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Research Article

RESERVOIR CHARACTERIZATION OF THE T20 SAND, 'TANGO' FIELD, NIGER DELTA, NIGERIA

Ideozu R. U[1], Uche-Peters Adiela[2] and Utuedor E[3]

[1]*Department of Geology, University of Port-Harcourt, Rivers State, Nigeria.*

[2] *Department of Petroleum Engineering, Nigerian Agip oil company, Port Harcourt,*

[3]*Department of Enviroment, DESOPADEC, Warri, Nigeria*

ABSTRACT

This research work focuses attention on the Reservoir Characterization of a hydrocarbon bearing sand in 'Tango' field of the Niger Delta. The environment of deposition is examined and the type produced as a model of the sub-surface reservoir. To achieve this, an integrated analysis of cores from wells, as well as biostratigraphic data and wireline logs of the T 20 sand were used for the study. The T.20 sand of study comprises one major depositional sequence. From the petrophysical study carried out through use of composite logs, amalgamated sand is found to be more porous and more permeable than the tidal channel. Core analysis revealed the existence of ten lithofacies. These lithofacies are grouped into facies association in a vertical sequence with a genetic significance using primary structures and shape of wireline logs.

INTRODUCTION

T20 sand comprises multi-storey sand bodies and heterolithic mixture of sand shale. These sand bodies have good reservoir quality, while the heterolithics have reservoir quality and act as baffles to vertical flow of hydrocarbon. Thus, this cause production problem in the T20 sand. The research work is intended to unravel the sequence stratigraphy of the T20 sand through the existing approach of use of cores and wireline logs. The overall depositional character of the T20 sand reflects the Petrophysical problems. Production problems could be field wide or peculiar to the Niger Delta depobelt. Porosity and permeability in the T20 sand are affected by the grain size distribution, clay composition, bioturbation, cementation and compaction. For example, there is a decrease in porosity and permeability in the area where shale content is relatively high. Therefore, the top and bottom parts of the T20 sand a baffle to flow of hydrocarbon.

GEOLOGY OF NIGER DELTA

The stratigraphy of the Niger Delta is intimately related to its structure. The development of each being dependent on interplay between sediment supply and subsidence rate. Short and Stauble (1967) recognized three subsurface stratigraphic units in the modern Niger Delta. The delta sequence is mainly a sequence of marine clays overlain by parallic sediments which were finally capped by continental sands.The stratigraphy of Niger Delta Basin are as follows:

- ***Benin Formation:*** The formation comprising over 90% sandstone with shale intercalations extends from the west across the entire Niger Delta area and southward beyond the present coast line. The thickness though variable is estimated at about 6000fts. It is coarse grained, gravelly, poorly sorted, sub-angular to well rounded and bears lignite streaks and wood fragment. The formation is characterized by structural units such as channel fills, point bars etc which indicate variability of the shallow water depositional medium. The Benin formation with very little hydrocarbon accumulation ranges in age from Oligocene to Recent.

- ***Agbada Formation:*** The formation is a sequence of sandstones and shales with sandstone dorminant in the upper unit and thick shales in the lower unit. It is very rich in microfauna at the base decreasing upwards suggesting an increase in the rate of deposition at the delta front. The grains are coarse and poorly sorted indicating a fluvatile origin.The Agbada formation covers the entire subsurface of the delta and may be continuous with the Ogwashi-Asaba and Ameki formations of Eocene- Oligocene age. It is over 10,000ft thick and are the major hydrocarbon bearing unit in the delta.

- ***Akata Formation:*** The formation underlies the entire delta and forms the lower most unit. It is a uniform shale development consisting of dark grey sandy, silty shale with plant remains at the top. The Akata formation is typically overpressured and believed to have formed during lowstands when terrestrial organic matter and clays were transported to deep water areas characterized by low energy conditions and oxygen deficiency (Statcher 1995). It is over 4000ft thick and ranges in age from Eocene to Recent and is believed to have been deposited in front of the advancing delta.

