CHAPTER 2

Geologic Background

2.1 Introduction

The study area is located offshore in the Nam Con Son Basin, Southern of Vietnam. Location of the Nam Con Son Basin as mentioned by Matthew et al. (1997) is at the junction of East Vietnam/South China Sea, Red River Fault, Malay/Natuna Basins (Figure 2.1). The area of the Nam Con Son Basin is approximately 100,000 km^2. Exploration activities in the Nam Con Son Basin began early 1970s. Expected petroleum reserves of Nam Con Son Basin are around 680 million converted BOE (mainly gas). Basin history and tectonic development of the Nam Con Son were outlined by many previous workers such as Hutchison (1989) and Matthews et al. (1997).

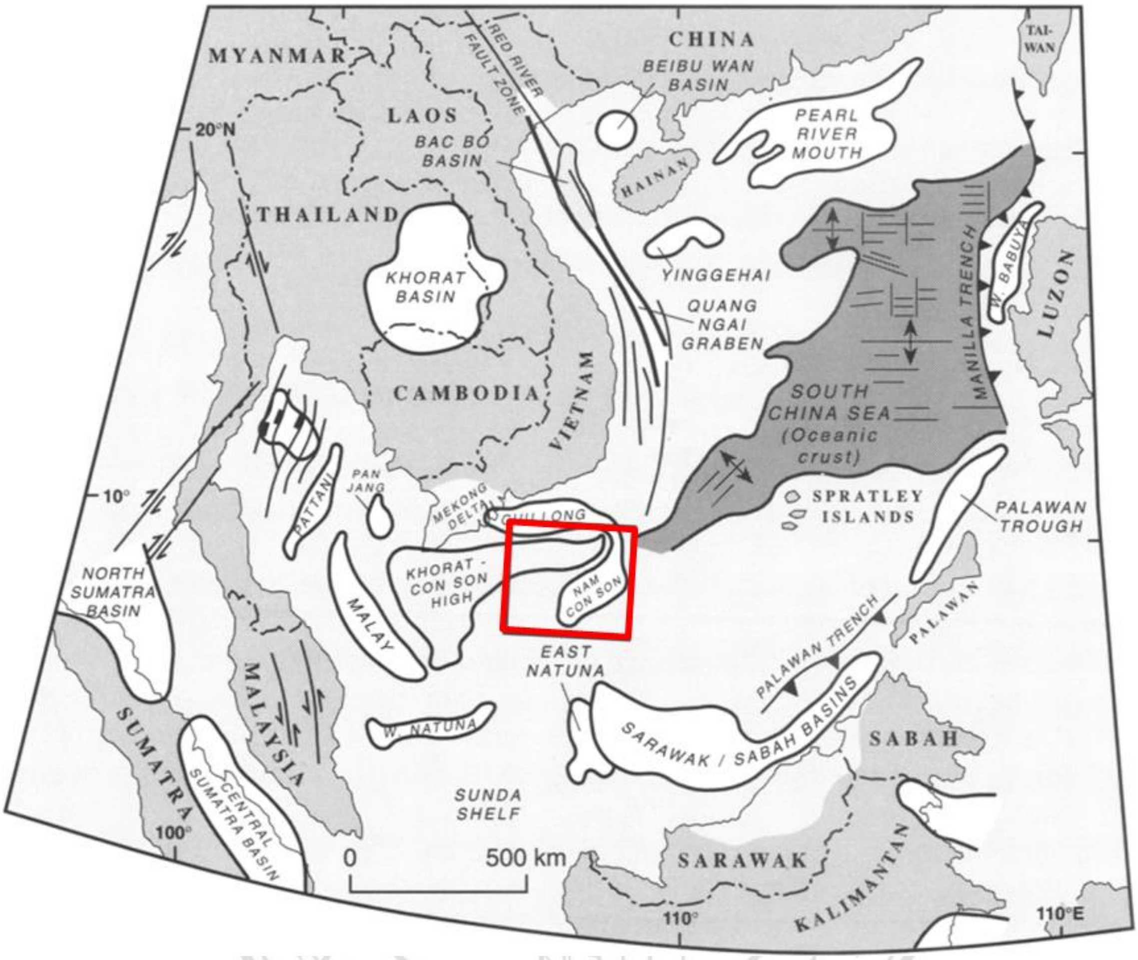

Figure 2.1: Location of major sedimentary basins within SE Asia (Matthews et al., 1997). The red block highlights location of the Nam Con Son Basin.

