鄂尔多斯盆地东部石千峰组浅层气成藏机制

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张清等. 鄂尔多斯盆地东部石千峰组浅层气成藏机制. 天然气工业,2005;25(4):12～13

摘　要　鄂尔多斯盆地东部神木地区上石盒子组、石千峰组频繁的含气显示逐渐引起勘探家的重视。从区域成藏地质条件分析入手,运用流体势、包裹体分析、同位素分析、超压异常计算及构造分析等研究方法,研究了盆地东部地区浅层天然气的沉积、储层等基本成藏地质条件,并建立了上石盒子组、石千峰组砂岩气藏的两阶段成藏模式:早白垩世末形成的山西组、下石盒子组早期高压气藏阶段;晚白垩世末形成石千峰组浅层气藏阶段,并在综合评价的基础上得出神木地区神 5 井—榆 22 井区是浅层天然气运聚的有利地区,具有较好的勘探前景,为该地区天然气勘探部署提供了依据。

主题词　鄂尔多斯盆地　东　浅层气　成藏形成　机理　生储盖组合　勘探方针

在鄂尔多斯盆地东部西倾大单斜的背景上,发育着一系列北东向展布的小型鼻状隆起,地层倾角不足 1°。近年来在该地区发现了位于区域盖层之上的石千峰组气藏,埋藏较浅,一般称之为浅层气。盆地东部石千峰组主要发育三角洲平原及三角洲前缘亚相,由于气候干燥,沉积物主要由浅灰、紫红色、灰紫色的碎屑岩构成。

一、烃源及储盖特征

1. 烃源特征

石千峰组地层泥质岩虽发育,但有机质极其贫乏,不具生烃能力。从上古生界不同层系天然气地化特征分析发现,石千峰组天然气与下部气藏同源,即烃源岩为山西组、太原组、本溪组的煤、暗色泥岩及灰岩,天然气从下往上的运移过程中,随着成熟度或运移距离的增加,天然气组分轻烃含量逐渐增高,$\delta^{13}C_1$ 含量变重。盆地东部紧邻上古生界有效供气中心,晚侏罗世至早白垩世烃源岩达到生排气高峰时,盆地东部生气强度达 $50\times10^8\ m^3/km^2$,排气强度为 $40\times10^8\ m^3/km^2$ 以上,最大生气速率为 $7.7\times10^{12}\ m^3/Ma$,最大排烃速率为 $7.2\times10^{12}\ m^3/Ma$,为石千峰组成藏奠定了物质基础[1]。

2. 储盖特征

盆地东部石千峰组主要为三角洲平原亚相的分流河道和三角洲前缘亚相的水下分流河道及河口坝沉积。据岩心及地面露头采样的薄片鉴定资料分析,砂岩类型主要为岩屑长石砂岩和长石岩屑砂岩。粒度以粗粒、粗—中粒、中粒结构为主,砂体底部含细砾。颗粒形态以次圆、次棱为主,分选中等。以线接触、镶嵌接触为主。主要储集层段千 5 的储集空间为粒间孔、溶孔、晶间孔和收缩孔。石千峰组中上部发育较厚的泥质岩类,区域盖层厚度为 100～120 m,泥地比 0.2～0.45,总体上盖层厚度大、封堵能力强,储盖组合好。以神 9 井为例,石千峰组底部有 12 m 优质储层,上部有 16 m 左右的有效泥质岩盖层,具有良好的储盖组合关系。

二、浅层气运移特征

石千峰组浅层气藏的形成必先突破上石盒子组区域盖层,在气源充足条件下,其向上的运移通道显得极为重要。据分析石千峰组浅层气主要通过异常压力释放产生的微裂隙、局部构造缝、局部地带可直接沟通烃源岩和储层的断裂等向上运移的。其中微裂隙对石千峰组浅层气藏的形成起着关键的作用。

