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doi:10.11911/syztjs.201405001

国际石油公司页岩气开发技术策略分析与展望

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摘 要:在页岩气开发早期,起主导作用的是中型独立石油公司,尽管某些大型石油公司也较早地参与了页岩气的开发,但取得的成果很差。为此,研究了独立和大型石油天然气公司所采用的页岩气开发技术策略,分析了其成功或失败的原因,并根据已开发的和新的页岩区块的图表数据及其理想的开发技术策略,认为将来在页岩气储层描述、甜点识别、钻井完井和增产措施优化方面也会有重大进展。

关键词:页岩气 勘探开发 技术策略 石油公司

中图分类号:TE37 **文献标识码**:A **文章编号**:1001-0890(2014)05-0001-08

An Analysis and Outlook of Technology Strategy for Shale Plays: Independents vs. Majors

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Abstract: The early influencers and leaders in shale plays were, most notably, medium-sized independents, Consequently, the majors who participated relatively early in the development of shale plays had very mixed results. This report examines the strategies for exploring for and developing shale plays as implemented by independents and by major oil and gas companies. It finds explanations for comparative success and failure, and charts and ideal strategy for both established and new/frontier shale plays. There will undoubtedly be improvements in the characterization of reservoirs, identification of sweet spots, as well as optimized drilling, completion, and stimulation.

Key words: shale; exploration and development; technology strategy; oil & gas company

20 世纪 80 年代到 90 年代,尽管受到石油工程技术的制约,但一些石油公司——如米歇尔(Mitchell)能源公司——仍然坚持在渗透率极低的细粒储层(文中主要是指页岩,但实际上包括细粒硅质碎屑岩和碳酸盐岩)中进行油气勘探开发探索。石油公司早期采用水平井开发页岩气,并在奥斯汀白垩层中进行了先导试验。后来,该技术在沃斯堡(Fort Worth)盆地以北的巴奈特(Barnett)页岩储层开发中进行了推广应用。同时,石油公司开始试验应用新的完井与增产技术,例如多级水力压裂技术、滑溜水压裂液(包括线性和交联凝胶)以及不同尺寸的支撑剂。

21 世纪初,由于天然气价格升高,以及在钻井、完井和开发方面的技术突破,使得用水平井开采巴奈特页岩变得经济可行。页岩气藏初期产量高、天然气价格高,这极大地促进了页岩气开采的发展,而且页岩区块的均质性强、横向分布广并具有达几万平方公里生产面积的"资源区带",从而引发了一场页岩气革命,形成了一个新的、直到现在还在继续发展的页岩油气勘探开发方向。

1 第一阶段:页岩气商业及技术策略的发展

在页岩气开发早期,起主导作用的主要是中型独立石油公司,后来部分公司很快发展成为大型独立石油公司。

随着大尺度模型的建立(引起了华尔街的高度关注),很多公司得以将以往行之有效的理念应用到大

收稿日期:2014-04-24;**改回日期**:2014-08-27。

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规模的页岩气钻井、完井和开发中,但专业的石油公司在页岩气早期开发阶段并不一定取得很好的开发效果,其主要原因在于:参与晚(独立石油公司已经租借了甜点区域);没能利用独立石油公司的关键开发策略;所参与的页岩区块还没有经过测试或者优选;取得了无开采价值的页岩区块;对于新进展反应迟缓;作业成本高;大规模应用各种工程技术,但是收效甚微;团队缺乏页岩区块或非常规区块的开发经验。

因此,尽管某些大型石油公司较早地参与了页岩气的开发,但取得的成果很差。例如,Shell 公司参与了位于俄克拉荷马州和堪萨斯州的密西西比灰岩区块的开发,但是由于开发效果差、成本高,仅仅几年后就将该区块卖掉。BP 公司与 Lewis 能源公司共同开发了伊格福特(Eagle Ford)区块的页岩气,虽然获得较好的开发成果,但 BP 公司仍然认为需要进一步降低成本。与 BP 公司类似,其他大型石油公司与较早进入页岩气勘探开发领域并获得丰富勘探开发经验的独立能源公司合作,取得了一定的成功。例如,挪威国家石油公司(Statoil)收购了在巴肯(Bakken)地区作业的布里格姆(Brigham)能源公司(并获得了其大部分专利技术),必和必拓公司(BHP Billiton)收购了油鹰(PetroHawk)能源公司,并在一段时间内保留了原首席执行官,以便于知识产权转移。同样地,其他大型石油公司也通过收购独立石油公司(而不是简单的租用区块),开始页岩气的开发。

