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Reservoir Characterization of tight Periyakudi reservoirs in Nagapattinam Sub-Basin of Cauvery Basin

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Abstract:

Cauvery basin, on the East Coast of India, is a Mesozoic rift basin, formed due to the fragmentation of Gondwanaland. The basin evolved as a rift basin in late Jurassic time and received syn-rift sediments during rift stage, later transformed into an interior sag basin during late Cretaceous and later to passive margin during Paleocene receiving sediments from adjoining structural highs. The syn-rift sediments are prevalent in all major half-grabens and are marked by clear seismic reflector/sequence boundary have lately become new hydrocarbon targets not targeted earlier due to the depth of their occurrence and poor petrophysical properties.

The Periyakudi field, a recently discovered field is located in the Nagapattinam Sub-Basin of Cauvery Basin has established commercial hydrocarbons from early syn-rift sediments dated Barremian and older (palynologically) has a large areal spread of more than 120 SKm northeast of the established Kovilkallpal-Adichiapuram area along the Pattukottai-Mannargudi fault escarpment.

The Periyakudi field is a four way dip closure on the foot-wall fan delta with a strati-structural entrapment as wedge-out against the Basement scarp. The syn-rift reservoir encountered in drilled wells is around 600 m thick sandstone intercalated with mature source rich shale. The youngest late syn-rift pack dated Albian-Aptian earlier classified as Andimadam formation is dominantly arenaceous with minor shale, while the deeper sediments dated Barremian and older early syn-rift drilled for the first time in this sub-basin has been classified into two litho-stratigraphic units the younger Periyakudi formation and the lower undifferentiated sequence. The sandstone reservoir has relatively poor petro-physical property classifying them into tight reservoirs requiring hydro-fracturing for commercial production. This study aims to describe and characterize the reservoir section of Periyakudi formation by integrating lithology log, well log data and inversion of the seismic data to define the reservoir system and help design field development plan of this play.

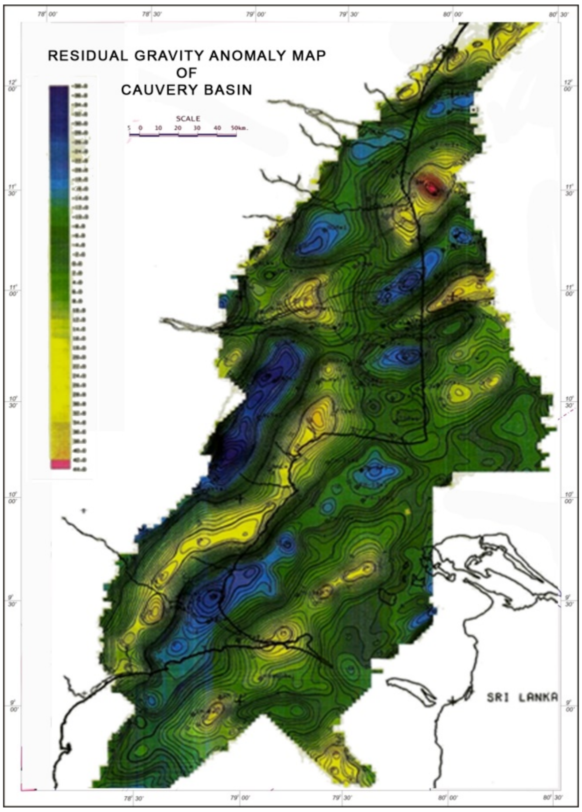

Fig. 1 Gravity Anomaly Map of Cauvery Basin

Geology of the Area

The Cauvery Basin is an intra-cratonic rift basin, evolved as a result of fragmentation of the Gondwana land during Late Jurassic / Early Cretaceous. The residual gravity map (Fig 1) over Cauvery basin shows three prominent lows the Ariyalur-Pondicherry depression in the north, the Tanjore-Nagapattinam-Tranquebar depression and the Ramnad-Palk Strait depression aligned in NNW-SSE direction and are separated by highs, Kumbakonam-Madanam ridge and Pattukottai-Mannargudi ridge respectively.

