鄂尔多斯盆地地表烃类的遥感探测研究*

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摘　要　利用遥感技术进行了鄂尔多斯盆地地表烃类的遥感探测研究。分析了鄂尔多斯盆地由于烃类微渗漏造成的"褪红"、粘土矿化、碳酸盐化及热惯量和地温异常等地表异常标志的成分特征与光谱响应。发现油区土壤具有典型"褪红"蚀变、粘土矿化与碳酸盐化的成分特征,"褪红"蚀变可造成油区土壤 TM1/3 和 TM2/3 的增高, 粘土矿化和碳酸盐化可造成油区土壤 TM5/7 增高。利用比值主成分分析方法从 TM 图象中提取出本区烃类综合蚀变信息。指出了乌审旗—榆林北、伊金霍旗—准格尔—神木、靖边—横山—乌审旗—盐池和环县—吴旗—延安等四个异常区。这些地表烃类异常区(带)与已知油气田和现有勘探结果具有较高的空间吻合率。

主题词　鄂尔多斯盆地　星载遥感　遥感图象　烃类异常

鄂尔多斯盆地在下古生界、上古生界、中生界延长组和延安组四套地层中发现了油气藏, 而上覆地层主要为第四纪黄土, 长期的烃类微渗漏必将影响表层和地物的理化状况。因此对全盆地地表烃类微渗漏特征、地表烃类的富集状况及地表烃类蚀变的时空分布规律的探测和评价, 对盆地含油气性的研究、评价与勘探及对鄂尔多斯盆地深盆气的认识等方面都有着重要的意义。本次研究采用了 TM 遥感图象进行地表烃类微渗漏及相关蚀变的探测和评价。近年来随着遥感技术的发展, 尤其是遥感器几何分辨率与光谱分辨率的提高, 人们已可以利用遥感技术直接探测到由于长期烃类微渗漏而造成的地表地物矿物成分甚至化学成分的微弱变化[1, 2]。这项技术已在国内外许多含油气盆地获得了成功应

说明本区碳酸盐岩相对富含沥青, 有良好的生油气潜力。这和前述还原环境的存在有利于原始有机质保存和烃源岩形成的地质—地化背景相符。在北部东区(因西区无 O_1x 样品, 无法比较), O_1s 的 II级样品约占有 26%, O_1x 则缺少 III级, 显示 O_1x 优于 O_1s, 这和前述 O_1x 总沥青含量高于 O_1s 是一致的。

结　论

1) 鄂尔多斯盆地北部下奥陶统马家沟组碳酸盐岩中普遍观察到了各种不同类型的沥青。从大多数沥青赋存产状和部分荧光色层分析, 这些沥青可归属原生—同层沥青。

2) 原生—同层沥青中基质型沥青代表了碳酸盐岩中原始有机质的输入和向烃类的转化(沥青化), 而充填型沥青则指示了所生成烃类的排驱和初次运移(形成初次运移沥青), 两类沥青的存在对烃源岩的判识提供了最直观可信的岩石学依据。

3) 原生—同层含量可作为烃源岩评价的重要指标, 尤其在高演化碳酸盐岩烃源岩评价中更具有实际意义。

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用[3~7]。其主要原理是含油气盆地地下油气藏长期的烃类微渗漏会造成地表烃类的富集, 并对表层和地物(如土壤、岩石和植被)的理化状况造成改变, 使得地物在可见—近红外及热红外波段的反射光谱发生变化, 而这种变化可以为卫星遥感器所捕获。通过对卫星遥感数据的处理可以将这些微弱的信息突出出来, 从而达到直接探测和评价地表烃类蚀变的目的[8]。

烃类微渗漏及其蚀变的地表异常标志与光谱响应

烃类长期的微渗漏必将引起地球化学环境的改变。这种长期的环境改变必将使表层地物岩石、矿物、土壤的理化性质、组成成分发生改变, 这就是烃类蚀变或烃类蚀变异常[3]。其中具有较高遥感光谱响应的烃类蚀变有: ①"褪红"蚀变, 即由于烃类微渗漏造成土壤或岩石中 Fe^{2+} 含量的增加和 Fe^{3+} 含量的降低; ②粘土矿化和碳酸盐化蚀变, 即由于烃类微渗漏造成土壤或岩石中粘土矿物和碳酸盐矿物含量的增加; ③热惯量异常和地温高异常。这些异常有些很明显, 肉眼都可识别, 有些则很微弱, 肉眼无法识别, 但都可以通过一定的技术将其提取出来。

