STUDY ON OIL-GAS RESERVOIR DETECTING METHODS USING HYPERSPECTRAL REMOTE SENSING

Qingjiu Tian [a, *]

[a] International Institute for Earth System Science, Nanjing University, Nanjing 210093, China-tianqj@nju.edu.cn

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ABSTRACT:

Oil-gas reservoir exploration using hyperspectral remote sensing, which based on the theory of hydrocarbon microseepage information and fine spectral response of target, is a new direction for the application of remote sensing technology. In this paper, Qaidam Basin and Liaodong Bay in China were selected as the study areas. Based on the hydrocarbon microseepage theory, the analysis of crude oil in soil in Qaidam Basin and spectral experiment of crude oil in sea water in Liaodong Bay, Hyperion hyperspectral remote sensing images were used to develop the method of oil-gas exploration. The results indicated that the area of oil-gas reservoir in Qaidam Basin could be delimited in two ways: the oil-gas reservoir can be obtained directly by the absorption bands near 1730nm in Hyperion image; and Linear Spectral Unmixing (LSU) and Spectral Angle Matching (SAM) of alteration mineral (e.g. kaolinite, illite) could be used to indirectly detect the target area in Qaidam Basin. In addition, combined with the optimal bands in the region of visible/near-infrared, SAM was used to extract the thin oil slick of microseepage in Liaodong Bay. Then the target area of oil-gas reservoir in Liaodong Bay can be delineated.
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1. INTRODUCTION

Oil and gas reservoirs hydrocarbon micro-leakage phenomenon is prevalently exist in theory. It is a comprehensive performance of multiple mechanisms transferring along various approaches, about 85% of oil and gas fields have the phenomenon of micro-leakage. For the existence of micro-leakage phenomenon, there are abnormal signs of hydrocarbon component and content of soil and sea surface which above the hydrocarbon reservoirs. By using remote sensed dataset, we can detect the unusual phenomenons of hydrocarbon components in the surface soil and water, and then explore the hydrocarbon content of the land and sea. “Hydrocarbon altered column” and “hydrocarbon alteration halo” which always formed in the land surface that above the hydrocarbon reservoirs become one symbol of land oil and gas exploration. The hydrocarbons that come from the micro-leakage or diffuse to the air above the land surface, or exist in the gaps between soils, or exist in the underground water, or absorbed by the mineral grain of soil, or interact with other materials and then form alternation bodies, they make the spectral characteristics of surface natural landscape abnormal which always display as soil adsorption hydrocarbon halo, haze shaped halo, res layer faded halo, low-value iron enrichment halo, clay halo, carbonate mineralization halo, and so on(Philp et al.,1982). Researches on the elaborate spectral characteristics performed by the hydrocarbons and micro-leakage halo of hydrocarbons in the land surface are the basis of theory and method of finding hydrocarbon by using the hyperspectal technology of remote sensing. Submarine hydrocarbon leakage is one of the phenomena of marine oil and gas reservoirs, and the thin film formed by the hydrocarbons is an important symbol of oil and gas reservoirs at the bottom of the sea. When abnormal range of hydrocarbons reach the status of relative saturation, hydrocarbons in the bottom of the sea continue vertical upward migration by the action of buoyancy, part of hydrocarbons form hydrocarbon-rich sea water column under the role of seawater solvation, a part continue to float to the surface to form thin film, different thickness of the thin film can produce a different color, it will become silver and invisible floating oil film after a few seconds, this special floating film, in theory, is not visible(Almond et al., 2000). The oil layer formed by the stable distribution of the sea floating film above the oil and gas reservoirs leakage source affect the electromagnetic radiation characteristics of sea surface, and thus can be detected by hyper spectral remote sensing technology.