当然,这并不意味着所有独立石油公司都取得了成功,或者所有大型石油公司所取得的成果都不理想,只是说明,由于大型石油公司参与的范围、广度和尺度更大,其进入(或退出)页岩气开发会显得更引人瞩目。

1.1　快速有效的区块定位

独立石油公司常常更关注于深入研究数年的 1~2 个页岩区块。该公司要么拥有已投产油田,其页岩区块作为边际油藏而最终投产,要么能够在不干扰(至少初期)市场的情况下快速扩展新的页岩区块。

巴奈特页岩　该区块是一个特例,由于其大部分的目的层位于沃斯堡市下方,因此在开发前必须召开大量的公众听证会,这使得该区块的页岩气开发广为人知。很多石油公司参与了该区块页岩气的勘探开发工作,而且由于开发技术很大程度上还处于试验阶段,因此各个公司之间的页岩气勘探开发经验差别很大[1]。

马塞勒斯(Marcellus)页岩　该区块页岩气产量主要集中在一个区域,其他储层已经投产多年。实际上,马塞勒斯页岩层是该区块的边际油藏。兰格(Range)和卡伯特(Cabot)等在该区块作业的公司拥有或者能够使用现有的基础设施,因此具有很好的初始有利条件[1]。

伊格福特页岩　该区块是一个典型的大型页岩气区块,拥有少有的广阔租借面积。可租借整个区块,对提高整体效益十分有利。同时,要求作业公司与土地所有者建立良好的信任关系,而这是一个外来者或者大型石油公司难以做到的[1]。

巴肯页岩　早在页岩的真实潜力被广泛认可之前,布里格姆石油公司(Brigham)和大陆石油公司(Continental)等就获得了该区块的租约。美国地质调查局对于该区块可采储量的预测持续偏低(预测储量为 6.4×10^8 m^3 原油当量),使得这些公司在矿区租借方面受益(当然也可能不利于获得公共融资)。目前,由于新技术的出现和新储层——如斯里福克斯储层(Three Forks)——的发现,该区块的可采储量预测值高达 76.3×10^8 m^3 原油当量[1]。

1.2　新的融资方法

由于页岩气区块规模巨大、水平井具有动用储量大的优势,并且区块各个位置都能获得均匀的开采(至少初期这样认为),预测的最终储量以及现金流得到了华尔街投资者的高度重视[2-3]。但是,对于多数独立石油公司,如果无法通过其他创新的方式获得融资,仍然很难在这种高度资金密集的页岩区块实施钻井作业。

大型石油公司通常囿于这样一个现实,即公司的大股东为大型机构投资者,通常要求利润分红并具有上涨的预期;然而,低市值的小型石油公司却十分激进,即投资者更愿意承担高风险以换取可能的高额汇报[1-3]。即便如此,如果股东活动家们取得了公司的控制权,则"高风险、高回报"的方式有时也会搁浅。而且,这种方式可能是高负债、低气价时代的唯一结局。然而,经常会出现一些具有远见卓识的领导者,他们在"概念验证"阶段起主要作用,而此后则需要有股东活动家加入,并建立一套审慎的规则,即成本控制和统一部署。冒险可能是个好办法,但并不总是奏效,这在很大程度上取决于公司的文化。

切萨皮克能源公司(Chesapeake Energy)　该公司通过股权融资、债务融资甚至以未来产量作为抵押进行融资的方法,发起了新的激进的公共融资。因为诱人的投资回报预期和潜在的股票回报,人们普遍认为值得为这种高资金消耗承担风险。虽然不

是所有的融资项目最终都能达到投资者的回报预期，但那是另一回事了。

桑德里奇能源公司(SandRidge Energy)　为了融资开发密西西比灰岩区块，该公司发行了“密西西比信托”产品。密西西比灰岩区块并不是页岩而是石灰岩，但是由于其规模巨大、平面展布广且适合于高密度多级水平井开发，仍然被视为“非常规区块”。信托证书是一种有价证券，它是通过普通股票的独立销售并且功能上作为一种有效的筹资工具。

