The Cretaceous Play of Tano Basin, Ghana

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Abstract

The cretaceous play of Tano basin which is located southeastern part of Ghana begun its tectonic activities in the last Jurassic era where there was a continental rifting between African plate and the South American plate. This lead to the creation of the West African Transform Margin. Tano Basin which is part of this margin and bounded on both sides by Romanche and St Paul fault became a depositional focus during the Cretaceous era with mostly fluvial and lacustrine clastic sediments. Three major play exist in the Tano basin which include: Albian Play, Cenomanian Play and the Turonian play with the Turonian play being the most productive. Source rocks in the basin are mainly of kerogen type II and type III. The field thus, produces oil, gas or oil condensate. Structural and Stratigraphic traps are both existent in the basin some types of traps being pinch out trap, salt domes, anticlines and faults. Porosity and permeability values in the basin is quiet high ranging from 17-23% of porosity and permeability values of up 3000mD. In all, the good overburden, the anoxic conditions in the basin, the deposition of the marine shale, the high porosity and permeability and the good trapping mechanism in the Tano Basin has rendered it very productive and a big player in hydrocarbon production in Africa.

Keywords: Tano Basin, Petroleum Systems, Petroleum Geoscience.

1. Introduction

Discoveries in the Tano basin pioneered a change in hydrocarbon production in West Africa where companies had more courage to venture in this high risk area in search of one of the world's most valuable commodity, crude oil. Now most of the countries along the Gulf of Guinea stretch are producers of hydrocarbons. Most of these hydrocarbons are produced from the deep Ivorian basin of which Tano basin is considered to be its eastern extension.

Tano basin is located in the southern eastern part of Ghana. A larger portion of the Tano basin is located offshore with just a little land extension. The portion of the basin which has proven to be of high hydrocarbon potential is located about 60km offshore Ghana with water depth ranging from 1200km to 1500km. D. Atta-Peters of University of Ghana has performed lots of research on both source rock evaluation and basin stratigraphy on Tano basin and his work was a great for this paper. Other information sources include the US Geological Survey (USGS) work on the Gulf of Guinea and HIS report on the Ivorian Basin.

1.2. Historical Background

Ghana is home to four sedimentary basins namely: Voltarian basin, Tano basin, Accra-Keta Basin, and Saltpond Basin. All these basins have seen some exploration works go on with the Saltpond basin being the first to discover accumulations of crude oil but in small qualities. Production from that basin begun with about 2000bbls/day to current level of just 500bbls/day. The Tano Basin and the Accra-Keta basins have been areas of interest for hydrocarbon exploration in the past decade with the Tano basin proving to be more productive.
There are currently three (3) fields located within the Tano basin which include:

- Jubilee Field: discovered in 2007 and produces oil and gas
- Sankofa & Gye Nyame Complex: discovered in 2008 and produces oil and gas
- Tweneboa, Enyenra & Ntomme (TEN): discovered in 2009 and produces gas and condensate oil.

Of all the fields, Jubilee field is the only currently producing field with the other fields current under development phases. It is also estimated that Tano basin holds about 5 billion barrels of oil with the jubilee field current producing 105,000bbl/day.

2.0. Basin Tectonics

The Tano basin is located in the West African Transform margins. Tano basin is a cretaceous wrench modified pull-apart basin which resides in between the Romanche and St Paul transform faults. The West African Transform Margin was formed from the Atlantic rift system which started in late Jurassic era. It was created due to paleo-continent separation of South American and African. There was a further propagation of the rifting African continent eastward direction away from the south of the Atlantic. This formed a continuous anoxic environment in the West African Transform Margin between the late Albian to Turonian times. This anoxic condition, which is good for preservation of source rock, together with the active rifting resulted in deposition and preservation of organic matter which formed the source rock.

The tectonic activities which led to the formation of the wrench type pull apart basin of Tano all begun early Aptian time. At this time, the north and south Atlantic had just started opening. Lakes were an important environment for deposition of organic matter during this time period and together with enough burial, generated hydrocarbons. By early Albian time period, both South America and Africa had fully detached with the last point of contact being around western Cote d'Ivoire. During this time, Tano basin became a depositional focus which resulted in the basin experiencing lots of deposition from fluvial and lacustrine environments with thick clastic sequence from African continent. This provided adequate thickness which is required for the maturity of the cretaceous source rocks mainly in the central and western parts of the basin. There was a significant uplift and erosion which occurred during middle Albian times which influenced the topography of the Tano basin and was very instrumental in the creation of the very productive Jubilee field.

Sandstones which were stratigraphically trapped during the Albian and Cenomanian times formed the main reservoir rock for most of the fields discovered with marine shale forming the seal. The trapping mechanism is both structural and stratigraphic. It is also predicted that the source rock was in close proximity to the reservoir rock and indicating minimal hydrocarbon migration with the basin.

