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## Delineation of prospective area in Palar offshore based on analysis of natural seepage model in Cauvery offshore

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### Summary

Natural hydrocarbon seepages detected in Cauvery offshore area are associated with NE-SW trending faults that are connected to a source area suggesting that these faults act as a conduit for migration. These seepages also show a positive correlation with hydrocarbon bearing wells indicative that same system might lead to an area of accumulation with the seepages acting as markers. Based on this model, seepages had also been delineated in shallow and deep Palar offshore which share a similar tectonic history. These seepages are also found to be associated with NE-SW faults connected with source Sriperambudur Formation. Based on this, prospective areas could be delineated for further exploration.

**Keywords:** Synthetic Aperture Radar (SAR), Seepages, petroleum system

### Introduction

The Cauvery Basin is a pericratonic rift basin located in the south-eastern part of the Indian peninsula that came into existence due to the break-up of Eastern Gondwanaland during Late Jurassic to Early Cretaceous. The basin at the basement level shows a structural grain dominated by a system of NE-SW trending horsts and grabens characteristic of rift extension. This resulted in a number of sub basins separated by basement highs namely Ariyalur-Pondichery, Tanjavur, Tranquebar, Nagapattinam, Palk Bay and the Gulf of Mannar that represent the different depocentres with varying sedimentary thicknesses (Fig 1). Subsequent to the initial rifting, drifting and rotation of the Indian plate continued until 96 Ma that caused the development of NW-SE cross faults after which the spreading center between India- Sri Lanka and Antarctica was aborted, followed by the rapid northward movement of India. This was followed by a south-eastward tilt of the basin which is probably related to the uplifting of western peninsular India during the passage of India over the Reunion hot-spot. Area wise the Cauvery Basin covers an area of 1.5 lakh sq.km comprising onland (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. Though a number of oil and gas fields had been discovered in the onshore part of the Cauvery Basin, the success is not

found to be significant in the offshore part. In this paper an attempt had been made to identify natural hydrocarbon seepages in the offshore area as indicators of an active petroleum system and then correlate them with the different elements of the petroleum system of Cauvery Basin and extrapolate the results in northerly adjacent Palar Basin.

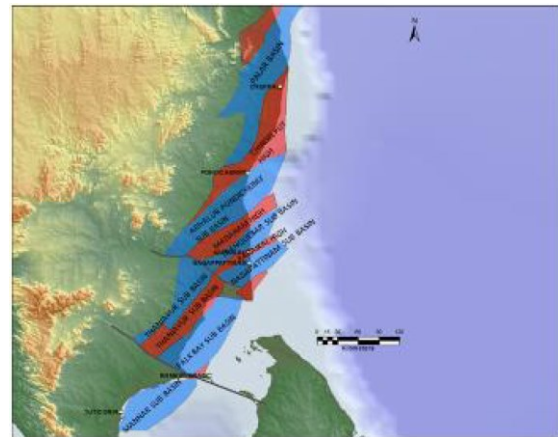


Fig1: Different sub basins of Cauvery Basin separated by NE-SW trending gravity highs. Most of the sub basins are found to extend in the offshore

## Hydrocarbon Seepage Detection

Seeps are surface expressions of migration pathways of hydrocarbons where leaking hydrocarbons seeping out of faults or conduits opening in the sea bed migrate to the sea surface. Detection of such seepages in offshore or deep offshore region provides a guideline for petroleum prospectivity assessment and exploration in the region and thus helps in lowering the cost and risk involved in the