The Tanjore-Nagapattinam-Tranquebar depression has two small lows corresponding to the Tranquebar depression and the Nagapattinam depressions respectively demarcated with Karaikal ridge, Vedaranyam ridge and Mandapam-Delft ridge respectively.

A closer look of the tectonic fabric in the Nagapattinam-Tranquebar Sub-Basin shows that the foot-wall and hanging wall shoulders are characterized by minor half-graben architecture found to be hosting syn-rift sediments. Majority of these extensional faults die out within Upper Cretaceous sequence and only very few faults extend into Tertiary sequence. Periyakudi field is located along the footwall of Pattukottai-Mannargudi ridge of the Nagapattinam Sub-Basin.

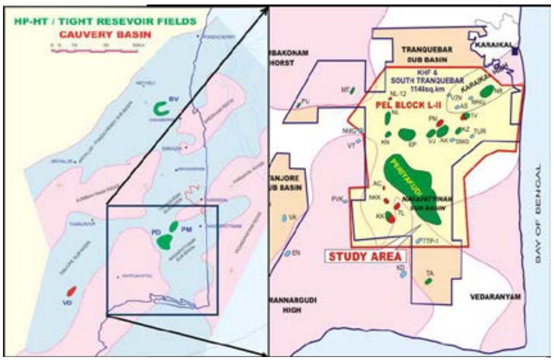

Fig. 2 Study Area

Entire stratigraphic succession from Late Jurassic/ Early Cretaceous to Recent is available in the study area. Oil and gas pools of various sizes and entrapment styles have been established in different stratigraphic units from Early Cretaceous to Oligocene. Established pools till date are mostly on Basement highs. In the basinal part, wells are few and except the two wells in Periyakudi they have not drilled the deeper sedimentary column as it is more than 10Kms.

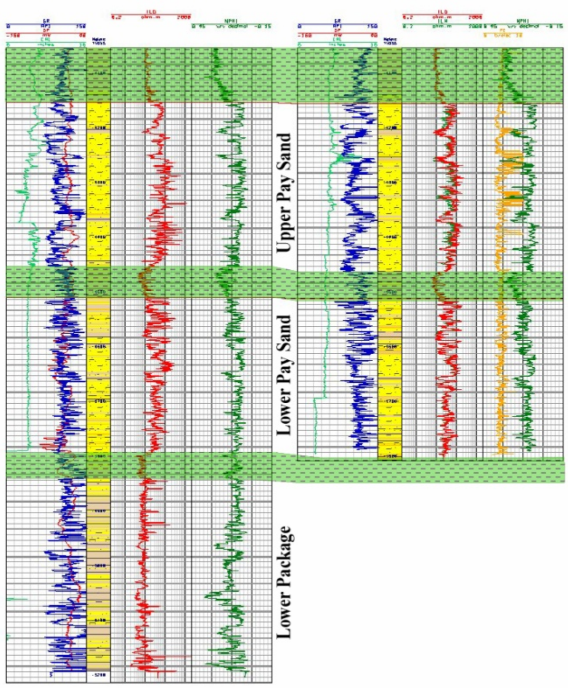

Fig. 3 Electro-facies of Periyakudi Formation

Method of Study

A part of seismic data covering an area of 380 SKm was selected comprising 300 Inlines and 850 Traces with 40X20 m bin was selected to carryout seismic inversion (Fig 2). The seismic data is fairly good over the selected area. Seismic to well matching was carried out in Hampsel-Russel Suite for both the wells drilled in the field. Low frequency velocity model was built using seven wells drilled covering only the upper sequences in the surrounding area of Kovilkallapal and Adichiapuram fields and one well in the basin axis since the wells drilled for syn-rift sequence are sparse. Six horizons comprising early post rift and syn-rift sequence were mapped on top of Turonian, Upper Pay Sand, Lower Pay Sand, Alternation Package, Base of drilled section and basement respectively were taken for seismic inversion. Seismic attribute analysis and acoustic impedance analysis were carried out for the upper and lower pay sand to understand the lateral and vertical variations in attributes to plan the appraisal/development wells in the field.