3.0. Stratigraphy

Deposition of rocks in the Tano basin begun during Aptian ages of the early cretaceous era. This corresponds to the period of continental rifting between the South American plate and the African plate which result in the creation of Tano basin within the Atlantic Ocean. This made the Tano Basin an area of focus for the deposition of clastic sediment from the African continent. There are three main play system within the Tano basin. These include the Albian play, the Cenomanian Play and the Turonian play. The Turonian play has proven to be the most productive of the field with huge discoveries such as the Jubilee field and the TEN field. The Cenomanian play also do have some substantial discoveries which include the Sankofo field.

A palynostratigraphical study was carried out by Atta-Peters, 2013 and Amoo Michael, 2014 to determine the stratigraphy of the Tano basin using data from a well north onshore of the Tano basin. In their work, the stratigraphy of the Tano basin starts with the deposition of Sandstone during early Aptian age with a mix of shale. this formed the basement rock for the basin at around depth of about 7000 to 9000ft. This was also followed by the deposition of another shale called the B-shale series during the early Albian age. The B-shale is considered as the most important system in the Tano basin since it was also found in most of the wells drilled across the Tano basin. It is also believed that it served as the main source rock in the basin. Sandstone was deposited after the Shale-B which serves a reservoir rock. Due to the showing of oil in this sandstone rock, it is assumed that there was a very short migration period for the generated oil from the source rock into the reservoir rock. The deposition of the sandstone was followed by breakup in sedimentation. There was an uplift and erosion event during the upper Albian age which signified a major unconformity in the basin.

The Cenomanian shale was deposited and this was followed by sandstone mixed with some huge deposits of limestone all happening within the Cenomanian age. The Turonian to Upper Santonian section is composed of medium brownish-grey shales and claystone, often non-fossiliferous, with occasional dolomite or limestone. It is generally thick, about 920 feet (280 meters). Most of the plays offshore Tano which have commercial accumulations of hydrocarbons have been discovered to lie in this time zone.

There was a further deposition of a shale rich zone mixed with occasional stringers of limestone and dolomite during the Campanian ages with a sedimentation rate of 127ft/million yrs. The Maastrichtian section is made up of a relatively thin deposition layer of claystone with occasional sandstone and dolomite. The Middle and Lower Eocene stratigraphic section consists of finely laminated dark grey/brown claystone with thin beds of fossiliferous dolomite and fine sandstone. Large portions of the Paleocene, Upper Eocene and Oligocene section are either only present as a thin bed or completely absent and attributed to extensive uplift and erosion associated with the Alpine Orogeny.

As the result of the burial during the Upper Cretaceous and further subsidence and burial during the Tertiary, hydrocarbons were generated in the axial part of the basin, charging the traps already in place.

4.0. Petroleum Systems

4.1. Source Rock

There are three source rock plays in the Tano basin: Upper Albian source rock, Cenomanian Source rock and Turonian Source Rocks with all made up of shales. which were deposited due to the creation of the pull-apart basin. The source rocks are very often interbedded with the reservoir rocks, which they charged and with which they are intimately connected.

Atta-Peters, 2014, carried out a research to evaluate the source rock hydrocarbon potential of the Tano basin by the use of some geochemical analysis which includes: Total Organic Carbon (TOC) and Rock-Eval. This research took samples from three different wells all located within the Tano basin [D. Atta-Peters, P. Garrey].

From the research, the kerogen types which are available in Tano basin are the type II and type III with few well samples show indications of type I and type IV. This proves that the basin has the potential to yield both gas and oil if thermally matured with adequate burial depth. In terms of thermal maturity, the data showed that most of the source rock samples proved to be in the range of immature to marginally mature source rock. The Tmax data also indicate that samples taking from a well south of the basin proved to be in the oil window with the samples from the two other well just below the oil window. [Figure 9].

The Total Organic Carbon potential of the source rock samples ranged from 1-4, indicative of good to very good TOC values. This fact is supported by the fact that most of the samples were of Type II and type III kerogen. Few samples showed an excellent TOC potential. With such good TOC values, the potential for the source to yield hydrocarbons is evident to see. This supports the discovery of oil and gas fields in the basin, [figure 8].

In summary, the source rock samples showed a good potential for generation of oil when buried in the oil window. From sedimentology of the field, most of the source rock has already enter the oil window which proves large generation of oil in the basin.

4.2. Reservoir

There are 3 main reservoir plays within the Tano basin. These plays are:

- Albian Reservoir play: Lower Albian to Upper Albian Age with Sandstone lithology.
- Cenomanian Series: Cenomanian age with Sandstone lithology.
- Turonian Series: Turonian Age with sandstone lithology.

There has been only one discovery in the Albian sandstone reservoir which encountered oil and gas with net thickness of 25m deep water Tano. This sandstone has porosity between 17% to 22%, permeability as high as 2000mD and has a maximum oil pay of 58m. The Cenomanian sandstone reservoirs have also not been so production in the accumulation of hydrocarbons in the Tano basin with only one discover from this play.