In order to make use of the information of hydrocarbon micro-leakage of the land surface and sea surface to retrieve the spatial distribution of oil and gas using hyper spectral remote sensing. First we should have a better understanding about the land surface hydrocarbon information of the micro-leakage and its alteration mineral as well as spectral characteristics of sea surface oil film. Early due to the limitations of spectral resolution of multispectral sensors, it is difficult to achieve the direct detection of the hydrocarbon information of land surface and sea surface film type; it becomes possible from the air to detect land surface and sea surface oil and gas hydrocarbon information because of the development of hyper spectral imaging spectrometer. Thus probing terrestrial and submarine tectonic region or local trap oil and gas, which can directly or indirectly, exploratory oil and gas reservoirs and delineate the oil and gas drilling target to achieve rapid, large area to find oil purpose, The domestic and foreign scholars have a more unified understanding of hydrocarbons of the land surface oil and gas. The absorption characteristics of oil and gas reservoirs micro leakage to land surface oil and gas hydrocarbons was mainly in the 1720-1750nm, 2310-2350nm wavelength (Cloutis et al., 1989). The absorption feature are stronger at 2310-2350nm, but there is overlap with other mineral absorption features (such as

* Qingjiu Tian: Professor in Nanjing University, China. The main research direction is Hyperspectral remote sensing.

calcite). It requires careful processing and analysis as diagnostic spectral feature of oil and gas hydrocarbons extracted, at diagnostic absorption features is weaker at 1720-1750nm. In order to effectively detect, we need high performance hyper spectral remote sensing instruments. Combing with the hydrocarbon alteration minerals (e.g.: kaolinite, illite, etc.) hyper spectral extraction models, we can also indirectly identify the target filed of land oil and gas reservoirs by using hyper spectral remote sensing technology. After hydrocarbons that naturally leaked from the undersea oil and gas reservoirs rise above the water, it will form a thin film in the sea surface, and then gradually spread to a thinner film layer. At present, the description of oil film is based on a series of changes of oil film in shape and hue, such as strip (Streamer), silver (Silver sheen) (Foudan et al., 2003) and so on, but it also need to distinguish oil films according to the variation of the spectrum of the film to facilitate the hyper spectral remote sensing exploration of oil slicks.

U.S. West Virginia University successfully detected oil and gas microleakage of California, Santa Barbara coast, and found several oil and gas fields between 1998 and 1999 by delineating the distribution of the hydrocarbon leakage of mineral alteration on surface through the AVIRIS Airborne Hyperspectral Imager with 224 bands (Heather, 2003). U.S. Geosat Committee detected the process of hydrocarbon leakage and migration on Australia's Northwest Ocean basins in 2001 by utilizing Probe-1 Hyperspectral Imager with 128 bands, then found several sea thin films with the length about 5-30 meters long sea thin films, and interpreted the distribution and transport of the oil film(Ellis et al., 2001). The GEOSCIENCE Company in Australia detected the process of hydrocarbon leakage and migration on Australia's Northwest Ocean basins in 2001 by utilizing HYMAP airborne hyperspectral remote sensing technology with 128 bands, then found several very thin oil films distribution areas on sea which were formed by the hydrocarbon microleakage of oil and gas undersea, and interpreted the distribution and transport of the oil film (William et al., 2002). After that, they successfully detected the surface hydrocarbon leakage and three undersea hydrocarbon microleakage reservoirs at offshore waters of USA California, Santa Barbara In 2003 by utilizing HYMAP Airborne Hyperspectral Imager with 128 bands which was developed by Hyvist Company in Australian, and combining with the effective identification and semi-quantitative analysis of components of hydrocarbon leakage oil and gas (Horig et al., 2001).

This article mainly researched the land and offshore oil and gas exploration of Qaidam Basin and the Liaodong Bay marine in China by combining with the spectrum of indoor and outdoor observation experiments and using of satellite HYPERION hyperspectral remote sensing technology.

