7th International Conference & Exposition
on Petroleum Geophysics

"HYDERABAD 2008"

P - 188

Use of Satellite Imageries to Identify Potential Hydrocarbon Microseepage in Off-Shore Areas.

S. Sengupta[1]*, K.K. Saha[2], Email: sidsen88@gmail.com
1 Remote Sensing & Geomatics, KDMIPE,ONGC, Dehradun,. 2. Tripura Asset, ONGC, Agartala.

Summary

Synthetic Aperture Radar (SAR) technology has the ability to image surface oil seeps that originate by slow leakage from oil- and gas-filled traps. Multi-temporal satellite data over such seeps delineate prospective areas and provide the locations for follow-up surface sampling from which key geochemical information of the reservoir oil can be obtained. Satellite radar can offer the oil industry an effective, low-cost technique for reducing the risk in high-cost exploration environments such as in the ultra deep frontier basins. The knowledge that surface seepage has a direct link to subsurface oil and gas accumulations is not new. Since 1992, a powerful platform for offshore seepage detection has emerged. This is satellite-borne active microwave radar, which now offers the industry wide-swath, multiple-repeat imagery over all of the world's continental margins, at any water depth.

Though the presence of seeps may not necessarily indicate the presence of a deeper, commercial accumulation, but it does confirm the presence of a petroleum system within a basin, with associated reduction in exploration uncertainty in relation to source. In fact, most of the hydrocarbon accumulations world-wide have experienced some hydrocarbon leakage, either as a result of fault seal failure often due to tectonic reactivation or due to of insufficient seal capacity in the top seal.

1.0 Introduction

With the global rise in crude prices the focus on offshore oil exploration has moved from deep water into ultra deep region, as exploitation of the accessible parts of the world's continental shelves reaches a saturation point. Development in 1000 m of water is now the industry standard, and exploration drilling in water depths as great as 2500 m is feasible, but at incrementally higher costs. Oil seepage detection by radar satellites, however, can offset some of these high costs by establishing the presence of an active oil source at a very early stage in exploration.

The knowledge that surface seepage has a direct link to subsurface oil and gas accumulations is not new. Indeed, seepage was the stimulus for the exploration drilling by the pioneers of our industry as long ago as 1860s in Pennsylvania and in Azerbaijan. Since 1992, a powerful platform for offshore seepage detection has emerged. This is satellite-borne active microwave radar, or SAR (Synthetic Aperture Radar), which now offers the industry wide-swath, multiple-repeat imagery over all of the world's continental margins, at any water depth. Radar images can recognize natural/man-made oil slicks (flat patches of the sea surface) which can be related to hydrocarbon seepage and can be helpful in areas devoid of seismic data.

2.0 Principle

Oil that has migrated to the sea floor is preferentially transported to the surface as a thin coating to the gas bubble plumes. At the surface, the gas bubble bursts and the oil spreads out rapidly to form a slick.

The satellite radar scanning over the ocean will emit a rapidly pulsed radar beam with wavelength ~5.3GHz, i.e.~5.6cm from the side of the satellite and the return beam, which is proportional to the roughness of the sea, is imaged. Higher backscatter from the rough sea appear as bright tones on the radar image and flat regions and slicks, smooth to the radar in the mm-cm range appear as dark or black tones, because radar backscatter return is low or zero.

Solid material, like large tar accumulations, ships and oil platforms, create a strong radar return, so appear bright on images (Alpers et al.)

2.1 Natural seeps vs. Slicks:

The low backscatter regions (dark areas) are not only being caused by the natural seepages but it can also occur due to several other reasons (which are mentioned as slicks here) are discussed below:

Wind Speed: Wind is an important factor where seep detection by SAR is concerned. When there is not enough wind, the waves are not created leading to weak radar backscattering and low contrast ratio. On the other hand, high wind speed leads to strong backscattering from both oil and clear water and therefore have less contrast (Espedal and Wahl, 1999). Hence, for optimum SAR measurement, the wind speed needs to be between 2 m/s and 5 m/s. Therefore, prior to purchase, all satellite radar data are retrospectively screened for wind speed, wave- height and swell.

Pollution: Fresh pollution from ships, rigs and terminals is conspicuous in SAR imagery and are mapped as slicks. As the polluted oil is dispersed, it becomes thinner, and is less obvious as pollution; and remains as remnant or fragmented pollution (Fig. 1).