Litho-stratigraphic classification

The Nagapattinam low is half-graben with the Mannargudi-Pattukottai high as the footwall and the Karaikal high plunge as the hanging wall has a thick pile of more than 7 kms of syn-rift sediments. The thick sediments deposited during syn-rift and early post-rift period were earlier differentiated into two litho-stratigraphic formation – Andimadam (Albian and older) and Bhuvanagiri (Cenomanian-Turonian) respectively. Based on the lithology and well log response from the drilled well the deeper Andimadam unit was divided into three formations, the Andimadam, Periyakudi and undifferentiated formation. The Periyakudi formation further comprise two member units the upper pay package and the lower pay package (Fig 3).

The lowermost undifferentiated unit comprises of alternating pyritised sandstone and micaceous shale beds and the undrilled section to the Basement. The sandstone are angular to sub-angular, poorly sorted with lithic basement wash, shale are dark grey and compact with moderate fissility with presence of siderite. The sediments are immature and have undergone very short distance of transportation, mainly fed by the footwall of Mannargudi-Pattukottai high.

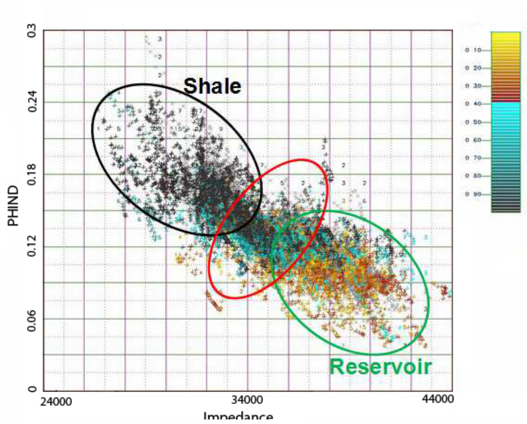

Fig. 4 Impedance vs Porosity Crossplot

The lower pay package comprises arenaceous unit with intervening shale. The sandstones are fine to very coarse, angular to sub-angular, moderately sorted. Growth of disseminated pyritic crystalline coating over quartz grains have been noticed at places. Muscovite, biotite micas and carbonate matter are also present. Weathered basement wash is present in the range of 10 to 40% consisting dominantly of quartz and feldspar. Shale is dark grey, moderately hard and highly compact with moderate fissility. At places the shale consists of fe-oxide content attributing an occasional semi-metallic luster. This unit is dominated by seismic reflections parallel to Basement onto which the younger syn-rift and passive margin sediments onlap or toplap.

The upper pay package has been dated as possible Barremian, and the extent is restricted to the lows surrounding the plunge of the Karaikal High trend. This package is separated from the older unit by 50 m shale and the younger unit by 250m thick shale. The lithology is similar to the lower pay package, petrophysical properties are slightly better than the lower pay package.

Electrolog Analysis

The syn-rift sediments comprising Andimadam and Periyakudi formation on the electro-logs were analyzed for reservoir and non-reservoir response. The cross plot of Impedance to Porosity (Fig 4) brings out a clear distinction between the shale and clean sands. The shale is characterized by low resistivity, low density, high neutron porosity and high sonic travel time while sands are characterized by higher resistivity, higher density, low neutron porosity and slower sonic travel time summarized in the Table-I:

Properties	Sandstone			Shale		
	Min	Mean	Maximum	Min	Mean	Maximum
Impedance	10650	11300	12500	8200	9600	10200
DT	55.97	70.18	82.68	65.73	81.39	97.00
NPHI	0.04	0.14	0.24	0.11	0.22	0.32
RHOB	2.44	2.57	2.68	2.36	2.55	2.65
Rt	20.00	30.00	100.00	2.50	5.00	10.00

The lithologically similar Upper Pay and Lower Pay show higher P-Impedance contrast with the shale that occurs below, within and above. The sands have higher acoustic impedance than the shale and within reservoir, the porosity has direct relationship with acoustic impedance, poorer the porosity higher is the impedance. This helped in carrying out deterministic inversion for p-impedance on the seismic data which was good for such studies.