1. 微裂隙是天然气向上运移的主要通道

燕山运动期盆地东部大面积回返抬升,下白垩统、侏罗系和上三叠统大面积剥蚀,前期处于超压异常的上石盒子组、石千峰组泥质岩上覆静压力减小,钙质含量较高的易碎泥质岩伴生超压释放过程产生大量微裂隙。从盆地东部上古生界 122 块包裹体样品测试结果显示,烃类包裹体主要赋存于微裂隙(见彩插图 2)和石英加大边之中,尤以微裂缝中烃类包裹体最为发育,约占总烃类包裹体的 70 %以上。从岩心录井、岩心镜下鉴定(见彩插图 3)、FMI 测井、

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野外露头等资料进一步证实了盆地东部上古生界存在大量的微裂缝,这些微裂隙成为下石盒子组及其以下地层天然气向上运移的通道之一。

2. 断裂的疏导作用

据地震剖面反映,盆地东部神木地区小断距及断层十分发育,绝大部分断层仅断开太原组顶部反射层,断距一般小于 50 m,断开地层也大多仅限于太原组、山西组和下石盒子组,个别断层可断到上石盒子组或石千峰组。断裂构造主要发育于盆地东北部神 5 井—榆 22 井区。这些断裂对下石盒子组及其以下地层天然气运移起到疏导的作用。

根据鄂尔多斯盆地生排烃史法确定的最早成藏时间、流体包裹体均一温度法测年以及自生伊利石 K—Ar 测年等方法综合研究认为,盆地东部石千峰组天然气运移主要在早白垩世、晚白垩世期。

流体势反映了流体压力、重力、毛细管力等多种动力作用结果,通过统计盆地不同时期上古生界天然气流体势,发现盆地东北部一直为天然气运移的主要指向。早白垩世末期,盆地北部流体势低于盆地南部,天然气主要向北运移;晚白垩世期,盆地东北部为低势区,天然气主要向盆地东北部运移。

三、浅层气的成藏模式

通过源岩生烃史、流体力势计算、运移通道的形成期次和岩石包裹体形成温度、压力测试资料分析认为:盆地东部地区发生过两期明显的烃类运移活动,其成藏过程分为以下 2 个阶段。

1. 早期高压气藏形成阶段

早白垩世末的一系列构造热事件和埋藏增温作用,使盆地东部上石盒子组到本溪组成藏体系全处在下部早期高压封存箱中。由于上下地层孔隙流体压力平衡,下石盒子组及其以下的超高压力不可能突破上石盒子组盖层,天然气直接运移进入烃源岩附近的山西组、下石盒子组储集体中,形成下部早期高压气藏。

2. 石千峰组气藏形成阶段

晚白垩世燕山运动地层回返抬升并遭受剥蚀后,上石盒子组、石千峰组超压释放,产生大量微裂隙,同时上石盒子组对下部天然气的超压封盖遮挡作用消失,在上下地层孔隙流体压差和气水密度差等综合因素作用下,下部高压气体在上下地层流体势差的作用下沿微裂隙向上运移,在上石盒子组的下部聚集成藏。受构造抬升剥蚀强度、微裂隙发育程度的东西差异影响,东部抬升剥蚀程度高的地区微裂隙发育,向上运移的通道畅通,垂向运移距离远,形成的气柱高,气显示层位高,天然气向上运移至石千峰组聚集成藏。

晚白垩世末以后,上石盒子组、石千峰组的过剩压力逐渐释放完毕,泥岩中的微裂隙从上至下逐渐愈合,并及时通过泥岩中析出的钙质、硅质胶结物充填胶结后,重新成为遮挡能力较好的区域盖层,天然气向上运移通道逐渐变少,运移活动也随之减弱,形成现今的石千峰组浅层气藏分布格局。