对异常标志如何进行提取是利用遥感技术进行烃类检测的核心。现将烃类蚀变的标志、光谱响应与信息提取方法及在鄂尔多斯地区的应用简述如下。

1."褪红"蚀变及低价铁富集的光谱特征

"褪红"蚀变的光谱特征直接关系到对褪红蚀变的提取。已知 Fe^{3+} 的吸收峰在 0.9 μ 附近, Fe^{2+} 的吸收峰在 1.0 μ 附近。另外, 二价铁矿物在 TM3 波段的反射率相对于 TM1–2 波段和 4 波段要高, 而三价铁矿物在 TM3 波段的反射率相对于其它波段并不突出。表1列出了鄂尔多斯地区典型油区和非油区土壤样品的 Fe^{2+} 和 Fe^{3+} 的含量及 TM 波段比值的统计值。

表 1　油区与非油区土壤铁含量与 TM 反射率比值对比表

项　目	含 Fe_2O_3 (%)	含 FeO (%)	TM1/3	TM2/3
非油区样点	3.61	0.57	0.630	0.796
油区样点	0.70	1.08	0.842	0.929
差　值	2.91	0.51	0.212	0.133

可以看出: 油区土壤样品具有典型"褪红"蚀变的化学组成, 即 Fe^{2+} 含量高, Fe^{3+} 含量低。油区与非油区土壤相比在 TM1 和 TM2 波段反射率都升高, 而在 TM3 波段反射率变化不大甚至略有降低。利用这一变化, 可以使用比值法来确定"褪红"蚀变的强度。在上表中列出 TM1/3 和 TM2/3 在油区和非油区的对比, 可以看出, 油区土壤具有较高的 TM1/3 和 TM2/3。这就是采用这两个比值提取"褪红"蚀变信息的原因所在。

2. 粘土矿化和碳酸盐化的光谱特征

粘土矿物和碳酸盐矿物的吸收峰集中在 TM7 波段。强的粘土矿化和碳酸盐化可以引起 TM7 波段反射率的下降。通过综合对比本区典型油田和非油区上方土壤的光谱曲线, 可以明显地发现油区土壤在可见—近红外波段明显低于非油区土壤。表 2 中列出了油区与非油区土壤样品矿物平均含量与 TM 各波段平均反射率对比情况。

表 2　油区与非油区土壤矿物成分及 TM 波段反射率对比表

矿物成分含量	蒙脱石	伊利石	高岭石	绿泥石	方解石
油区样点	6.91%	9.15%	3.18%	2.56%	1.30%
非油区样点	3.66%	7.58%	2.72%	1.06%	0.38%
差　值	3.25%	1.57%	0.46%	1.50%	0.92%

TM 反射率	TM1	TM2	TM3	TM4	TM5	TM7	TM5/7
油区样点	16.95	21.74	30.72	33.73	46.79	35.24	1.328
非油区样点	21.68	32.65	41.46	42.89	50.87	47.82	1.064
差　值	4.73	10.91	10.72	8.16	4.08	12.58	0.264

由表 2 可以看出: ①油区土壤中粘土矿物和碳酸盐矿物方解石含量明显高于非油区土壤, 具有典型的"粘土矿化"和"碳酸盐化"特征, 其中以蒙脱石化和伊利石化最为显著, 其次为方解石化、绿泥石化和高岭石化; ②油区土壤在 TM 各波段平均反射率明显低于非油气区土壤, 其中 TM7 波段降低幅最大, 达 12.58, 这是由于粘土矿物和碳酸盐矿物的吸收峰主要集中于这个波段而造成的; ③表中 TM5/7 的对比也很明显, 即油气区具有高的 TM5/7, 这对信息提取至关重要, 可通过比值法突出粘土矿化和碳酸盐化信息。