The Turonian series is the most successful and important of all the three plays in terms of accumulation of hydrocarbons in commercial quantities. Giant discoveries in this play include the Jubilee Field and the Tweneboa, Enyenra and Nttome (TEN) field. Porosity values in this play ranges from 17-23% with permeability of 100-3000mD. The oil saturation in the play also ranges from 60-90% and has a net to gross ratio in the range of 30-80%. The API of the oil in this play is 32-38^o.

4.3. Seal and Trap

The seal play in the basin includes the Albian shale series, Cenomanian Shale series, Turonian Shale series and the Turonian Shale series. Marine shale forms most of the seals in the basin with the trapping system being both stratigraphic and structural traps.

Most of the seals are in close proximity to the reservoir rock and hence a very short migration of the crude oil is expected. The proof quality seals can be experience in the wells showing fairly high pressures. Unconformity surfaces and local fault patterns also contribute to seal integrity. Down-to-the basin faults can act as barrier to hydrocarbon leakage where a reservoir is juxtaposed against relatively non-permeable rocks. The Albian play have mainly structural traps with Dome, Fault block, and Anticline forming the traps. The Cenomanian play has both structural and stratigraphic traps formed with Draping structure, Clastic depos lens, pinch out, faults and anticline being some of the trap types. The Turonian play also has both structural and stratigraphic traps as the trapping mechanism. Some of types of traps in this play include Clastic depos lens, pinch out, normal faults and anticline.

5.0. Summary

The evolution of the Tano basin mainly occurred in the cretaceous era. It all start during the late Jurassic era but sedimentation and formation of the basin was in the cretaceous era. The basin is one of the most productive alone the West African Transform Margin and has been producing since December 2010. The basin type is that of a wrench pull a part basin with faults, anticlines and pinch out as the main type of traps. The shale type is mainly of marine shale with the predominant reservoir type being sandstone reservoir. Porosity is medium to high in the field with permeability been very high across the basin. The field is currently producing 105Mbbl/day and is expected to increase to about 250MBbl/day after all fields have been brought on stream.

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Figures

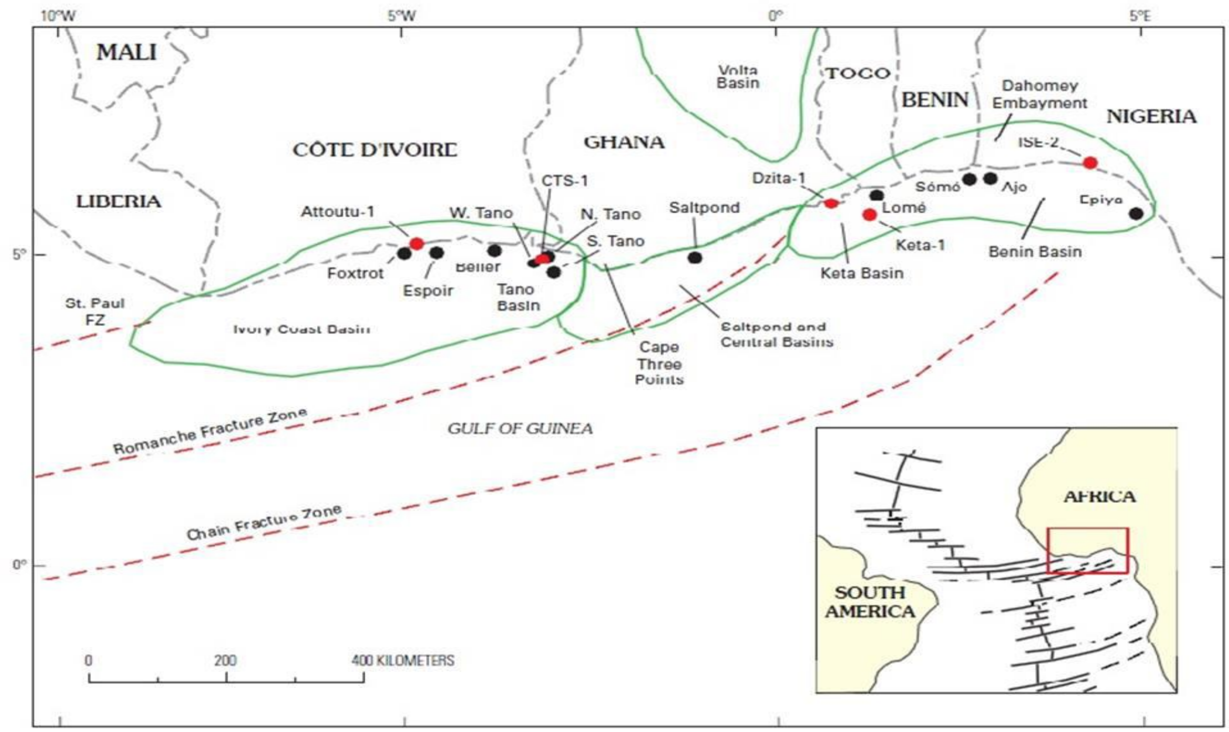


Figure 1: Showing the location of Tano Basin within the St. Paul and Romanche transform fault zones. (USGG report, 2006).