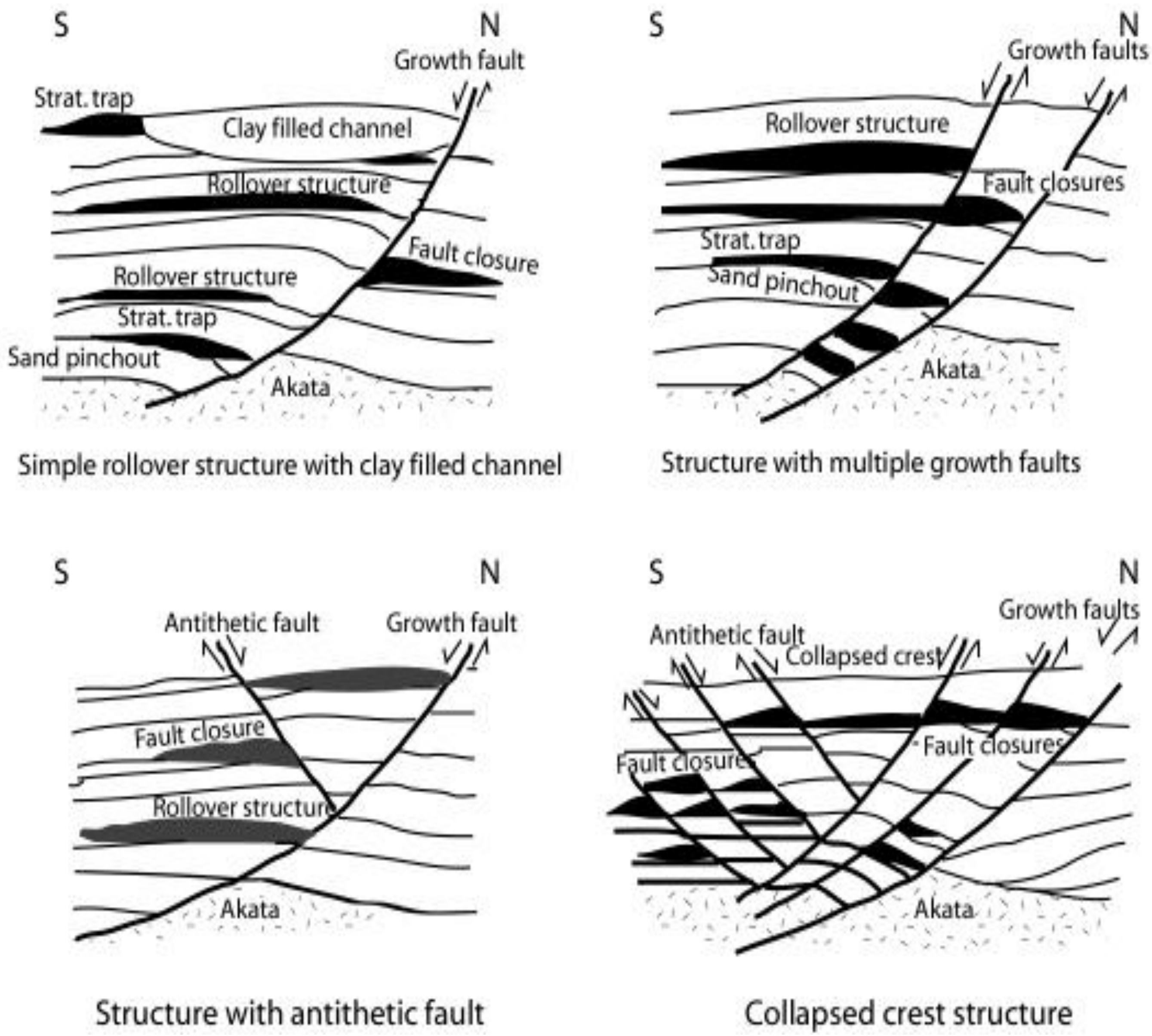

Figure 1: Principal types of oilfield structures in Niger Delta (After Weber, 1971).

