Detection of Natural Hydrocarbon Seepages Using SAR Technology and Associated Subsurface Studies in Offshore Mahanadi Basin for Delineation of Possible Areas of Hydrocarbon Exploration*

H. D. Dave[1], S. Mazumder[1], J. K. Samal[1], K. K. S. Pangtey[1] and D. S. Mitra[1]

Search and Discovery Article #40738 (2011)
Posted April 29, 2011

*Adapted from extended abstract presented at GEO-India, Greater Noida, New Delhi, India, January 12-14, 2011.

[1]Remote Sensing & Geomatics KDMIPE, Dehradun (davharsh@gmail.com)

Abstract

Hydrocarbon seepages in oceans are direct indicators of the existence of a petroleum system in deep water basins and detection of such seepages helps in lowering the cost and risk involved in the exploration activities. Detection of offshore oil seepages by radar satellites offers a cost effective means of locating such offshore oil reserves. Seeps are surface expressions of migration pathways of hydrocarbons where oil and gas seeping out of faults opening in the seabed are transported 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. However, if oil is present in the sea surface, it dampens the wave signature and is detected as a dark area on a bright surface. The amount of the backscattered radiation in the oil covered region detected by the SAR sensors is less than the surrounding sea as the oil decreases the aerodynamic roughness of the ocean and consequently decreases the radar backscatter (Bartsch et. al. 1987).

An attempt had been made to identify such hydrocarbon seepages in Mahanadi offshore area from ENVISAT ASAR and ERS data and correlate them with free air gravity, and available seismic data so that they can be tied up with sub surface features, instrumental in generating or contributing oil for the detected seepages.

Study Area

The study area (Figure 1) is confined to Mahanadi Offshore area covering roughly 140,000 km^2 up to 2,500 m isobaths in offshore region with sediments ranging in age from oldest Permo-Triassic Gondwana sediments to Recent sediments. The basin has a polycyclic history with oldest Permo-Triassic Gondwana sediments deposited in the continental grabens with the subsequent stage in Late Jurassic constituting of development of horst graben features along pre-existing weak zones followed by development of a delta system and a subsequent main transgression and ending with the flow of Rajmahal lavas (Bastia R. 2007). Mahanadi shelf received continental-deltaic sediments in Late Cretaceous-Paleocene times and carbonate sedimentation during the Eocene. Oligocene is the period of non-deposition/erosion in the basin with the Miocene witnessing regional subsidence and marine transgression both in offshore, onshore, with very high subsidence rate in Middle Miocene, and younger periods. At that time, the basin experienced tilting, with west experiencing uplift and east undergoing subsidence. This led to renewed influx of clastics and progradation of deltaic sediments over tectonically altered Miocene section this continues until the present day. Hydrocarbons of possible biogenic origin have so far been encountered in the Plio-Pleistocene channels within sand reservoirs. In the shelf of Mahanadi Basin, no thermogenic hydrocarbon has been encountered. Thermal maturity modeling suggests the threshold of maturity in the south southeastern part in the passive margin setup, especially the Eocene-Oligocene successions (Bhowmick, 2009).

Seepage Studies

Seepages identified from SAR data were analyzed to eliminate similar signatures generated due to ship or tanker generated pollution slicks or biogenic algal signatures based on the following parameters:

- Wind Speed
- Scale, Shape, Size and Aspect Ratio
- Repeat Cycle

Based on these parameters the identified seepages are classified as per degree of confidence into High, Medium and Low categories. Twenty-four such seepages had been identified in Mahanadi Offshore Basin and classified as per the above parameters (Table 1). Although four seepages of medium degree of confidence had been observed, no seepage of high degree of confidence had been observed in the study area (Figure 2).

Correlation with Collateral Subsurface Data

Free Air Gravity

The identified seepages were overlain on the Free Air Gravity map of the Mahanadi Offshore region (Tiwari et. al., 2003). From the Free Air Gravity data prominent of NE-SW high trend is observed that changes to an E-W direction whereas a prominent N-S cross-trend is observed further northward. The only seepages of medium degree of confidence are found to occur at the intersection of the two trends (Figure 3).

