City and Regional Planning

CRP 514: GIS

FIRST SEMESTER (111)

REMOTE SENSING IN PETROLEUM SEEPAGES DETECTION

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Abstract

This paper represents the combination between data of petroleum geology and remote sensing maps, it concerned in how to find petroleum seep locations, and integrate all available data to confirm remote sensing data. This study come as result of intensive remote sensing study in early stages of oil exploration, it can give an idea about general geology, rock types and some structures, but sometimes can detect petroleum seepages, oil and gas seeps to the surface thru fractures or permeable beds, that made some traces in the earth surface or sea surface which is very important in petroleum exploration, which is can lower the cost of exploration, also seepage is direct indication of presence of oil and gas in subsurface and can determine the oil quality without drilling, Natural seeps have been active for hundreds to thousands of years and that from source of green house gases but it's not that significant due to evaporation, dissolution in sea water, and ate by some organism. Seeps can Easley identify by remote sensing, but there are some difficulty of using remote sensing in oil seepage is that it reveals some areas to be altered, whereas they are not. Detecting petroleum seepages by remote sensing will not be applicable in areas covered by vegetation, buildings or darkened hard rocks. In offshore area, it is probable that seepage may not be present at its actual location due to water column. In areas affected by seepage, we try to study the impact of seepage on mineral composition, and try to combine seepage map with geological & geophysical data for a good interpretation. Many methods were employed in this paper to get the results this methods are ASTER images, Landsat ETM+, ASTER VNIR and SWIR images, Scanning electron microscopy (SEM) analyses, Landsat Thematic Mapper (TM), Multispectral Scanner (MSS), and other geological techniques used for detect oil and gas seepages like thin section, X-ray diffraction XRD, and scanning Electron microscopy SEM. After combining these methods together with geological data, we have a better understanding about the fracture system in the area. Also, results of geochemical analysis help us to know that seepage forms the oxidation zone on the surface and affects the stability of some minerals like calcite, which changes to Kaolinite.

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1 Introduction:

Oil and gas seeps are important in petroleum exploration for many reasons, because it can be indicators of petroleum or natural gas reservoirs in the subsurface, and the quality of petroleum can also be recognized before drilling, also seeps are indicators of some structures like fracture zone, and in some cases seepage represent geo-hazards and sources of pollution and greenhouse gases.

Due to important of seeps, and concern become globally, so a new global dataset of onshore gas and oil seeps (GLOGOS) was created. GLOGOS includes more than 1150 seeps from 84 countries (version August 2009) and it is continuously renewed, as we can see clearly Fig (2), but there are seeps in some places not recognized due to place may be far away in ocean or in country which people haven’t concept of seepage or its not interesting topic.

The exploitation of natural seep deposits dates back to 40,000 years ago. Humans used bitumen for construction of buildings and water proofing of reed boats, among other uses and natural asphalt was employed in the construction of the walls and towers of Babylon. There were oil pits near Ardericca (near Babylon), as well as a pitch spring on Zacynthus (Ionian Islands, Greece). (http://en.wikipedia.org/wiki/Oil_seep).

When the petroleum compounds seeps and contaminated with soil and rock in the surface, this contamination will affect the stability of some minerals and seepage form big oxidation zone in altered area, and according to (Shi et al., 2010) “Hydrocarbons that escaped from underground reservoirs cause oxidation-reduction reactions either in situ or along vertical migration paths and result in anomalies in sediments and soils, as shown in Fig (1). Microbial and botanical anomalies; mineralogical alterations; and change of electrical and magnetic properties occur in near surface sediments (Donovan, 1979; Segal and Merin, 1989; Schumacher, 1996)”.

According to (Shi et al., 2010) “Among these anomalies, bleaching of red beds, enrichment of ferrous iron, alterations of clay minerals and carbonates, and botanical anomalies exhibit diagnostic spectral features that allow detection by remote sensing techniques (Sabins, 1999; Almeida , 2002; Fu , 2007)”. Change the reflectivity of these materials, to reflect different wavelengths depend on the degree of contamination and the types of oil were seeped, so it is easy to detect by remote sensing.

Using direct detection and indirect detection in remote sensing to identify the petroleum seeps, direct detection is detect mineral alteration related to the seepage and indirect detection is the impact of oil and gas seeps like effect appear in vegetation structure.