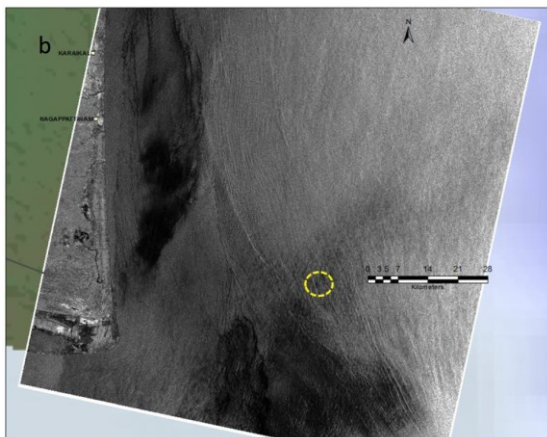
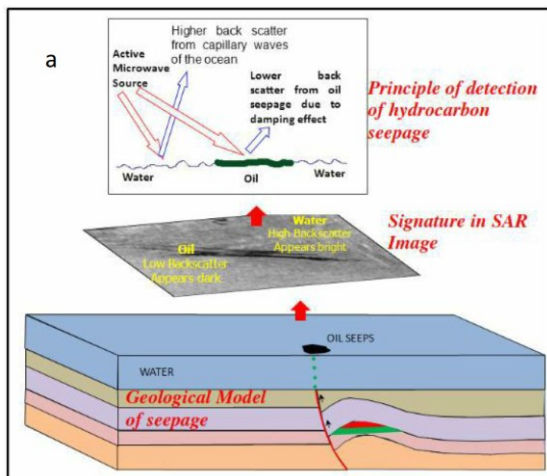
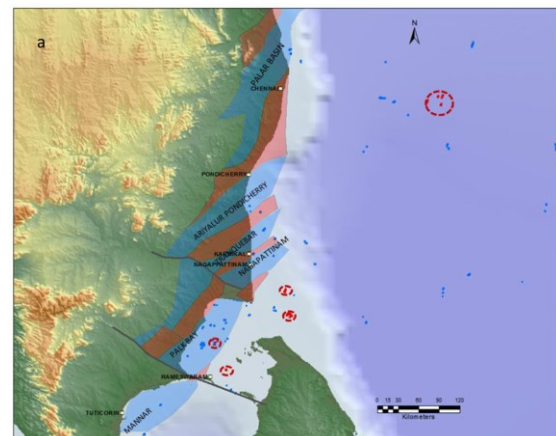


Fig2: a. Principle of detection of hydrocarbon seepages in the ocean surface using SAR (Synthetic Aperture Radar) (after Dave et al, 2012). B. Seepage identification based on ENVISAT SAR images in the Cauvery offshore south of Nagapattinam

exploration activities. Space-borne active microwave radar or SAR (Synthetic Aperture Radar) provides a powerful and cost effective mode to detect such oil seepages as discussed in detail by Mitra et al, 2012. Normal sea surface is covered by wind generated capillary waves that reflect

the radar energy to produce a bright image. However, if oil is present in the sea surface, as a result of the seepage it dampens the wave signature in the microwave ranges and is detected as a dark area on a bright sea surface in SAR images (Fig 2 b).

Based on the principles discussed in detail by Dave et al, 2011, a number of seepages had been identified in offshore Cauvery Basin (Fig 3a), that had been subsequently filtered to rule out pollution or biogenic slicks and then analyzed on features like shape, size and repetivity and graded as per their degree of confidence to be natural seepages (Dave et al, 2012). Areas of seepage repetitions had been assigned a higher degree of confidence as they are indicative of proximity to a seepage source which in turn implies a conduit to a mature petroleum system. In the Cauvery offshore, only seepages of a medium to low degree of confidence had been identified. Though the low confidence seepages are found to occur along and across the entire offshore Cauvery Basin and the northerly adjacent Palar Basin, maximum of the high confidence seepages are found to occur in the Palk Bay sub basin of the Cauvery Basin and in the deep offshore part of the Palar Basin in a region further west of the 85 East Ridge (Fig 3b).