Existing Interpreted Seismic Data

Though the available structure contour maps prepared at Cretaceous, Paleocene, Eocene, Oligocene and Mid Miocene levels (Gupte et. al., 2006; Mukhopadhyay et. al., 2009; Ramana et. al., 2004) show no presence of faults, seepages are found to occur on the same trends of regional faults affecting Cretaceous and Eocene levels in KG Offshore Area extrapolated in Mahanadi Offshore area (Figure 4). Hence, it might be probable that these Cretaceous faults might be continuous in the Mahanadi area that also might cause the seepages.

Geochemical data

The available Surface Geochemical adsorbed gas data indicate that the adsorbed gases are of thermogenic origin and petroliferous in nature and have seeped most likely from condensate/wet gas pools.

Conclusions and Discussions

A total number of twenty-six seepages had been identified in the study are varying in confidence levels from medium, to low. Most of these seepages are found to be distributed along a NE-SW gravity trend in the shallow water area, which also parallels the coastline in these parts occurring along channel axes. Also overlain with bathymetry data most of these seepages are found to occur on a very abrupt change in bathymetry, which probably delineates the shelf break in the area. Both the change in gravity as well as bathymetry (Figure 5a and Figure 5b) is found to be more or less correlated, and is also found to be coincident with the tectonically interpreted Coastal Monocline. This might imply the shelf break as well as the gravity trend is probably manifestations of the Coastal Monocline.

From this, it can be probably suggested that the faults that resulted in the development of the monocline might be opening up to the surface and are instrumental in the occurrence of the seepages in this area.

Also in the deep-water areas, the seepages are found to occur along an E-W gravity trend with a cluster of them occurring along a junction of the EW trend with a NS gravity high trend. This NS gravity high trend is probably due to 90° East Ridge. The only instance of seepage repetition in the study area is also found to occur in this trend intersection zones suggesting that it might be an area of intersection of deep-seated faults that probably acted as conduits for hydrocarbon seepage.

Seepage originating from condensate/lighter HC are always less persistent than heavier oil slicks and takes more time to form oil film on the sea surface. The signature of seepage on SAR image will be captured only if the time of satellite over pass coincides with that of oil film formation, otherwise the signature remains unnoticed. Hence, the lack of repeativity of the surface seepages in multi-date satellite data might be attributed to the lighter nature of the hydrocarbons in the basin. This might be the reason for a lower degree of confidence during the classification of the seepages.

The opinion expressed by the authors is not necessarily the opinion of the organization, which they represent.

References

Bartsch, N., K. Gruner, W. Keydel, and F. Witte, 1987, Contributions to oil spill detection and analysis with Radar and Microwave radiometry: Results of Archimedes II Campaign, IEEE Transactions of Geoscience and Remote Sensing, v. 25, p. 677-689.

Bastia R., 2007, Geologic settings and petroleum systems of India's East coast offshore Basins: Concepts and Applications: Dehradun, India, 204 p.

Bhowmick P.K, 2009, Phenerozoic Petroliferous basins of India: Glimpses of Geoscience Research in India, p. 1-16.

Gupte, S.S., et al., 2006, Interpretation report of 3D data of area-B NELP Block MN-OSN-2000/2 Mahanadi Offshore: unpublished report, ONGC, Dehradun, India.

Mazumder, S. and Saha, K.K., 2006, Detection of oil seepages in oceans by remote sensing: Society of Petroleum Geophysicists, India (SPG), 6th International Conferences & Exposition on Petroleum Geophysics 2006, Kolkata, West Bengal, India, p. 1172-1178.

Mazumder, S., et al., 2009, Study of offshore oil seep detection using SAR technology and seep-seismic study in Kg offshore basin: unpublished report, ONGC, Dehradun, India.

Mukhopadhyay, C., et al., 2009, 2D seismic interpretation report block NEC-DWN-2000/2 Mahanadi Basin: unpublished report, ONGC, Dehradun, India.

Ramana D V et al, 2004, Interim report of Mahanadi Shallow water Block, MN-OSN-97/3 covering two 3D areas, unpublished report, ONGC, Dehradun, India.