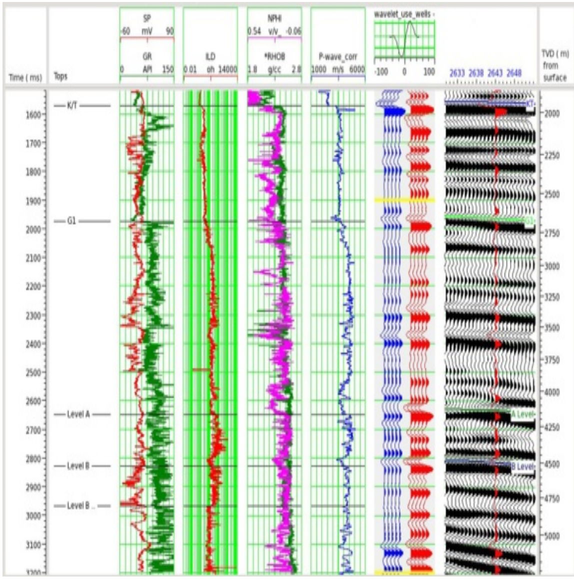

Fig. 5 Seismic to Well tie of Well A

Post-stack Acoustic Inversion

Model based deterministic inversion was carried out using Hampsel Russel Suite of Software. The well-seismic tie and wavelet extraction process produced the synthetic seismogram, time-depth relationship, well log and markers in the time domain. Wavelet was extracted initially using the seismic data and then at each individual well followed by composite wavelet using all the drilled wells. The seismic tie and estimated wavelet at wells is demonstrated in figure (Fig 5).

Cross plot analysis of well logs (Fig 4 and Table 1) across the Periyakudi Pay sand clearly brings out separation of clean reservoir and shale facies in terms of acoustic impedance contrast at well locations, however a small interference between the mixed lithology like sandy shale, shaly sand or siltstone falling in the middle of the clean reservoir and argillaceous facies will have some impact in determination of the lithological interpretation from the seismic inverted volume. The clean reservoir sands have P-Impedance in the range of 10650 – 12000 (kg/m^2*s) while the shale which forms the cap/seal has range of 8200 – 12200 (kg/m^2*s).

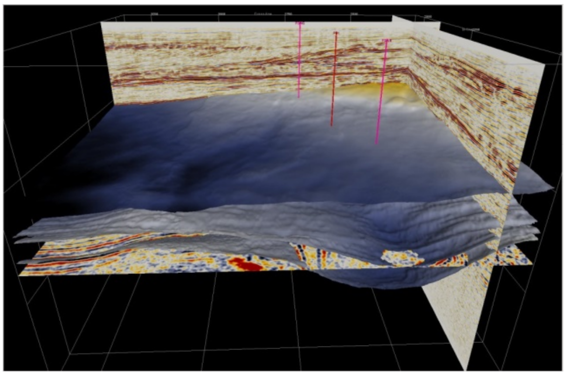
Fig. 6 Horizon Modeling for Inversion Studies

Two regional horizons corresponding to Cretaceous and Turonian top and five horizons corresponding to Andimadam top, upper pay top, lower pay top, lower pay base, lower sequence base and Basement were correlated in the study area. To keep the model simple, faults were not taken into consideration and all horizon were grazed along the Basement/fault escarpments or underlying sequence as the younger sequence either on-lap or older sequence wedge out against basement (Fig 6) to prepare a robust geological model. Model based deterministic inversion with low frequency model using conditioned sonic and density logs has been taken into consideration. Since there are only two wells in the study area a velocity model using well sonic logs, stratigraphic picks, horizons and RMS stack velocity was constructed and the same was used for kringing during deterministic inversion to characterize the reservoirs from the non-reservoir. Utilizing the velocity variation laterally helped in propagating lateral distribution of reservoir properties laterally. The modeled impedance to well derived impedance were in close conformity (Fig 7). Porosity volume was then generated using EMERGE to establish latero-vertical extension of the reservoir that would aid building field development model.