德文郡(Devon)能源公司　为了获得开发伍德福德(Woodford)等页岩区块所需的资金，该公司与国际国有公司展开了合作。投资公司并不期望通过出售股票而得到快速的投资回报，而是希望通过技术交流和知识转移，来开采自己国家的页岩气资源。

油鹰能源公司　该公司通过各种渠道获得了初期融资，在伊格福特页岩区块，完成了首批“概念验证”井，即在识别的油气富集区或甜点区钻井。

大陆石油公司　该公司作为多级水力压裂的先行者之一，在巴肯页岩区块获得了很高的初期产量。利用在巴肯页岩气区块获得的杠杆收益(此时油价高)，该公司购买了位于俄克拉荷马州南部的伍德福德 SCOOP 高含气页岩区块。

与勘探阶段一样，非常规区块的开发阶段同样依赖于创新[4-5]。一些公司处于高额债务与低迷气价的双重困境，有人认为，在收购这些公司的资产时，其他公司显得过于审慎，原因在于投资者们期望一个稳定的增长速度，就好像“概念验证”都意味着一帆风顺一样。然而不幸的是，随着对油藏认识的不断加深，非常规资源的开发更需要高度创新。

1.3　新技术的应用

石油公司在页岩气勘探开发过程中使用的几项突破性新技术，其中大部分都是由独立石油公司与油服公司联合快速开发出来的。为了保证租期内的生产(HBP)，公司必须尽可能快地钻井来加快作业进度，而在这之前，公司会将区块用作“现场实验室”，对早期的单井进行测试与评估[6-7]。如果有1～2口井的测试结果显示独立石油公司所使用的技术方法会引起严重的问题，他们可以及时调整甚至彻底更改钻井方案和钻井计划。

通过地球化学方法确定含油气边界　利用直接手段来确定总有机碳含量(TOC)和热成熟度，从而确定含油气边界。此外，有一些间接计算/预测有机碳含量的新方法，也取得了一定成效，例如利用已有测井数据的计算方法(Passey 法)[8-9]。

水平钻井/地质导向钻井　水平钻井和随钻地质导向钻井需要配合新型钻头、钻杆以及钻井泵。初期，小型石油公司能够针对几口井进行试验并解决关键问题，但不会将研究推广到一个包含 50～60 口增产井的钻井计划中[10]。

用于有效识别甜点及地质导向的成像技术　米歇尔能源公司及其他公司提出了一种方法，综合了地质、地球物理信息，能够生成并解释三维地震图像，从而在钻前以及导向钻进时揭示油气富集区(甜点)。在存在地质风险(包括水层和异常压力地层)的储层中钻进时，地质导向尤为重要[6-7]。

降低储层伤害的新型流体　掌握黏土矿物以及井的其他元素的特性，对于开发不堵塞裂缝或裂缝区域的新型流体至关重要[6,10-11]。

实时温度和压力监测工具　随钻测井(LWD)是一个重大的技术突破。其中，可实时传递信息的耐高温传感器发挥了重要作用[12]。

人工及天然裂缝系统　在富含天然裂缝的地层中钻进，可能会对钻井作业带来显著影响，在产气层——例如马塞勒斯(Marcellus)和海尼斯威尔(Haynesville)——尤其如此[13]。更好地了解裂缝延伸方向(如图 1 所示，其中，图 1(a)为模拟得到的裂缝有效连通性和电导率，图 1(b)为压裂后裂缝的有限连通性和电导率[12])，可以更好地优化压裂支撑剂、压裂液、施工压力及压裂工艺。

