苏里格庙气田盒$_8$ 段砂岩 AVO 正演模型研究

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潘仁芳等. 苏里格庙气田盒$_8$ 段砂岩 AVO 正演模型研究. 天然气工业,2002;22(5):7～10

摘　要　正演模型研究是采用 AVO 方法进行气藏检测的基础。选择合适的井在合成地震记录层位标定的基础上,研究含气砂岩的地震反射振幅随炮检距的变化关系和各种 AVO 属性参数的特征,以及含气砂岩与非含气砂岩在各项特征上的差异和变化。含气砂岩 AVO 异常属性特征的确定可以指导利用地震 CMP 道集的 AVO 反演结果进行可靠的含气砂岩储层分布预测。正演模拟结果证实:苏里格庙气田二叠系盒$_8$ 段含气砂岩主要为第 Ⅲ类 AVO 异常响应,异常特征十分明显。

主题词　苏里格庙　AVO　正演模拟　合成地震记录

合成地震记录及其意义

通常,合成地震记录用作地震层位的标定,在 AVO 正演模型研究中,这一功能也是很重要的,但更重要的是通过不同相位子波所做的合成地震记录与邻井实际地震记录的对比,确定所要分析的地震道集的相位角。并以此为基础,在进行 AVO 反演前,对地震道集资料进行相位转化。因为 AVO 反演要保证地震反射振幅极性与地层实际反射系数的极性一致,这样才能使 AVO 的属性参数真正具有地质意义,如:$P+G$ 视为泊松比的参数对待,$P-G$ 视为横波速度的参数参待。

苏里格庙地区最明显的地震反射标志层[1,2]是石岩系底部附近的煤层反射,由于煤层的地震速度明显低于上覆砂岩层的速度,其顶部反射应是一个负极性的波谷反射。通常,由于我们的地震资料采用负极性显示,即所谓的 SEG Normal Standard (SEG 正常极性标准),地震反射振幅的极性与实际地层的反射极性恰恰相反,即负极性显示成波峰,正极性显示成波谷。因此,合成地震记录的负极性显示应与实际地震资料得到最好的对比。如果情况相反,则表明地震资料为正极性显示,或其它最小相位显示。

由于美国和加拿大并不采用 SEG Normal Standard (Castagna ,2001,个人电子通信),而采用与地层实际反射极性相一致的地震振幅显示。因此,我们在采用北美软件产品时,应充分考虑到这一点,并对地震道集资料进行相位校正,否则,我们所做出的预测则正好与实际结果相反,但更为重要的是地震资料的零相位问题,小相位或混合相位的地震剖面对于厚度仅 10 m 左右的气层影响是相当大的。因此,合成记录标定则是为了给地震剖面一个准确的校正相位角。

层位标定的另一个目的是为 AVO 正演模拟做准备,因为在进行 AVO 属性参数计算时,要应用准确的入射角数据。尽管入射角可以根据 Snell 定律推导,但在射线追踪时,必须有准确的时深关系进行约束,否则,入射角数据会出现系统的偏差。另一方面,地震反射在道集上的能量变化也会因此而受到影响。因此,在进行 AVO 模拟前,必须通过合成地震记录进行准确的层位标定。

苏里格庙地区的地震资料主要是负极性的,但也有个别剖面是正极性的。

图 1 是苏 6 井合成地震记录,合成地震记录的负极性显示与邻井地震道对比吻合最好,煤层顶部地震反射为波峰。从图中可以明显看出:如果采用正极性合成地震记录与之对比,由于有两套煤层出

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现,地震反射相对其它井较为复杂。对于与其它井可以对比的上面的煤层而言,因煤层顶部为负极性反射,在正极性合成地震记录上只出现强波谷上下的两个波峰,与实际记录不相吻合,但负性极的合成地震记录却可以吻合得很好,表明地震资料为SEG正常极性标准。苏6井有两套气层,气层顶部的地震反射分别是煤层反射上方的第一个和第二个正振幅波峰,地震反射时间分别是1.78 s和1.804 s。