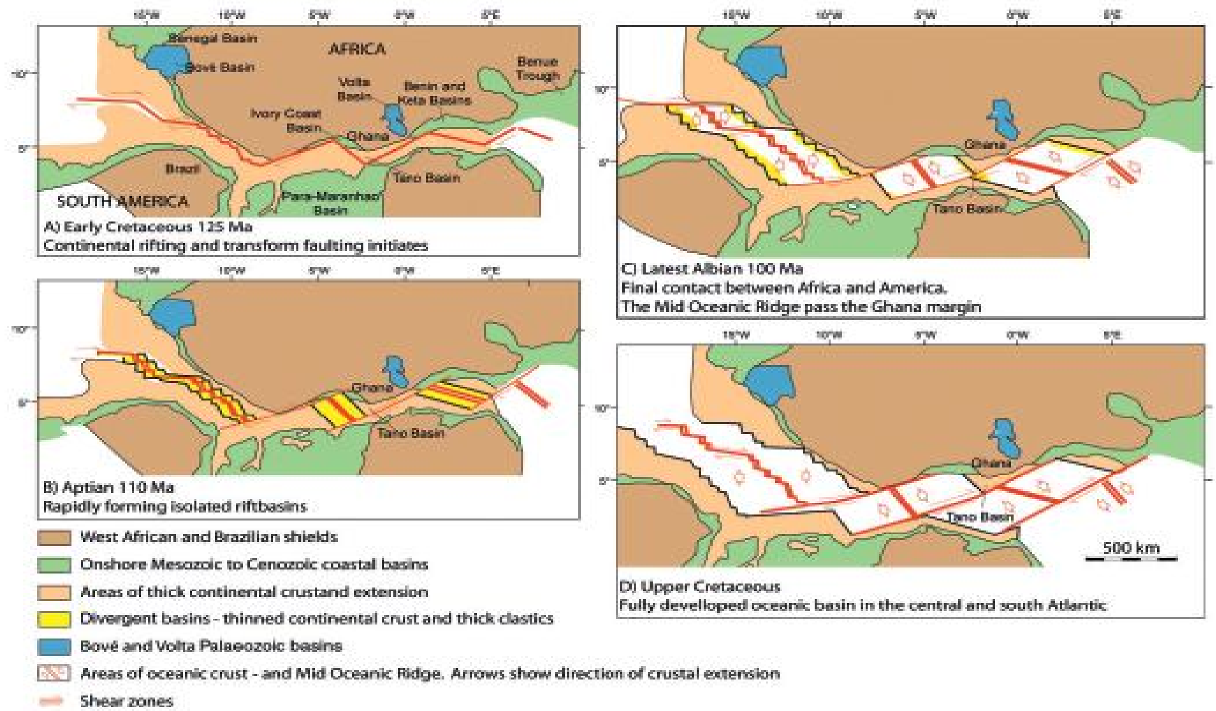


Figure 2: Plate tectonic evolution of the equatorial Atlantic Ocean. Redrawn from (Mascle et al. 1988 as cited by Lars H. Rüpke et al, 2010.).