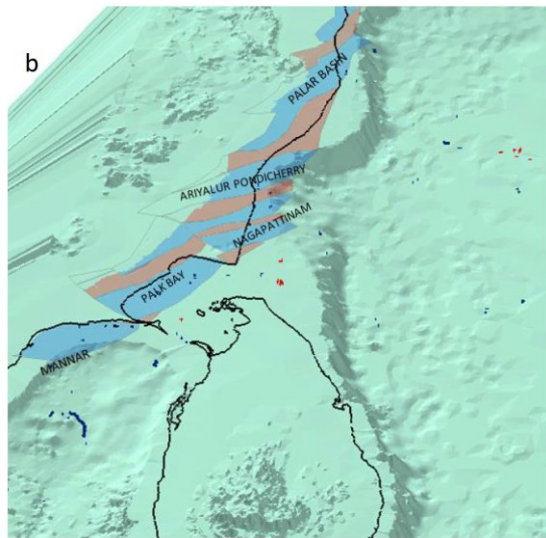


Fig3: a. Seepages identified in Cauvery and Palar offshore region. The red coloured seepages indicate those with a medium degree of confidence whereas those in blue are indicative of a low degree of confidence to represent natural seepages. b. an overlay of the seepages over the 3D perspective of the bathymetry of the area shows seepages both in deep and in shallow offshore areas

### Correlation with the elements of Petroleum System of the area

Based on the maturity of organic matter, the effective mature source rocks in the basin are largely limited to the synrift succession belonging to Albian and older periods. Within the syn-rift, deposition cycles are largely fluvial and are essentially controlled by episodic tectonic creation of accommodation, by extension, and consequent subsidence. In these systems, source rocks are deposited in the fluvio-lacustrine condition. The source rock type is generally type- III and type-II. This is also the same for the Palar Basin where the source facies are believed to be in the middle part of the Sriperambudur Formation of a lower Cretaceous age (Rangaraju et al, 1993). The reservoirs in the Cauvery basin are distributed in sediments of all ages from late Jurassic – Albian to Oligocene, with maximum accumulation in the Cretaceous succession.

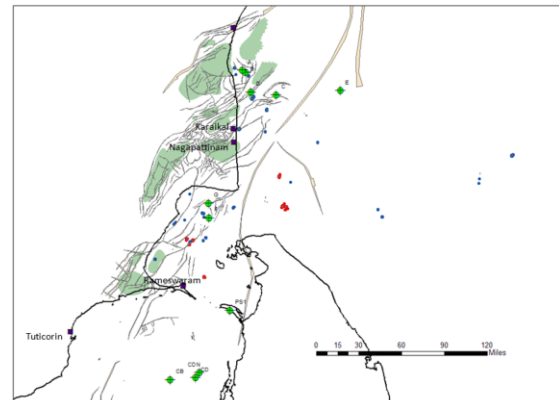


Fig 4: Seepages in offshore Cauvery Basin found to be associated with NE-SW trending faults that are connected to the source pod areas marked in green. Hydrocarbon bearing wells in offshore Cauvery Basin (wells A to G) and offshore Sri Lanka (CB, CD, CDN and PS 1) are also found to be associated with seepages

A correlation of the source pod areas of the Cauvery Basin with faults upto Albian (Fig 4) along with the identified seepages in the area show that most of the seepages are associated with the NE-SW trend of faulting especially in the Palk Bay sub basin suggesting that these faults might be the conduit of migration from the source rock. Most of the hydrocarbons bearing wells in Cauvery offshore (A to G) are found to be associated with these seepages and adjacent to the NE-SW trending faults. The seepages are found to be more in areas where the main trend intersects with the NW-SE Turonian cross trend. Recent discoveries by Cairn in 2011 in western offshore part of Sri Lanka in wells CB, CD and CDN when correlated also are found to show a positive correlating relationship with the seepage areas. Another well PS 1 drilled on the island of Mannar that encountered some gas in Lower Cretaceous sandstone also is found to be associated with seepage and adjacent to a NE-SW trending fault.

The NE-SW faults that had been mapped in the Cauvery offshore had also been observed in the offshore Palar Basin. From the disposition of these faults, they appear to be continuous extending from the onshore part to the offshore. Seepages are found to be mostly associated with these NE-SW trending faults (Fig 5) that seem to be connected to the Sriperambudur Formation that acts as a source and the faults as conduits for migration. However for the seepages in the deep offshore part (area S) though apparently there are no NE-SW trending faults, E-W trending faults had been envisaged from morphotectonic analysis based on drainage data in the onshore region and

magnetic trends in the offshore region. This E-W trend is a product of post-rift state of stress in this region and is active even at present as evidenced from fault plane solutions in Pondicherry offshore. These E-W trending