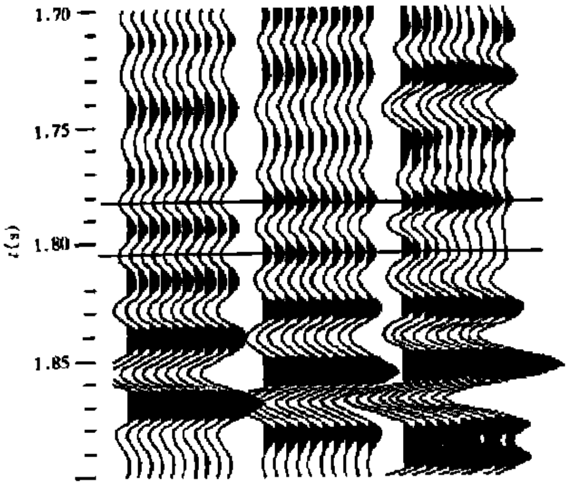

图1　苏6井合成地震记录

注:图中左边是正极性合成记录,中间是负极性合成记录,右边是邻井地震道,横线表示气层顶面

图2是苏10井合成地震记录,合成地震记录的正极性显示与邻井地震道对比吻合最好。从图中可以明显看出:如果采用负极性合成地震记录与之对比,与实际记录不相吻合,但正极性的合成地震记录却可以吻合得很好,表明地震资料为与SEG正常极性标准相反的极性。苏10井钻遇的气层顶部的复合地震反射是煤层反射上方的第三个负振幅波谷,地震反射时间为1.74 s。

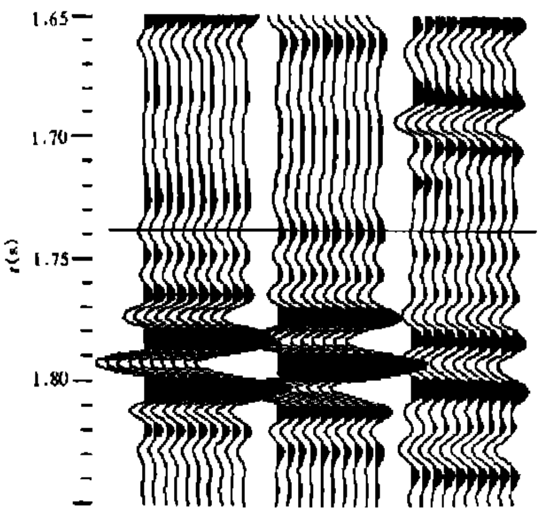

图2　苏10井合成地震记录

注:图中左边是正极性合成记录,中间是负极性合成记录,右边是邻井地震道,横线表示气层顶面

AVO正演模型特征

苏里格庙气田的盒$_8$段含气砂岩具有什么样的AVO异常相应,苏6井和苏10井等6口井的AVO正演模拟结果给出了答案。

苏6井和苏10井的AVO正演模拟结果(图3、4)均显示出:在正常反射状况下,由于衰减和频散作用[3~5,9],随着炮检距的加大,非含气地层的反射振幅是逐渐减小和变化微弱的;但当储层砂岩的孔隙中含有气体时,反射振幅却逐渐增加(统一按负极性