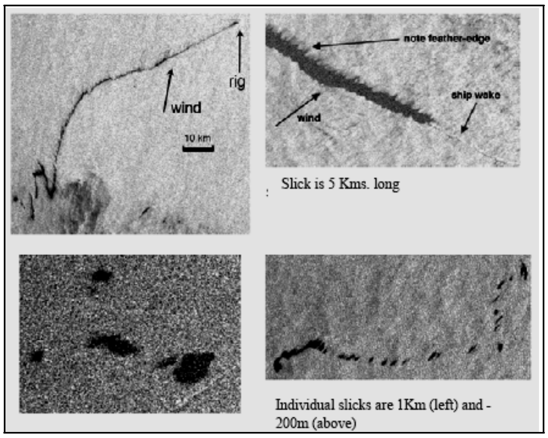


Fig1. Typical pollution slicks
Top: Conspicuous fresh pollution from platform (left) and ship (right). Note the 'feather-edge' where wind directly moves the thicker slick Bottom left: Thin emulsified remnant pollution from sub sea storage tanks in the Arabian Sea.
Bottom right: Fragmented pollution from ship, six days after discharge.

Biogenic slicks: Many of the slicks observed have neither a pollution nor a seepage oil origin; they are formed from a predominantly biogenic natural film originating from the decayed plankton. Natural film slicking is observed on SAR images only at low wind speeds (Fig. 2). Slicking of this sea-surface natural film is created from alternate dilation and compression resulting from near surface circulation or shearing along currents. As wind-speed rises further, the circular motion stops and in the absence of oil, natural film slicks disappear. The development and decay of natural film slicks, therefore, occur in minutes-to-hour time frames.

Fig 2: Typical natural film slicks (Image size 25 x 25km)

Other Metrological Phenomenon: Anticyclones and cyclones, rain cells, weather and wind fronts, convergence zones, atmospheric gravity waves etc. also account for seep
detection.

2.1.1 Parameters for distinguishing oil seeps:

Slicks on the sea surface are frequent and widespread and are comprehensively imaged on weather compliant radar images. Identifying and distinguishing natural seeps from other slicks involve the incorporation of other data like meteorological, oceanographic and contextual information. Along with it several other factors, which are useful in distinguishing, are noted below:

Temporal scal*e* – the receptivity of slicks and associated ocean features e. g., currents and waves change in minutes to hours but for oil slicks it is in hours to days and since seepage can repeat over years we can expect the slicks to repeat over the same area even after few months or years.

Spatial scale- of slicks in relation to ocean features:
Typical scales for slicks are 10^{-2} to 10 km, currents 10 to 10 km and fronts, internal waves -10^4 to 10^5 kms.

Important related information are Size, shape and aspect ratio, Slick/ Ocean backscatter ratio.

Nature of slick edge: sharp, feathered, gradational, ablated etc. feather-edges usually indicate wind influence on thicker slicks (Fig. 1).
Point of origin: Inferred emission point and drift, direction influenced primarily by tide and current, e.g. 'corkscrew' or "nested" multi-emission point slicks.
Orientation and relation to oceanographic and weather features: wave alignments, swell, internal waves, currents and current shears, tides, fronts, fluvial outflows, rain cells, oceanic calms (doldrums), upwelling, inferred sea temperature and salinity, reefs and shoals, inferred biological productivity.
Association with rigs, platforms (bright spots on image): loading/offloading points, harbors and

terminals, ships (bright spots and wakes) and shipping lanes and other contextual information and to bathymetry and other collateral information.

3. Scene and area selection :

Four Radar satellites – ERS-1, ERS-2, Radarsat and Envisat were available for collecting the requisite SAR data. All the available quick-look imageries were initially inspected from the respective websites, for the selection of the proper scene and then availability of the scenes with National Remote Sensing Agency (NRSA), Hyderabad were checked.

3.1 Background of the area under study

The Krishna-Godavari Basin along the east coast of India covers the deltaic and interdeltaic areas of the Krishna and Godavari rivers and extends into the offshore. This basin is situated along the edge of a rifted passive continental margin, which developed during the separation of India from Antarctica in the Late Jurassic. This rifting episode is superimposed on an earlier northwest southeast "Gondwana graben trend" such as the Pranhita-Godavari graben, which extends from onshore into the Krishna- Godavari Basin. The onset of the Late Jurassic rift developed the potential for early lacustrine fill of the half grabens. It is a pericratonic rift basin characterized by en- echelon interior fractures and sags. The basin comprises a number of northeast-southwest trending horsts and graben defined by fault-blocks movements (Rao, 2001).