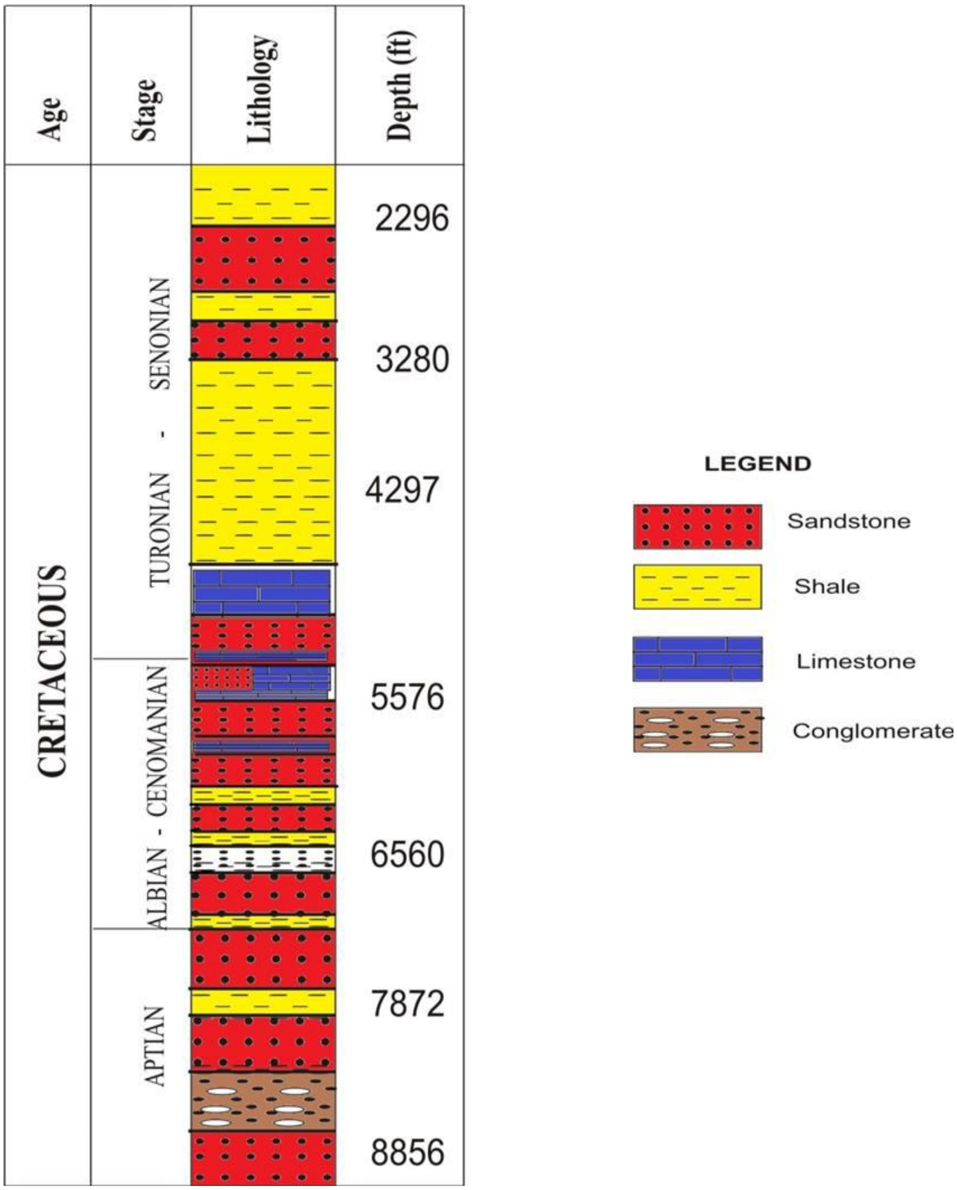


Figure 3: Palynostratigraphical study showing the lithology and stratigraphy sequence of the well (Amoo Michael, 2014)