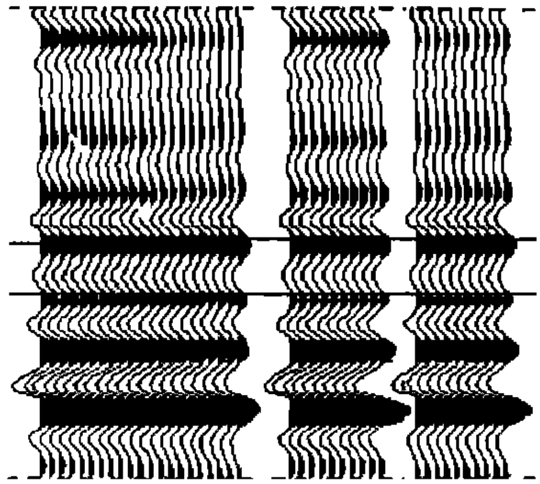

图3　苏6井AVO正演模拟

注:图中左边是正演道集,中间是近道叠加,右边是远道叠加,横线表示气层顶面

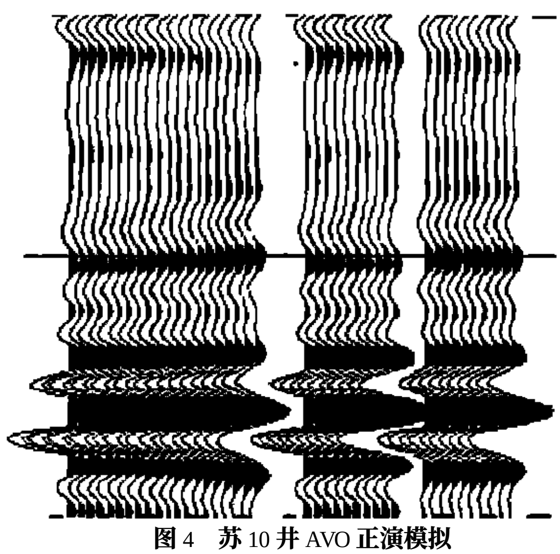

图4　苏10井AVO正演模拟

注:图中左边是正演道集,中间是近道叠加,右边是远道叠加,横线表示气层顶面

振幅模拟)。这种特点在其它各口井的 AVO 正演模拟中均明显地表现出来了。

振幅随炮检距变化关系

振幅随偏移距变化是 AVO 研究中最原始和最基本的分析方法。苏里格庙地区盒$_8$段含气砂岩均表现出明显的异常特征:含气砂岩的顶面地震反射为负极性,振幅随炮检距增加呈负向加大;底面地震反射为正极性,且振幅随炮检距增加呈正向加大,非含气砂岩的振幅随炮检距变化不明显。

1. 含气砂岩的实例

桃 5 井也是工区内含气性最好的井之一,盒$_8$段砂岩含气厚度大,含气性好,且上、下两个砂层都含气。测井解释两套含气砂岩的顶部埋深分别为3 269.9和 3 322.8 m,气层的底界面埋深分别为3 276.9和 3 336.6 m,对应的含气层厚度分别为 7.0和 13.8 m。上下两气层均有非常明显的地震反射振幅随炮检距增大的加大现象,且地震反射振幅强度大。这种现象说明气层较上下围岩具有更高的孔渗条件,只有这样才能形成较大的反射系数(图 5)。这种情况在 AVO 反演剖面上将表现出明显的 AVO 截距和斜率的负异常。

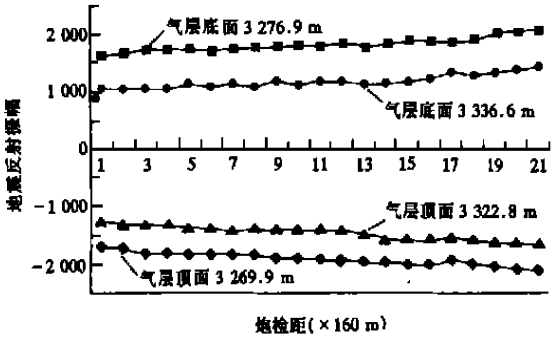

图 5 桃 5 井正演模型地震反射振幅随炮检距变化

2. 弱、非含气砂岩的实例

苏 8 井是工区内含气性较差的一口井,盒$_8$段砂岩只有下部含气,且含气段较薄。砂岩(非含气)顶面的地震反射振幅随炮检距几乎无变化,而气层顶界面上的地震反射振幅不仅不随炮检距增加而加大,而且还减小。这种现象是正常地层反射界面的振幅衰减现象,这里所说的"正常地层"即指不含气(或弱含气)的砂岩层。反射振幅随炮检距的变化与地层厚度无关,只与地层的含气性有关。这种变化进一步地说明了地层含气性与地震反射振幅随炮检距变化的一致性关系(图 6)。