Location of the Study Area:

The hydrocarbon bearing (T20) sand is located in the ' Tango' field of the central depobelt of the Niger delta. It lies between latitudes 50 and 6° N, and longitudes 60 and 7° E. (The names given above are coined as the real names are concealed for proprietary reason)

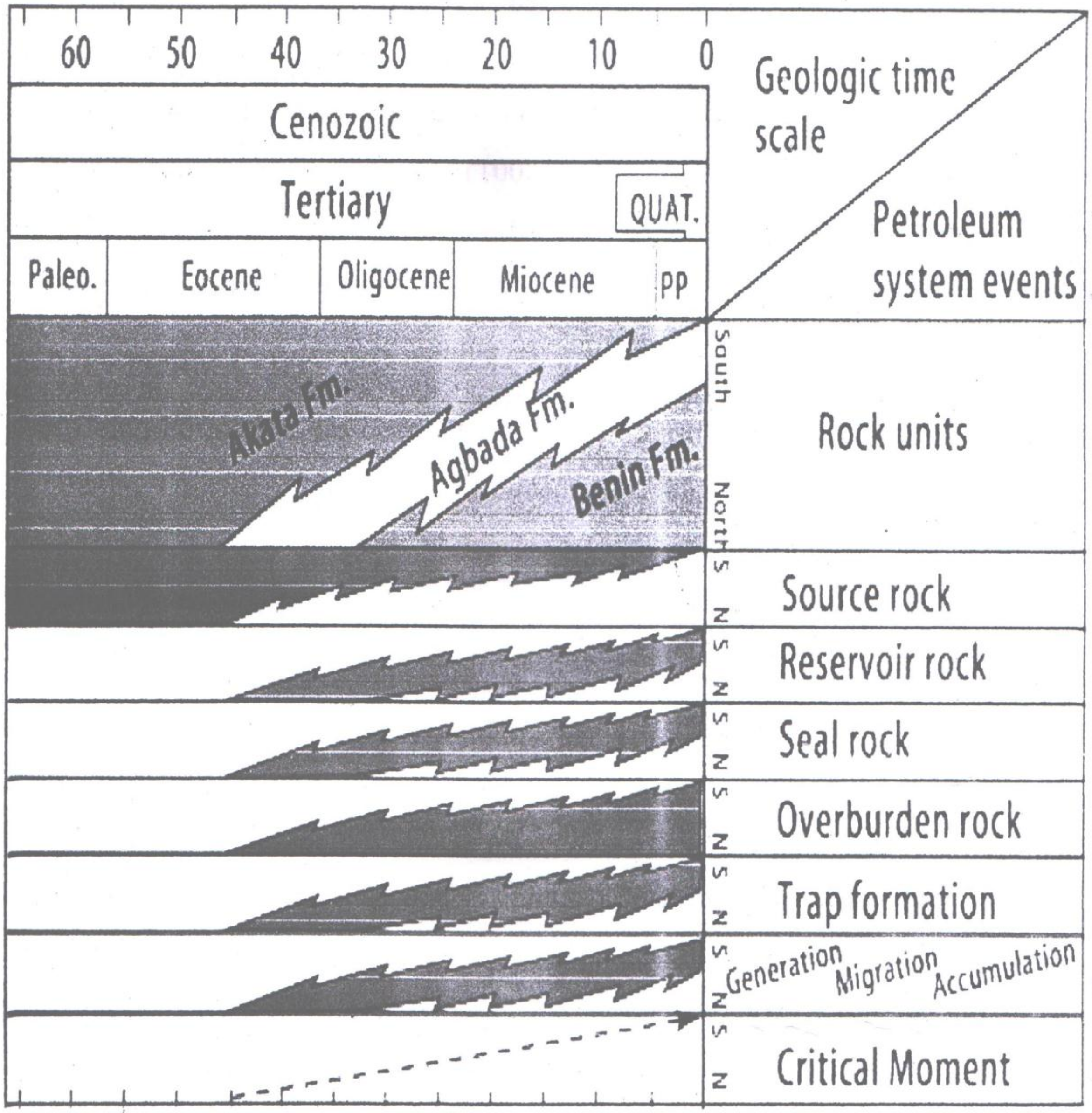

Figure 2: Events chart for the Niger Delta (Akata/Agbada) Petroleum system
(Modified from Tuttle et. al., 1999)

METHODOLOGY

There are three methods of study used in the analysis of the T20 sand. They are core description, the use of wireline logs and biostratigraphic data interpretation.

