P-037

Mapping Hydrocarbon seepages using satellite SAR data in Eastern Offshore - Essential Input in Oil Exploration

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Summary

Hydrocarbon seepages in oceans are direct indicators of the existence of a petroleum system under the sea bed. Active microwave radar or SAR (Synthetic Aperture Radar) provides a powerful and cost effective mode to detect such oil seepages. In this paper an attempt had been made to understand the relationship between the seepages and probable hydrocarbon prospects in the Eastern Offshore regions of India. Based on SAR data, regions of seepage repetitions had been detected and are found to be associated with faults and tectonic elements attached with source pods suggesting that seepages are manifestations of active migration, mature source and a shallow reservoir. Using the same premises and the same methodology, a possible hydrocarbon system had also been envisaged in the isolated and distally located 85 E Ridge

Introduction

Hydrocarbon seepages in oceans are direct indicators of the existence of a petroleum system implying possible rich hydrocarbon resources under the sea bed. Hence detection of such seepages helps in lowering the cost and risk involved in the exploration activities as well as provides a guideline for petroleum prospectivity assessment and exploration in the region. The space-borne active microwave radar or SAR (Synthetic Aperture Radar) provides a powerful and cost effective mode to detect such oil seepages with its ability of wide area coverage, high temporal resolution, cloud penetrating ability as well as consecutive day and night coverages of any area.

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 due to their buoyancy in the form of thin oil films covering bubbles of gas.

At the sea surface, these gas bubbles burst with the oil films forming oil layers on ocean surface. In normal conditions, capillary waves on the sea surface reflect the radar energy to produce a bright image known as the Sea Clutter. However, if oil is present in the sea surface, 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 1). A detailed description about the methodology and processing of SAR images to detect seepages had been dealt in Dave et al, 2011.

In this paper hydrocarbon seepages in the eastern offshore basins of India that had been detected by SAR studies had been documented and subsequently compared with the tectonic elements and petroleum systems of the area in an attempt to understand the relationship between the seepages and probable hydrocarbon prospects in the area.

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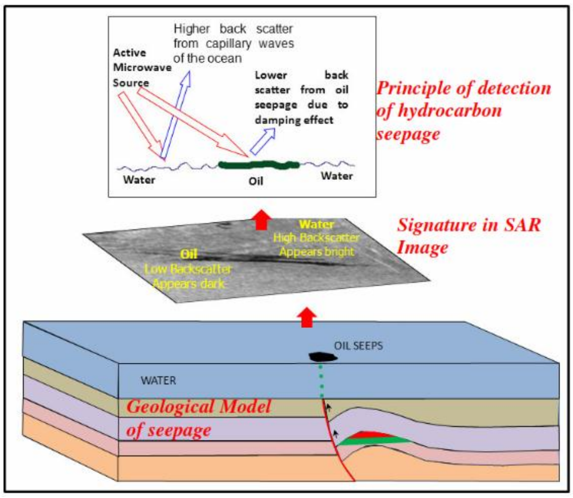

Fig 1: Principle of occurrence of hydrocarbon seepage on an ocean surface and its detection in SAR images: Hydrocarbon leaking out of reservoir to the sea floor along a fault and subsequently floating up to sea surface. At sea surface, backscattering from oil much less than surrounding sea water resulting in oil appearing dark in a SAR Image compared to water

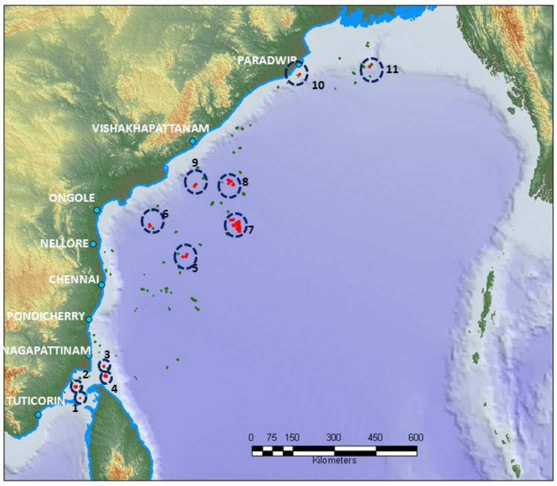

Fig 2: Natural hydrocarbon seepages in the Eastern Offshore of India with the areas of seepages marked in green whereas the areas of seepage repetitions are marked in red

2. Seepage Studies

Seepages identified from SAR data in the eastern offshore were analyzed to eliminate similar signatures generated from ship or tanker generated pollution or biogenic algal signatures. Once such erroneous signatures had been identified and removed, natural hydrocarbon seepages were checked for repetitions of seepage in a particular area over a time period of several months to years. Such areas of seepage repetitions had been assigned a higher degree of significance as they are indicative of proximity to a seepage source which in turn implies a conduit to a mature petroleum system. Based on the seepage analysis about 11 instances of such seepage identification had been observed in the Eastern Offshore areas (Fig 2).

