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Petroleum Source Rock Evaluation of the Argillaceous Sediments in a part of Nagapattinam Sub basin, Cauvery Basin.

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Summary

The paper attempts to characterize the petroleum generation capacity of the Albian and older sections in three deep wells in Nagapattinam sub-basin of Cauvery basin.Since these synrift sediments are encountered for the first time in the sub-basin it will lead to new understanding on the genesis of oil and gas in the sub-basin.

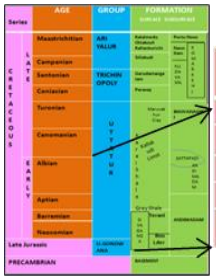
Keywords: Source Rock Evaluation, Cauvery Basin

Introduction

The Cauvery Basin extends along the East coast of India covering an area of 1.5 lakh sq. Km comprising on land (25,000 sq.km) and shallow offshore areas (30,000 sq km). In addition, there is about 95,000 sq km of deep-water offshore areas in the Cauvery Basin. The Cauvery Basin is an intra-cratonic rift basin, divided into a number of sub-parallel horsts and grabens, trending in a general NE-SW direction. The basin came into being as a result of fragmentation of the Gondwana land during drifting of India-Sri Lanka landmass system away from Antarctica/Australia continental plate in Late Jurassic / Early Cretaceous. The initial rifting caused the formation of NE-SW horst-graben features. Beginning from Blandford in 1865, innumerable workers have contributed to a wealth of knowledge on Cauvery Basin. The present study is an attempt at correlating Albian and older sediments in three deep wells in Nagapattinam sub basin based on Geochemical data

Present Study

Nagapattinam sub basin is a northeast-southwest trending sub-basin located between Karaikal ridge in the north and Vedaranniyam terrace in the south. The sub-basin occupies an area of 2710sqkm including 980sq.km offshore. With the drilling of three deep wells –AC-D, TA-D and PD-A-in the sub basin, new stratigraphic successions which has been only envisaged so far has been encountered. Petroleum Sequence Stratigraphy study (2007) of the Cauvery Basin has delineated up to the Barremian section in the Nagapattinam sub basin (Fig-2).



Sequence Boundary	Identified
M I 60 (Late Albian*)	Entire Basin
Within Albian	Ariyalur-Pondicherry
M II 70 Barremian	Entire Basin, ExceptTranquebar
M III 20 Valanginian	Tanjore andRamnad
M III 10 Late Jurassic?	Tanjore andRamnad

PSSS,2007

Fig-2 Generalised Stratigraphy of Cauvery Basin (adapted from Ravindran etal,Petrotech,2005) ; PSSS data for Albian and Older.

Data on the detailed geochemical study of the sediments from Albian and older for the wells under study has been integrated with lithology, thickness of shale, electrolog characteristics, age boundaries, sedimentological attributes and environmental interpretation. Vertical distribution of the Total organic carbon content and generation potentials have been laid out in a stratigraphic environment.

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Results and Discussion

Geochemical Attributes of Albian –PreAlbian and Older Sediments: The sedimentation within the Nagapattinam sub basin and the Cauvery basin as a whole was controlled by tectonics and is responsible for repeated transgressions and regressions. The vertico-lateral facies change in Cauvery basin can be explained by tectonics, sea level changes and sediment influx in the basin. Since the change is not regular throughout the basin, variations in lithofacies, biofacies, thickness variations and sedimentation breaks occur (Sahu,2008).The Albian and older sediments are evaluated in terms of organic matter abundance, type and thermal maturity.

Albian: The thickness of the Albian section in the studied wells vary from 517 to 750m and is entirely dominated by calcareous and non calcareous sandstone with very thin intervening laminae of shale. Paleontological studies suggest the deposition of the sediments in inner to outer shelf conditions. The lithostratigraphic definition is Andimadam after the prototype well, Andimadam-1 in Ariyalur Pondicherry sub basin.