四、结　论

综合分析鄂尔多斯盆地东部成藏地质条件,发现东北部神木地区神 5 井—榆 22 井区是石千峰组浅层气勘探的较有利区(图 1),本区地处榆林以东,东止黄河,南到子洲,北到神 5 井,有利勘探面积 4200 km^2。首先神 5 井—榆 22 井区临近东部生烃中心,烃源岩厚度大,其中下伏煤系地层累计厚度为 14～26 m,暗色泥岩累计厚度达 80～130 m,生气强度为 27.45 $\times10^{12}$ m^3/km^2,热演化程度高,镜质体反射率 R_o 已高达 2.2 %,进入了过成熟干气生成阶段,为石千峰组浅层气藏形成提供了充足的气源条件;其次该区发育两条近北东向展布的河流三角洲沉积体系,主要储层段千 5 砂体厚度大(25～30 m),连续性好,地层埋藏浅,成岩压实作用较弱,砂岩中发育残余粒间孔、溶蚀孔、微裂隙等,储层物性相对好,孔隙度分布范围 5 %～10 %、渗透率为(1～10) $\times10^{-3}$ μm^2,为石千峰组浅层气藏形成提供了储集条件;据流体包裹体资料、岩心镜下鉴定等资料表明微裂缝及断裂在该区发育,为下石盒子组及其以下层位天然气向上运移提供了通道;由流体势及超压计算表明,本区长期处于低势区,是烃类运移的长期指向和天然气成藏的最有利地区;气层上部有较厚的泥质岩类封盖,石千峰组累计泥质岩厚度在 120～140 m,泥地比为 0.4～0.45,直接盖层千 4 泥质岩厚度 15～20 m,具有利的圈闭条件。综合以上各种有利条件可知,盆地东北部神木地区神 5 井—榆 22 井区有较好的勘探前景。

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(收稿日期　2005-02-19　编辑　黄君权)

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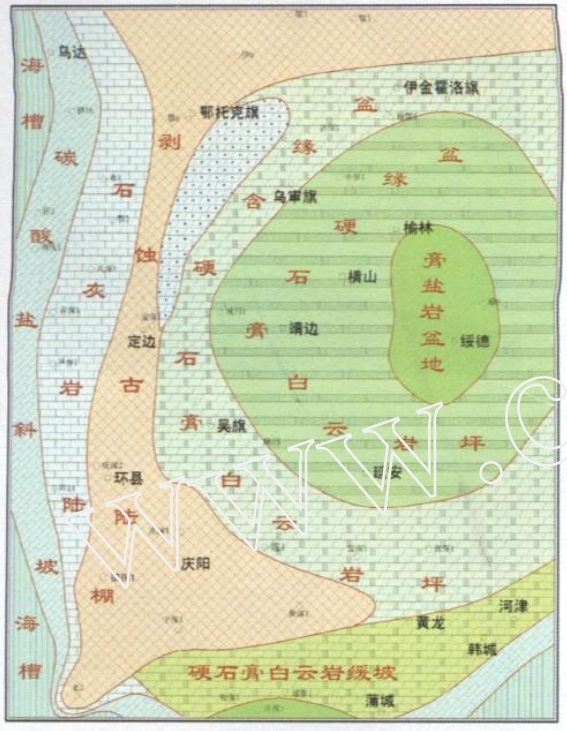
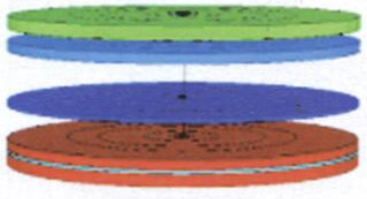
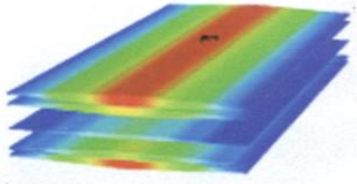


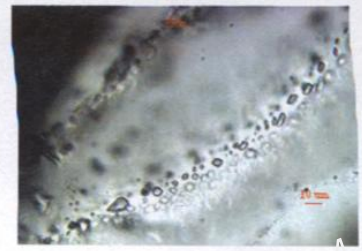
图版1　鄂尔多斯盆地马五期岩相古地理略图(杨华,p.7)



图版5　充分大砂体多层径向模型(徐文,p.45)