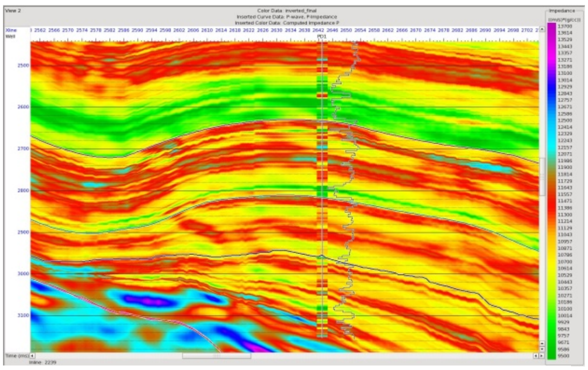
Fig. 7 Modelled to well Impedance Section

Attribute Interpretation

Window based amplitude extraction along the pay horizons (Fig 8)as well as proportional slice for maximum impedance (Fig 9)were carried out depicting the extension of the upper and lower sand units. The extension of the upper and lower Periyakudi pay sands in latero-vertical direction is well depicted by geo-body capture from inverted volume.

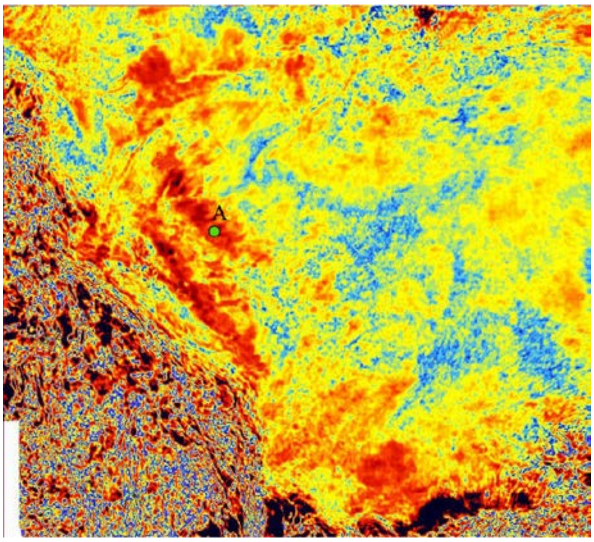

Fig. 8 RMS Amplitude Map

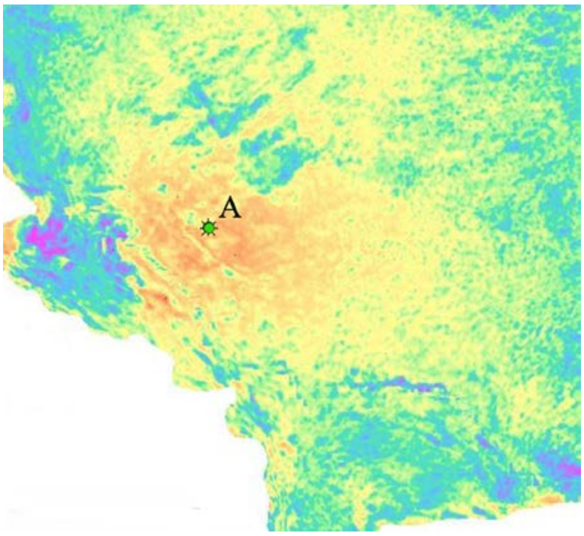

Fig. 9 Maximum Impedance Map

Conclusions:

Stratigraphic inversion coupled with pseudo log property mapping has emerged as potential tool for interpreters to define the reservoir geometry and quality with confidence. Stratigraphic inversion and pseudo log property mapping successfully brought out the precise sand geometry of Periyakudi Sands in Nagapattinam Sub-basin as dump and fan delta flow unit entering from the Pattukottai-Mannargudi ridge and spreading into the south-eastern part of the sub-basin. The large areal extent, massive thickness of reservoir sands and richness of source facies, make these synrift sequences very attractive targets for exploration. The recent strikes demonstrate that these plays are likely to become major contributor for future exploration and exploitation in Cauvery basin. The study will help in bringing out a development program to develop and exploit the tight high pressure reservoir.

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Views expressed in this paper is of the authors only and not necessarily be of ONGC.

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