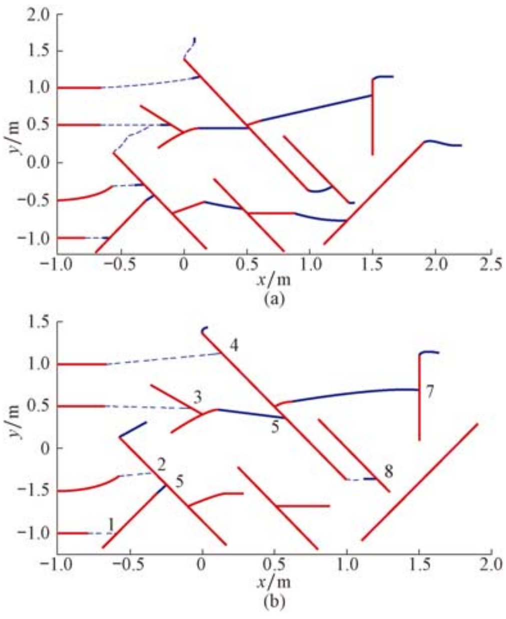

图 1　裂缝延伸方向

Fig. 1　Mapping fracture pathways

压裂液和水力压裂设计　其关键是需要掌握压

裂液的性能，并且要认识到，尽管所有页岩区块具有一些共同特征，但每个页岩区块都是不同的。比如，在巴奈特页岩区块进行水力压裂时，瓜胶是一种关键的压裂液添加剂。然而，这种添加剂的加量还需要进一步优化，某些情况下还需加入交联剂(如锆交联剂)，使胶体发生交联，从而形成一种更耐高压、与支撑剂配合更好的聚合物[6]。

更加深入地了解岩石力学性质 对于自喷井、非自喷井或产量迅速递减的井，掌握岩石力学性质非常重要，特别是孔隙结构、喉道和裂缝的研究。毫无疑问，独立石油公司会尽最大的努力去研究钻井、完井以及生产过程中岩石结构的变化[12]。

用于岩性识别的 X 射线衍射技术(XRD) XRD 等新技术正被用于黏土矿物识别，以模拟和预测钻井、完井和压裂过程中的反应。图 2 为北美页岩 XRD 矿物识别分析结果[8]。

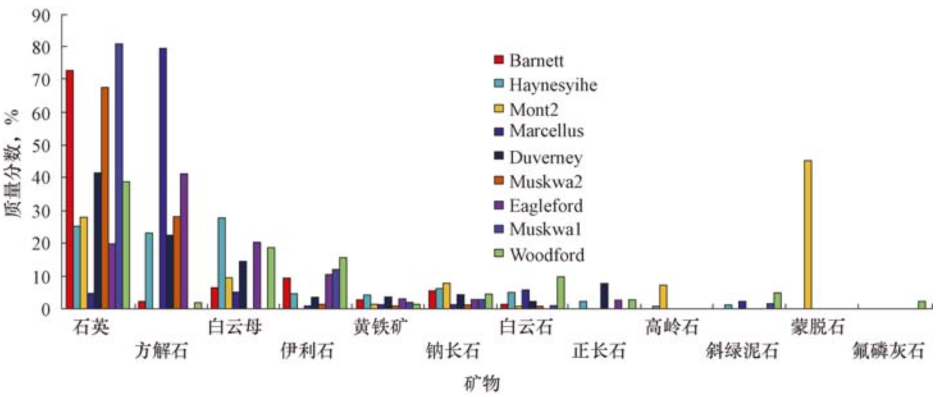

图 2 北美页岩 XRD 矿物识别分析结果

Fig. 2 Minerals from XRD analysis for North American shales

“现场实验室”法 与一些作业者要求遵循“井工厂”模式不同的是，实际上，作业公司高度创新、敢于尝试新的钻井完井技术和处理方法。由于这些新技术会比其他技术更有效，这意味着作业者在早期阶段的开发成效差异很大，而且获得的经验教训也有利于后来的工作[14-15]。

以团队为核心的组织结构(分散式领导) 团队可能很小，成员来自各个领域，通常是工程师、地质师、岩土工程师和地球物理学家共同协作。团队可快速决策，并且团队领导的快速决策不需要通过冗长的审核过程。

1.4 面临的挑战

页岩区块勘探的第一阶段在工程技术上取得了巨大成功，使得在页岩中的钻井、完井成为可能，后续才能生产大量的油、干气和湿气。然而，瑞士信贷集团的报告显示，页岩气井第一年的产量递减率很大，例如密西西比灰岩气井产量递减率高达 80%，巴肯斯里福克斯页岩气井产量递减率也达到 65% 左右。为了控制递减率、更好地开发储层，研究的重点转移到了加密钻井(水平井)[2-3]。

除了气井产量递减率高，还存在其他的技术挑战，包括：大型水力压裂的成本逐渐升高；井场和基础设施需要优化；更好地找准甜点；确定最佳井距和井网密度；确定一个区块的含油气边界(“死油气线”)；确定新的含油气层，特别是在含多层油气层或“叠加层”的页岩区块[10,16]。