The Upper Jurassic to lower Cretaceous (Syn. Rift) and Tertiary (Late Post-Rift) sediments in the offshore comprises of lacustrine shale in the axial part of the grabens followed by an interbedded sandstone and shale unit deposited under marginal marine and partly continental environment. The late Post-Rift demonstrates a classical deep-water depositional system and many seismic sequences were identified (Bastia, 2006).

3.2 Detailed study of the natural seep in the eastern offshore region:

The area was selected on the basis of the results of the adsorbed gas analysis of the Report of Geochemical Prospecting Laboratory, Chennai, 2005. The study established that the adsorbed hydrocarbons are thermogenic, and oil and gas/ condensate prone in nature. The reported area of adsorbed gas were NELP I blocks namely KG-DWN-98/4, KG-DWN-98/5 and KG-OSN-97/1 (Raghavendran, 2004; Vyas, 2005).

The available – ERS-1, ERS-2, and Radarsat images were scanned and it was observed that there could be some possible seepages in the blocks KG-DWN-98/4 and KG- OSN-97/1. As a result of which these two areas were taken up for the study in the Eastern offshore region. The available ERS-1 images over the area are enlisted in the Table below and are shown in Fig. 3a & 3b with the separate colours slicks representing different dates and the different blocks:-

4. Image processing:

The standard PRI product ERS image required some pre-processing like generation of geometric correction and geo-registration.

The intensity of each of the SAR image represents the proportion of microwave backscattering from that area. The pixel intensity values are converted to a physical quantity called the backscattering coefficient or normalized radar cross- section measured in decibel (dB) units with values ranging from +5dB for very bright objects to -40 dB for very dark objects. Accordingly, radar backscatter coefficient was also calculated from the ERS image.

Histogram Equalization Enhancement technique was applied for contrast enhancement in the image. SAR images have a major problem of grainy appearance due to the presence of speckle, which disrupts the visual interpretation of the image. Speckle filtering was used to remove the speckle in the radar image. Out of the several types of available filters, the enhanced Lee filter using a window size of 3 x 3 was found most suitable for our study.

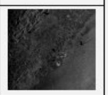
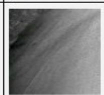
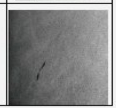
Satellite	Orbit	Frame	Date	Images
ERS-1	7965	3249	23/01/93	
	7965	3267	23/01/93	
	8695	3249	15/03/93	
	8967	3267	03/04/93	
	5188	3267	13/07/92	

Fig.3a Five images, the ERS-1 image of January, 1993 was chosen based on the wind and scene availability parameters.

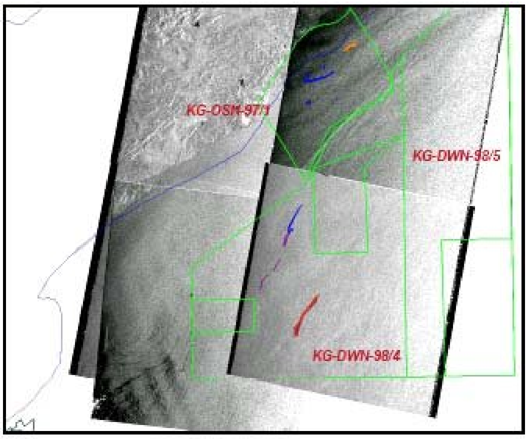
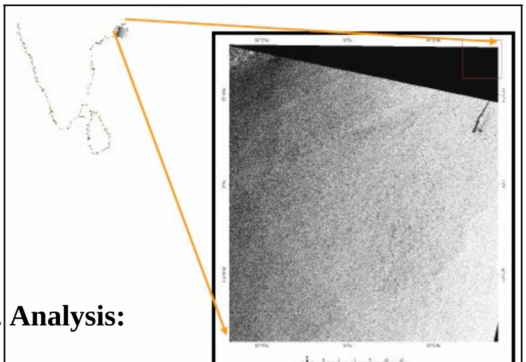


Fig 3b. Possible seep/spill off the eastern coast detected from the available quick looks which are later vectorised with different colours representing different dates in the NELP I
block – KG-DWN-98/4 and KGOSN-97/1

To distinguish the oil seeps/pills from the oil look- a likes an edge detection filter- with a window size of 3 x 3 was applied to the image.