2. REMOTE SENSING DETECTION METHOD OF QAIDAM BASIN RESERVOIS

2.1 Study Area and Hyperion Image Description

SeBei gas filed in the eastern of Qaidam Basin, which located in northeastern of Tibetan Plateau, was chosen as study area. The Geological condition is Saline Lake, saline soil and salt rock. In addition, the district structure is quaternary. The mainly lithology is dark grey sandy shale, with a small part of clay siltstone and brown carbonaceous mudstone. Most of the surface is covered with floury soil and salty sand soil. Groundwater is shallow, the content of salt easy to dissolve is high, much of that is ultra chlorine saline soil, and part salty soil (Palmer et al., 1999; Palmer et al., 1994). Accordingly, the vegetation in this area is sparse, and has less community composition, simple structure and low coverage. It is very suitable to explore oil and gas using hyperspectral remote sensing images for this area. A sight of Hyperion hyperspectral image acquired on August 11, 2005 was selected in the study, and its coverage was shown in Figure 1(© Hyperion Image Copyright 2005). The image coverage is within the scope in favour of developing gas, and the lower image covers most SeBei-2 gas field, lower of which is marsh, while the upper image is Hump mountain anticline structural belt. Hump Mountain and SeBei-1 gas field are respectively located in the upper and lower image. Meanwhile, we can identify clearly a small amount of cloud and cloud shadows.

2.2 Spectrum Experiment and Analysis of Petroleum Hydrocarbon in Soil

We measure the reflectance spectrum of soil with different content of oil in the lab, and analyses the sensibility to spectral response and spectral feature of crude oil in soil. Spectrometric instrument is Field Spec ASD field spectrometer produced in American spectrum Device Company. Spectral range from 350 to 2500nm, with a spectral resolution of 3nm(350-1000nm)and 10nm(1000-2500nm).Putting dry Qaidam soil samples weight of 100g into plastic disc with diameter of 10cm and depth of 2cm, floating with glass bar, and measuring soil spectra without oil and water. Pouring the soil whose spectra had been measured into glass bottle, taking crude soil at a volume of 0.5ml into the bottle using injector, putting the cap on the bottle, shake hardly until crude oil and soil fully mixing, and then putting the soil back the disc and floating, and measure the spectra. Determine repeatedly spectra of soil whose volume dose are respectively 1ml, 1.5ml, 2ml, 2.5ml, 3ml, 3.5ml, 4ml, 4.5ml, 5ml, 5.5ml, 6ml, 6.5ml, 7ml, 7.5ml, 8ml, 8.5ml and 9ml .

Measuring the spectrum of soil with different content of crude oil for five times, taking the average to mapping, and then comparative analyzing. As shown in Figure 1, with the increasing of the content of crude oil in soil, reflectance spectra curve present the following features: (1) the reflectance of whole spectrum curve is lower and lower; (2) the decrease of reflectance value of overall spectrum curve is more and more slowly; (3) gradually increased the double absorption peak feature occur around 1748nm, the primary peak around 1726nm, and the secondary around 1761nm, and their feature are more and more obvious; (4) gradually increased the double absorption peak feature occur around 2330nm, and their absorption depth increased gradually, primary and secondary peak feature is not obvious.

Double absorption peak feature around 1748nm and 2330nm diagnosing that whether the soil contains oil hydrocarbons (Cloutis et al., 1989; Ellis et al., 2001). As shown in Figure 1, the peaks are located at 1670nm and 1748nm, around 1748nm. The primary absorption of the valley at 1726nm begins to occur when the content of crude oil in soil is up to 1.5ml/100g. As CO_3^- in soil at 2350nm generates the absorption feature that wide at left but narrow at night (Foudan et al., 2003), the absorption peak composing of three bands at 2330nm, 2348nm and 2348nm has already existed before adding crude oil. Moreover, with the increasing of the content of crude oil in soil, the reflectance values at 2308nm and 2349nm tend to be equal.