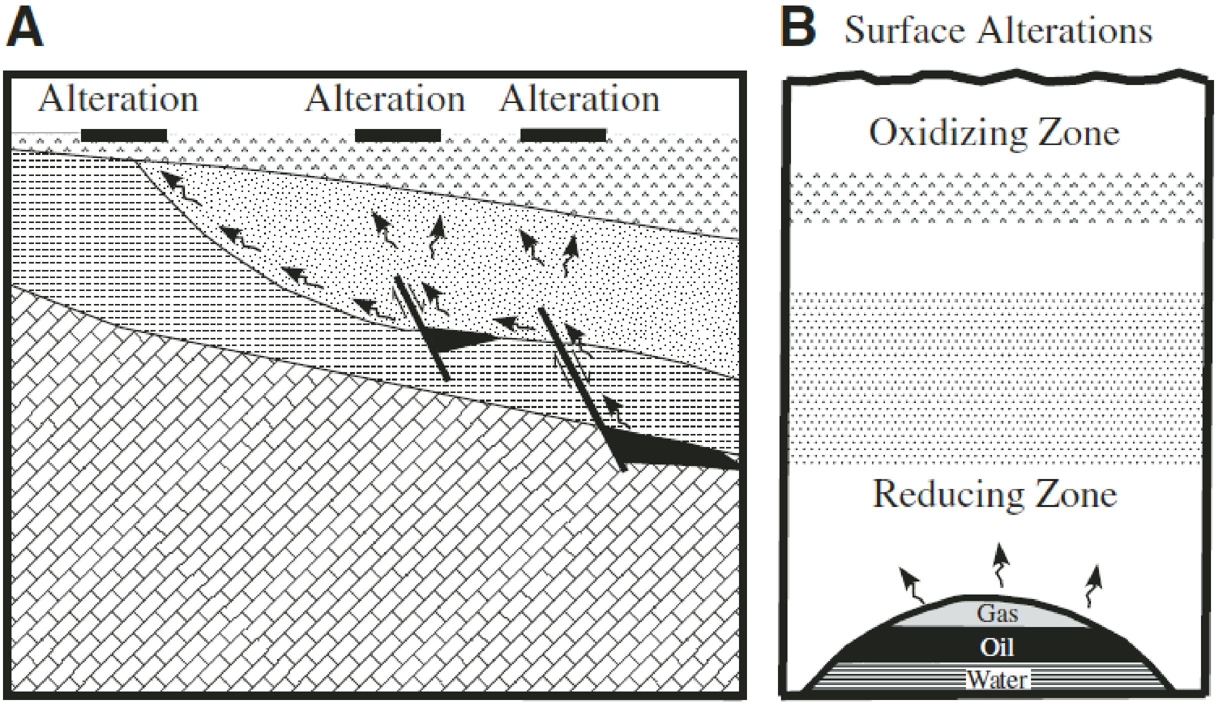

Fig. 1: (A) Processes by which microseeping hydrocarbons migrate from the reservoir to the surface through faults, fractures as well as stratigraphic boundaries (modified from Schumacher, 1999). (B) Generalized model of hydrocarbon induced geochemical alterations of soils and sediments (modified from Schumacher, 1996).

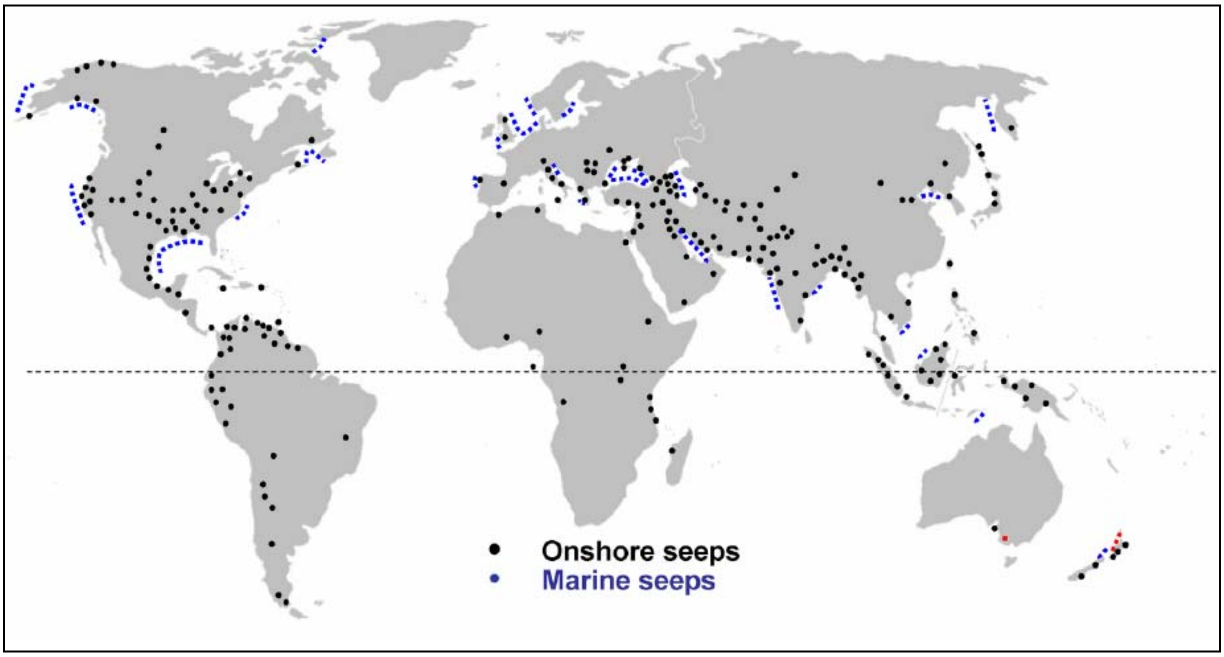

Fig.2: Global distribution of petroleum seepages (Etiope, 2009).

2 Objectives and Methodology:

The objective of this paper is to summarize some published papers all concerned in oil seepage detecting by using remote sensing techniques. The objective of these papers are to provide and locate seeps of oil and gas using remote sensing techniques, and provide the impact of petroleum seepage on the mineral composition (called alteration), as well as the reasons that allowed the seepage.

Different methods were employed to investigate Hydrocarbon seepages and all these methods work together to give accurate result and more details, and this methods are ASTER images (Advanced Spaceborne Thermal Emission and Reflection Radiometer), Landsat-7 enhanced thematic mapper plus ETM+, ASTER VNIR and SWIR images, and Landsat Thematic Mapper (TM), all these methods were used as remote sensing techniques and confirm by field checking or geological and geochemical techniques.

Beside the remote sensing tools we use geological and geochemical methods, the tools were used in geology and geochemistry are Scanning Electron Microscope with Energy Dispersive Spectrometer (SEM/EDS), thin section study and X-ray diffraction (XRD). Also Raster images using SAR Technology and makes correlation with Collateral Subsurface Data gravity, Seismic and geochemical data.

3 Literature review:

The seepage of petroleum has been intensively studied in recent years; the reason for this considerable attention is their economic importance for lowering the cost and risk. Petroleum seepages occur in many part of the world and considered as very important phenomena in economic point of view as well as environmental impact. In this paper I have two case studies, the first one is concern in offshore and the second is show seeps in land.

3.1 Case study 1: Detection of Natural Hydrocarbon Seepages Using SAR Technology and Associated Subsurface Studies in Offshore Mahanadi Basin for Delineation of Possible Areas of Hydrocarbon Exploration

This study located in India, Mahanadi offshore area, and it concerned in HC seepages in offshore area, by using radar images, the radar have SAR sensor to measure backscatter radiations, the output of the radar images appear like black and white depend on the surface covered in the survey, however seepage in offshore area appears as oil layer in sea surface, connected or isolated. This phenomena can be detected by the contrast in colors between oil layer and sea surface, and appear as dark area in bright background represent sea surface. The dark areas give low backscattered radiation (oil layer in this case) and sea surface give high backscattered radiation.

3.1.1 Results:

According to (Dave et al., 2011) "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 many parameters such as Wind Speed during survey, Scale, Shape, Size and Aspect Ratio, and Repeat Cycle".

The results of SAR data are divided into three degree of confident high, medium, and low based on the parameters that help to identify seepages. Seepage locations identify using SAR data are shown in fig. (3). SAR data combined with geophysical and geochemical data, free air gravity show intersect of two high gravity trends coincide with seeps in medium degree of confidence, as show in table (1).