A. Core Description:

The analysis of the reservoir T20 sand involves the use of integrated cores from the well taken from the top to bottom of the T20 sand. The total length of cores described for the well are about 292ft. Core is described in terms of the primary sedimentary structures, bioturbation, grain sizes, sorting, colour, diagenetic processes as well as lithology.

B. Primary Sedimentary Structures:

Pettijon and Potter defined primary sedimentary structures as those formed at time of deposition or shortly thereafter and before consolidation of the sediments in which they are found. These sedimentary structures are as a result of physical, chemical and biological processes occurring in an environment. Based on the processes of formation of these sedimentary structures, lithofacies are classified.

C. Wireline logs:

Use of wireline log data is to guide and aid the sedimentological interpretation of the cored sequences employed. In order to ascertain the porosity and permeability values of the reservoir sand, a composite log is used. These include gamma ray log, bulk density log and resistivity log.

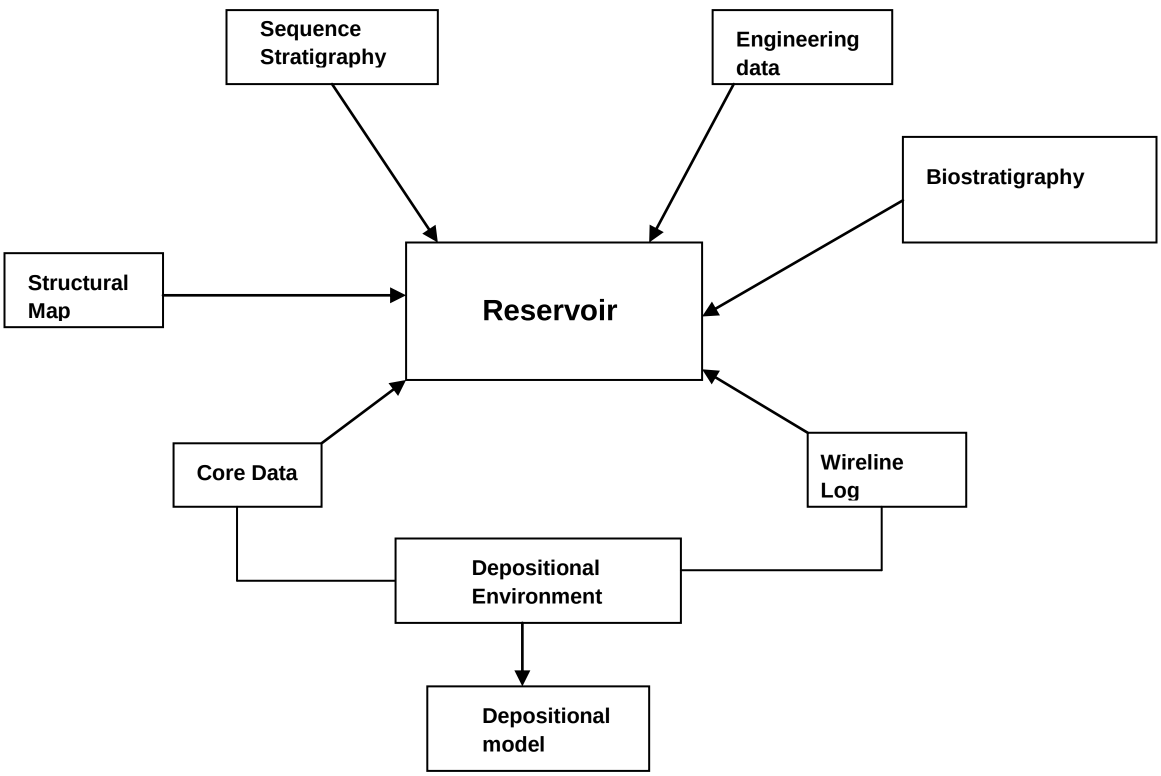

Figure 3: Data Requirement for Reservoir characterization.