3. 热惯量异常和热异常的光谱特征

研究表明油区具有高的热惯量并存在热异常。卫星热红外通道具有较高的温度分辨力(达 1~2 ℃), 温度响应在 TM6 波段, 因此常用来提取热异

常信息。

地表烃类信息的提取方法

几种烃类异常标志在 TM 遥感图象上都有一定的光谱效应,但都十分微弱,因此增强信号就成了提取这些信息的关键。围绕这个问题国内外专家发展了许多技术,较成功的有比值及组合比值法和主成分分析法[8,9]。其中比值—主成分分析法是一种较有效的信息提取方法。结合上述分析,在鄂尔多斯地区确定了下列信息提取方法。

1) TM1/3 提取“褪红”蚀变信息。具体方法为:对 TM1 和 TM3 波段数据进行大气散射校正,通过比值法生成 TM1/3 比值图象,对比值图象灰度做概率分布检验,确定全区 TM1/3 的背景值及异常下限值,将灰度值大于异常下限值的象元提取出来,最终生成“褪红”异常专题图象。

2) TM5/7 提取粘土矿化及碳酸盐化信息:对 TM5 波段及 TM7 波段灰度作比值运算,对比值图象作分布检验、背景值及异常下限值的确定[10],最终生成粘土矿化和碳酸盐化蚀变专题图象。

3) 对 TM6 波段原始图象灰度经过分布检验、背景值及异常下限确定,最终生成区域热异常图象。

利用上述方法所形成的异常信息还是十分微弱的。主成分分析方法可以对几种异常图象进行方差极大旋转,将一些微弱的信息集中于几个互不相关的主向量,有助于突出这些微弱的信息。在本区也进行了比值异常图象的主成分分析,表3为鄂尔多斯盆地东西两部分的比值主成分分析特征向量矩阵,从中可看出第一主分量主要反映 TM5/7 信息,第二主分量主要反映 TM1/3 信息,第三主分量主要反映 TM6 信息。从表 3 也可以看出,本区烃类蚀变信息以粘土矿化与碳酸盐化信息为主,其次是“褪红”蚀变信息,第三为热异常信息。综合上述三个利用主成分分析异常图象,将等级大于背景值加二倍标准差的象元提取出后生成烃类蚀变信息综合图象或综合强度图象。为了突出异常同时也要求地物清楚,选择 TM5 波段作背景,赋予绿色,TM3 波段赋予蓝色,异常赋予红色,由此合成了鄂尔多斯盆地全区地表烃类检测图。图象整体呈蓝绿等冷色调,水体呈蓝色,异常呈红—橙—黄色,地物也十分清晰。

表 3　鄂尔多斯盆地东、西两部分 TM 比值图象主成分分析特征向量矩阵

区域	比　值	第一主因子	第二主因子	第三主因子
西区	主向量特征值	7 487.9	192.7	81.0
	TM1/3	0.112	0.914	0.210
	TM5/7	0.778	-0.223	0.357
	TM6	-0.511	0.011	0.718
东区	主向量特征值	8 810.9	1 174.9	145.9
	TM1/3	-0.251	0.994	-0.270
	TM5/7	0.916	0.018	0.370
	TM6	0.001	0.021	0.614