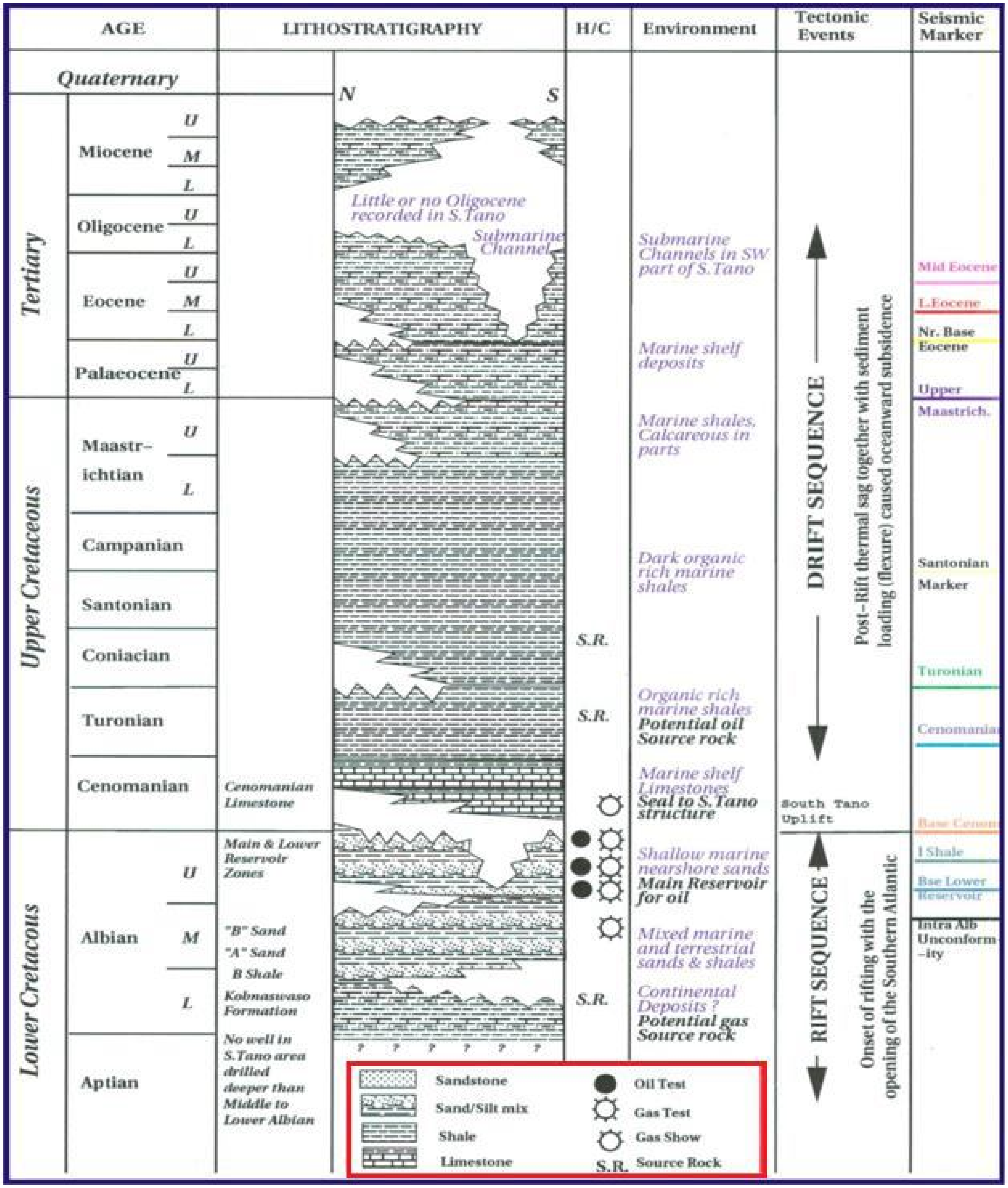
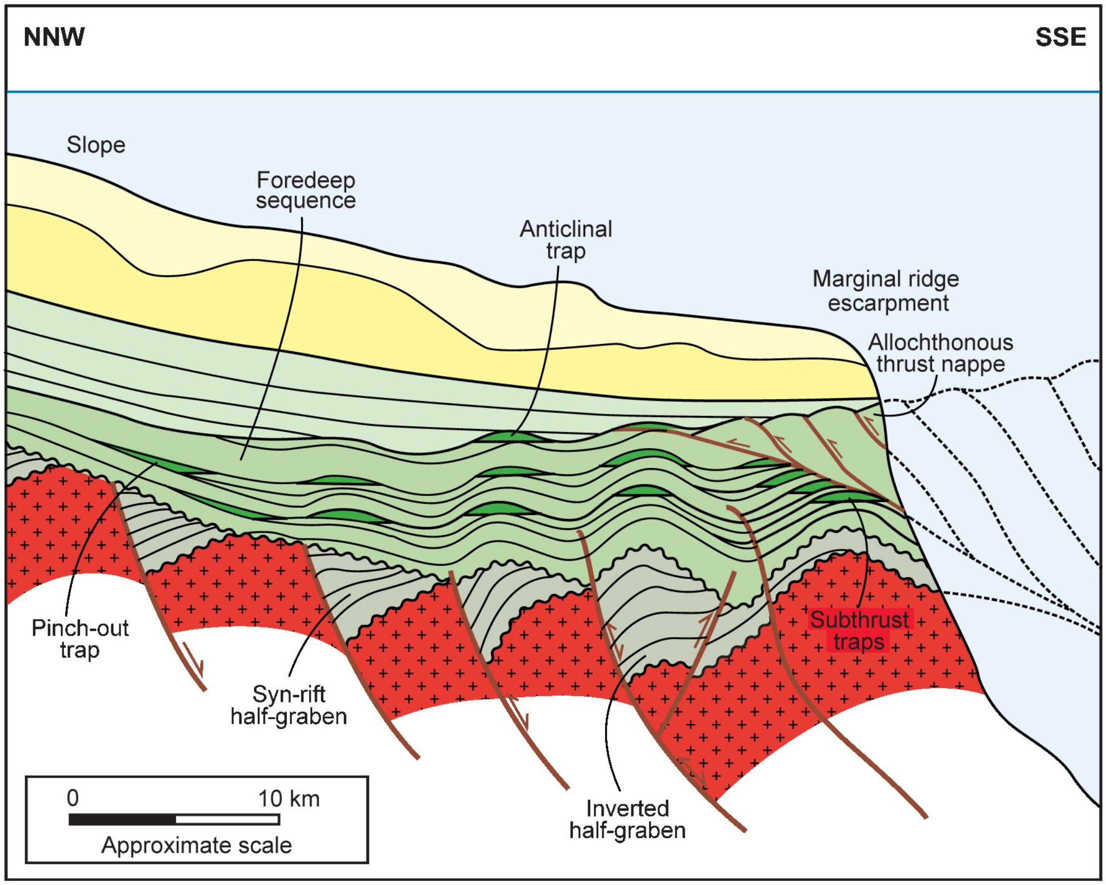


Figure 4: Summarized Stratigraphy of the Tano Basin (GNPC, 2004 as referenced by Amoo Micheal)

PLAY TYPES IN CAPE THREE POINTS AREA, GHANA



New and "unusual" play types in the deepwater exploration model of the Marginal Ridge, Cape Three Points Deep, Ghana, include structural closures within the Cenomanian foredeep sequence over inverted syn-rift structures, stratigraphic updip pinch-out traps within the Cenomanian foredeep, en echelon structural closures within the Senonian and sub-thrust (nappe) traps, both structural and pinch-out.