Saha K.K., H.D. Dave, S. Sengupta, T.J. Majumder, and R. Bhattacharya, 2007, Feasibility study of offshore oil seepage detection using SAR technology, collaboration project: unpublished report, Remote Sensing and Geomatics, KDMIPE, Dehradun and SAC, ISRO, Amhedabad, India.

Saha K.K., S. Sengupta, 2007, Feasibility study of offshore oil seepage detection using SAR technology, Remote sensing and Geomatics: KDMIPE, unpublished report, Dehradun, India.

Subrahmanyam,V., A.S. Subrahmanyam, G.P.S. Murty, and K.S.R. Murthy, 2008, Morphology and tectonics of Mahanadi Basin, northeastern continental margin of India from geophysical studies: Marine Geology, v. 253, p. 63-72.

Tiwari, S., and D. Sar, 2003, Integrated analysis of Geoscientific data of Mahanadi basin and evaluation of hydrocarbon potential including review-Gravity and Magnetic data analysis: unpublished report, ONGC, Dehradun, India.

Figure 1. Area of study in Mahanadi Offshore for detection of natural hydrocarbon seepages.

Seepage No.	**Length (kms) 0.5-10**	**Width (kms) 0.1-5**	**Shape**	**Wind speed (m/sec)**	**Repeat**	**Degree of Confidence**
1	1.35	1.03	Oblong	>2	No	Low
2	1.35	0.17	Elongated	3	No	Low
3	0.74	0.15	Elongated	>2	No	Low
4	1.58	0.12	Elongated	3	No	Low
5	1.00	0.21	Elongated	3	No	Low
6	2.38	0.39	Elongated	2-3	Yes	Medium
7	0.71	0.25	Elongated	2-3	Yes	Medium
8	0.74	0.25	Elongated	2-3	Yes	Medium
9	4.20	0.50	Elongated	2-3	Yes	Medium

Table 1. Example of Classification of identified hydrocarbon seepages based on their degree of confidence.