2.2 Regional Tectonic Setting

The Nam Con Son Basin is described as a rift basin which its evolutional history is linked to the rifting and seafloor spreading that characterized the opening of the South China Sea. In the deepest part of the basin, sediments ranging can go up to 14 km in age from Upper Cretaceous to Quaternary. A tectonostratigraphic summary of the Nam Con Son Basin (Fraser et al., 1994) is illustrated in Figure 2.2.

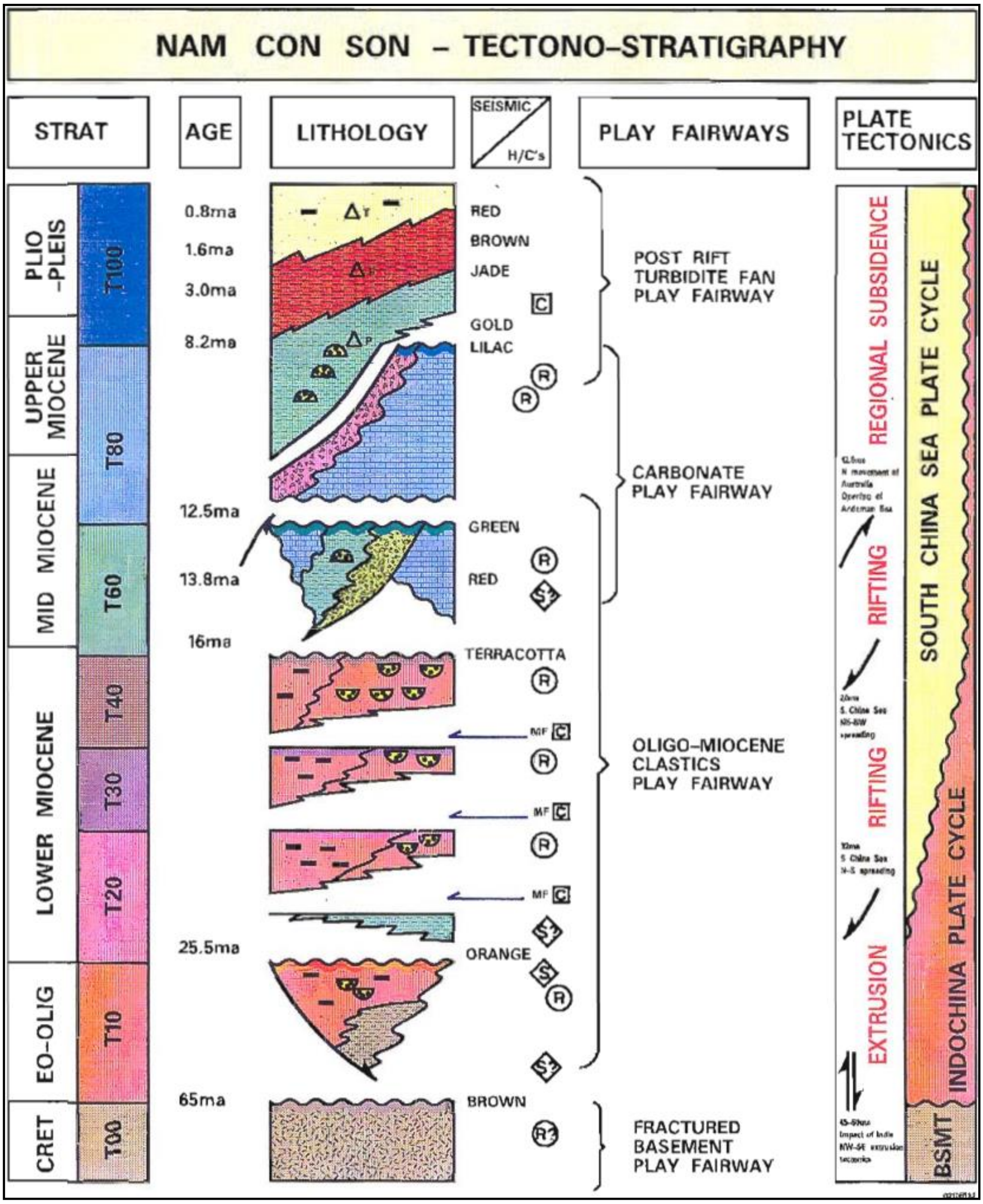

Figure 2.2: Tectonostratigraphic of Nam Con Son Basin (Fraser et al., 1994).

The tectonic evolution of Nam Con Son Basin can be divided into different phases (Figures 2.3 and 2.4). The first rifting phase in the Nam Con Son Basin occurred in the late Eocene to early Oligocene and it was associated with the onset of North to South of the South China Sea. The first early rifting event was followed by a tectonic quiet period lasting from late Oligocene to early Miocene (T20 – T30). During the early