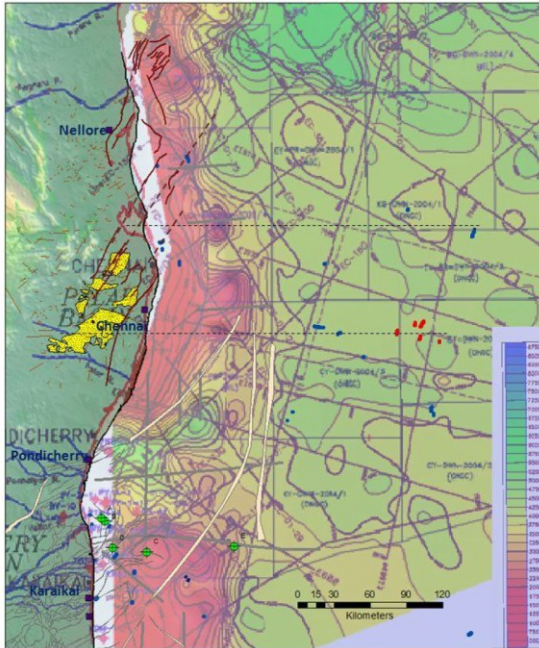


Fig5: Seepages in Palar offshore occurring along NE-SW basement trends that appear to be connected to Sriperambudur Formation acting as source. In deep offshore E-W trends might act as conduits with the sediment thickness as represented from the isopach map implying a separate petroleum system to exist in the area (after Singh et al, 2010)

faults might act as possible conduits for migration to their present position overlying deep offshore region from the onshore or considering the sediment thickness in the area a separate petroleum system may exist at the place that acts as a source for the hydrocarbon seepages. In any of these cases it renders the area as prospective for exploration.

In both the cases of Cauvery and Palar the above seepages can be fit into the Medium Leakage type model of MacGregor, 1993 that is found in extensional settings and Passive margins with unfaulted post rift sections. In such a case, the seepage patterns are strongly associated with faulting and different structures. The relation between surface seepage and subsurface accumulation seems to be dependent on structural style and its geometry (Fig 6).

#### EXTENSIONAL ASSOCIATION

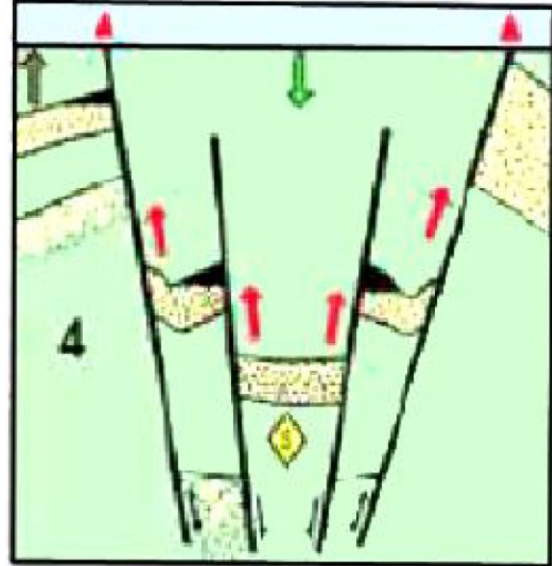


Fig6: Medium leakage type model of McGregor in extensional settings in a rift basin (after Williams, 2010)

However in the present context of Cauvery and Palar basin, the model suffers from the drawback that most of the faults are found to be limited to the deeper horizons and not found to continue up to the sea beds in the seismic section (Fig 7 a & b) (Singh et al, 2010). This might be explained by the reactivations of the faults under the present state of stress that leads to a sub seismic throw thus enabling it to reach the sea bed with a sub seismic resolution and throw and thus act as a conduit to seepage.

Evidence of such fault reactivation is observed in offshore Pondicherry based on marine geophysical studies like magnetic, gravity and high resolution shallow seismic as well as fault plane solutions (Fig 8).