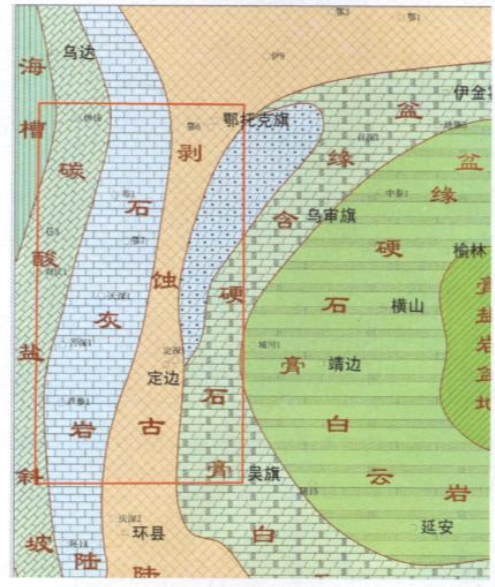
图版6　多层透镜状砂体模型(徐文,p.45)



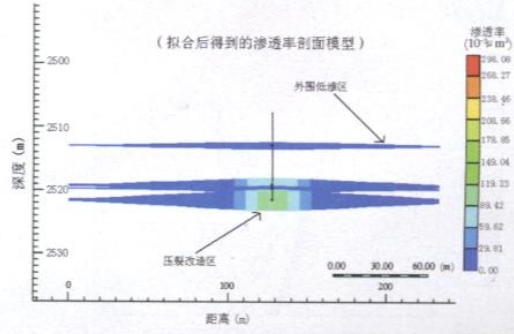
图版2　胜1井,1917.8m,包裹体赋存于微裂缝中
(张清,p.12)



图版3　神8井,1826m,铸体薄片指示微裂缝
(张清,p.12)



图版4　工区地理位置图(郑聪斌,p.27)



图版7　山2段气井拟合后渗透率剖面(徐文,p.46)

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GAS RESERVOIR FORMATION GEOLOGICAL CONDITIONS OF YULIN FIELD IN E'ERDUOSI BASIN

Fu Jinhua, Wei Xinshan and Shi Xiaoyin (Research Institute of Exploration and Development, Changqing Oil Field Branch, PCL). *NATUR. GAS IND.* v. 25, no. 4, pp. 9—11, 4/25/2005. (ISSN 1000—0976; **In Chinese)**

ABSTRACT: The target strata in Yulin gas field lie in the bottom of Shanxi Formation of Permian, Upper Palaeozoic. On the basis of analyzing and chemically examining a large numble of samples, through comprehensively studying the reservoiring geological conditions as hydrocarbon generation, petrophysical property, reservoir-caprock assemblage and lithologic trap type, by use of mathematical statistics, it was considered that Yulin gas field is located in the greatest hydrocarbon-generating intensity area in the basin and its hydrocarbon source rocks are the Permo—Carboniferous coal measure strata, thus possessing the material conditions of forming large-sized gas fields. The P_1s^2 (the second member of Shanxi Formation, Lower Permian) reservoir is mainly composed of the medium-coarse quartzose sandstones of delta distributary main channel that have the features of low-porosity and low-permeability but it can become a main productive zone in the field because of the high effective reservoir being developed on the background of low-porosity and low-permeability owing to the effects of these factors as sedimentary environment, lithologic property and grain size, etc. The type of trap is the large-sized lithologic trap showing a north-south extent band. The lithologic traps can be further divided into two types, i.e. primary and secondary lithologic traps, according to forming mechanisms. The gas reservoir formation is of an unique reservoiring pattern of shallow water dalta. Through drilling currently, it is proved that the reservoir sand bodies in Yulin gas field have been continuously finding out in its southwest, thus opening up a vast range of prospects for gas exploration.

SUBJECT HEADINGS: E'erduosi Basin, Yulin gas field, Gas reservoir formation, Medium-coarse quartzose sandstone

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RESERVOIRING MECHANISM OF SHIQIANFENG FORMATION SHALLOW GAS IN EAST E'ERDUOSI BASIN

Zhang Qing, Sun Liuyi, Huang Daojun and Yu Zhongping (Research Institute of Exploration and Development, Changqing Oil Field Branch, PCL). *NATUR. GAS IND.* v. 25, no. 4, pp. 12—13, 4/25/2005. (ISSN 1000—0976; **In Chinese)**