Result of seismic data shows the presence of fault in south west of study area, as shown in fig.(4), but in study area seismic cannot confirm presence of this fault, and the Geochemical data show the gases are thermogenic origin and produced with oil and have seeped most likely from condensate/wet gas pools.

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 (Dave, et al., 2011).

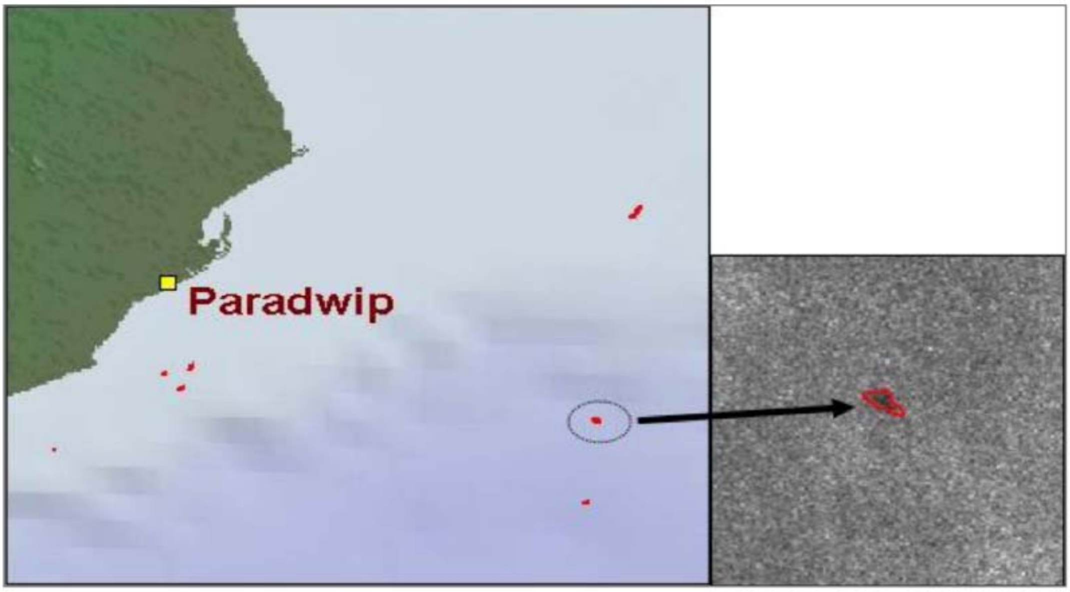

Fig. 3: Hydrocarbon seepages identified in Mahanadi Offshore. The highlighted seepage indicative of Medium degree seepage (Dave, et al., 2011).

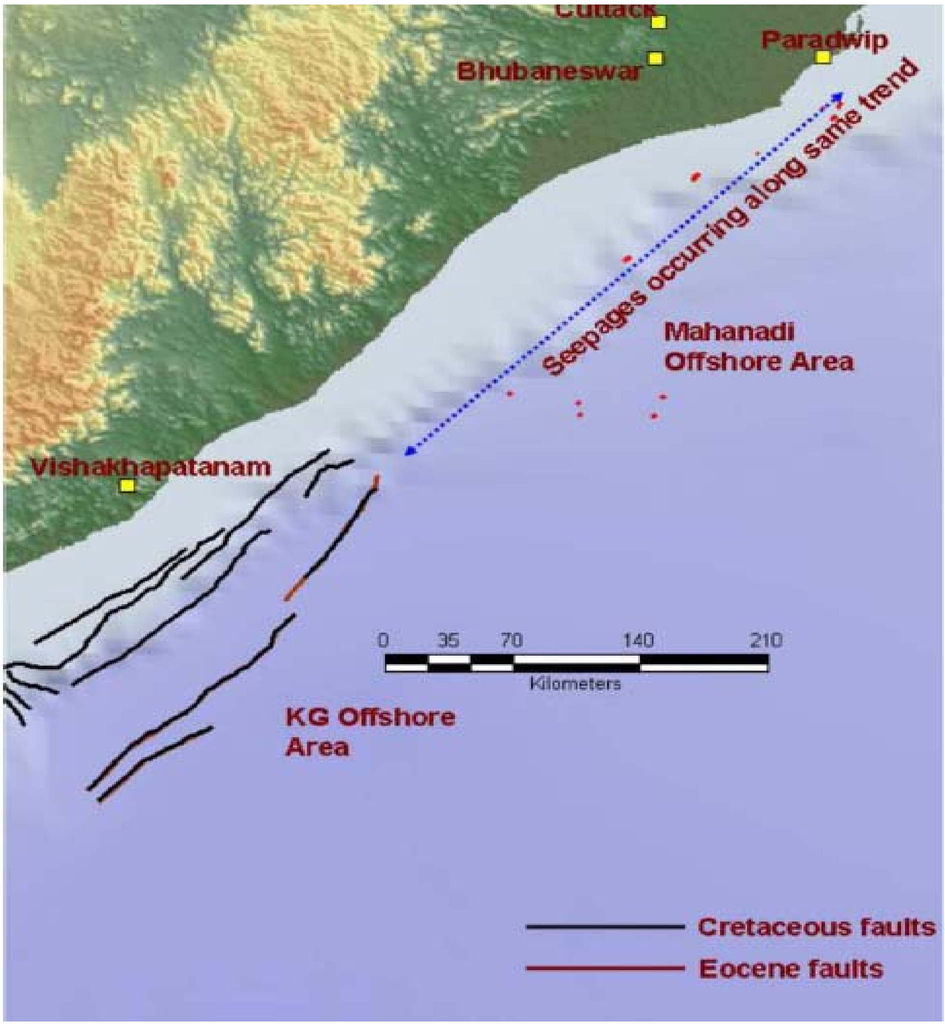

Fig. 4: Seepages in Mahanadi offshore occurring in the same trend of the faults mapped in KG offshore (Dave, et al., 2011).

3.2 Case study 2: MAPPING HYDROCARBON SEEPAGE-INDUCED ANOMALIES IN THE ARID REGION, WEST CHINA USING MULTISPECTRAL REMOTE SENSING

In this paper authors were used a remote sensing techniques to locate petroleum seepages in the Kuqa depression basin, southern Tian Shan Mountain, west China, and actually its inshore area away from sea as shown in Fig(5). Many methods were employed in this study; the spectroscopy and ASTER multispectral remote sensing used to investigate hydrocarbon seepage-induced anomalies. Remote sensing data combined with field investigations, geochemical and mineral analyses of selected samples.