RESULTS/INTERPRETATION

Lithofacies Description:

Various kind of sedimentary structures are seen through physical examination of cores from well. These include, planar cross bedding, current ripple marks, lenticular bedding, rootlets, hummocky cross stratification, reactivation surface Bioturbation Structures and many more. These inorganic primary sedimentary structures are produced as a result of interactions between the physical and biological characteristics of the sediment and the fluid, gravity, as well as the hydraulic environment. Lithofacies are identified based on core description and log shape of the reservoir T20 sand in Tango field. Individual lithofacies are composed of different types of sedimentary structures and may be distinguished by the presence of bedding units with a characteristic sedimentary structure, a limited grain size range, a certain bed thickness, perhaps a distinctive texture or colour.

(i) Planar laminated sandstone: The lithofacies, planar laminated sandstone comprises fine to medium sand particles. It is moderately to well sorted, grey in colour and consists of planar grain lineation of coarse and medium grains which form laminae on foresets (figure 4)

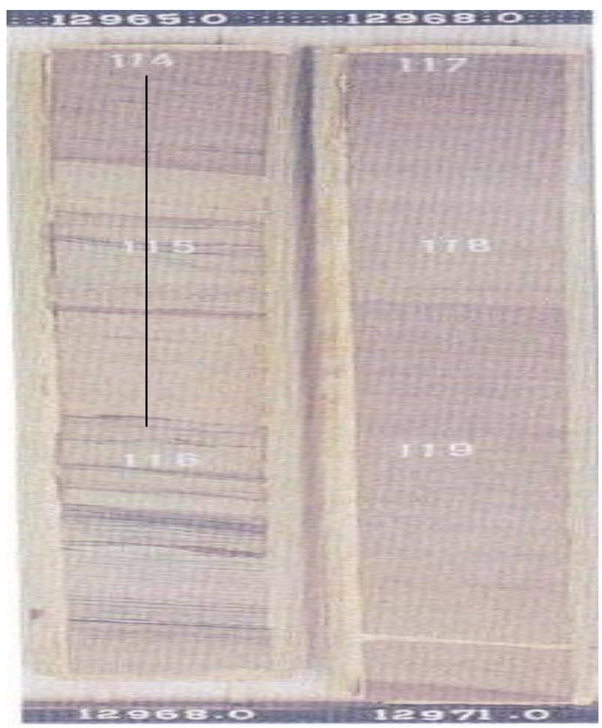

Figure 4: Planar laminated sandstone.

The lithofacies is about 2cm to 4cm thick, it has an erosional relationship with overlying lithofaices coarse grained cross bedded sandstone and gradational relationship with underlying lithofacies wave rippled sandstone. However, very fine grains of mud are conspicuously absent and there is no presence of bioturbation activities in this lithofacjes. In essence, it is an indication of high energy or shallow marine environment.

***(ii) Wave rippled sandy Heterolith**:* The lithofacies is composed of fine to very fine grained sand intercalated with draped dark grey mudstones. It is well sorted and well cemented. Bioturbation is moderate. There is the dominance of Paleophycus trace fossils; intercalation of sand with mud is an indication of bed load and suspension depositions. Wave ripple structure is an indication of low energy setting while marine assemblages of Paleophycus indicate a lower shoreface environment

(iii) Current rippled bioturbated sandy Heterolith: In this lithofacies, the sediments are well sorted. The grain sizesrange from fine to very fine with current ripple bedding. These rippled sandstones are draped by wavy dark grey mudstones. The clay content in this lithofacies is observed to be moderate. There is a moderate occurrence of bioturbation activities, although there are restricted burrow traces of Planolites and Skolithos. Presence of well -sorted sand is an indication of low energy transportation while intercalation of sand and mud is a sign of bed load and suspension type of transportation and deposition. However, the restricted assemblages or burrows of the trace fossils is an indication of stressed environment as could be seen in mouth bars channels. Figure 5