Miocene period, the seafloor spreading changed its axis to NE–SW direction forming the second rifting phase of the Nam Con Son Basin. The second rifting phase in the Nam Con Son Basin was followed by regional tectonic events happened around late mid – Miocene period marking the end of second rifting phase. This event is evidenced by the regional unconformity (MMU – T65) observed clearly on seismic profiles (Figure 2.3), the T60 sequence in this figure defined same as T65 due to the difference between the companies in different exploration periods. The post rift section is marked by thermal sag and late Miocene – Pleistocene thick delta prograding wedge.

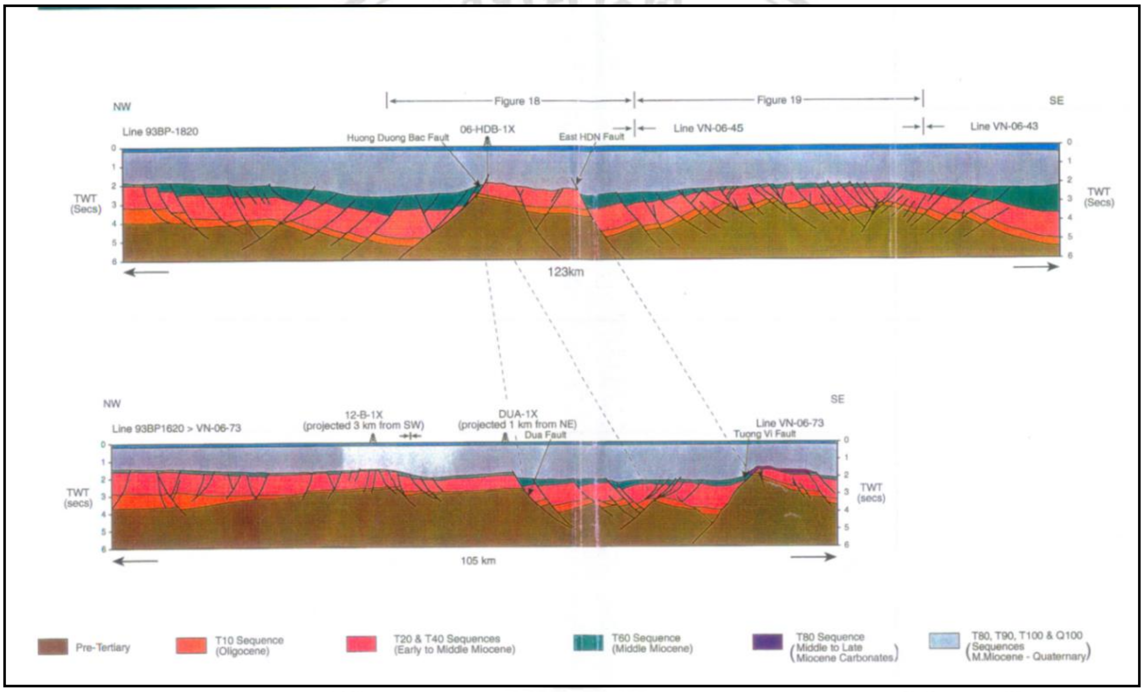

Figure 2.3: Example of a seismic section crossing the Nam Con Son Basin (PetroVietnam, 2016, personal communication).