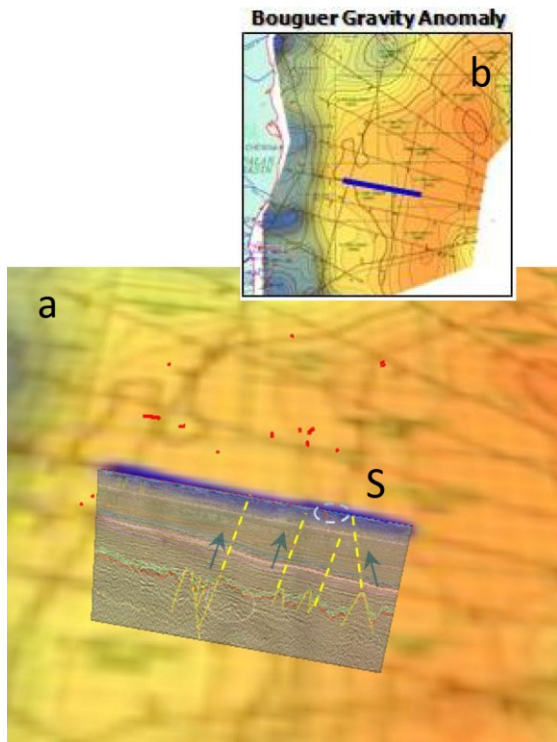


Fig7 (a & b): Seismic line in Palar deep offshore part showing an extensional setting similar to McGregor model with the faults in the deeper part if extended sea bed found to correlate with the disposition of the seepages (Area S)

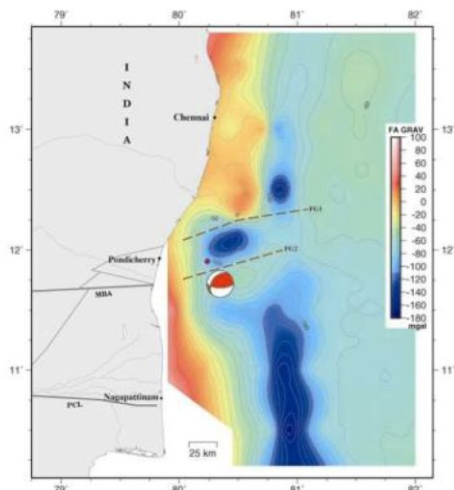


Fig8: Fault plane solution in Pondicherry offshore showing reactivations of an already existing fault (Murty et al, 2002)

### Conclusions

From the above analysis of hydrocarbon seepages in Cauvery offshore a positive correlation is observed between the seepages associated with the NE-SW trending faults and the source rock and the hydrocarbon bearing wells. This also implies a MacGregor model of medium leakage might be instrumental in causing the different seepages in the area. A similar pattern of relationship between the seepages and the petroleum system elements is also observed in Palar Offshore where it hasn't been explored till now. Based on this it can be said that the areas of seepages in both shallow (Area P) and deep offshore (Area S) in Palar Basin might be prospective from hydrocarbon point of view (Fig 9).

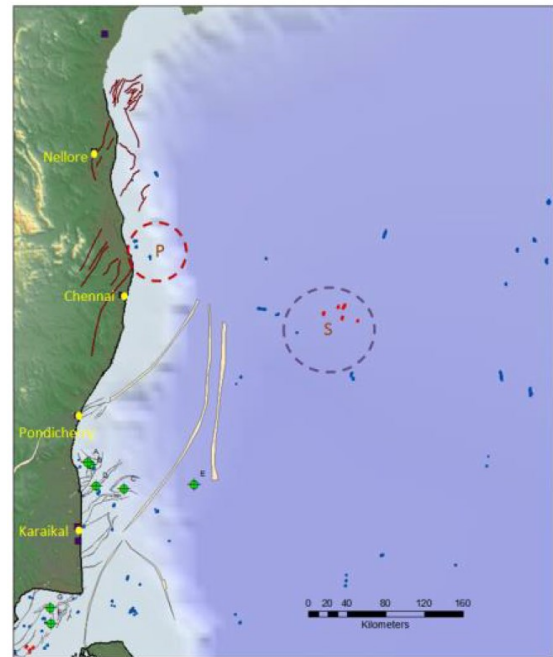


Fig 9: Probable prospective areas S & P in Palar offshore

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