ABSTRACT: The frequently-appearing gas shows in Shihezi Formation and Shiqianfeng Formation at Shenmu region in East E'erduosi Basin have brought to the explorationists' attention. Proceeding from the regional reservoiring geological conditions and by use of these methods as fluid potential analysis, fluid inclusion analysis, isotope analysis, overpressure anomaly calculation and tectonic analysis, etc., the authors investigated the basic geological conditions (including sedimentation and reservoir) of the shallow gas in the east part of the basin, and established a two-stage reservoiring pattern for the Shihezi Formation and Shiqianfeng Formation sandstone gas reservoirs, i.e. the Shanxi Formation and Lower Shihezi Formation early high-pressure gas reservoir stage formed at the end of Early Cretaceous and the Shiqianfeng Formation Shallow gas reservoir stage formed at the end of Late Cretaceous. On the basis of comprehensive evaluation, it was concluded that the area of well Shen-5—

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well Yu-22 at the Shenmu region is of good prospects for gas exploration, being favourable to shallow gas being accumulated here, thus providing a basis for deploying gas exploration at the region.

SUBJECT HEADINGS: E'erduosi Basin, Shallow gas, Reservoiring pattern, Exploration, Direction

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INDUSTRIAL CLASSIFICATION AND EVALUATION OF THE PERMIAN SANDSTONE RESERVOIR IN SULIGE GAS FIELD IN E'ERDUOSI BASIN

Bao Hongping, Jia Yani and Yu Zhongping (Research Institute of Exploration and Development, Changqing Oil Field Branch, PCL) *NATUR. GAS IND.* v. 25, no. 4, pp. 14—15, 4/25/2005. (ISSN 1000—0976; **In Chinese)**

ABSTRACT: In order to raise the actual significance of reservoir classification and evaluation, a reservoir classification and evaluation system being able to be applied to the practical production in a region was set up in consideration of the gas reservoir features and reservoir characteristics of various regions in the process of gas exploration and development, so as to realize its industrial application. By taking the Permian sandstone reservoir in Sulige gas field in E'erduosi Basin as an example, in light of the relation between conventional petrophysical analysis data and exploration well testing productivity, the reservoir industrial classification method and evaluation index which are suitable for the gas reservoir geological features of the field were trially established on the basis of investigating the gas reservoir features and reservoir characteristics of the field. According to the key petrophysical parameters, the reservoirs in the field were divided into four types, each being corresponding to different industrial values. The exploration practice indicated that such a reservoir classification might well summarize the petrophysical distribution and grade difference characteristics of the sandstone reservoirs in the field, and could set up a good correspondent relation with gas well testing productivity, Therefore it may be used for a reference to evaluating correctly the industrial value of the reservoir and the layer-selection of gas well test, and to drawing up the program for gas reservoir stimulation.

SUBJECT HEADINGS: Sandstone, Gas reservoir, Reservoir, Classification, Evaluation, Sulige gas field, E'erduosi Basin

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CHARACTERISTICS OF TAIYUAN FORMATION LIMESTONE RESERVOIR OF PERMIAN IN EAST E'ERDUOSI BASIN

Wei Xinshan, Wang Feiyan, Wang Huaichang and Li Xuemei (Changqing Oil Field Branch, PCL). *NATUR. GAS IND.* v. 25, no. 4, pp. 16—18, 4/25/2005. (ISSN 1000—0976; **In Chinese)**

ABSTRACT: In order to find out the natural gas in new sections and new horizons to provide a stable and sufficient gas source for "West-to-East Natural Gas Transmission", a research on the Taiyuan Formation limestone of Permian in East E'erduosi Basin was carried out on the basis of analyzing the data on core observation, cast thin section, scanning electron microscope and isotope assay. The Taiyuan Formation limestone was deposited in an epicontinental sea tidal-flat environment and its reservoir rocks are mainly conposed of bioclastic micrites, micritic bioclastic limestones and bioclastic limestones. The reservoir rooms may be divided into three types, i.e. primary pores, secondary pores and fractures, and the secondary solution pores and fractures are the most important reservoir rooms. The compaction and cementation are the main destructive diageneses but the corrosion and karstification are the main constructive diageneses. The secondary solution pores and fractures caused by the karstification are well developed in the limestones. The reservoir is

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