2.3 Structural and Stratigraphic development

The Nam Con Son Basin stratigraphy is based on previous work by Matthews and Todd (1993) and Breare (1993). Many researchers continue and base on recent interpretation of new seismic data, wire-line log and core data. These recent works provided the basis of composite sequence stratigraphy. This recent composite sequence stratigraphy is labeled numerically upward as larger numbers are younger: prefix T indicating Tertiary and Q indicating Quaternary composite sequences. The general chronostratigraphic diagram of the Nam Con Son Basin is provided by BP (PetroVietnam, 2016, personal communication). (Figure 2.4).

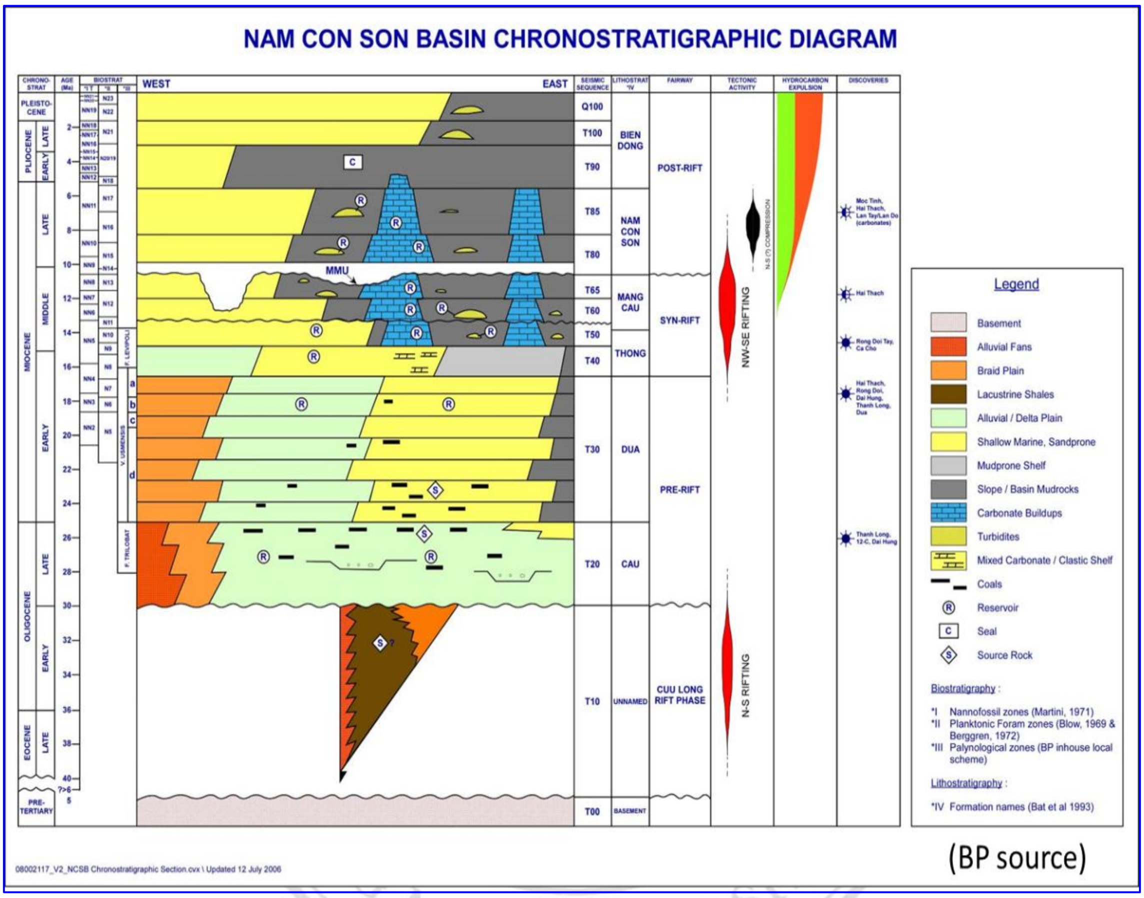

Figure 2.4: Chronostratigraphic diagram of the Nam Con Son Basin (PetroVietnam, 2016, personal communication).