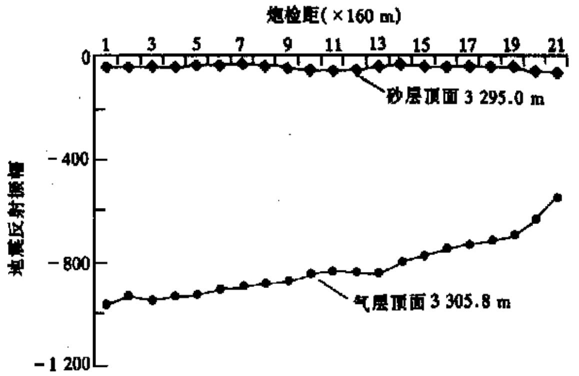

图 6 苏 8 井正演模型地震反射振幅随炮检距变化

属性参数交会分析

AVO 截距和斜率的交会结果(图 7)显示出:气层砂岩样点的分布都在第 Ⅲ象限,非含气砂岩的样点分布都在第 Ⅰ和第 Ⅳ象限。表明含气砂岩顶部的地震反射极性一定是负极性,而非含气砂岩顶部的地震反射极性基本上都是正极性。这是由于砂岩的速度较泥岩的速度高,而当砂岩含气后,其速度下降,并且下降到比泥岩速度更低的程度。含气砂岩顶面的负极性地震反射振幅由弱到强均有分布,指示含气状况的 AVO 斜率也是如此,这可能归因于岩石物性及含气性的差异所致[8]。

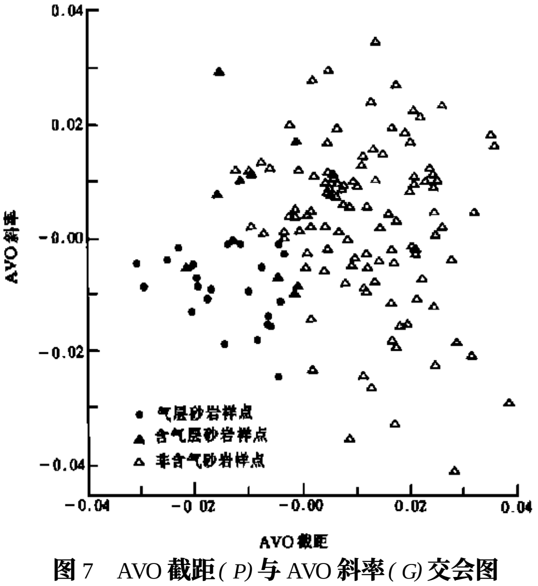

图 7 AVO 截距(P)与 AVO 斜率(G)交会图

从图中我们可以得出结论:AVO 截距是划分含气砂岩与非含气砂岩的标准参数,如果 AVO 截距大于零,则砂岩不含气;如果 AVO 截距小于零,则砂岩含气。AVO 斜率是确定含气程度的参数:如果 AVO 斜率小于零(样点在第 Ⅲ象限),则表明砂岩含气状况好;如果 AVO 斜率大于零(样点在第 Ⅱ象限),则

表明砂岩的含气性一般。

含气砂岩分类

含气砂岩AVO分类不仅涉及到对特定砂岩的特征总结，更重要的是确定其特征，用于对AVO反演结果的解释，以指导含气储层的检测。

根据对AVO正演模型结果的分析和与AVO异常砂岩的对比，我们认为苏里格庙地区盒$_8$段含气砂岩主要为第Ⅲ类AVO异常，这类砂岩也是最好的一类含气砂岩。另外，也有少数含气砂岩为第Ⅱ类与第Ⅲ类的过渡型和第Ⅳ类。第Ⅱ类与第Ⅲ类的过渡型是储集物性欠佳的含气砂岩，第Ⅳ类含气砂岩是储集物性尚好，但气饱和程度尚差。这种特征与榆林和乌审旗地区的山西组含气砂岩有所区别[2]。

对于储集物性欠佳的含气砂岩，它们可能有两种类型的储盖组合，一种是气层砂岩的盖层为泥岩，另一种则是被该砂岩上部的致密层遮盖。对于前一种情况，结论比较直接，因为砂岩孔隙条件差，砂岩速度与泥岩速度接近，当砂岩的孔隙被气体所饱和时，由于气体含量小，降速效应也不明显，只能形成较微弱的反射。对于后一种情况，气体仅存储在孔渗条件相对较好的砂岩层下部，依靠砂岩内部的排替压力封存，储集气体的部分只是相对较好，一般来讲，这种所谓的相对较好不可能表现得很好。