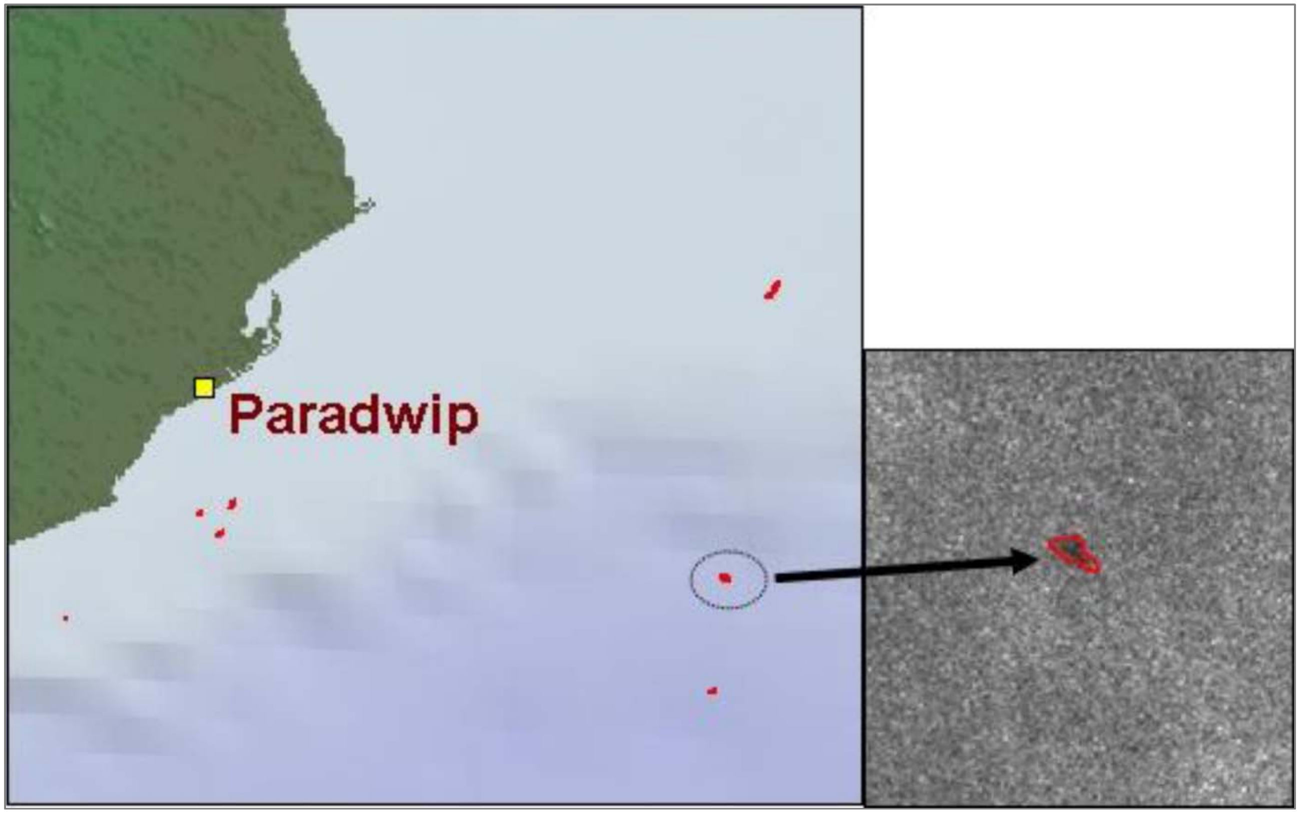

Figure 2. Hydrocarbon seepages identified in Mahanadi Offshore. The highlighted seepage indicative of Medium degree seepage.