Pre T10 sequence: Subaerial erosion of structurally and compositionally complex basement terrain had been intruded by granites. The compositional variation seen across the basin suggests strongly that the Tertiary basins have been developed on top of a Mesozoic magmatic arc, backarc and forearc complex. Pre T10 sequence is presented by brown horizon as in Figure 2.2.

T10 sequence: Subsidence was sufficiently regional during the late Oligocene to allow accumulation and preservation of fluvial and coastal plain facies. A combination of seismic and biostratigraphic evidences suggest that the T10 sequence is a rift-fill in its lower part, and the upper part (late Oligocene) was deposited regionally during a phase of little fault motion. Top T10 sequence unconformity is presented by orange horizon in Figure 2.2.

T20 sequence – Cau formation: Information from wells sections demonstrates that the base of this sequence was deposited during or after a regional transgression and the widespread development of a marine mudstone forming a potential regional seal. The occurrence of this marine mudstone immediately overlying the top T10 unconformity suggests that the unconformity may result from sediment starvation due to early Miocene flooding event. The early Miocene unconformity may therefore be explained by unconformity and subsidence. The occurrence of shoreface, coastal plain, estuarine and fluvial facies above marine mudstone suggests that sediment supply became sufficiently high to move the facies belts to east direction early Miocene flooding. The upper most part of the T20 sequence is characterized by more marine shoreface facies. Top T20-T40 sequence is presented by pink horizon in Figure 2.2.

T30 - T40 sequence – Dua formation: This sequence is onlapped by marine clastics onto the T20 horizon, this suggests that rift phase controls the structural and stratigraphic geometries at the base of T30 – T40 sequence. There is a reduction in clastic sediment supply, this suggested that by the onset of carbonate platform growth, a sedimentary evolution compatible with West to North West movement of the shoreline. The interpretation of regressive cycles in well sections in the upper part of this sequence may result from uplift of the footwalls to the active normal faults.

T50 – T65 sequence – Thong Mang Cau formation: The structural and stratigraphic characteristics of the base of this sequence are similar to base of T40 sequence, onlap onto rotated faults blocks in response of extensional movement. Well sections demonstrate that there are initiation of carbonate platform growth and deep marine clastic deposition. These facies suggest that the rift phase which key control on development of the T40/T65 boundary punctuated ongoing regional subsidence. The top of T65 sequence expressed as an angular unconformity across the top anticlines throughout the alliance acreage. These anticlines were formed during intension period that was proved by seismic sections. Top T65 sequence is presented by green horizon in Figure 2.2.

T80 –T85 sequence – Nam Con Son formation: There was reactivation of several pre-existing faults occurred after development of T65 unconformity. These are largely coincident with the margins of middle to late Miocene carbonate buildups, it suggests that the youngest carbonate buildups distribution is controlled by reactivated faults. Most recent extensional phase interrupted regional subsidence, in similar way to many of the previous phases of movement. Top T85 sequence is presented by purple horizon in Figure 2.2.

T90 – Q100 sequence – Bien Dong formation: Regional subsidence controls on downward movement of the basin during the Pliocene and Quaternary. During the earliest part of this stage of basin development, submarine channel and canyon systems were major developed and filled with deep marine clastics.