第Ⅳ类含气砂岩表明：储集层的高孔隙性已使砂岩的速度低于上覆层的速度，含气与否不会改变其反射极性。由于含气饱和度小，泊松比变化小，因此，反射振幅随炮检距的变化不大，有时可能还减小（图7）。

上述是特别针对苏里格庙盒8段含气砂岩的AVO异常响应特征而做的分析，同样对于其它地区盒$_8$段或其它的砂岩，要具体情况具体分析。但在任何情况下，都必须有AVO的正演模型分析作为AVO反演结果解释的指导。否则，对AVO异常响应的解释则可能因为固有的模型而将气藏检测引入错误的结论[6]，甚至对AVO技术产生怀疑。

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中、韩、俄就开发俄罗斯伊尔库茨克气田重开谈判

据援引韩国工商能源部消息，韩国、俄罗斯和中国就开发西伯利亚伊尔库茨克气田的谈判，在中断一年后目前已经恢复。

韩国天然气公司、俄罗斯石油公司和中国石油天然气集团公司在2000年11月曾达成协议，开始就开发伊尔库茨克天然气进行可行性研究。研究包括天然气开发和建设一条4000公里长的管道穿过俄罗斯和中国进入韩国。

可行性研究于2001年年初开始，因三国的磋商陷于停顿，研究被搁置，目前计划在2002年年底前完成。

伊尔库茨克气田已探明的储量为1.2万亿立方米，需开发的天然气和建设管道预计总投资110亿美元。若三国同意联合开发该气田，韩国可望从2008年开始，在30年内每年获得96.6亿立方米的天然气。

韩国方面有9家公司参与了伊尔库茨克气田开发的财团，其中包括韩国天然气公司、LG国际和国营的韩国国家石油公司。

陈 敏　摘自《石油参考》

ABSTRACTS AND AUTHORS

FACTORS CONTROLLING THE FORMATION AND EVOLUTION OF MESOZOIC AND PALEOZOIC OIL/ GAS RESERVOIRS AND THEIR EXPLORATION TARGETS IN SOUTH CHINA *

Zhao Zongju (Hangzhou Institute of Petroleum Geology), Zhu Yan (Geoscience Department in Zhejiang University) and Li Dacheng (Hangzhou Institute of Petroleum Geology). *NATUR. GAS IND.* v. 22, no. 5. pp. 1～6, 9/25/2002. (ISSN1000 - 0976; **In Chinese)**

ABSTRACT: According to the characteristics of multi-stage tectonic reconstruction and the complexity of hydrocarbon evolution, Mesozoic and Paleozoic oil and gas reservoirs in South China can be divided into three types: the primary, the secondary and the regenerated hydrocarbon reservoirs. The distribution of the primary and the secondary reservoirs is mainly controlled by paleouplift and paleoslope near the source rock sedimentary sag, and the distribution of the regenerated reservoirs is by the secondary or later-stage hydrocarbon-generating center. Those existent industrial reservoirs of Paleozoic and Mesozoic in South China were formed especially in late periods, significantly in Tertiary. There the source rocks were found with multi-stage generating hydrocarbon and multi-stage forming reservoirs. The oil and gas exploration should be concentrated on the reservoirs generated and formed at the later periods. Yanshan Movement which occurred from Late Jurassic to Early Cretaceous played a decisive role in conservation and destruction of the primary reservoirs, controlling the distribution of the secondary and the regenerated reservoirs - the significant genetic models of the existent Mesozoic and Paleozoic oil/ gas reservoirs. The exploration of the secondary gas reservoirs will be in upper Yangtze area while the exploration of the regenerated reservoirs in middle and lower Yangtze area. The beneficial areas of oil and gas exploration have already been certified by those exploration results discovered from Zhujiadun gas field in Yancheng sag of North Jiangsu Basin and Kaixiantaixi oil-bearing trap in the southern Chenhu area of Jianghan Basin.