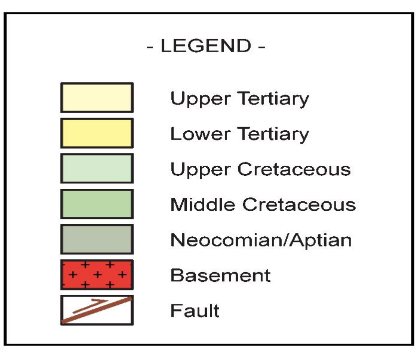
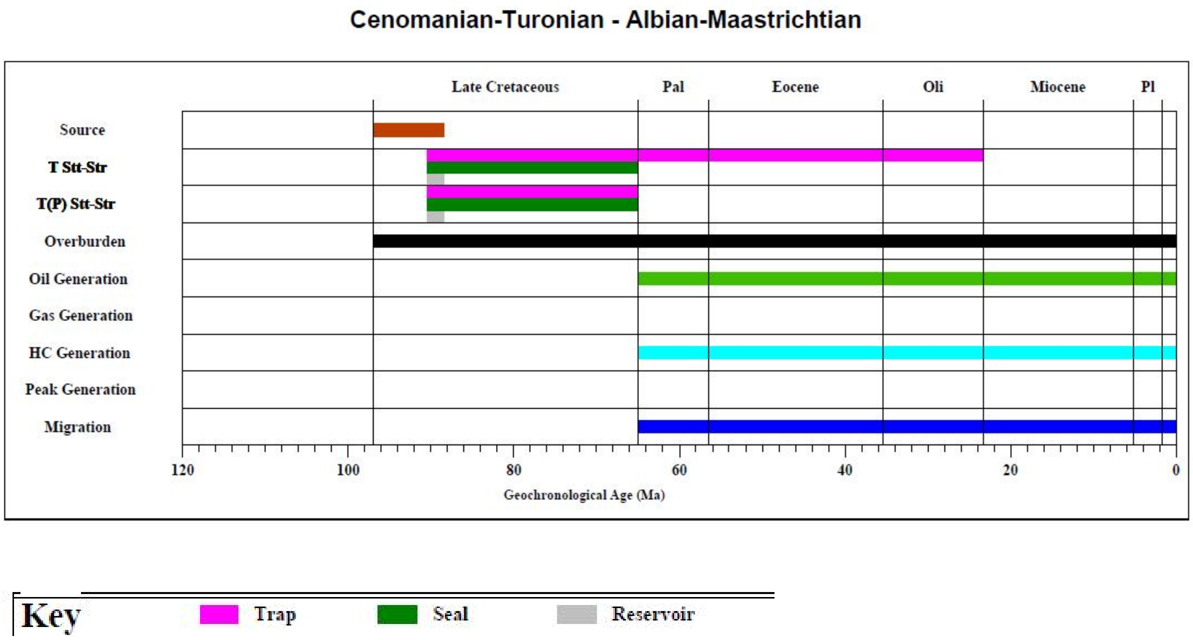


Figure 5: Play types in Cape Three Point, Offshore Tano Basin Ghana. *(IHS Report, 2011)*



T stt-str: Turonian Stratigraphic and Structural play
T(P): Turonian proximity Stratigraphic and Structural play

Figure 6: Cenomanian-Turonian – Albian Play History Time Chart for Tano Basin. (*IHS Report, 2011)*

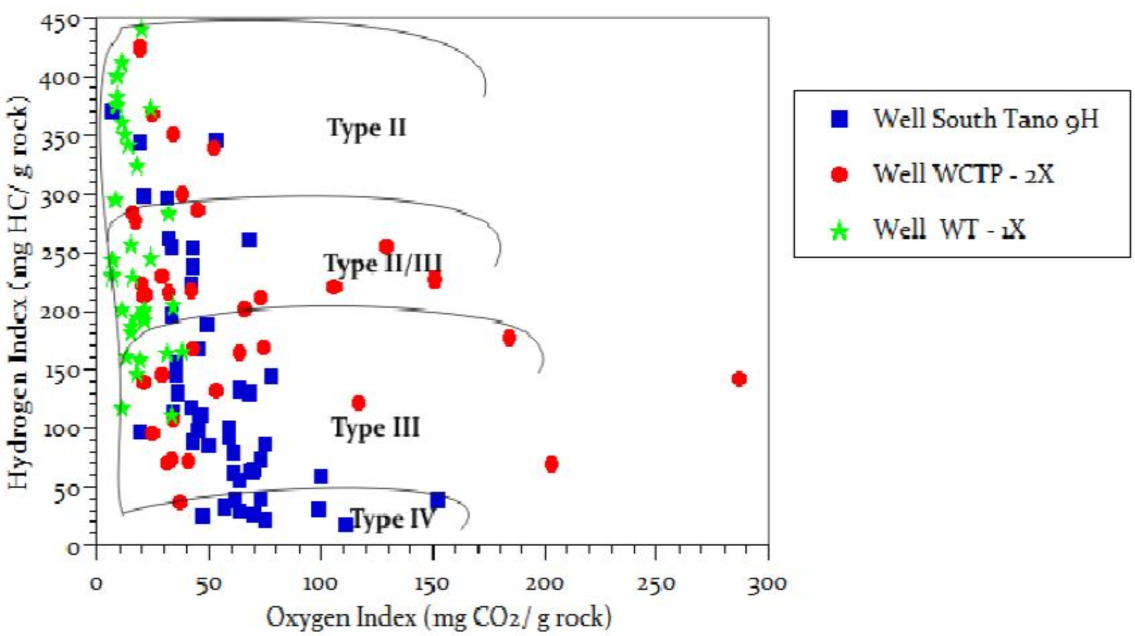


Figure 7: Modified Van Krevelen diagram for Tano Basin [D. Atta-Peters, 2014]