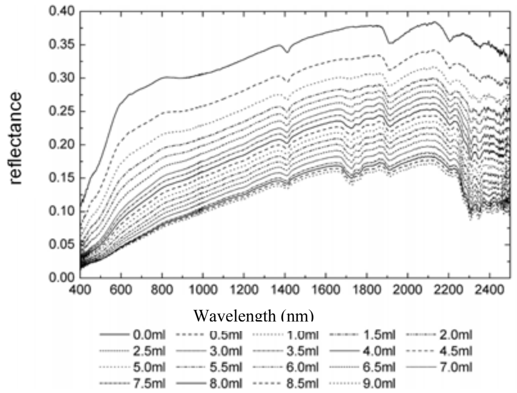


Figure 1. Comparison of different amount of crude oil in soil spectrums

Deducing from the above analysis that when the content of crude oil in soil is little, the diagnose characteristic of double absorption at 1748nm and 2330nm for petroleum hydrocarbons in soil is very weak or not, and vulnerable to be interfered by other soil composition, so that reduces the accuracy of detection result using the feature for petroleum hydrocarbons in soil; when the crude oil is up to certain amount, it can make a hyperspectural remote sensing detection for soil with petroleum hydrocarbons using the diagnosis characteristic of spectrum.

2.3 Hyperion Images Processing and Analysis

As the analysis method for hyperspectral data developed by AIG(Analytical Imaging and Geophysics LLC), we select 196 independent valid bands from the original 242 bands; get rid of 22 bands affected strongly by vapour within the spectrum range around 1356-1417nm, 1820-1932nm and over 2395nm. Checking out the remain 175 bands one by one, and repairing the bad line with average on its adjacent columns or rows; removing the serious strip abnormal in some bands(especially SWIR band) using global balance method; correcting the smile effect in images by minimal noise transformation; convert the radiation image calibrated into apparent reflectance image with ENVI FLAASH atmosphere correction module; at last, based on the Landsat7 ETM image in the same coverage area, choosing the ground control points(97 points)by interactive method and correcting Hyperion image with a correct polynomial by the most neighboring sampling and control the precision within half of a pixel.

Extracting some spectrum of typical pixels in the SeBei gas field from the Hyperion reflectance image. The following features can be known: (1) water absorption at 1.35μm and 0.93μm is very obvious, the water absorption at 1.4μm and 1.9μm is strong and wide, and these water bands have large influence on neighbouring data; (2) the absorption feature of ferric ion is visible at 0.5μm and0.7μm, and the absorption bands of water and oxygen result in less obvious performance for the absorption ferrous ion; (3) the absorption of hydroxyl ion at 2.2 is obvious; (4) carbonate ion absorption at 2.31-2.35μm is evident, and some curves show the double absorption feature at 2.31μm and 2.35μm; and this show the absorption feature of Hydrocarbon key(C-H)within the bands; (5) the absorption of hydro carbons occur within bands range from 1.72 to 1.75μm; but is not obvious, as the content hydro carbons in soil is small, and the presence of mixed pixel due to the low spatial resolution of 30m.

2.4 The Extraction of Hydrocarbon Information Using Hyperion data

The hydrocarbon microseepage information of oil/gas deposits either onshore or offshore can be directly detected using hyperspectral remote sensing data, of which identifying the distinct absorption features related to micoseepage is the key element. Taking full advantage of remote sensing technology, microseepage information can be determined through the spectral absorption signature in the above surface. The established Three-Band-Ratio algorithm amplifies the absorptive signature, which utilizes the ratio of the spectral absorption feature in 1748nm or 2330nm (point b and reflectance: Rb) of hydrocarbon in soil and the reflectance (Ra, Rc) of two points (a, c) in the shoulder of the above absorption feature. The ratio can be calculated as follows:

$$HI = (\lambda_B - \lambda_A)\frac{R_C - R_A}{\lambda_C - \lambda_A} + R_A - R_B \quad (1)$$

Where Ra; λa, Rc;λc= the reflectance/wavelength pairs for the two shoulder points of the absorption feature.

Values of HI can be a good indicator of hydrocarbon microseepage information: if HI>0, the value means the existence of hydrocarbon microseepage; additionally, the lager the value, the lager the hydrocarbon concentration it represent.