According to (Shi et al, 2010) "Spectral enhancement, by means of principal component analysis (PCA) and band rationing of Landsat-7 enhanced thematic mapper plus (ETM+) data, has been successfully used in several studies to recognize surface anomalies and alternation

(Almeida , 2002), Band ratios of TM have been used to identify the location of ferrous iron (Almeida, 1999; Almeida, 2002) and bleaching of red beds, clay mineralization, and ferric iron (Freek, 2002)".

ASTER sensor has 6 bands comparing with 2 bands of Landsat TM and ETM+, so it can easy detect the mineral alteration, and by using Scanning Electron Microscope with Energy Dispersive Spectrometer (SEM/EDS), thin section study and X-ray diffraction (XRD) were also conducted to determine the relationship between mineral composition, spectral features and surface changes.

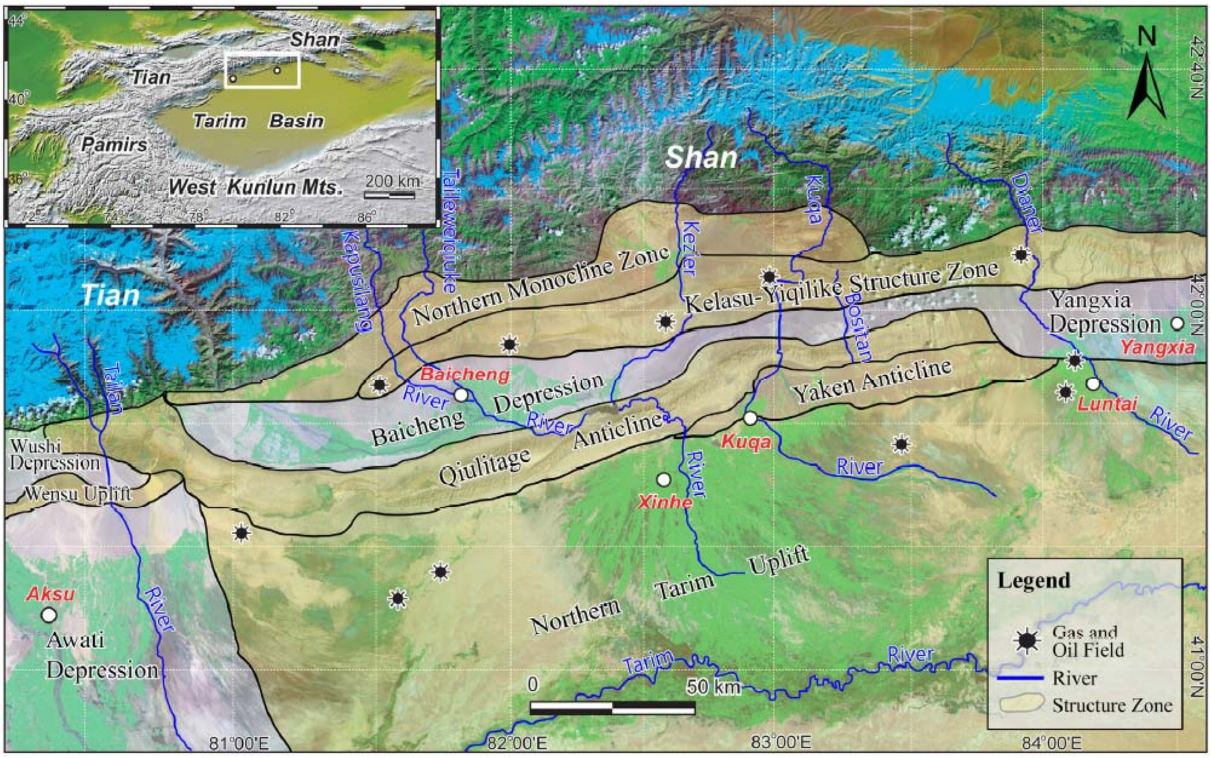

Fig. 5: Structure sketch of Kuqa depression basin overlaying on ETM mosaic image (Shi et al., 2010).

3.2.1 Results:

Results showed that ASTER band ratios of 2/1 and 4/9 can reveal successfully mineralogical alterations induced by hydrocarbon seepages such as bleached red bed and secondary carbonates, also the result of lab work specially work under microscope show in altered rocks micritic carbonate, calcite cement, and crystallization are very common instead of hematite that is very common in the unaltered samples of red sandstone.

In altered rock, Authors found some of the feldspar mineral partially turned to Kaolinite (clay mineral), also in altered samples they find carbon pitch, and the output of scanning electron microscopy SEM the result show presence of granular calcite covered by tabular clay minerals as shown in Fig (9).

The mineralogical compounds using X-ray diffraction XRD in alteration samples show increasing of carbonate minerals like Calcite, Dolomite, and Siderite, as shown in Fig (10), and from result combinations we obtain more results and more accurate, so the combination between SEM and XRD show the presence of ferrous oxide and carbonate minerals in altered samples.

3.2.2 Spectral measurement and image processing:

The RASTER sensor has multi-bands, and we are using this band to show certain type of rocks and calibration was done between wavelength of RASTER images and wavelength measured in laboratory using analytical spectral device ASD, the results of this calibration are:

- The unaltered ferric oxide minerals can be estimated from RSTER band ratio of 2/1, because ferric oxide minerals (red beds) show high reflectance in band 2, and by 2/1 ratio the red beds show as white color.
- The ferric oxide content in the rock can be estimation by RASTER band ratio 5/4.
- The altered carbonate minerals appear in light color in RASTER band ratio 4/9.

According to Red, Green, and Blue (RGB) color composite theory and the bands ratio, unaltered rocks appear as yellow, brown color, while altered rocks appear as gray-blue, light blue in the false color composite image, as shown in Fig (8), so we can clearly pick out the altered rock region.

