

川东高陡构造钻井工艺的合理配套探讨

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韩烈祥. 川东高陡构造钻井工艺的合理配套探讨. 天然气工业, 1998; 18(2): 32~ 35

摘 要 川东地区高陡构造分布广, 勘探前景可观, 但复杂情况众多。文中根据高陡构造的地质构造特点和钻井地质特点, 将高陡构造分为主体构造(Ⅳ类)和翼部潜伏构造(㊸类)两类, 推演其钻井工艺的合理技术配套方案。提出Ⅳ类构造应实施以清水强钻、钻具安全、深下技术套管和钻直井技术为主的配套技术, ㊸类构造则应实施利用地层自然造斜规律钻中靶井、综合治理井眼失稳、高效暂堵与保护产层、深部高压地层的井下动力钻具配金刚石钻头快速钻进技术。希望对川东地区今后的钻井工作起到一定的参考作用。

主题词 四川 东 陡 倾角 构造 钻井工程 地质学

川东地区由于受喜山期构造运动强烈的挤压或压扭作用, 形成了一系列平行褶皱, 在近期的剥蚀中, 因地层、构造的综合作用, 形成了广泛分布的、具正向地貌特征的高陡构造。

在对高陡构造石炭系的含气性有了突破性认识^[1]以后, 川东地区在高陡构造上钻的探井越来越多, 1991 年已占川东工作井的 80%, 且 1990 ~ 1992 年在高陡构造带上完成的 69 口井中获气井就达 40 口, 无阻流量超过百万立方米的气井达 25 口。高陡构造已成为川东地区天然气勘探开发的主要战场。

然而, 由于高陡构造各部位的地质环境有别, 钻井中实施相同的工艺技术就会影响钻井速度、效益乃至安全。近年来川东高陡构造上已有多口井进行侧钻, 或难以实现地质目的而提前完钻(如渡 1 井)甚至全井报废(如七里 29 井)。因而, 有必要针对高

陡构造的地质工程特点, 探索安全、快速钻探该类构造的合理钻井工艺技术的配套方案。

高陡构造的主要地质特点

1. 川东高陡构造的地质构造特点

(1) 地面正向构造多为高耸的大山, 相对高差 500~ 800 m; 轴部(即长轴附近)出露地层多遭受过不同程度的剥蚀, 一般为中、下三叠统可溶性碳酸盐岩, 且裂缝发育; 两翼出露地层为侏罗系, 地层比较完整。

(2) 背斜褶皱强烈, 两翼陡峻, 甚至直立倒转, 一般有一陡翼和一缓翼, 两翼地层沉积均匀, 为单斜构造。

(3) 地腹石炭系、二叠系是应力集中层段, 轴部被多个断层切割解体, 呈陡断凹凸相间的格局: 即上

地面, 造成井筒积液, 影响产能。为此, 采取了排水采气的方法, 取得了显著的社会效益及明显的经济效益。仅化学排水一项, 1990~ 1996 年就累增气量 $1\ 603.59 \times 10^4 \text{ m}^3$, 创经济效益 833.87 万元。

胜利油气区浅层气藏的开发, 依靠科技进步和科学管理, 加强了基础研究和配套工艺技术的应用, 取得了一定的成绩。但是, 也存在着很大的问题, 后备资源严重匮乏, 储采比失调。今后, 应积极开展攻

关, 进一步提高浅层气藏的采收率。

本文是在综合了大量内部科研报告的基础上形成的, 在成文过程中, 得到了李振泉、孙国、曹刚、孟阳等同志的指导与协助, 在此表示诚挚的谢意。

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盘正向构造、中部断凹(或断垒)和下盘潜伏高带或背斜圈闭(如大天池构造的明达潜伏构造、七里峡构造带翼部的符家坡、渡口河背斜圈闭)。