Based on the Three-Band-Ratio algorithm and Absorption-Depth method noted above, Remote Sensing images are used to explore the presence of hydrocarbon. For Hyperion data, the reflectance values for λa, λb, λc, wavelengths of 1699.4nm, 1729.7nm, and 1749.79nm are chose respectively. The values of HI result from the Hyperion hyperspectral data (EO1H1370342005223110KV.L1R) required in august 11th, 2005 are shown in Figure2 (a), and Figure2 (b). Results of the two methods are almost consistent comparing the images: high values locating in the Camelback Mountain gas-bearing structure-north part of our study area as well as a nearly linear distribution along with the Camelback Mountain structure. Additionally, there also exist some high value points in area of SeBei Gas Field. Since human eyes are more sensitive to color hues than to gray tones, a colorful hydrocarbon microseepage image is composited using band155 (1699.4nm), band165 (1800.29nm) and the above calculated HI gray image (Figure2(c)). In the Figure 2, Blue hues which express the information of hydrocarbon, indicate that the deeper of the its hue, the more hydrocarbon microseepage concentration.

Image Figure 2(c) shows that hydrocarbon microseepage areas, for which the blue hue region of the image stands, located obviously in two areas: the south SeBei Gas Field and the North Camelback Mountain gas-bearing structure of the study area. Given that hydrocarbon, concentration might be high in soil near Gas Field, and it is reasonable that there might be obviously hydrocarbon microseepage along the Camelback Mountain gas-bearing structure fraction, information concluded from the calculation coincides well with known the natural gas and anomaly gas distribution.

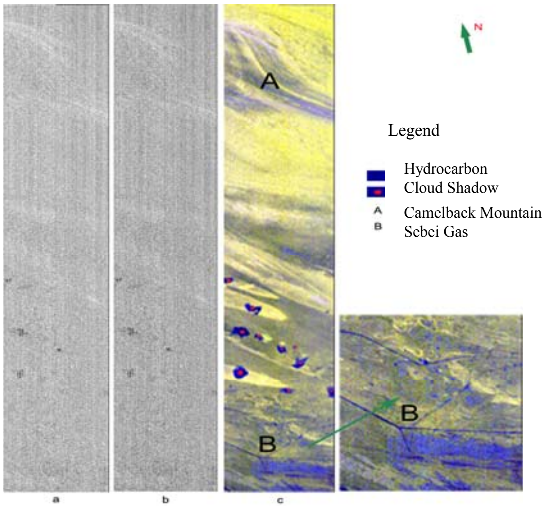


Figure 2. Extraction of Hydrocarbon Seeps

2.5 The Extraction of Alteration Minerals Using Hyperion data

The identification of alteration minerals using Hyperspectral Remote Sensing can detect hydrocarbon microseepage and locate oil/gas deposits indirectly. This article combines the method Linear Spectral Unmixing (LSU) and algorithms of Spectral Angle Matching (SAM) for determining the mineral composition counterparts of hyperspectral Remote Sensing endmember. Identification precision is enhanced by using methods of subtracting the hyperspectral image bands rationally and algorithms of determining endmembers. What is more, integrating materials derived from field surveys of geology, a complex progress ensures the accuracy of image endmembers' corresponding minerals concentration and composition. According to the geochemical data of mineral composition, our studying area is characterized by three main alteration minerals: clay minerals (of which illite is the represent type), carbonate minerals (of which calcite is the represent type) and other minerals (of which rock salt is representing).