With the exception of AC-D which is showing streaks of source rocks within the Albian, no significant source rock development is observed in case of TA-D and PD-A wells within the Albian section.

Aptian:
The Aptian section is essentially argillaceous and silty. In TA-4 this section is not differentiated. Thickness of this unit is 430m and 570m in AC-D and PD-A respectively. Coarse irregular sand grains embedded in calcareous/argillaceous matrix characterise this unit. Sandstone is dirty and is dark brownish in colour when compared to the normal light grey calcareous sandstone of Andimadam Formation. A new formation name- Adichapuram- is proposed for this unit. Occurrence of siderite along with shale and sandstone indicates shallow burial depth. The ferruginised nature of the shale suggests the possible exposure of this shale after its deposition.

The fine grained sediments within the Aptian section are Effective source rocks with very good organic matter richness (0.86-5.09; 1.00-3.70 % for PD-A and AC-D respectively). But the hydrocarbon generation potentials are fair which is indicative of partial oxidation of the organic matter. Better preservation conditions are observed at PD-A locale (S2 1.98-9.71; 1.33-5.80 mg HC/g rock) for PD-A and AC-D respectively.

The biostratigraphic studies indicate that the sediments are deposited in marginal marine.

Barremian:
A thickness of around 600-700m is present in TA-D and PD-A while in AC-D only 63m of this unit has been penetrated and is mainly shale. This sequence is marked by arenaceous lithology comprising of weathered basement wash beds with intervening shale beds/layers at TA-D and PD-A locales. Shale is dark grey, brownish grey, moderately hard, and highly compact suggesting of a high degree of compaction. Periakudi formation is the nomenclature assigned to this section.

The entire 63m drilled in AC-D indicate development of fair source rocks. Good development of source rocks occur at PD-A (TOC 1.12-3.93; Av1.99% and S2 1.64-8.95; Av 2.96 mgHC/g rock) within the fine grained sediments sandwiched between sandstone sections occurring at the top and base of this unit. Fine grained sequences occurring within this section at TA-D is enriched in organic carbon contents (TOC 0.69-5.72; Av 2.32%). The source rocks have good hydrocarbon generation potentials (S2 1.28-6.26 mg HC/g rock).

Hauterivian:
The thickness of this unit is 20m and 70m in TA-D and PD-A respectively. The sedimentological attributes are similar to the Barremian section and is classified as Periakudi formation. Free sand grains occur (10 to 20%) within this unit. The shale comprises Fe-oxide content and hence has an occasional semi-metallic lustre. It is associated with fine biotite micaceous matters. Fe-oxide rich claystone is brownish red to chocolate brown coloured, moderately hard, often silty and compact showing tendency to shale, in the bottom most part of this section.

Source rock facies within the shaly section in PD-A and TA-D is marked by very good organic matter contents (TOC 1.54-2.20; Av 1.84% & 1.96-3.74;Av 2.74%) with very good hydrocarbon generation potentials (S2 2.91-5.54; Av 4.08mg HC/g rock; 5.10-10.78; Av 7.19 mg HC/g rock) for PD-A and TA-D respectively.

Valanginian and Older:
The creation of depression due to riftogenesis in the pre-rift landsape gave rise to this unit in the form of gravity driven and fluvatile deposits. This undifferentiated section is marked by highly dense and continuous alternations of sand/sandstone and shale beds/layers. The basal part is associated with very fine laminae of dirty white/off white, light grey, silty clay matrix. Shale is dark grey, dark chocolate brown, moderately hard and compact, fissile, micaceous (biotite) and also indurated. The highly platy shale fragments give semi metallic shining, which probably show ferruginous coating.

This unit has experienced the best conditions for source rock development. The organic matter richness is very good (0.88-12.0;Av3.36%) and Rock Eval pyrolytic yields are very good to excellent (2.61-27.83; Av 11.91 mg HC/g rock)) indicating good preservation of organic matter in PD-A and the Geochemical characteristics are comparable to the basal unit in TA-D (TOC 2.94-8.14; Av 4.01% and S2 4.39-17.05 Av 7.03mg HC/g rock). The frequency and density of sand/sandstone and shale beds/layers in the form of alternations are almost same throughout this section which shows certain degree of apparent cyclicity in PD-A. Presence of coaly shales are observed in PD-A as well as TA-D.