结 果 分 析

从异常的形态看,基本呈零星点状分布,从其空间分布特征来看,地表烃类异常集中的分布区主要有以下几个(见图 1)。

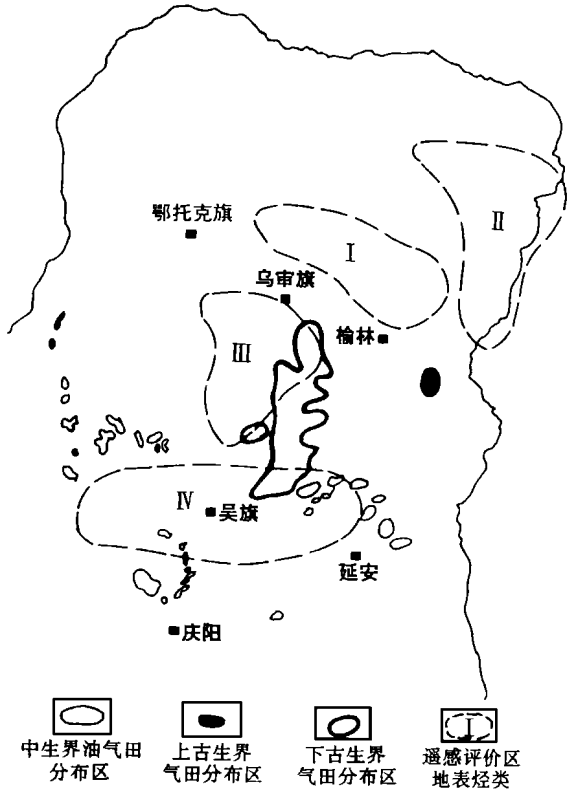

图 1　鄂尔多斯盆地地表烃类遥感探测及评价图

1) 乌审旗—榆林北异常区(Ⅰ):该异常区主要位于榆林、乌审旗、乌审召及秃尾河所围限的近椭圆形区域内,分布集中,是本区最强的地表烃类蚀变聚集带,构造位置上该异常位于陕北斜坡东北边缘与伊盟隆起的交接部位,也是下古生界东部生气中心北部及上古生界北部生气中心的东边缘,是中部气田的上倾方向。另外在伊盟隆起的南部(如鄂 5、鄂 8 井)都在奥陶系风化壳钻遇高产气流,是奥陶系气藏的预测远景区。因此该烃类异常区与中部气田及

伊盟预测区长期的烃类微渗漏有密切关系。

2) 伊金霍旗—准格尔—神木异常区(Ⅱ) : 该异常区位于盆地的东北部, 构造上属于伊盟隆起的东部及伊盟隆起、陕北斜坡和晋西挠褶带交接的三角部位及上古生界镇川堡、子洲气田的上倾方向。这与已有化探资料吻合很好, 与盆地东北部分布的油苗带吻合较好, 有资料表明这些油苗主要来自上古生界的煤系烃源岩, 所以该异常可能是上古生界气在陕北斜坡的北部遮挡造成的。如果是这样, 对于盆地上古生界深盆气的认识是一重要证据, 从遥感图上看, 其蚀变强度和分布都是比较强的。

3) 靖边—横山—乌审旗—盐池异常区(Ⅲ) : 该异常是盆地中部近环状分布的异常区, 位于下古生界盆地靖边鞍部与西部生气中心(即盐池凹陷) 的交汇部位。与化探、钻探及地震吻合得非常好, 是中部气区勘探的一个新目标。

4) 环县—吴旗—延安异常区(Ⅳ) : 呈面状、星点状分布, 与盆地南部油苗区吻合较好, 与中生界油区及化探结果空间分布基本一致, 所以这一异常蚀变带主要来自中生界油田的烃类。

从盆地地表烃类的空间分布及其与油气田的空间位置来看, 具有以下特征: ①地表烃类异常区(带) 与已知油气田(包括中生界、上古生界及下古生界油气田) 都具有较高的空间吻合率, 反映出这些地表烃类异常区(带) 是油气田烃类长期微渗漏的结果; ②地表烃类异常区(带) 集中分布于构造交接部位或气田的上倾遮挡方向(如Ⅰ、Ⅱ和Ⅲ区) , 反映出烃类沿构造裂缝微渗漏而造成地表烃类蚀变的特征; ③在目前勘探基础上, 地表烃类遥感探测结果和已有化探、钻探及地震等勘探成果具有较好的吻合性, 反映了在北方黄土—沙漠地区地表烃类遥感探测的可行性; ④对于地表烃类异常区, 还须结合其它资料进行详细评价, 通过基于 GIS 的遥感—非遥感资料的复合, 可以对盆地烃类的聚集评价提供新的信息。