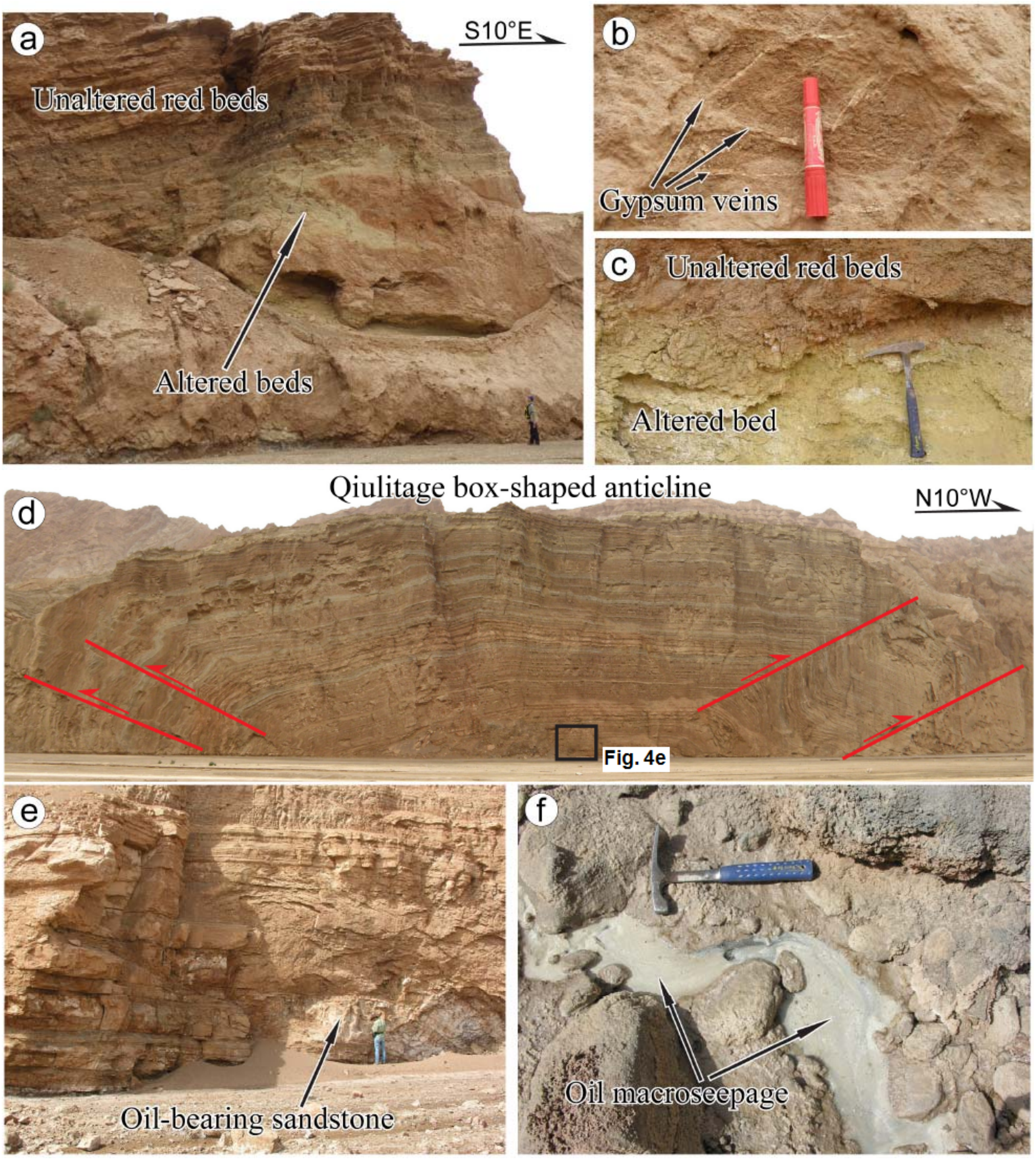

Fig. (6): Photographs showing surface alteration and oil seepage along the Qiulitage anticline. (a). Surface of the altered rocks. Note the alteration of red beds: altered rocks appear as greyish green, yellowish green along the crest of the anticline. (b) Multiple sets of gypsum veins. (c) Surface of the altered rocks in a large scale. (d) Qiulitage box shaped anticline. (e). Oil-bearing sandstone in the core part of the Qiulitage box-shaped anticline. (f) Oil macroseepage along the Qiulitage anticline (Shi et al, 2010).