SUBJECT HEADINGS: South, Paleozoic, Oil and gas reservoir, Genesis, Controlling factors, Exploration target

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STUDY ON THE AVO FORWARD MODELING OF SANDSTONE HE-8, PERMIAN, SHULIGEMIAO GAS FIELD *

Pan Renfang (Jianghan Petroleum Institute), Zhao Yuhua and Shi Songqun (Research Institute of Changqing Oil Company, PetroChina Limited Company). *NATUR. GAS IND.* v. 22, no. 5. pp. 7～10, 9/25/2002. (ISSN1000 - 0976; **In Chinese)**

ABSTRACT: Forward modeling study is the initial step for carrying out gas detection by using AVO (amplitude versus offset) analysis. On the basis of the strata labelled by the synthetic seismogram for the appropriately-selected wells, it is well analyzed that the seismic reflection amplitude varying with offset, and AVO attribute properties of gas-bearing sandstones, and the differences and variations of all features between gas-bearing and gas-free sandstones. Identification of abnormal attribute properties for a specific gas-bearing sands will lead to correct detection of gas occurence in sands reservoir via AVO inversion from seismic CMP gathering (common points). As a consequence, from the forward modeling, it is proved that gas-bearing sandstones in He-8, Permian, Shuligemiao gas field, are mainly the AVO abnormal response of Type Ⅲ with extremely obvious features.

SUBJECT HEADINGS: Suligemiao, AVO, Forward modeling, Synthetic seismogram

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STUDY ON BIOGAS IN BOHAIWAN BASIN AND ITS SURROUNDINGS *

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ABSTRACT : While generating rocks , afterthrough thermal evolution to a certain degree , were put into the microbial action zone by tectogenesis , its organics were made by the microbes into biogas , which is also called epigenetic biogas. The existance of epigenetic biogas was proved both by the experiments and geological analysis. Its geological significance is discussed here as well. Thus , gas exploration area will be expanded to a large extent for the significant discovery. It is thought that this bio-methane can also be developed in the shallow coal bed and even microbes can be used to enhance the production capacity of shallow methane. This biogas will be possibly found in such areas like the naked zones or the shallow zones of carbonate rocks in South China.

SUBJECT HEADINGS : Biogas , Epigenetic biogas , Microbial action zone , Generating rock , Thermal evolution , Structure elevation

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GEOCHEMICAL CHARACTERISTICS OF THE NATURAL GAS FROM WELL WULONG-1 , CHUXIONG BASIN, AND ITS GEOLOGICAL SIGNIFICANCE *

Li Xiumei , Liu Yinghui and Wen Jingping (Scientific Research Institute of Petroleum Exploration and Development , Dian-Qian-Gui Oil-field Company , Sinopec) . *NATUR. GAS IND.* v. 22 ,no. 5. pp. 16～19 ,9/ 25/ 2002. (ISSN1000 - 0976 ; **In Chinese)**

ABSTRACT : Through comprehensive analysis of logging , the component and isotopic composition of the natural gas sampled from Well Wulong-1 , Chuxion Basin , in various ways (gas logging ,well testing and head space gases) ,indicate that the natural gas is a dry gas contained in the fractures of rocks. The hydrocarbon gas of the natural gas is an oil-type thermal pyrolysis gas , originating from over-matured source rocks in Up Triassic. Carbon dioxide in the depth from 3140 to 4620 meters belongs to the inorganic mantle-source gas ;in the depth from 2411. 3 to 2425 meters , belongs to the inorganic crustal source gas ,as for which the particularity of the ingredients of natural gas is probably related to the invasion of the ingeous rocks. The co-existance of organic and inorganic gases demonstrates that many favorable zones will be possibly found for exploring industrial reservoirs in the northern part of Chuxiong Basin with good conditions for exploring reservoirs not only with the conventional gas but with the inorganic carbon dioxide with deep source.

SUBJECT HEADINGS : Genesis of natural gas , Isotope ,Mantle-source gas ,Crustal source gas ,Oil-type thermal pyrolysis gas ,Oil geology ,Chuxiong Basin

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SCREENING INDICATING BACTERIA FOR MICROBIOLOGICAL EXPLORATION OF NATURAL GAS *

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ABSTRACT : The indicating bacteria has significant influences on the results of microbiological exploration. It is well compared and studied the recognized zones with reservoirs and those without reser-