The above processing steps were also applied to all the images of eastern offshore regions, which resulted in a smoothened image of 23/01/93 (orbit 7965 frame 3267) as shown in Fig. 4 with the slick.



5. Analysis:

Two types of analysis were performed, one is the direct analysis on a set of parameters helped in the discrimination process and the Contextual analysis i.e. gathering other related information from different sources about the slick.

.

5.1 Direct analysis:

A number of characteristics are considered in the present study that would provide the signatures of an oil spill. Detailed methodology used in the present study is as per the methods of Fiscella et al., 2000. Unfortunately, no information is currently available on the oil spill signatures/databases. Brief details of some of the characteristics are given below:

5.1.1 Backscatter reduction value inside the spill area:

The seepage slicks should have a uniform backscatter reduction value of -5 to -+10 dB.

5.1.2 Homogeneity of the surrounding area:

The standard deviation of backscatter reduction values from the mean in the non-spill area is taken for this purpose. The probability of presence of an oil-slick is increased if the surrounding area is homogenous while if it is heterogeneous then the area might be oil-slick look-alike (Solberg and Volden, 1997). The homogeneity could be determined by studying the histograms generated for the oil spill area and the corresponding non-spill area.

5.1.3 Length/ width aspect ratio:

For a seep the length should be between 0.5 to 10 km and width between 0.1 to 1 km and the aspect ratio within 5:1 to 10:1

5.1.4 Intensity ratio:

The ratio between the mean backscatter reductions of the area of spill to the non-spill area is considered. If the contrast (intensity ratio) is high then it will be due to the presence of oil and the probability of look-alikes is increased if the contrast is low (Solberg and Volden, 1997). Table 1 summarizes the characteristics of slicks in the Eastern offshore region.

Slick 1

Spill Area								Non-Spill Area			
Area (A) in sq km	Perimeter (P) km	length (L) km	width (W) km	Min	Max	Mean (MS)	Stdev (DVS)	Min	Max	Mean (MNS)	Stdev (DVNS)
4.94691	28.58963	11.29895	1.2353	-20	1.131	-15.846	5.325	-20	1.443	-3.95	3.305

Slick 2

Spill Area								Non-Spill Area			
Area (A) in sq km	Perimeter (P) km	length (L) km	width (W) km	Min	Max	Mean (MS)	Stdev (DVS)	Min	Max	Mean (MNS)	Stdev (DVNS)
0.8	9.28621	2.03959	0.65-0.11	-20	1.167	-15.145	5.387	-20	1.443	-3.95	3.305

Table-1 Showing the slick characheristics of KG offshore

5.2 Contextual analysis:

The following contextual information has been studied to enhance the interpretation.

5.2.1 Shape:

The roundness and the patchiness of the slick suggest its affinity to be a look-alike and the linearity of the slick points to natural seepages and oil spills from pollution.

5.2.2 Shipping lane:

The information regarding the shipping lanes has been obtained from the Coast Guard of India, New Delhi. For the eastern region, there is no shipping lanes passing through the region and so this factor is not considered.

5.2.3 Wind parameters:

The wind parameters were obtained from the Indian National Center for Ocean Information Services (INCOIS), Hyderabad.

5.2.4 Edge characteristics:

The nature of slick edge can be sharp, feathered, gradational, ablated etc. feather-edges usually indicate wind influence on thicker slicks (Fig. 5).

5.2.5 Point of emission:

The point of origin or the inferred emission and drift is to be determined. The direction of flow is influence primarily by tide and current, e.g. 'corkscrew' or "nested" multi-emission point slicks (Fig 5).

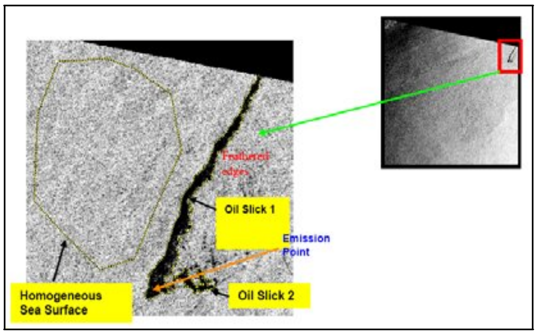


Fig 5: The extracted slicks to showing the shapes and the feathered edges and emission point

6.0 Results:

The analysis is given in Table 2 as follows for the Spills 1 and 2.