(4) 石炭系含气范围窄,平面呈线状。上、下盘构造圈闭油气保存条件较好,一般为含气区带;主断层下盘的凹曲带含气条件较差。

(5) 纵向上地面构造与地腹构造之间往往发生偏移而不在一条垂线上。

2. 川东高陡构造的钻井地质特点

根据川东高陡构造的地质构造特征,其钻井地质特征可划分为两类:轴部正向构造(简称 iv 类构造)和翼部潜伏构造或背斜圈闭(简称 ㊸类构造)。分别概括如下:

(1) iv 类构造的钻井地质特征

大池干井构造带、南门场构造中段、温泉井构造、沙罐坪构造、大天池构造西翼、云安厂构造(云安 1、3、5、9 井)等均属此类。其钻井地质特征为:

1) 由于正向构造对应的地面构造往往为遭受过不同程度剥蚀的地面构造轴部,因此目的层埋藏较浅,大部分地区侏罗系完全剥蚀,与翼部比较并深减少 1 500 m 左右。

2) 由于地面构造褶皱强、出露又大多为三叠系易风化的碳酸盐岩地层,故地层弯曲破碎严重、溶蚀后的裂缝延伸深(各构造依出露地层新老不一而不同,池 1 井清水钻至长兴组仍井漏失返)、连通性好,上部井段容易发生放空、恶性井漏及井壁掉块卡钻(云安 9 井嘉陵江组及以上地层钻进中多次放空、井漏不返)。

3) 地震剖面上构造形态不清,地层产状难以量化,不宜设计大位移的自然造斜中靶井。如池 60 井原计划作为自然造斜中靶的试验井,后因 $f_{311.2}$ mm 井眼严重井漏导致造斜失败, $f_{215.9}$ mm 井眼造斜钻进中又出现钻具事故,结果未钻达地质预定的目的层。

(2) ㊸类构造的钻井地质特征

具有此类构造特征的有明月峡构造带、大天池构造带东翼、铁山构造,及高峰场、新市、渡口河、黄龙场等构造,具体表现为:

1) 地表往往有一层浮土,清水开钻井场容易渗漏而影响基础强度。

2) 由于地表条件好,地震剖面构造清晰,可通过移动地面井位,利用地层自然造斜钻中靶井达到提高钻速的目的。天东 22 井、七里 24 井、天东 3 井、天东 53 井等一大批井都成功地实施了利用地层自

然造斜钻井中靶工艺。

3) 纵向上地层沉积完整,构造应力大,地层倾角大,石炭系埋藏深、钻井易斜,侏罗系兼有水化膨胀和地应力引起的井眼失稳问题。月东 1、3 井钻进中为平衡侏罗系的地层垮塌,使用密度大于 1.42 g/cm^3 的钻井液又造成下部井段多处井漏。

4) 构造保存条件好,上部地层部分井产水,受雷口坡组、嘉二³层等石膏层的覆盖,嘉二²层开始进入异常高压气层或水层,产层较多,压力较高。月东 1、月东 3 井从嘉二²至石炭系共有 5 个层系有气水显示;而主体构造月 1、月 4 井从飞三段才有显示。

5) 地覆发育断层或地层陡带,加之地面条件恶劣使构造解释误差过大,出现井加深或井眼落入断凹。常常需要通过定向纠斜来钻中地质目标靶区,易出现卡钻事故。

6) 距高陡构造主体较远的向斜区域的局部背斜圈闭,其含气情况规律性差,有的高压高产、有的则无显示(如天西 3 井),钻井液密度设计和井控都有一定难度。如高峰场、新市、渡口河、黄龙场等构造。

7) 在高陡构造轴部的倾没端,地层倾角逐渐减小,但由于构造曲率较大,自然造斜中靶井的方位预测较困难(如门 3 井)。长轴倾没端的地层特性也与翼部相似,且钻井难度减小。如马槽坝构造、五百梯构造、环山构造、南门场构造南、北倾没端的门 3、4、5、6 等井一带。