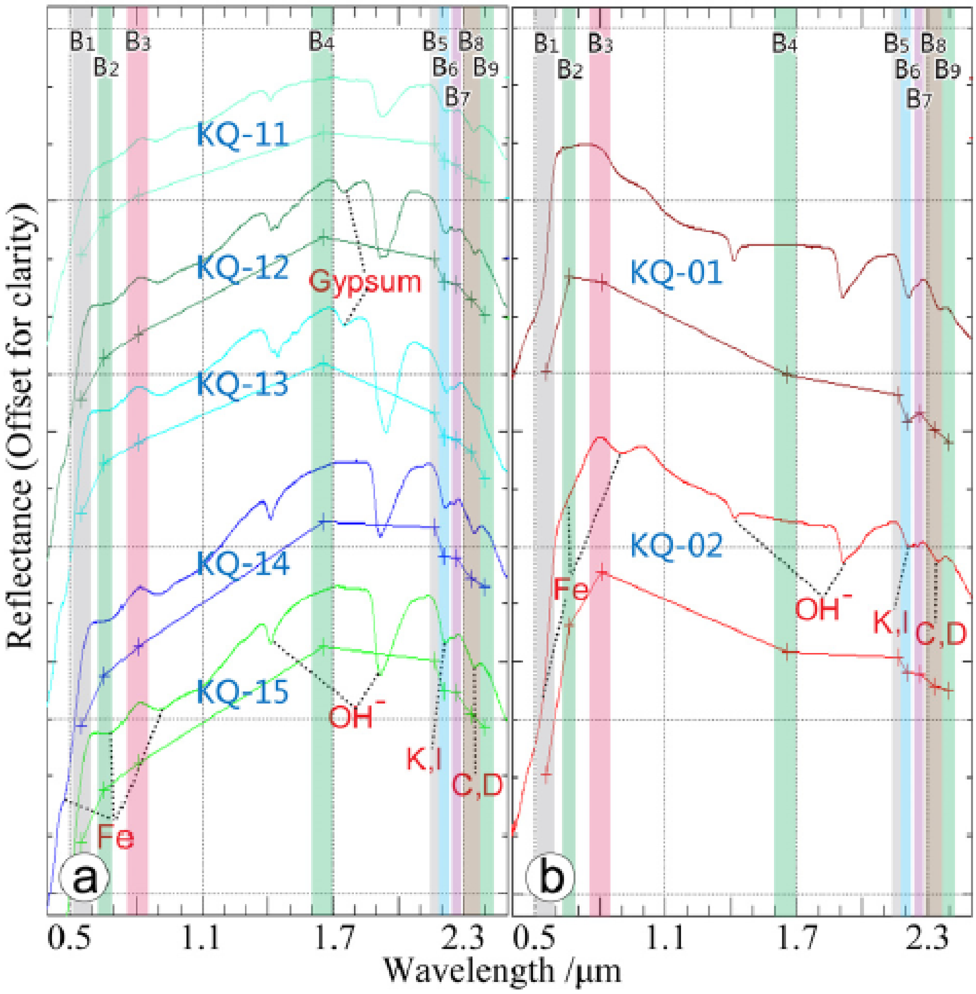

Fig. 7 (a): Reflectance curves of typical altered samples (KQ- 11~15) collected from the Qiulitage anticline. Curves with plus symbols are spectra in ASTER spectral resolution resampled from laboratory spectra. Location of the samples is shown in

Fig. 4c, d. Diagnostic clay, hydroxyl ion, gypsum and iron absorption features of altered samples are identified by their patterns within the green rectangles. (b) Reflectance curves of unaltered samples (KQ-01, 02) collected from the Qiulitage anticline. I: Illitte, K: Kaolinite, C: Calcite, D: Dolomite (Shi et al, 2010).

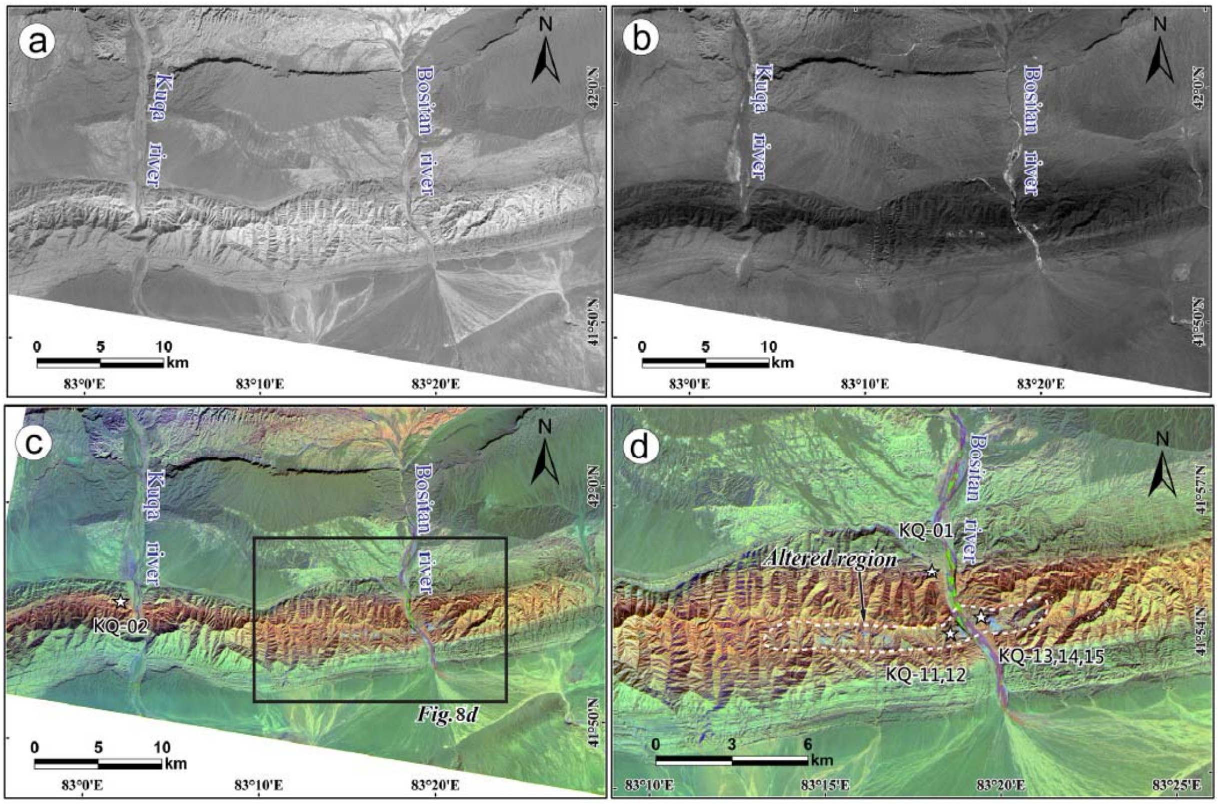

Fig. (8): ASTER images of the study area. (a) Grayscale image of ASTER band ratio 2 ⁄ 1. (b) Grayscale image of ASTER band ratio 4 ⁄ 9. (c) False color composite image of ASTER band ratio 2 ⁄ 1 (R), 3 (G) and 4 ⁄ 9 (B).

(d) Enlarged ASTER false color composite image. Note altered rocks due to mineralogical alteration induced by hydrocarbon seepage showing as grey-blue to light blue (Shi et al, 2010).