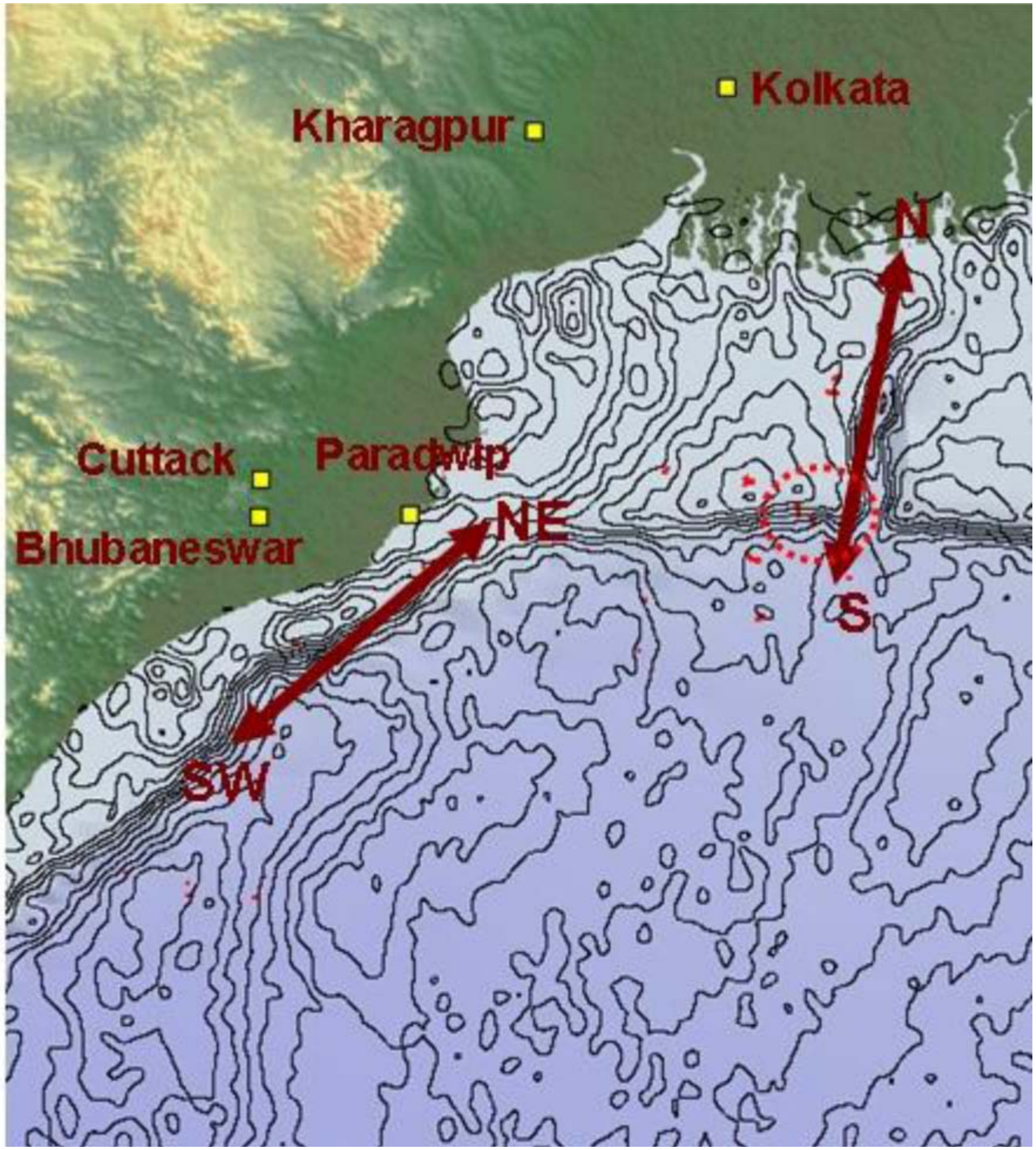

Figure 3. Free Air Gravity map of study area showing NE-SW and N-S trends Seepage of Medium degree of confidence occur at the intersection of the two trends.