除上述钻井地质特点外,川东地区还具有地层硬、岩石与可钻性差(V 级以上占 60%~70%、且须家河组研磨性极强,长兴组一下二叠统又含燧石与黄铁矿夹层)、多数产层含 H_2S (最高达 493 g/m^3)、压力梯度差异大。尤其是下二叠统,因属于低孔、低渗地层,在受到强大地应力作用下油气缺乏运移条件,往往呈现出异常高压(压力系数 $1.80 \sim 2.45$)。因此,必须根据一口井所处的构造部位,采取对应的技术措施,才能安全、快速地钻达地质目的层。

高陡构造的钻井工艺措施选择与配套

如上所述,高陡构造的不同部位的钻井地质特点是不同的。因此,无论是从钻井工程设计还是钻井施工上,都应根据井位所处构造部位采取不同的、具有针对性的钻井措施。

1. iv 类构造的工艺配套方案

对于 iv 类构造,往往油气保存条件较差,从地表至嘉陵江组易钻遇连通地面的裂缝,常发生井漏失

返、掉块卡钻、蹩跳钻严重等复杂情况与事故。因此,应采取以下措施:

第一,应尽量靠近地面水库、堰塘、河流布置地面井位。钻进中一旦遇到井漏失返,则作试钻分析^[2],制定合理钻井参数、抢接管线、组织水源,修补井壁,储备稠泥浆,去除大尺寸钻铤,实施清水强钻工艺。这项技术不仅能避免因长期堵漏而引起的人力、物力、财力的巨大浪费,且可实现平衡钻井、提高钻井速度;不足之处是取不到地质岩屑资料,需随时注意沉砂及掉块卡钻。池 24、门西 2 等多口井等都成功地实施了清水强钻工艺,且获得了良好的技术经济效益。门西 2 井还探索了保持井下平衡条件下的清水强钻工艺技术。茨竹 1 井上部井段亦适合清水强钻,但由于嘉陵江组要钻遇大的断层,断下盘可能显示 ⊕ 类构造的特征,应注意井喷,并尽快造斜。

第二,不宜在该部位设计自然造斜中靶井,因为地层较破碎,倾角也不大,井斜方位不再单纯依赖地层倾向,随机性较大。可根据条件设计成水平位移稍宽余的直井。

第三,应在钻具中加接减振器、少用钻具稳定器,以防止钻头、钻柱的早期损坏和卡钻事故的发生。必要时应对部分严重“大肚子”井段实施水泥补壁工艺。

第四,该类井由于上部井段裂缝与地面连通性好,因此,技术套管的管鞋位置应尽量下深,在充分调研与分析的基础上,下至嘉陵江组底部至飞三段顶部或更深的层位,否则将可能导致地下井喷,被迫提前下生产套管,不能实现地质目的;或长期堵漏造成材料、时间的巨大浪费。地处云安厂构造的云安 3 井,由于对其钻井地质特征认识不够,技术套管设计下至嘉二²层、实钻提前在嘉二³层下入,下二叠系统设计钻井液密度为 1.75 ~ 1.80 g/cm³, $f_{215.9}$ mm 井眼开钻用 1.65 g/cm³ 的钻井液钻进即发生井漏,堵漏 12 次;后密度降至 1.35 g/cm³,钻至飞仙关组又试压堵漏 28 次仍达不到设计要求,平衡密度约为 1.46 g/cm³,共损失 1 612 h。

第五,雷口坡组软石膏地层注意井斜急剧增长。池 40 井在该层段 1 175 ~ 1 475 m 用塔式钻具组合、80 ~ 100 kN 钻压钻进,井斜角由 3°30′ ↘ 18°10′,被迫定向纠斜。

2. ⊕ 类构造的工艺配套方案

⊕ 类构造的钻井难度主要表现为垮塌、井斜及多产层、多压力系统问题。因此,应做好以下几方面

的工作。

第一,地面井位应根据地下靶区、地层自然造斜能力反推地面井位坐标,再根据地面条件与靶区范围调整地面井位。这类井能否快速中靶取决于三个基本条件:一是地层产状是否均一。二是地面井位是否接近理论井位,这是快速钻进自然造斜中靶井关键的一步;设计井眼轨迹时,应根据地层倾角大小控制井斜角的大小,应坚持井口钻直(地面至表层以下 300 m 井段)、中下部控制狗腿度的井眼轨迹控制原则。三是钻井施工过程中的井斜控制措施能否按设计进行,切忌盲目控制过小的井斜角或随意大幅度放开钻压钻进。没有条件移动地面井位的井,应采用满眼钻具组合控制井斜增长率、钟摆钻具组合降斜的组合工艺或上部适当控制井斜、下部井段定向纠斜的工艺组合,以达到缩短钻井周期、控制钻井成本的目的。