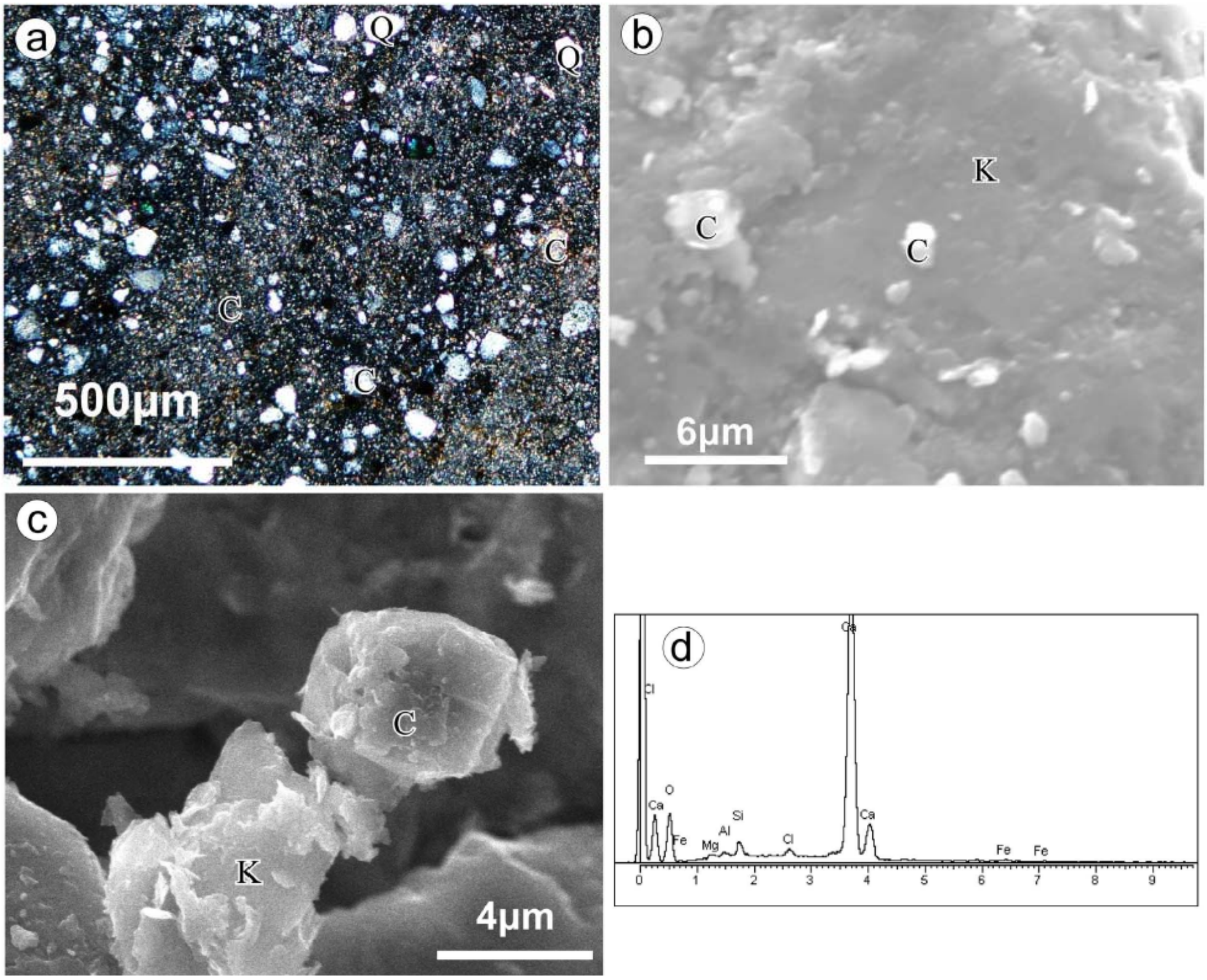

Fig. (9): (a): thin section photo of altered rock sample by orthogonal polarization microscopic study. (2) Scanning electron microscopy (SEM) photo of altered rock sample. Granular calcite mineral particles overlying tabular/platy kaolinite mineral. (3) SEM photo of tabular/platy kaolinite mineral and Granular calcite mineral particles. (4) X-ray energy dispersive spectrum (EDS) of calcite in the altered rock sample. C-Calcite, Q-Quartz, K-kaolinite (Shi et al, 2010).

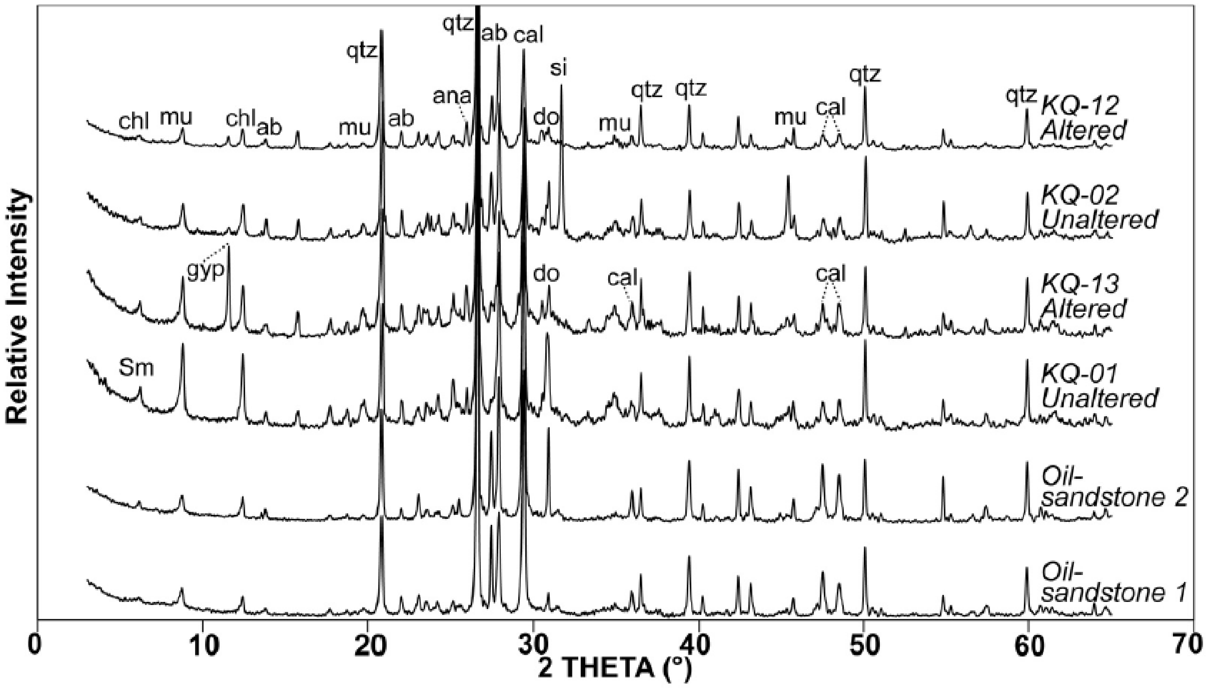

Fig. (10): X-ray diffraction analysis showing mineralogical components of the rock samples collected from the Qiulitage anticline. Ab- albite; ana- analcime; cal-calcite; chl- chlorite; do-dolomite; gyp-gypsum; il- illite; mu-muscovite; qtz-quartz; si- siderite; sm- smectite (Shi et al, 2010).