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OF FEIXIANGUAN FORMATION IN DUKOUHE GAS FIELD IN EAST SICHUAN

Yang Tianquan, Huang Xianping and Zhou Xiao (Research Institute of Geological Exploration and Development, Sichuan Petroleum, Administration). *NATUR. GAS IND.* v. 19, no. 6, pp. 11~13, 11/25/99. (ISSN 1000-0976; **In Chinese**)

ABSTRACT: The gas reservoir of Feixianguan Formation, Lower Triassic, in Dukouhe gas field is one of the important gas reservoirs found in Sichuan Basin in recent years and also is the gas reservoir with the best quality reservoir beds and the most abundent resources in comparison with the gas reservoirs found in Feixianguan Formation in East Sichuan at present, being of predicted gas-bearing area of more than 100 km^2 and gas resource extent of tens of billions cubic metres. The reservoir rocks of the gas reservoir are mainly the residual oolitic dolostones formed by dolomitization, then the oolitic limestones; the effective thickness of the reservoir bed is large, because the pores, cavities ard fractures are developed in it and make it be of multiple void types; the storage rooms are mainly the residual intergrannular and intragrannular solution pores and cavities; and the fractures and pore throats are the migration channels. The gas reservoir belongs in lithological trap, being of the properties of normal pressure and high hydrogen sulfide content. There are five lithological traps predicted by seismic exploration at the nearest Wubaochang region, being of gas resources of tens of billions cubic metres, where may be taken as the important exploration targets.

SUBJECT HEADINGS: Sichuan Basin, East, Early Triassic epoch, Reservoir, Ooide, Dolostone, Source-Reservoir-Cap assemblage, Gas reservoir formation, Exploration region

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AN ANALYSIS OF THE ORIGINAL-COEXISTING BITUMEN IN LOWER ORDOVICIAN IN EERDUOSI BASIN

Wu Zheng and Yang Yuanchu (Chengdu College of Technology) and Wang Xinhong (Xiamen University). *NATUR. GAS IND.* v. 19, no. 6, pp. 14~17, 11/25/99. (ISSN 1000-0976; **In Chinese**)

ABSTRACT: Through an organo-petrological observation on the carbonate rocks in Majiagou Formation of Lower Ordovician in the north part of the basin for near one hundred times, it is found that the existing form of the bitumen in the carbonate rocks is various, being roughly divided into matrix type and filling type. The former is dispersed, floccular and bedded and the latter is mainly the pore-cavity type (including the intercrystalline pores, intercrystalline solution pores and anhydrite moldic pores) and fracture type (including the stylolites and structural fractures). According to various existing forms (occurrences) of the bitumen mentioned above and the chromatographic effects of the hydrocarbon, such kind of bitumen is belonged in the original-coexisting bitumen. It is considered that the generally existing matrix-type bitumen represents the entrance of the original organic matters and their transformation into oil and gas (forming original bitumen) but the filling-type bitumen indicates the displacement and primary migration of the neogenic oil and gas (correspondently forming primary migration bitumen). Exactly because of the coexistance of the original bitumen and primary migration bitumen, the most audio-visual and creditable petrological basis can be provided for determining the carbonate source rocks. In addition, according to the roughly positive correlation between the original-coexisting bitumen content and the residual organic carbon or pyrolytic hydrocarbon-generating potential, etc., it is further indicated that the original-coexisting bitumen content may be taken as an important index of evaluating the carbonate source rocks (especially the high-evolution carbonate source rocks). In view of the above, the evaluation of hydrocarbon-generating potential was carried out for the carbonate rocks in Majiagou Formation in the north part of the basin.

SUBJECT HEADINGS: Carbonate rock

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AN INVESTIGATION ON REMOTE SENSING PROSPECTING FOR THE SURFACE HYDROCARBONS IN EERDUOSI BASIN

Wang Yunpeng, Geng Ansong and Liu Dehen (Guangzhou Institute of Geochemistry, Academia Sinica). *NATUR. GAS IND.* v. 19, no. 6, pp. 17~20, 11/25/99. (ISSN 1000-0976; **In Chinese**)