第二,侏罗系的井眼稳定问题必须予以认真研究对策,简单地从钻井液密度上考虑平衡,严重影响机械钻速。这类地层一般属砂、泥、页岩,总体上仍属塑性地层,地应力不会很大。在高陡构造环境中既有地应力因素,又有泥页岩的水化膨胀因素导致的井壁失稳,施工中应注意分析。如果岩样中泥页岩居多,应重点从控制钻井液滤失量、提高钻井液矿化度(如 K⁺ 含量)、动切力指标、适当增大循环排量(也可采用接钻具分流器提高排量、降低循环压耗的方法)、及时发现和清除刺坏钻具、避免定点循环等途径下功夫,若含有较多的砂岩等脆性岩石的掉块,方可重点通过提高钻井液密度来平衡地层坍塌压力,并且仍应结合加强钻井液抑制性来控制井眼质量。同时还应坚持 $f_{311.2}$ mm 钻头开钻就杜绝清水钻进的做法。最新研究表明,大井眼尺寸、大井斜角(地层上倾方向)、长浸泡时间也影响井眼稳定。

第三,由于该类构造天然气保存条件较好,因此,面临一个多产层的安全钻井问题。首先, $f_{215.9}$ mm 井眼钻进期间,从地质上应树立有目的层而不是唯目的层的勘探原则,过去曾钻过不少三叠系、二叠系的专层井,在对川东石炭系气藏有了突破性认识后,才将石炭系作为川东探井的主要目的层。但是如果在一口井中同时存在多个具有工业性价值而压力系统又不一致的气藏时,尤其是有飞仙关组鲕滩与长兴组生物礁等常压孔隙性气藏存在时(如渡口河构造等),应增加取心和中途测试,了解压力与产能两个参数后再决定采用堵死上部气层或提前下套管或更改目的层提前完井,这才是安全、稳

套管破坏的计算机仿真软件研究

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摘 要 文中主要介绍了套管破坏的计算机仿真软件开发的思路流程图及其应用。油气田提供与套管相关联的原始数据、资料→试验(套管、岩石参数试验)→建立计算机仿真数学模型→开发仿真软件→仿真试验→实际试验→修正仿真模型→仿真试验与实际试验吻合→仿真软件开发成功,即为套管破坏仿真软件开发的总体思路。该仿真软件可研究地层岩石粘弹塑性蠕变、地层错动、套管外内压及地层温度作用下套管的变形破坏过程,可模拟预防不同地层套管破坏的各种可行方案,为研究油气田套管破坏提供了经济、简便的途径和新方法。

主题词 套管损坏 模拟 流程图 应用

计算机仿真是近 30 年发展起来的一门综合性技术科学。计算机仿真实质上就是建立一些数学模型,并输入计算机,在计算机上进行实验研究的过程。仿真的内容和种类是非常丰富的,我们所开发的“套管破坏的计算机仿真软件”仅是仿真领域内的一个特例。

计算机仿真在石油天然气工程中将逐步得到运用和发展,比如井控的计算机仿真,三牙轮钻头破岩过程的计算机仿真,泥浆泵性能的计算机仿真等都解决了实际试验无法实现的问题。井下套管破坏过程是一个非常复杂的力学系统问题,如地层错动、岩石遇水膨胀、蠕变以及地质构造运动等,如果要想设