Spectrums of the three minerals noted above are obtained from reference JPL spectral library. Application of linear mixing for different proportions of the three minerals, control increment of 5% each time, a group of simulation spectrums are derived, with intervals containing both clay and carbonate's common absorption features at wavelengths from 2.0 to 2.5μm. Efforts to find the best matching simulation spectrum for endmember have been made by using SAM and SFF spectral analysis methods at the same time. Supposing that simulation spectrum's counterpart minerals composition can be termed as the corresponding composition of mixed minerals to endmembers, the mixed minerals concentration and composition as counterpart of endmembers are determined by combining the field survey geology materials simultaneously.
Figure 3 shows the identification results of alteration minerals using SAM algorithms. Rock salt and carbonate minerals of high concentration are concentrated at the upper-middle part of the image, where the true colour composite image appears a greyish high reflection area. The area is characterized of development of yardang landform and the surface of the land is covered by saline sandy soil (of which silicon and rock salt are the main form), and the abundance of fragments of carbonate, sand, and rock salt might be result in the weathering and sedimentary movement. Meanwhile, a minor concentrate also exist in the top of Sebei Gas Field's 2 well, for the reason that seeping hydrocarbons reaching the near-surface as well as the moisture environment near marsh generate a circumstance of deoxidization leading to the carbonate's alteration. What is more, the moisture surface environment can also facilitate the rising of concentration of rock salt.

The main distribution of high concentration of illite and carbonate near Sebei Gas Field's 2 well and marsh area coincidents with the petroleum indication of our studying area. As is known to us that Gas Reservoir is a concentrating place of hydrocarbon, the exploit of gas and the moisture condition near marsh area contribute greatly to the region's alteration of clay and carbonate minerals. Banded spreading areas similar as known petroleum indications along Camelback Mountain anticlinal structure can be illustrated by that seeping hydrocarbons are present in the form of transversely cutting off the structure, and in fact cause the abundance of clay minerals and carbonate minerals alteration.

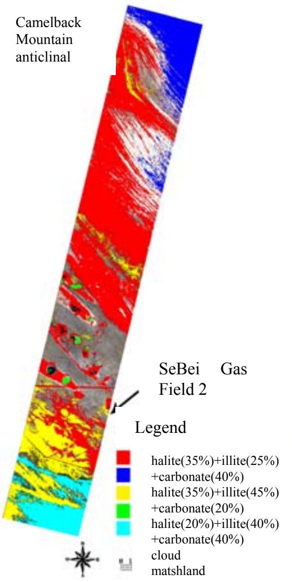
Figure 4 shows the identification result of alteration minerals by using LSU algorithms. Identification result exposed more serious problems such as mixture type of minerals, overlapping, and the underrate of distribution area (Figure 4) than SAM, which turns out that the areas of alteration minerals derived from LSU method are smaller than that of SAM, as well as some difference in locations of minerals.

Several minerals do not emerge in the anticipated area according to the identify result. For example, illite and carbonate of high concentration seldom appear in the SeBei Gas Field and Camelback Mountain anticlinal structure. The difference might be attributed to the algorithms. SAM measures similarity by calculating the angle between the N-Dimension space reference spectral (endmembers spectral) and the unknown spectral (Hyperion image spec tral) whose result is subject to spectral shape, but of little relevant to spectral reflectance. However, method LSU suffers from effects both spectral shape and reflectance. The SeBei Gas Field 2 well Camelback Mountain anticlinal structure leading to a development of yardang landform, as well as its near to marsh, a moisture soil altogether contribute to the depressing of reflectance, posing a situation that while identification worked for SAM algorithm, it does not feasible for LSU method.

Conclusion: based on alteration minerals' diagnostic absorption spectral feature and the low signal-to-noise ratio of Hyperion, assuming the mixture of the 3 minerals' spectrum noted above consists the endmember spectrum of image in this study, a combination of method Linear Spectral Unmixing (LSU) and algorithms of Spectral Angle Matching (SAM) can effecively determine the mineral composition counterparts of hyperspectral image endmember. A resampling result of Hyperion's 175 bands has been used to identify the alteration minerals using both SAM and LSU methods. Accessing the identification precisions of different methods, the comparison result indicates that a resampling-based SAM method fits the known gas reservoir distribution best.

class	SAM		LUC	
	area	ratio	area	ratio
halite(35%)+illite(25%) +carbonate(40%)	160.0	37.4	117.9	27.5
halite(35%)+illite(45%) +carbonate(20%)	34.4	8.0	22.1	5.2
halite(20%)+illite(40%) +carbonate(40%)	47.4	11.1	21.0	4.9
cloud	1.6	0.4	0.7	0.2
matshland	26.1	6.1	20.1	4.7
un-classified	158.8	37.1	246.5	57.6