3. Seepage Correlation with Tectonic Features & Structural Elements.

The identified natural seepages and their repetitions had subsequently been correlated with the major tectonic features and structural elements in the area. These structural elements include Basement Faults as well as faults that had been mapped at the top of Cretaceous up to Miocene level (Dave et al, 2009). An overlay of these faults with the natural seepages show that most of the identified seepages are associated with these faults implying that these faults might have acted as a conduit for the hydrocarbons to reach the sea bed from the respective petroleum systems.

However it can be debated that none of these faults interpreted from seismic data had been mapped in younger horizons or as such found to open in the sea bed. In this context, it can be argued that as per Shurr, 1982, most of the surface lineaments had been induced by basement faults, in which their displacement along the faults are found to be decrease upwards to a sub seismic scale and additionally single discrete faults are found to branch out upwards into multiple faults. Following the same premise in this case, faults mapped in the basement and the other deep seated horizons in the Eastern Offshore that couldn't be traced in younger horizons might be believed to be continuous up to the sea bed in a sub seismic resolution that are instrumental in causing the seepages.

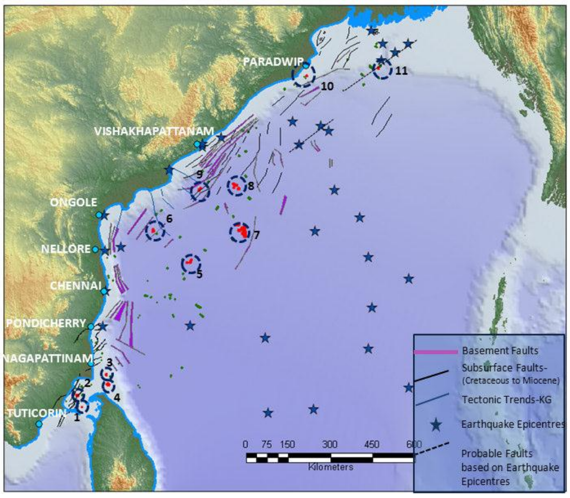

Fig 3: Hydrocarbon seepages and their repetitions correlated with faults mapped using seismic data and earthquake epicenters in the Eastern Offshore. Here areas of seepages are marked in green whereas the areas of seepage repetitions are marked in red

Additionally earthquake epicenters (source: earthquake.usgs.gov) in the eastern offshore areas had been also been plotted to have an idea about active faults in this region some of which are found to correlate the mapped faults from seismic faults. Based on the existing trend of the mapped faults the earthquake epicenters had also been joined to define probable faults that had also been found to correlate with the seepage repetitions (Fig 3).These interpreted faults can be assumed to be active under existing stress conditions and these along with the faults that had been mapped using seismic data probably act as conduits resulting in surface seepages.

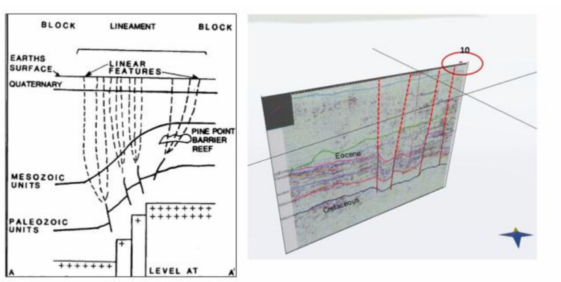

Fig 4: A. Shurr, 1982 Model showing basement faults continuous up to surface in as sub seismic resolution branching out midway and B. in a similar way faults mapped in seismic in Easter Offshore maximum upto Eocene assumed continuous up to surface sub seismically where it coincides with area of seepage repetition.

Based on the works of Macgregor' 1992 intensity of seepage is controlled largely by present day tectonics and are found to be concentrated over tectonic features such as active faults and uplifted basin margins with best seep-accumulation relationships particularly those involving shallow reservoirs in active compressional settings. In a similar context, works of Biswas and Majumdar, 1997 on seismicity and fault plane solutions showed that the that the intraplate region of the entire Bay of Bengal is seismically active with prevalent N-S compression analogous to the Himalayan arc. It can be derived from the above studies that the natural seepages detected from SAR data in the Eastern Offshore areas actually are associated with active faults in a compressional setting and hence have a high probability of being related to a shallow subsurface reservoir.

4. Correlation of Seepages with Source Pods

For a further aspect of the study the seepages identified had also been correlated with the source pods in different basins in the East Coast (Fig 5A). From the correlation it could be observed that most of the seepage repetitions are associated with faults that are connected to source pods. This is indicative of the fact that the seepages are actually indicators of active migration from a shallow reservoir connected to a mature source.