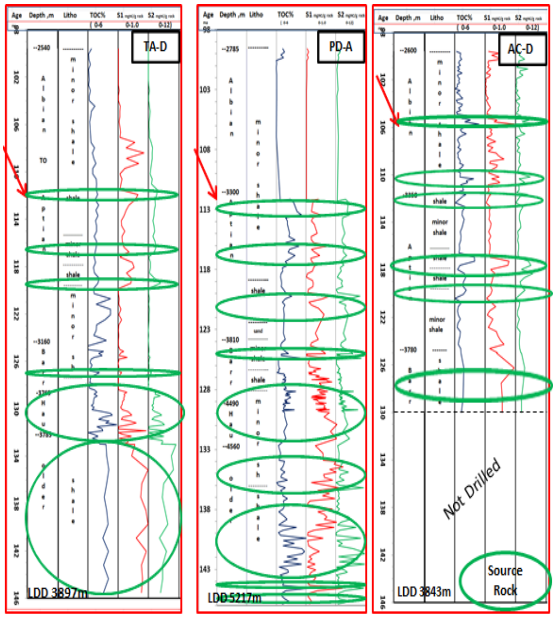

Fig-3 Source Rock Distribution in TA-D, PD-A and AC-D in Nagapattinam sub basin.

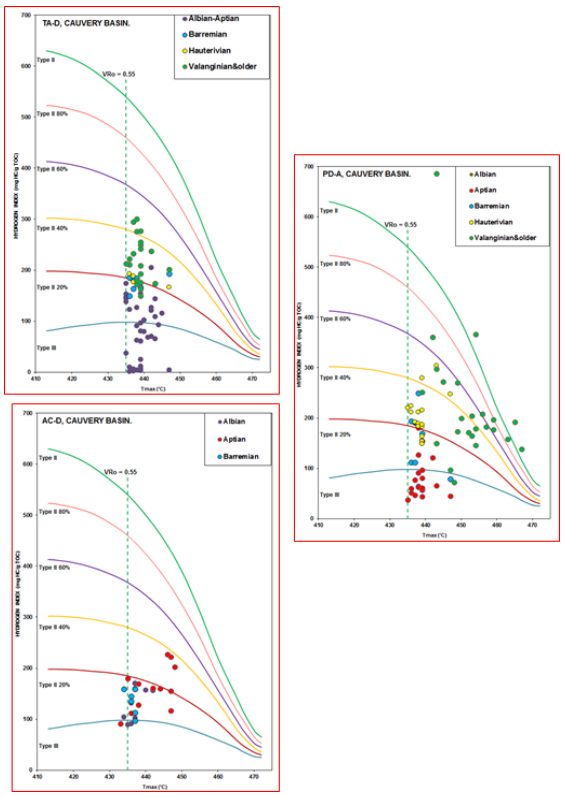

Fig-4 Plot of HI vs Tmax for the Sediments in TA-D, PD-A and AC-D in Nagapattinam sub basin.

The source sequences evidence a major input of Type-II organic matter with varying contributions from Type-II organic matter.The Type-II contribution is up to 40% for the oldest sequence in PD-A and TA-D. The organic matter preservation shows a decrease from Older unit to Albian section.

Maturity:
Vitrinite Reflectance data on the wells has been included in this study. For each well, plots of Vitinite Reflectance with depth were created and stratigraphic units and source rocks encountered in the well are also included. The top of the oil window at TA-D and PD-A locales occur at 2820m and 3110m respectively, while in AC-D it is shallow (2220m). The basal source rock units are in peak generation stage. The change in gradient is widespread in the wells under study. Significant change in the gradient occurs at the G1 marker level, Albian, Barremian and the oldest unit. These sedimentation breaks as depicted in the VRo profiles correspond to the well defined unconformity surfaces in the Cauvery Basin.