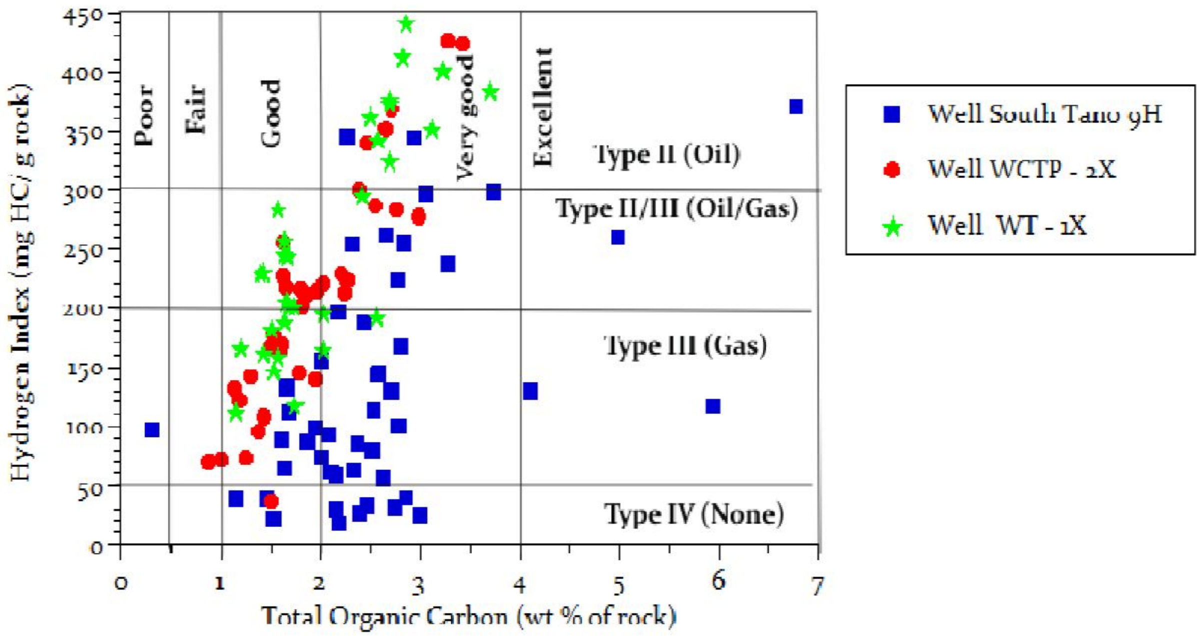


Figure 8: Plot of HI versus TOC indicating hydrocarbon potentiality and generating potential

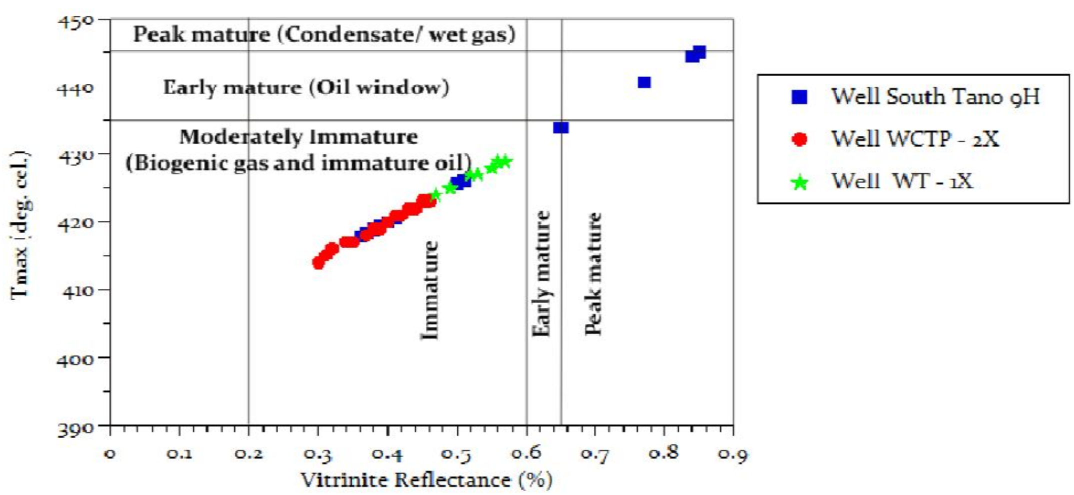


Figure 9: Plot of Tmax versus Vitrinite Reflectance (Ro) showing the maturity level (Atta-Peters, 2014)