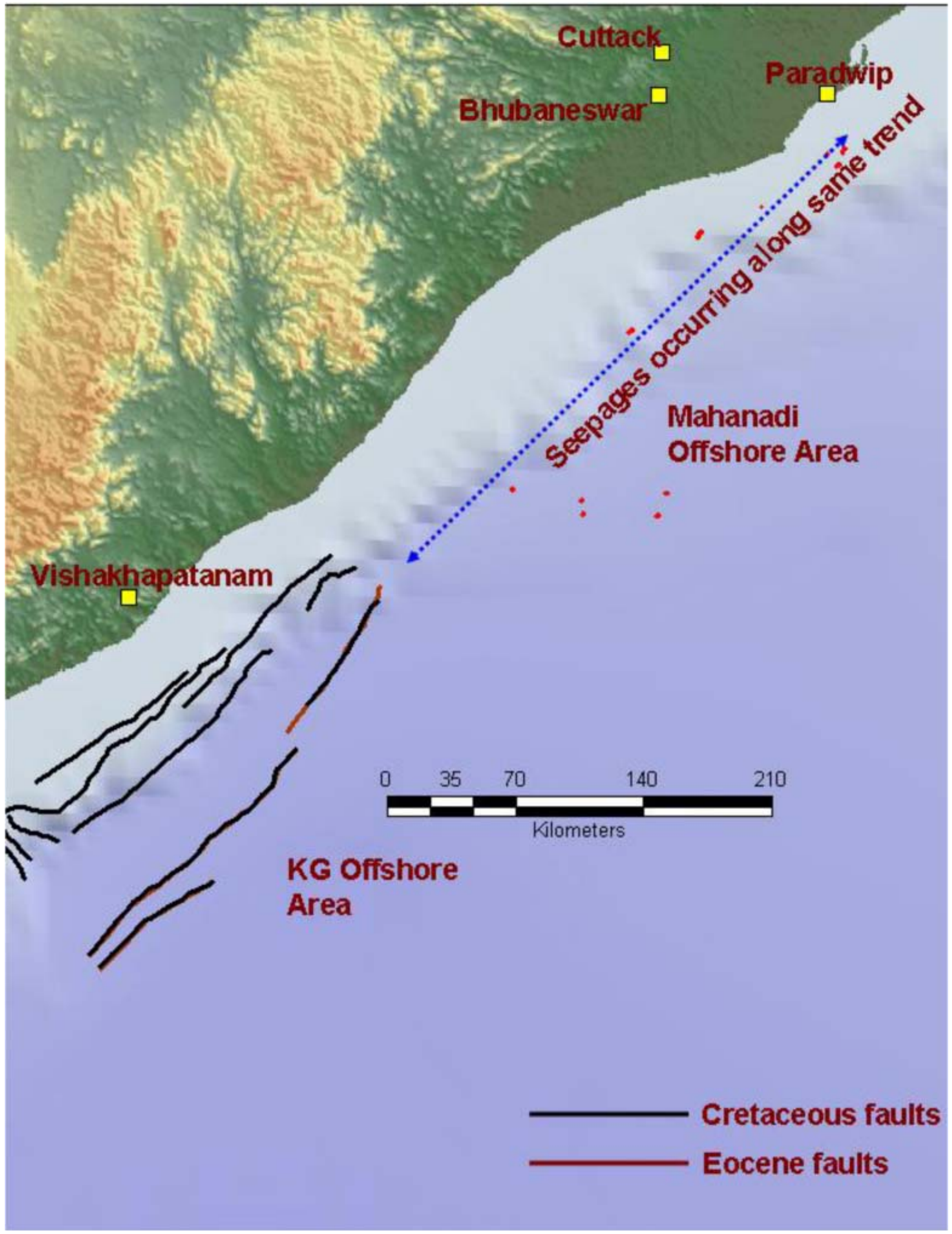

Figure 4. Seepages in Mahanadi Offshore occurring in the same trend of the faults mapped in KG offshore.