妥的技术措施。

第四, $f 215.9 \text{ mm}$ 井眼在嘉陵江组至飞仙关组底具有长段高压、高可钻性级值的均质碳酸盐岩及膏盐层,特别适合开展井下动力钻具配合 Ballaset 钻头快速钻进技术的应用。在充分作好井眼与设备工具准备的前提下,可通过减少钻头受热破坏(适当加大排量、连续钻进约 6~ 8 h 停钻循环 10 min)、冲击破坏(加水力悬浮器、钻具稳定器、使用前捞净井下落物)、冲蚀破坏(做好钻井液净化工作)且及时起钻(因井下原因泵压异常、井下其它复杂情况等),提高钻头单只进尺和机械钻速、降低钻井成本。

最后还应注意用 $f 660.4 \text{ mm}$ 钻头开钻(井深 20~ 30 m),并保证固井质量,保障井口安全。

川东高陡构造翼部都要钻遇须家河组石英砂岩、二叠系黄铁矿夹层,应设计专用新型钻头,提高钻头进尺与钻井安全性。针对二叠系多断层高压梯度梯度的特点,进入二叠系之前应在钻井液中加入

足够的润滑剂。

结 论

由于高陡构造不同部位的钻井地质特点不同,因此,钻探高陡构造的工艺技术措施也绝不能采用雷同的配套技术。只有划分出井位所在构造部位,才能制定出有针对性的技术对策。这一点对川东地区的钻井安全与经济效益尤为重要。

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A CURVE FITTING METHOD FOR ESTIMATING DYNAMIC RESERVES OF WATER DRIVE GAS RESERVOIR

Zhang Lunyou and Li Jiang (Geological Exploration and Development Research Institute of Sichuan Petroleum Administration). *NATURAL GAS IND.* v. 18, no. 2, pp. 26~ 29, 3/25/98. (ISSN 1000-0976; **In Chinese**)

ABSTRACT: In respect of the water drive gas reservoirs, in especial the active ones, the water invasion rate is an important parameter for monitoring and recognizing the development performance and drive type of gas reservoir, being also a difficult problem of troubling the reservoir engineers all the time. The domestic and foreign scholars have done a great number of researches on the problem, however, their estimation results are always not tallied with the practice because of the excessively idealized hypotheses. Through an analysis on the conventional material balance equation, the relation among water invasion volume factor, recovery percent of natural gas reserves and relative pressure, i. e. $\omega = R^B$ and $\phi = 1 - \frac{1-R}{1-R^B}$, is found, where B is an important parameter indicating water invasion intensity; the procedure of solving such a parameter and estimating dynamic reserves by use of the curve fitting method is proposed and a relevant computer program has been successfully worked out, being very simple and convenient to operate. In addition, the domestic and foreign examples are quoted to further verify the correctness and practicability of such a method.

SUBJECT HEADINGS: Water drive, Gas reservoir, Material balance equation, Reserve calculation

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A STUDY ON THE PRODUCTION RULE OF THE SHALLOW GAS RESERVOIRS IN SHENGLI OIL AND GAS REGION

Sheng Ruyan, Zhang Weiwei and Ding Liangcheng (Institute of Geosciences, Shengli Petroleum Administration). *NATURAL GAS IND.* v.

18, no. 2, pp. 30~ 32, 3/25/98. (ISSN 1000-0976; **In Chinese**)

ABSTRACT: The shallow gas reservoirs in Shengli oil and gas region are mainly distributed in the Guantao Formation and Minghua Formation of the Tertiary and the Pingyuan Formation of the Quaternary. Gas reservoir types are mainly the lenticular lithological reservoirs, the structural-lithological reservoirs being in the minority. Owing to the fact that the gas formations are shallowly buried, being of early diagenesis and loose cementation, as well as most of the gas-bearing sand bodies have edge/bottom water, the gas wells are possessed of the development characteristics of being easy to be watered and sanded, and being of a short stable production period. Through the development practice for more than twenty years it is thought that a stable and reasonable working system is the basis of prolonging the flowing period of gas well; the initial sand control in a new well is the necessary guarantee for prolonging the life period of gas-bearing sand body; the successive separate layer recovery from down to up is the basic principle of exploiting the shallow gas reservoir; a reasonable perforation density is the prerequisite to prolonging the water-free gas production period of the gas well with edge/bottom water; and decreasing wellhead backpressure and drainage gas recovery are the effective ways for increasing the gas-bearing sand body's recoverable reserves.