ABSTRACT: An investigation on prospecting for the surface hydrocarbons in Eerduosi Basin was carried out by use of

remote sensing technique. The composition properties and spectral responses of the surface anomaly marks, as the "red-fading" clay mineralization, carbonation, thermal inertia anomaly and geothermal anomaly, which were formed by the micro-leakage of hydrocarbons, in Eerduosi Basin are analyzed in the paper. It is found that the soils at oil-bearing regions are of the composition properties of typical "red-fading" alterration, clay mineralization and carbonation, i. e. the increase of TM1/3 and TM2/3 and that of TM5/7 in the soils at oil-bearing regions were formed by the "red-fading" alteration and the clay mineralization and carbonation respectively. The comprehensive alteration information can be extracted from TM images by use of ratioing principal component analysis method. Four anomaly areas, i. e. Wushenqi-North Yulin, Yijinhuoqi-Zhungeer-Shenmu, Jiangbian-Hengshan-Wushenqi-Yanchi and Huanxian-Wuqi-Yanan, etc., were delimited. These surface hydrocarbon anomaly areas (zones) have a ralatively high coincidence rate with the known oil and gas fields and the existing exploration results.

SUBJECT HEADINGS: Eerduosi Basin, Satellite remote sensing, Remote sensing image, Hydrocarbon anomaly

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SEISMIC TRACE ANALYSIS OF BAOTA LIMESTONE OF ORDOVICIAN IN CENTRAL SICHUAN

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ABSTRACT: Central Sichuan-South Sichuan intermediate zone is one of the priority regions of natural gas exploration in Sichuan Basin, being located at the Central Sichuan portion of the Leshan-Longnusi ancient uplift and being of an area of about 7 000 km^2. In this area, the existing structures are gentle, being of a flank dip at angles of 1° to 5° in general, small fold amplitudes and closures, and undeveloped faults. Therefore the results were not good in conventional seismic exploration. For this reason, the F-LOG method was mainly adopted in the investigation and the copying and load-carrying of the seismic horizontal stacking results of 19 lines (24 sections) and the calculation, correlation and interpretation of the F-LOG and residual F-LOG profiles of 44 064 common depth points on 11 lines (12 sections) were achieved, these lines with a total length of 718.135 m passing through the intermediate zone. The works of seismic trace analysis and geological horizon calibration of the five wells, i. e. Longnusi key well, well He-12, well Moshen-1, well Guangcan-2 and well Lai-1, passed through by the seismic lines were carried out. In light of investigation, the Wangjiachang structure was found and proved, the Baota limestone of Ordovician in the structure pinching out toward updip direction in the north to form a combination trap with the anticlinal structure.

SUBJECT HEADINGS: Sichuan Basin, Middle, Ordovician period, Limestone, Seismic data processing, Seismic interpretation, Combination trap

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COMPREHENSIVELY UTILIZING 3-D SEISMIC DATA FOR INVESTIGATING LITHLOGICAL TRAPS

Yang Fei, Peng Dajun and Shen Shouwen (Chengdu College of Technology) and Li Zhijun, Zhang Kaowen and Kang Yangen (Geophasical Company of Tuha Petroleum Exploration Headquarters). *NATUR. GAS IND.* v. 19, no. 6, pp. 25~29, 11/25/99. (ISSN 1000-0976; **In Chinese**)

ABSTRACT: Because the 3-D seismic exploration is of many advantages as high density acquisition, high fidelity and various flexible display modes, etc., it has been an objective demand for oil and gas exploration to utilize the 3-D seismic data for investigating lithostratigraphic change, predicting the direction of sources, delineating sedimentary systems and sedimentary facies, seeking for sandstone-developed areas and evaluating favourable oil-and gas-bearing areas. The 3-D seismic exploration working area involved in the paper is located at the west part of Taibei depression in Tuha Basin. Before the reservoir studies were carried out, four wells had been drilled in the area, producing only little oil and gas, which couldn't be satisfied certainly. For this reason, the lithological trap investigation has been carried out on the basis of full 3-D seismic migration data. According to the geological properties of the 3-D seismic exploration working area, in combination with the drilling and logging data and by use of the methods of seismic microfacies, sedimentary microfacies and reservoir formation condition analy-