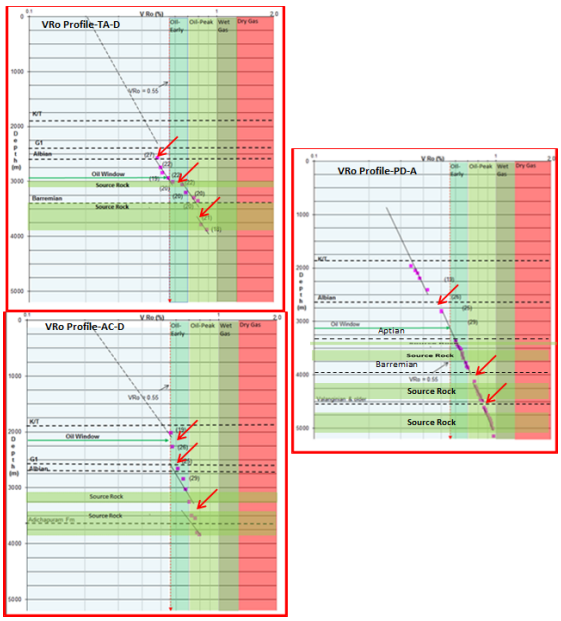

Fig-5 Vitrinite Reflectance Profiles of TA-D, PD-A and AC-D in Nagapattinam sub basin

Molecular level study

The m/z 191 mass chromatograms of all the source sediments are characterized by the presence of ubiquitous hopanes, C30 dihopane, high relative abundance of C30 hopane, almost equal abundance of Tm and Ts, and the complete series of C31 to C35 homohopanes. The regular stair-step progression of C31-C35 homohopanes is consistent with sub-oxic bottom waters during deposition (Fig-6).

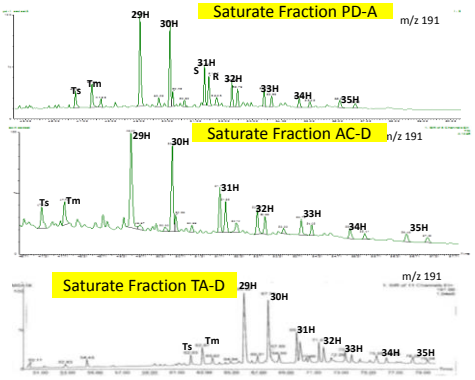

Fig-6 Distribution of Hopanes in Source Rock Extracts

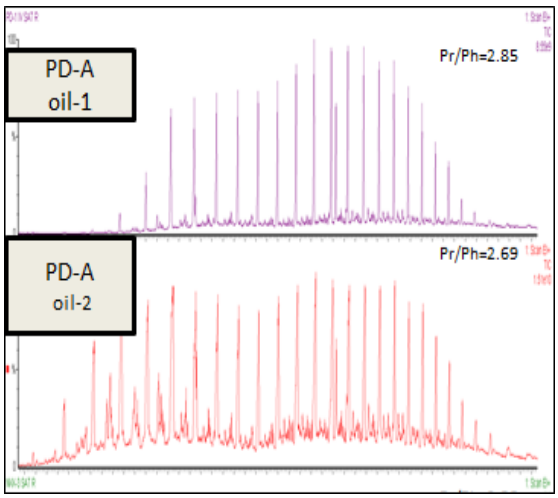

Fig-7 GC Fingerprint of Oils showing Mixed Input

Biomarker data on the oils from two objects in the study area, PD-A (Fig-7) indicate that these oils are derived from a source rock having mixed organic matter input (Type III +II), deposited under marine-shelf conditions (Goswami, 2012).

These indicate that these sediments were deposited in a shallow marine environment with significant input of transported land derived organic matter.