Table 1. Comparison of SAM and LSU results of Hyperion image



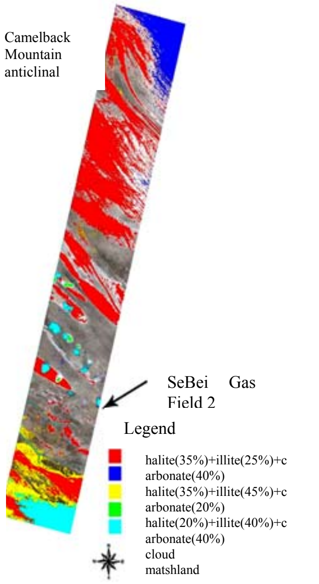


Figure 3. Identification results of alteration minerals with SAM
Figure 4. Identification results of alteration minerals with LUC

3. METHOD OIL-GAS RESERVOIR DETECTING IN LIAODONG BAY

3.1 Study Area and Hyperion Image

Submarine topography in Liaodong Bay falls from the top, east and west side to the centre. The maximum depth of it is 32 m and the top of the Bay is connected with Liaohe Plain. Liaodong Bay, the submarine of which is gentle, is great influenced by the mainland. And lots of rivers pour into it. What's more, Liaodong Bay is the third biggest oil and gas field in China. The submarine is rich with oil and gas, which lead to the significant microseepage. In this paper, four adjacent Hyperion images were separately obtained in October 2006 and in May 2007(© Hyperion Image Copyright 2006, 2007). These images are not only covered with the detected or being exploited oil-gas fields, but also included with areas which are serious polluted by land-sourced pollutants in the estuary of Shuangzi and Daliao River. At last, the reflectance images were calculated by the methods in Section 2.3

3.2 Spectrum Experiment and Analysis of Oil Slick

The experiment was conducted in the tranquil gulf which is near the estuary of Shuangzi River. The crude oil samples from Liaodong Bay were selected as experiment material and FieldSpec-FR was chosen as equipment. In the experiment, tiny crude oil was dropped into water. Then the oil slick was diffused from light yellow, yellow and translucent to iridescent (very thin oil slick). To measure the spectrum of different oil slick above, FieldSpec-FR was kept with the same angle and height during the experiment. Finally, the mean value of three spectrums of each oil slick was calculated.

The result of the spectrums was shown as Figure 5. The reflectance of water which was covered with oil slick was higher than that without it. The characteristics were more obvious in the visible light region (The wavelength is less than 701nm that corresponding to b1-b7 in Hyperion image). When the wavelength is less than 508nm (corresponding to b6 in Hyperion image), the reflectance of water which was covered with oil slick was higher than sea water, while the slope which was indicated the changing rate was lower. Besides, the absorption feature was shown gradually in the range of 350nm-508nm with the decreasing of the oil slick's thickness. And the characteristic absorption peaks of oil slick reflectance were not obvious except in the region of ultraviolet to blue.

It can be found that the available range of wavebands was mainly in visible range. What's more, the range of wavebands could be increased to 895nm combining the analysis of the curves of Hyperion images. In addition, only 47 bands of Hyperion image can be used in our study because of the non-calibration bands (Band1-Band7).

