1 is greater than the accommodation rate due to the influence of little global sea level at the sedimentary deposition (Figure 4).

Figure 4. Depositional sequence identification based on GR log motifs.
DS-2 consists of LST-2, TST-2 and HST-2 system tract deposited at Oligocene-Early Miocene period. DS-2 formed when the Barisan Mountains uplift so that the Barisan Mountains become a source of sediment at sedimentary deposition. The transported sediment form an interconnected fluvial delta system [11]. It can be seen from the LST-2, TST-2 and HST-2 deposits which have almost the same thickness of about 98 ft, which indicates that the sediment supply on DS-1 and the accommodation rate are the same. DS-3 and DS-4 were deposited during the Early Miocene-Middle Miocene period. DS-3 and DS-4 were formed when there was a regional subsidence and the slowing of Barisan Mountains uplift. These sequences formed in marine depositional environments. DS-3 is deposited when the accommodation rate is greater than the sediment supply. It can be seen in thickness of HST-3 deposits about 176 ft which is thicker than TST-3 deposit 106 ft (Figure 4).

DS-4 formed in a deep marine depositional environment were at the final stage of sediment deposition, there was maximum transgression global sea level [11]. DS-5 consists of LST-5, TST-5 and HST-5 system tract deposited at the Middle Miocene-Pleistocene period. DS-5 was formed when the regional subsidence began to slow down and the uplift of Barisan Mountains began to increase back into a source of sediment deposition accompanied by local faults that exist at this stage. The depositional environment at this stage gradually changes to a shallow marine system. This can be seen from the thickness deposits of LST-5, TST-5 and HST-5, which are getting thinner 497 ft, 312 ft and 126 ft (Figure 4).

![Figure 5. Petroleum system model of the study area.](image-url)
After determining depositional sequences in this study area, we can determine which depositional sequence can be inferred as hydrocarbon reservoir and its correlation in petroleum system. The potential source rock in this area is DS-1 because this depositional sequence has a depositional environment with euxinic conditions. Euxinic conditions are conditions where the global sea level loses oxygen and a high-temperature change occurs so that sediment formed in this condition can potentially become a source rock [11]. The euxinic shale at upper TST-1 deposit could be a source rock in this study area. Hydrocarbon migration in this area was through three major faults and trapped by shale deposits (Figure 5). Reservoir potential was found in Petani Formation (DS-5) in late Miocene-early Pliocene period, which indicates biogenic gas [12]. Shale in MFS-5 and HST-5 can be a trap, whereas the reservoir in the LST-5 sandstone deposits to the TST-5 deposits (Figure 5).

4. Conclusion
The depositional sequence in the study area has five depositional sequences (Pematang to Petani Formation), which are predominantly formed in marine depositional environments. Stratigraphic sequence analysis used in this study is identification of stratigraphic surface markers using GR log, then mapping these markers into the seismic line that has been integrated with well data to determine distribution of each stratigraphic sequence in the study area. Stratigraphy sequence studies in this study determine which depositional sequence can be inferred as source rock, hydrocarbon reservoir, seal rock and its correlation in petroleum system. The potential source rock found in this area is DS-1 which has a lacustrine depositional environment with euxinic conditions. The euxinic shale at the upper TST-1 deposit can be a source rock with hydrocarbon migration through three major faults trapped by shale deposits. Reservoir potential is in Petani Formation (DS-5). Shale in MFS-5 and HST-5 can be a hydrocarbon trap (seal rock), whereas LST-5 and TST-5 sandstone deposit can be a reservoir.

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