It is categorized as Rank 3 seep due to the presence of good backscatter reduction value, moderate intensity ratio, proper length to width aspect ratio, homogeneity, good shape but some feathering edge characteristics have rendered this spill as Rank 3 seep. The other scenes like 8967/3267 and 8695/3249 were studied and apart from one slick, which is given as Rank 3 seepage all the others, are given pollution rank 2 annotations. As a whole, it can be concluded that the area has very little natural seepage and they are of a very low rank and can thus be attributed to be created due to pollution.

The wells drilled in the area were superimposed over the seepages as shown in Fig. 7. All the wells drilled in this area were dry and abandoned but were not exactly on the identified slicks. Though very low ranking seepages were found in this area yet no cluster of seepages as expected in natural seepages were developed and thus the spills that are identified cannot be conclusively said to be due to natural causes due to paucity of sufficient number of repeat data.

7. Discussion & Conclusion

Seeps repeat in time as the other images of different years show low backscatter region over the same area (Fig. 6) but the repetivity is not as frequent as it might be expected. This is because seepage is rarely limited to a single point,oil and gas escape from many individual sea-floor vents comprising a seepage-complex that can extend over hundreds of kilometers. Natural seepage is rarely continuous and the rate and volume of seepage varies with time. For example, the vents get blocked by secondary carbonate (formed by the oxidation of methane at the sea sediment boundary) often forming pronounced seafloor mounds. At this juncture, hydrate formation results from the blocking and freezing of gas and oil. These geologic and some environmental factors determine that the seepage is episodic. However, more number of images and more recent images will provide information about the present status of seeps.

The planned survey and the geochemical analysis of the sea bottom samples points to the presence of Oil and Gas reservoir in the area of study (Fig.6). The results are also supported by the presence of multi date seeps recognized by SAR images around the area. Hence a more systematic approach using seep – seismic study is recommended for further exploration in this area.

	Slick
Slick Shape	Narrow elongated
Presence of bright object near to the slick	None
Edge characteristics	Sharp
Wind Speed (m/s)	Within limit
Swell Wave height	Within limit
Proximity to the shipping lanes	No
Presence of platforms	None
Fish processing area	Not known
Backscatter reduction value within the slick (Mean)	—10 dB
Surrounding area- homogenous/ heterogeneous (standard deviation of the area outside spill)	Homogenous; 3.305
Length/ Width aspect ratio	9.1467
Intensity ratio (contrast)	4.011
Inference drawn	**Rank 3 Seep**

Table -2 Showing slick analysis

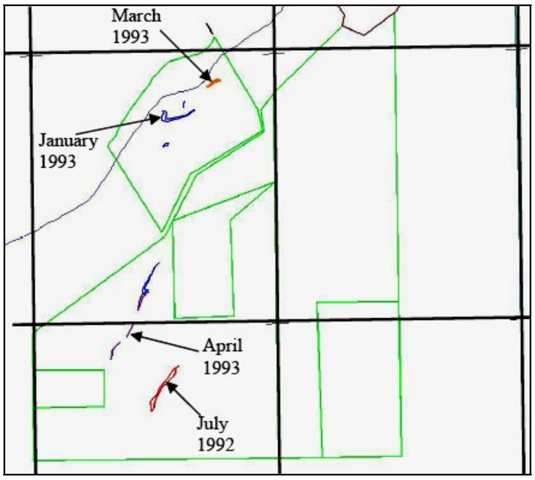


Fig 6: Repeat of the slick over the KG offshore area with the corresponding dates (all ERS image)

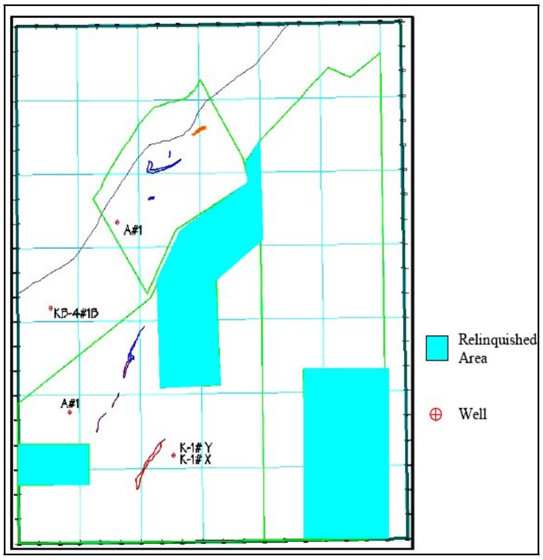


Fig 7: Figure showing positions of the wells and the seepages in the Eastern offshore basin