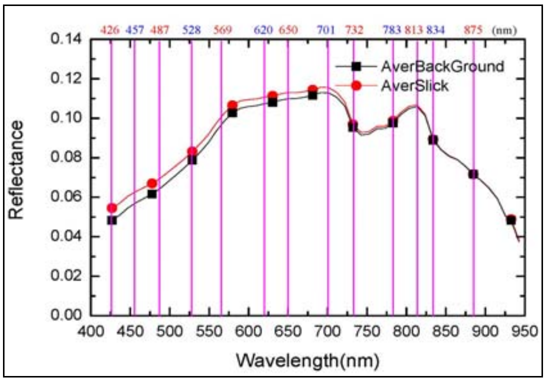


Figure 5. Reflectance of the offshore thin oil slicks

3.3 Extraction of Oil Slick in Liaodong Bay

Water bodies were first isolated from the four scenes Hyperion images. On this basis, spectral angle mapper (SAM) was used to extract petroleum hydrocarbon on the sea surface. Then according to the analysis, differences of spectral characteristics between water which was covered with oil slick and the one without it can be reflected on the bands with the central wavelength of 426nm, 426nm, 457nm, 487nm, 528nm, 569nm, 620nm, 650nm, 701nm, 732nm, 783nm, 813nm, 834nm and 875nm in Hyperion image. Hence, oil slick can be extracted by the bands and their combinations above.

In the oil slick extraction process, average spectrums of different oil slick obtained from the experiment were chosen as reference spectrums. The spectrums above were first resampled to have the consistent band numbers and wavelength. Then the resampled spectrums and the maximum spectral angle 0.05 were used to classify. The classification result of SAM was shown as Figure 6. Comparison with the result and a known distribution map, the extraction effect of oil slick was good.

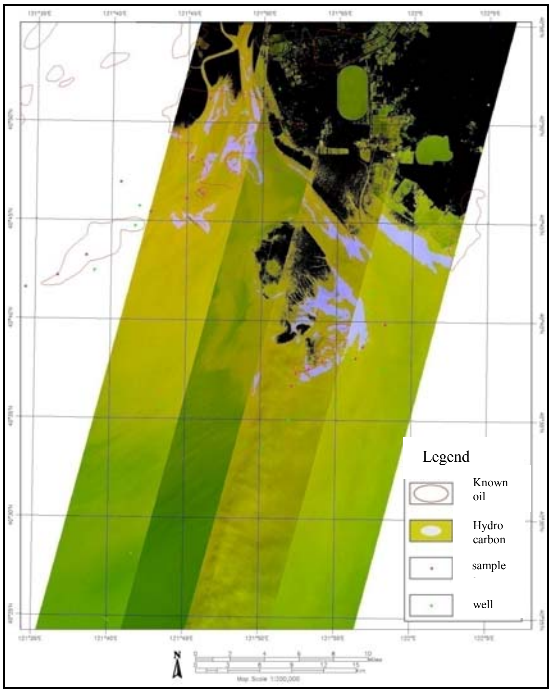


Figure 6. Hydrocarbon information extracted from Hyperion image by SAM

4. RESULTS

(1) When the content of crude oil in soil is little, the double absorption characteristic in 1748nm and 2330nm for petroleum hydrocarbons in soil is very weak, and it is easy to be interfered by other soil composition. Then the accuracy of detection using the feature for petroleum hydrocarbons in soil was reduced. When the crude oil is up to certain amount, it can make a hyperspectural remote sensing detection for soil with petroleum hydrocarbons using the diagnosis characteristic of spectrum.

(2) The reflectance of water that was covered with oil slick was higher than seawater, while the slope that was indicated the changing rate was lower. The broad absorption feature was shown in 508nm with the decreasing of the oil slick's thickness. And the absorption characteristic peaks of oil slick reflectance were not obvious in the other band regions.

(3) Based on the three bands in Qaidam Basin's Hyperion image, which was near the absorption characteristic peaks in 1730nm, Three-Band-Ratio algorithm and Absorption-Depth method were used to extract oil-gas hydrocarbon and delineate the target area of oil-gas reservoir.

(4) Based on the identification of characteristic spectrum of alteration mineral and Hyperion image in Qaidam Basin, Linear Spectral Unmixing (LSU) and Spectral Angle Matching (SAM) can be used to determine he mineral composition counterparts of endmember. Then the target area of oil-gas reservoir can be determined indirectly.

(5) Combining with the optimal bands in the region of visible/near-infrared, Spectral Angle Matching (SAM) was used to extract the thin oil slick of microseepage in Liaodong Bay. In addition, the spectral angle was determined by experience.

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