Figure 5: Current rippled bioturbated sandy Heterolith

Reservoir Characterization:

The reservoir T20.000 sand is composed of some good quality sandstones interbedded with mudstones.. From petrophysical property of the T20 sand obtained in well the porosity and permeability values of the sand are calculated using wireline logs. A very high decrease in porosity and permeability is an indication of low sand/shale ratio in the environment of deposition. High water fraction is an indication that the environment is not a potential for oil. From the gamma ray log of the T20 sand, the zone shows a gradation with the shelf mud. Hence, it is inferred to be part of the basal area (bottom seal) of the T20 sand or source of hydrocarbon. Having a critical examination, a depth range of about 1500- 2300 ft taken from the gamma ray log signature of well of the T20 sand, confirms the depth range as the tidal channel environment. A relationship exists between these petrophysical properties and their depth of occurrence. Hence, from the description of the cross plot, resistivity and bulk density values in the environment decrease with depth while porosity and permeability increase with depth in the same environment.

Taken the minimum and maximum porosity and permeability values in this environment as 15% and *25%,* 6MD and 15 40MD respectively. The average porosity and permeability is calculated to be about 21% and 585MD respectively. Also, at this depth range, there is a high oil saturation value 0.9 as against water saturation of 0.4. From the core description of well, the lithofacies in the tidal channel environment grades from coarse grained cross bedded sandstone at the base to very fine sandy heterolith at the top. Thus, the increase in clay content upward in the tidal channel is responsible for the upward increase in resistivity and bulk density and upward decrease in porosity and permeability as well. The decrease in grain sizes is also another reason for the reduction in permeability. Thus, channel top is expected to form baffle to vertical flow of hydrocarbon in the T20 sand. It grades into the flood plain environment which forms the top seal of the reservoir T20 sand. The high oil fraction relative to the water fraction in the tidal channel at a depth range of 1500 to 2300 ft is an indication that, this part of the T20 sand is a potential for hydrocarbon accumulation. We recommend that more exploration activity be carried out in this part of the T20 sand. Most part of the T20 is inferred as stacked channel using gamma ray log of the T20 sand from well. In the description of the petrophysical properties of this depth range, there is a high resistivity value, low bulk density, very high permeability as well as very good porosity values. Taking the mean of the sum of the porosity and permeability values in the stacked channel of petrophysical properties, then the average porosity and permeability is 25 % and 1225 MD respectively. Furthermore, the stacked channel shows a very high oil fraction close to one and a water fraction close to zero. The high resistivity value of this part of the reservoir with respect to the tidal channel described earlier is attributed to the fact that, it has a lesser clay content than the tidal channel. This may be as a result of larger grain size sand in the environment of deposition. Example is seen from the lithofacies containing cross-bedded sandstones and planar laminated sandstone . However, a very high oil fraction with little or no water fraction in this environment relative to other parts of the reservoir makes it an ideal part to explore in the T20 sand more than other sections of the reservoir. The poor petrophysical properties in this part of the reservoir relative to the stacked channel environment is attributed to the clay composition or sandstone inter-bedding with mudstone. The point where oil fraction mixes with water fraction is inferred to be the oil/water contact (OWC). Unequal variation in the porosity and permeability is an indication of sand/shale intercalation in this part of the T20 sand. Therefore, the mode of deposition in the environment is through bed load transportation and suspension fall-out. Resistivity decreases while bulk density increases. Water fraction exceeds the oil fraction. Also at a depth range of about 12328 to 12350ft, porosity and permeability show unequal variation downward in the T20 reservoir sand. Resistivity shows a variable signature as well as bulk density downward. In the plot, oil fraction co-exists in equal proportion with water fraction and at 12340ft, oil fraction mixes with water fraction, this part of the reservoir coincides with the tidal deposits. Due to progradation and retrogradation of sediments which result in the depositional styles of reservoir sand bodies,.