4 Discussions and Conclusion:

Remote sensing data should be confirmed by ground shooting (field checking), and do geological and geochemical analysis, the lab work show alteration affect the reflectivity of the minerals and by extension the hall area that affected by petroleum seepage.

In second case study show the mineralogical compounds using X-ray diffraction XRD in alteration samples show increasing of carbonate minerals like Calcite, Dolomite, and Siderite it indicate hydrocarbon seepage, also the altered samples show changing in mineralogical composition, so seepage can change the stability of some minerals and form ideal condition for deposition of carbonate minerals, that according to this study in this area and maybe there are some other factors can affect also the type of oil was seeped should be consider, but here we consider oil seepage the main factor and ignore the chemistry of seeps itself. Presence of carbon pitch which is a direct indicates ancient migration of petroleum.

The combination between SEM and XRD show the presence of ferrous oxide and carbonate minerals is direct indicate of hydrocarbon seepage, because the altered surface is an oxidation zone produced by seepage as shown in fig. (9) & fig. (10), also the field investigations combined with the chemical, spectral and mineralogical analyses in laboratory also demonstrated that these abnormal alterations, revealed by ASTER multi-spectral data, are indeed associated with hydrocarbon seepages.

ASTER band ratio of 2/1 and 4/9 can easily detect iron oxide bearing rocks and carbonate minerals, which can be used to pick out the unaltered rocks and altered rocks. The results show that ASTER multispectral images can detect successfully mineralogical alterations induced by hydrocarbon seepages like bleached red bed and secondary carbonates (formed due to seepages of hydrocarbon), which indirect of the presence of hydrocarbon system at depth.

In case study one as shown in fig. (4) this coincidence may be indicating the presence of fault or fracture system in this area that allow oil and gas escaping from deep reservoir to sea surface, in another place onshore area the alteration samples location and the alteration intensity are mainly related to the fault or fracture system. Moreover the type of hydrocarbon was seeped, and the fractures characterization as well control the type of seepage size is it microseepage or macroseepage.

But, the seismic data show no presence of fault, but the seepage trends found in the same trends of the regional fault and it is not known that the regional fault continue upward to the shallow level (area of interest), so we expect the regional fault may extend to the shallow level or to the surface, and caused seepage of oil, so seepage is one of the strong evidences that support presence of fault system, and in this case fault system in KG offshore may continue to the NE (area of interest) and in some parts this fault may opening up to the surface and allow the seepage.

According to the Radar image results we have twenty-six seepage locations had been identified but it different in the degree of confident medium and low degree of confident as shown in table

(1) all these seepages in along facture zone or fault and this fracture allow escaping oil and gas to the sea surface.

Geochemical data show the gases origin, and it indicates the presence of condensate or wet gas in the subsurface and multi-data satellite data show high extension of this oil stain that indicate lighter seepage of oil. Radar image cover study area many time, the seepages extend and be more bigger, that indicate this oil is more light and easy to move, and lighter oil consider as a high quality oil this confirm geochemical data.

The most components in oil tend to be lost rapidly through evaporation when oil is spilt, and some marine organisms will reduce oil concentration in the marine water especially in the shallow water. Sedentary animals in shallow waters such as oysters, mussels and clams that routinely filter large volumes of seawater to extract food are especially likely to accumulate oil components, as shown in fig (11).

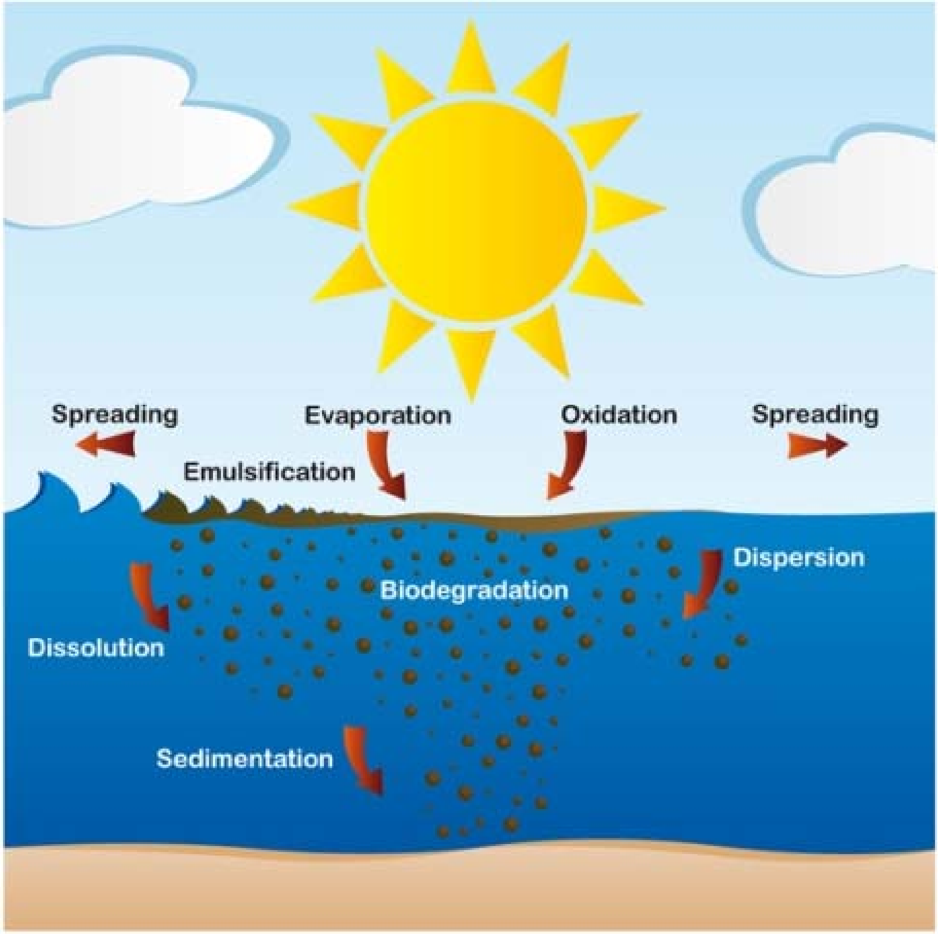

Fig (11): show the Processes influencing weathering of oil in the sea.
(http://oceanworld.tamu.edu/resources/oceanography-book/oilspills.html).

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