In case of the seepage repetitions overlying the region of 85°E Ridge which lies in the oceanic crust in the distal part of the basin, though the seepages are found to be associated with basement faults, no source pods had been mapped in the area or the existence of a petroleum system in the area is yet to be probed. However an overlay of Free Air Gravity data over the area along with the seepage repetitions shows the seepages are associated with a gravity low (Fig 5 B & C). These confined lows are believed to act as a source kitchen area for generation of hydrocarbon with more than 1.5 km of Cretaceous sediments within the lows whereas the reservoir facies are defined by sediment dispersals from Godavari region during Cretaceous and Older Tertiary and from Mahanadi and Ganges system in Oligocene and younger ages (Nayak, 2011). The association of an isolated gravity low, a basement fault and a seepage repetition in the 85°E Ridge suggest the existence of a prospective petroleum system in the region that is manifested as the seepages with the fault acting as a conduit to the sea bed.

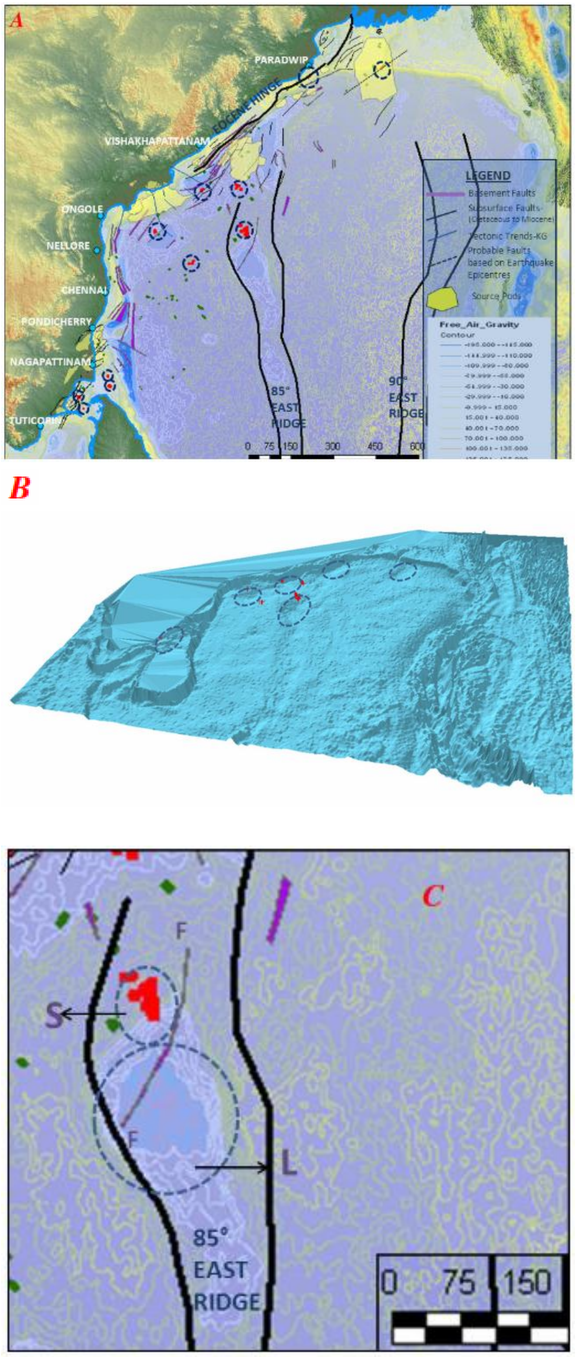

Fig 5: A. seepages correlated with faults and source pods showing most seepage repetitions associated with faults that are attached to source pods B. 3D perspective model of Free Air Gravity of eastern offshore showing seepage repetitions associated with areas of gravity lows that might have acted as kitchens. C. Seepage repetition associated with a gravity low and fault in 85 E Ridge suggesting the existence of a petroleum system

5. Conclusions

The relationships between the identified seepages repetitions, faults and source pods in the Eastern Offshore areas narrows down the area of investigation thus reducing cost and resources involved in exploration. Additionally this type of approach also helps to bring out the probable existence of younger and shallow reservoirs based upon the premise of the continuity of faults in sub seismic resolution up to the sea bed with the seepage repetitions acting as a marker or flag to the faults acting as a conduit. In case of a purely seismic approach these probable prospects might have been overlooked Additionally the association of such seepage repetitions with an isolated gravity low in the 85 °east Ridge further strengthens the idea of existence of a petroleum system in the distally located 85 °east Ridge. Thus an isolated approach based entirely on seismic or on geochemical data though helps to map source pods or deep seated faults in the offshore area which probably fails to reveal the entire petroleum system of the area. However if an integrated approach is followed involving SAR data to identify offshore hydrocarbon seepages, available earthquake epicentres along with seismic and geochemical data a detailed idea about the prevailing petroleum system might be acquired.

The views presented in this paper are solely of the authors themselves and are not necessarily of the organization they represent.

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