Log Correlations

Correlation of the Geochemical data and electro logs is given in Fig-9.The older Source sequences in TA-D and PD-A are correlatable on the logs. The top of the sequence is marked by high Gamma ray and low Rt values on electro log which may be probably due to presence of K-feldspar, biotite mica and pyritised black siltstone within this sequence. A seismic section passing through PD-A and AC-D is presented in Fig-8 and the older unit is clearly discernable. Better preservation conditions of the organic matter as compared to PD-A locale is envisaged in the low to the east of PD-A and will be a prolific source for oil and gas in the basin.

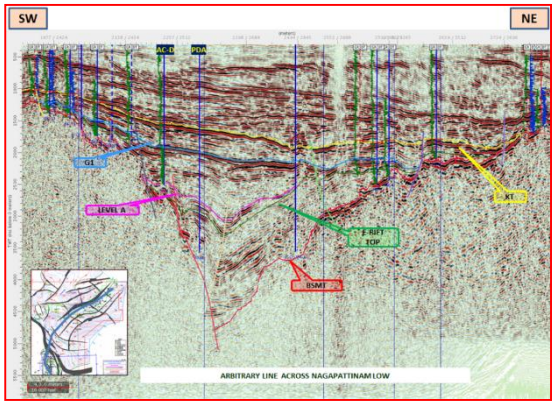

Fig-8 Seismic line Passing through Nagapattinam Low

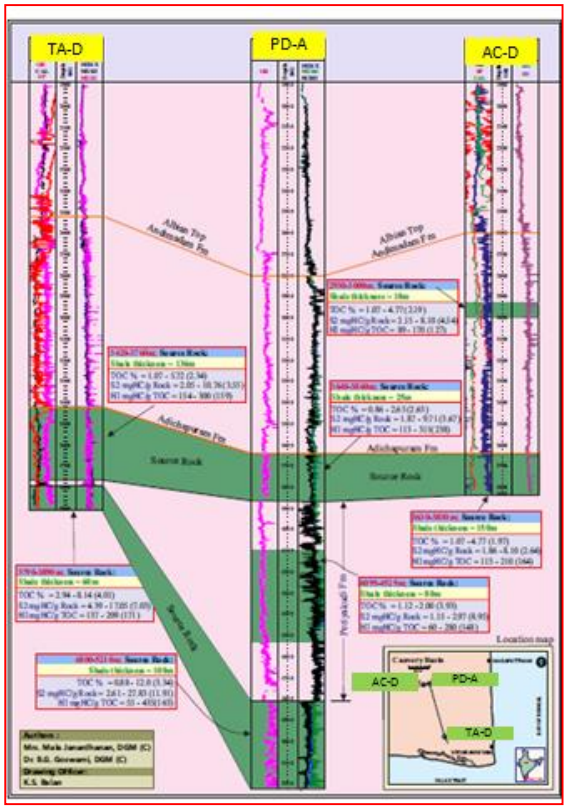

Fig-9 Well Log Correlation of TA-D, PD-A and AC-D in Nagapattinam sub basin.

Conclusions

The source rock distribution in the wells under study follows a mappable pattern across the wells with definite organofacies variation arising probably due to varying inputs and depositional environments.
The basal shales within the oldest units in PD-A and TA-D are the best source rocks encountered in the whole of Cauvery basin till date. The TOC range from 0.88-12.0; 2.94-8.14 and generation potentials vary from 2.61-27.83; 4.39-17.05 for PD-A and TA-D respectively.

The characteristics of the organofacies within the Hauterivian section is indicative of the continuation of the sedimentary environment.

The Barremian times indicate excellent organic matter richness but the generation potentials are fair and hence the organofacies within this unit may be considered transitional.

Similar conditions are envisaged during Aptian times as evidenced by the source rock characteristics

The Albian section is predominantly arenaceous and only the Early Albian unit has experienced favourable conditions for development of source rock. The minor shales within the Early Albian section is organically lean with fair hydrocarbon generation potentials.
Better preservation conditions of the organic matter is envisaged in the lows and will be a prolific source for oil and gas in the basin.

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