SUBJECT HEADINGS: Shengli Oil Field, Shallow gas, Oil and gas production, Sand control, Separate layer recovery, Drainage gas production

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A DISCUSSION ON THE REASONABLE MATCHING OF DRILLING TECHNOLOGY FOR THE HIGH-STEEP STRUCTURES IN EAST SICHUAN

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ABSTRACT: In East Sichuan, the high-steep structures are widespread, their exploration prospects being considerable, but the geological conditions are complex. According to the properties of geological structure and drilling geology of the high-steep structures, they are divided into two types, i. e. the major structures (Type iv) and flank buried structures (Type ㊦), and their reasonable technique matching plans of drilling technology are deduced respectively. It is proposed that the matching techniques of the water pressurization drilling, drilling tool safeguard, deepening protective casing and drilling straight hole are mainly carried out for Type iv structures, and those of the drilling medium target wells by use of formation's natural de

flecting rule, comprehensively harnessing borehole destabilizing, highly efficient temporary plugging and a rapid drilling technique by downhole power drilling tools with a diamond bit for protecting payzones and deep high-pressure formations are put into effect for Type ⊕ structures, which will play a reference role in drilling in this region in the future.

SUBJECT HEADINGS: Sichuan, East, Steep dip, Structure, Drilling engineering, Geology

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A STUDY ON COMPUTER EMULATION SOFTWARE FOR CASING FAILURE

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ABSTRACT: The flow chart of developing the computer emulation software for casing failure and its application are introduced. A total thought is: the original relevant casing data and information collected from oil and gas fields → testing (casing and rock parameter testing) → setting up computer emulation mathematical model → developing emulation software → emulation test → practical test → correcting emulation model → showing no difference between the emulation test and the practical test → successfully developing emulation software. By use of the emulation software, the casing deforming-destroying process under the actions of the rock viscoelastic-plastic creep, formation offset, casing internal and external pressures and formation temperatures can be studied, and various feasible plans of preventing casing failure in different strata can be simulated, which provides an economic and convenient new method for studying casing failure.

SUBJECT HEADINGS: Casing failure, Simulation, Flow chart, Application

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PRACTICE AND KNOWLEDGE OF ULTRADEEP WELL PRODUCTION TEST FOR SULFUROUS NATURAL GAS IN SICHUAN

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ABSTRACT: The ultra-deep well production test for sulfurous natural gas is a very difficult technique and it is also an important task of production test engineering at present to unceasingly summarize the past experiences in ultra-deep well production test, to introduce foreign advanced techniques of production test and to untiringly carry out scientific researches for the key problems. So that, this paper gives an outline of the ultra-deep well production test for sulfurous natural gas in Sichuan, summarizes its properties and existing technological level as well as relatively ripe techniques and equipments, analyzes the technical difficulties in ultra-deep well production test and proposes the trend and principal contents of scientific researches for the key problems in the future. The following view points and knowledge are also proposed, i. e. it should be early involved in ultra-deep well production test; the most difficulty in production test is to acquire pressure through shutting-in well; anti-corrosion techniques must be overall adopted in the production test in sulfurous natural gas well; there must be a complete set of the downhole tools and pipe strings being able to suit the conditions of high temperature and high pressure as well as the surface equipments there and a set of comprehensive design software conforming to the ultra-deep well production test should be drawn up.

SUBJECT HEADINGS: Sichuan gas field, Natural gas, Hydrogen sulfide corrosion, Ultra-deep well, Oil production test

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AN OPTIMUM PERFORATION DESIGN METHOD FOR PREFRACTURING WELLS

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ABSTRACT: Because the hydraulic fracturing operations are almost finished in the perforated wells and the fracturing fluid is pumped into through these perforations to complete the fracturing operation, the different perforation parameters would inevitably produce varying effects on the operating results. Through analyzing the influence of the perforation parameters (perforating density, perforation diameter, phase and perforating