9. Acknowledgments

The authors are grateful to ED-Chief KDMIPE for assigning the project and for his encouragement during the course of the work. and Shri R.M. Baruah DGM (Geology) for encouraging the team during the project tenure and for their help at different stages of the work.. Thanks are due to Dr. D. S. Mitra, DGM (Geology) ,Shri H.D. Dave, Suptdg. Geologist and Shri J. K. Samal, Sr. Geologist, for their spontaneous help and support throughout the project.

The authors wish to thank Shri S. Bhattacharya and Dr.T.J. Majumdar, Space Applications Centre, ISRO, Ahmedabad for their help and active support in analyzing some of the SAR images. Thanks are also due to Mr. Balakrishnan and Director, Indian National Center for Ocean Information Services (INCOIS), Hyderabad for providing relevant wind related parameters. The authors are also thankful to Dr. R. R. Navalgund, Director, SAC, Dr. Ram Rattan, Assoc. Director, RESIPA, Shri J. S. Parihar, DD, RESA and Dr. Ajai, GD, MESG/RESA for their keen interest in this study.

The opinion expressed by the authors are not necessarily of the organization they represent.

References:

Alpers, W., and Espedal, H. A., Oils and Surfactants. SAR Marine User's Manual, pp. 263-275.

Bastia, R., 2006, An overview of Indian sedimentary basins with special focus on emerging east coast deep water frontiers. The Leading Edge, V. 25, No. 7, pp. 818 -829.

Colon, P. C., and Yan, X. H., 2000, Low- backscatter ocean features in synthetic aperture radar imagery. John Hopkins APL Technical Digest ,V. 21, pp. 116-121.

Espedal, H. A., and Wahl, T., 1999, Satellite SAR oil spill detection using wind history information. International Journal of Remote Sensing, V. 20, No.1, pp. 49-65.

Fiscella, B., Giancaspro, A., Nirchio, F., Pavese, P., and Trivero, P., 2000, Oil spill detection using marine SAR images. International Journal of Remote Sensing, V. 21, No.18, pp. 3561-3566.

Hovland, H., Johannessen, J., and Digranes, G., 1994, Slick detection in SAR images. Proceedings of IGARSS'94, pp. 2038-2040.

Plasterie, P., and Chagalov, D., 2006, Wave Equation versus Kirchhoff pre-stack depth migration algorithms – An Australian case study. AESC, Australian Earth Science Convention Melbourne, Extended abstract.

Raghavendran, K., et.al., 2004, Geochemical prospecting for hydrocarbons in four blocks of NELP-I (Deep waters – K G Offshore Basin). Internal Report, Geochemical Prospecting Laboratory, Regional Laboratory, Chennai.

Rao, G. N, 2001, Sedimentation, stratigraphy, and petroleum potential of Krishna-Godavari basin, East Coast of India. AAPG Bulletin, V. 85, No. 9, pp. 1623- 1643.

Saunders, D. F., Bruson, K. R., and Thomson, C. K., 1999, Model for hydrocarbon microseepage and its related near-surface alterations. AAPG Bulletin, 83, 170– 185.

Schumacher, D., 1996, Hydrocarbon-induced alteration of soils and sediments. In: D. Schumacher and M.A. Abrams, eds, Hydrocarbon migration and its near-surface expression. AAPG Memoir, 66, 71–89.

Solberg, A. H., and Volden, E., 1997, Incorporation of prior knowledge in automatic classification of oil spill in ERS SAR Images, IEEE Transactions on Geoscience and Remote Sensing, V. ?, pp. 157-159.

Vyas,D.,et.al.,2005,Geochemical prospecting for hydrocarbons in KG-DWN-98/4 Block (Area "J" prospect of NELP I) Deep waters KG offshore Basin, Internal Report. Geochemical Prospecting Laboratory, Regional Laboratory, Chennai.