In this independent study, Well A is a combined exploration and appraisal well drilled in the Nam Con Son Basin, offshore Vietnam. The prospective structure is within the Tertiary clastics sequences of the central Nam Con Son Basin. In detail, Well A is drilled to appraise the post-rift upper Miocene of a gas discovery located 2.2 km to the SSE of the first exploration well. Another purpose of Well A is to explore the syn-rift middle Miocene interval (Thong, Mang Cau formation) and the pre-rift lower Miocene (Dua formation). The total depth of Well A is 4155 m at the end of Dua formation. The formation tops at Well A location are shown in Table 2.1. Follow final well report, Well A explores two main reservoirs that contain movable hydrocarbon. The post-rift sandstone is encountered at 2999.5 m (MD) near the base of Bien Dong formation and is represented by approximately 15 m gas/condensate bearing sandstone. Sandstone encountered within the syn-rift middle Miocene section has gross thickness 64 m with top and base at 3583 m and 3647 m (MD) respectively. However the sandstone interval is separated by a mudstone – dominated interval from 3616 to 3638 m. The thin sandstone in the lower part from 3638 to 3647 m (MD) is interpreted not to contain movable hydrocarbon.

Table 2.1: List of formation tops and bases at the Well A location.

Formation Tops	**MD (m)**	**TVD (m)**	**TVDss (m)**
T100	2055.0	2054.8	2025.8
T90	2516.8	2516.5	2487.5
T85	2700.9	2700.6	2671.6
Top UMA 15	2999.1	2998.8	2969.8
Base UMA 15	3014.4	3014.0	2985.0
MMU (T65)	3244.5	3244.0	3215.0
Top MMF10/15	3254.6	3254.1	3225.1
Base MMF10	3270.9	3270.5	3241.5
Top MMF15	3287.0	3286.5	3257.5
Base MMF10/15	3294.6	3294.1	3265.1
Top MMF30	3583.0	3582.1	3553.1
Base MMF30	3616.0	3615.0	3586.0
T30	4007.6	4006.6	3977.6

2.4 Petroleum System

Petroleum system of the Nam Con Son Basin is mainly discussed by Tin and Ty (1994) and Matthews et al. (1997).

Source rocks: The presence of source rocks are widely distributed in the Nam Con Son Basin, there are two main source rocks sequences that are Oligocene lacustrine claystones and Miocene fine-grained clastics, all of source rocks in the Nam Con Son Basin are kerogen type II and III. Maturity of source rocks indicates the major potential of gas generation.

Reservoir rocks: In the Nam Con Son Basin, there are 4 major reservoir rocks containing hydrocarbon. The first reservoir rock is Pre-Cenozoic fractured basement rocks with up to 16 - 20% of porosities. The second is Paleogene reservoir rocks involving Oligocene clastics deposited in shallow marine, coastal marine conditions, and mainly composed quartz sandstones with porosity up to 12 - 16%. Reservoir thickness proved by wells data varies between 2 m and 80 m. The third is lower Miocene reservoir rocks which deposited under deltaic, coastal marine and shallow marine conditions with thin silt and claystone layers. The porosity of this potential reservoir rocks varies from 18 % to 25 %. The last potential reservoir rocks are Miocene limestones with the porosity up to 25%.

Seal rocks: There are two main regional seals in the Nam Con Son Basin. The first is Oligocene to lower Miocene shelf mudstones. The mudstones which belong to Cau Formation seal the underlying upper Oligocene clastics. Clay and shale thickness is around 100 m to 400 m which can be a good regional seal. The second seal rocks are the deep marine Miocene mudstones which overlie the regional late middle Miocene unconformity. Main properties of Miocene mudstones are shale intercalated with silt and thin sandstones beds. The thickness of shale sequence can go up to 45 m.

Traps: Both structural and stratigraphic traps are potential in the Nam Con Son Basin. The structural traps contain T10 – T65 sequence clastic reservoirs which are mostly three-way dip and fault, and two way dip and faults closures. The others principle structural trap style is fault – segmented four way dip anticlines. In some cases, these anticlines appear to have been tightened and inverted by mild contraction during the middle Miocene period. Late Miocene carbonate traps are also remarkable in the Nam Con Son Basin, it has four way dip seal of deep water mudstones overlying the carbonate buildups. Besides, the flank portions of the carbonate buildups can also be good stratigraphic traps. Finally, fractured weathered basement high can also be potential traps due to the proven fractured basement trap of Bach Ho field nearby.