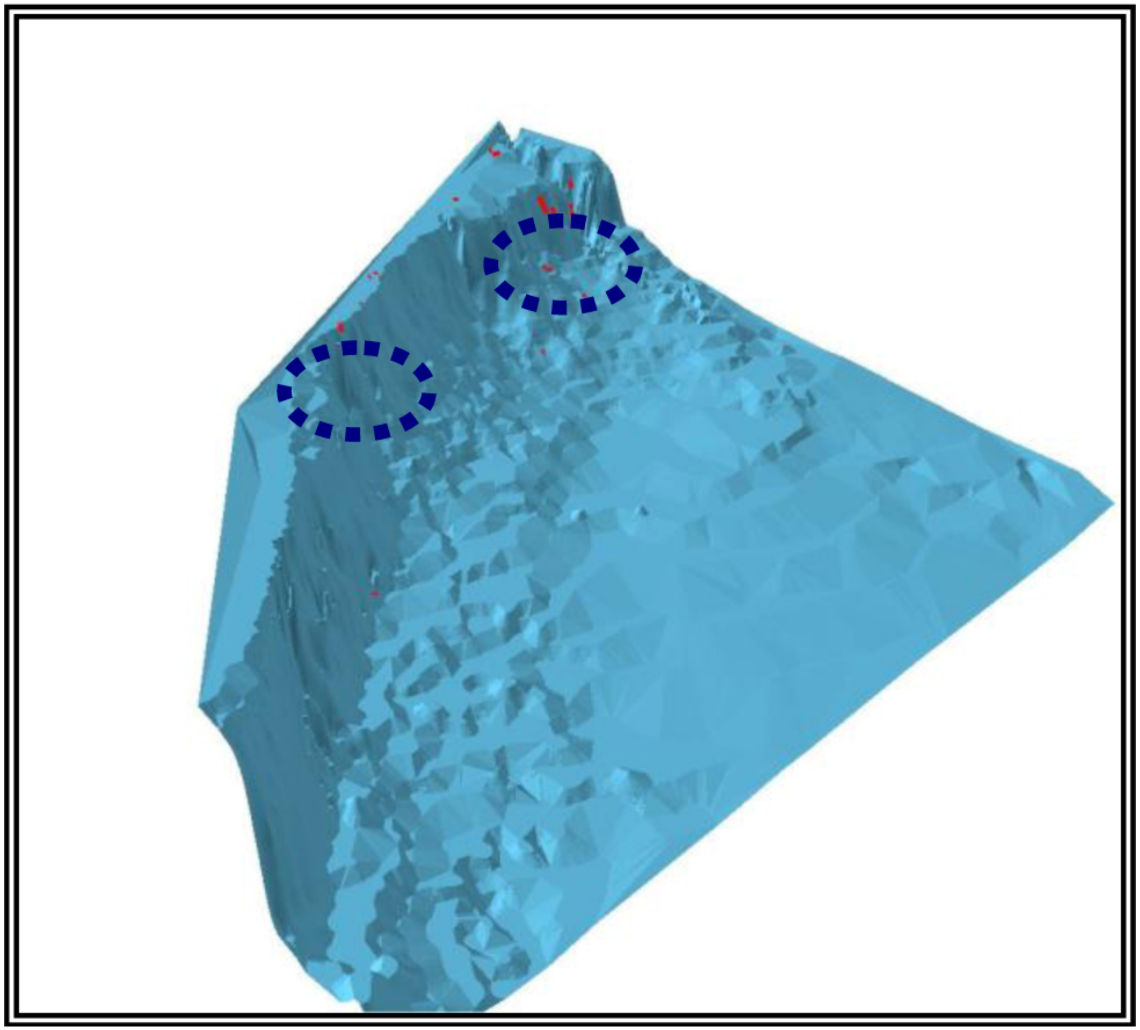

Figure 5a. Correlation of identified seepages with Bathymetry.

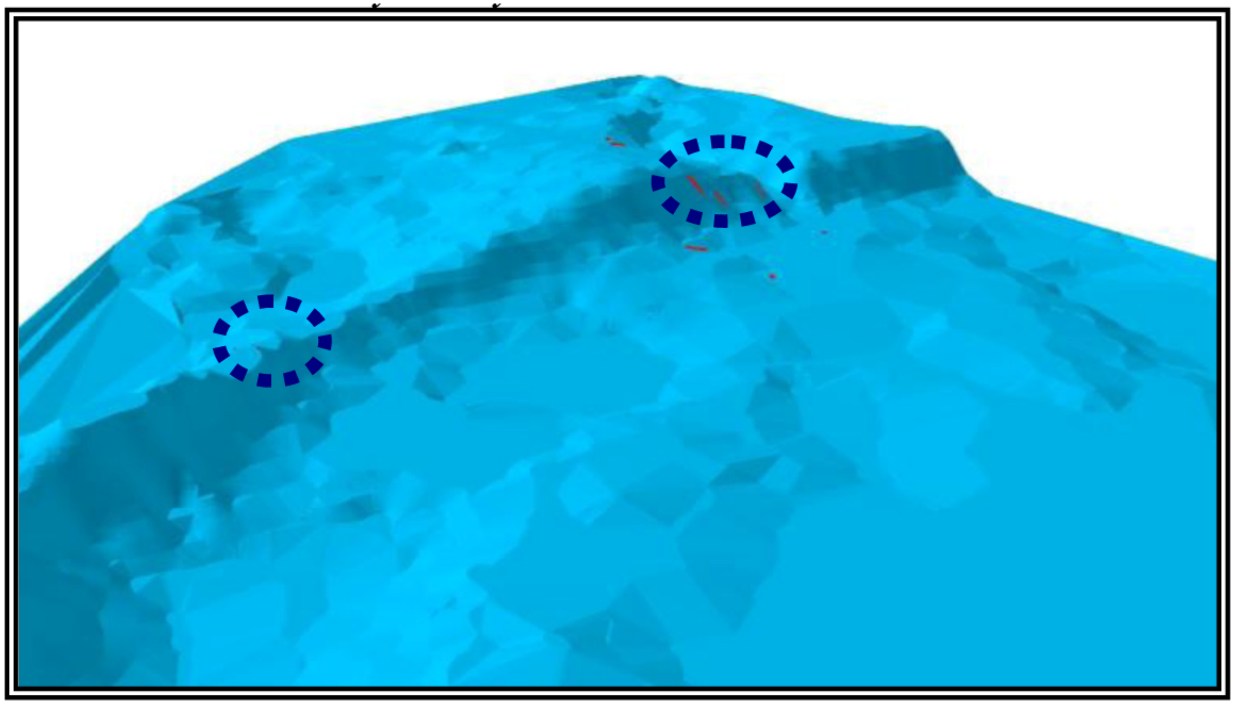

Figure 5b. Correlation of identified seepages with Free Air Gravity.