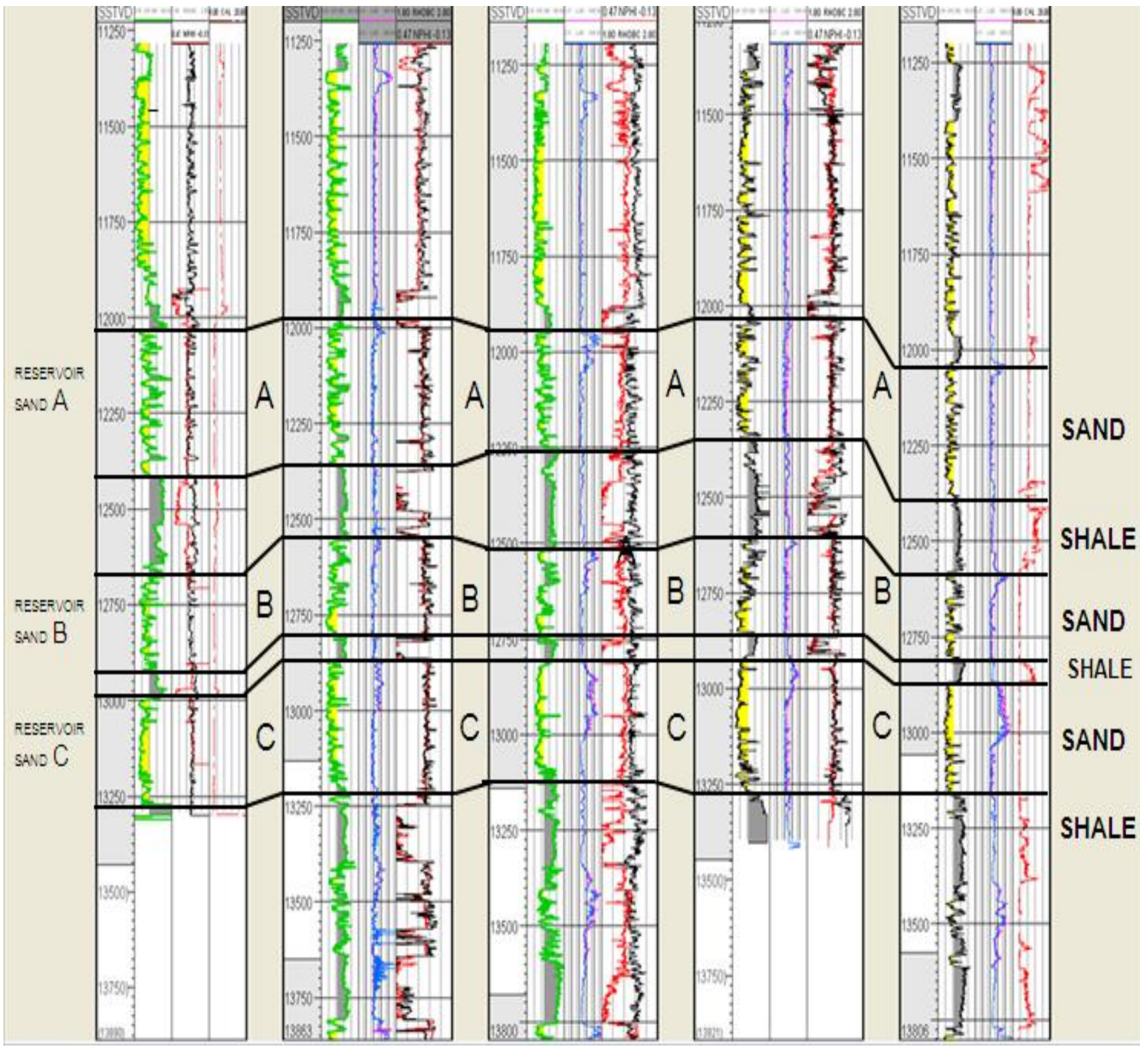

Figure: Correlation of T20 Reservoir sands across the wells

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