2 第二阶段：页岩气开发技术策略优化

目前，页岩区块开发处于一个新阶段，包括钻井完井作业优化，从而得到更高的初期产量，降低单井产量递减率，提高可采储量。第二阶段的关键问题在于，大型石油公司和独立石油公司需要实现开发效益，并且提高投资组合的质量。其目标主要包括：获得作业区块；从生产中获得快速的现金流；从实践中学习；使用革新性的技术；优化基础设施；缩短递减率高的生产阶段；探索加密井网的新途径，以提高最终采收率。

2.1 常规方法

通用工作流程已经被 Williams-Kovacs 及 Clarkson 发展成型[13]，他们提供了一种页岩气开发流程，如图 3 所示。

2.2 特殊方法

页岩区块的开发过程可以概括为勘探、评价和开发 3 个方面。

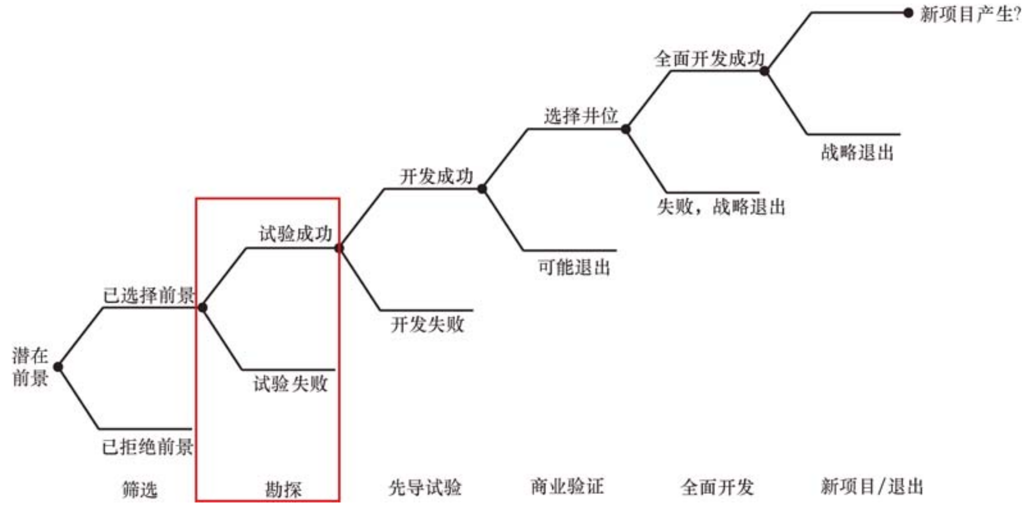

图 3　页岩气开发流程概述

Fig. 3　Workflow of the shale gas development process

2.2.1　勘探

勘探的主要目的是识别页岩储层中最高产的部分(即找到甜点),其主要工作包括:获得作业区块(租借或购买),大型盆地分析研究,典型剖面、测井、地震、地球物理等。

2.2.2　评价

评价的目的是为先导试验井和水平生产井做准备。

1) 先导试验井设计。主要目的是保证设计的科学性,并为进行中的室内研究收集数据,其主要工作包括压力监测、测试井、测井和取心、压裂前后的先导试验。

2) 水平井。主要目的是指导压裂设计优化以及作业,其主要工作包括更高密度的井间距、支撑剂密度优化、提高井网密度、使用更多支撑剂[17]。

2.2.3　开发

开发的目标是保持投资和生产优化间的平衡[1]。

投资　资本有效利用、对冲保值以及良好的中游合同。

叠加区带中的新区域　针对每个叠加层的多底井;作业区域倍增;降低风险与支出。

布井　优化井间距以及位置(包括叠加井和加密井)。

作业效率　基础设施、中游作业、产出水/流体处理。

井网密度优化(加密井网/垂直间隔钻井)　井距离为 200 m 的 1.6 km 长的井(0.3 km^2 空间间隔);井距离为 100 m 的 1.6 km 长的井(0.2 km^2 空间间隔);确定新钻井生产效果(老井的 80% 或者 60%);确定裂缝干扰/流体行为/流动通道。

随着页岩气的发展,工程技术优化尤其重要[18]。研究一种优化方法时,主要是要用有效的模型/建模考虑变量,包括物理性能以及财务和经济方面的变量,如图 4 所示[13]。

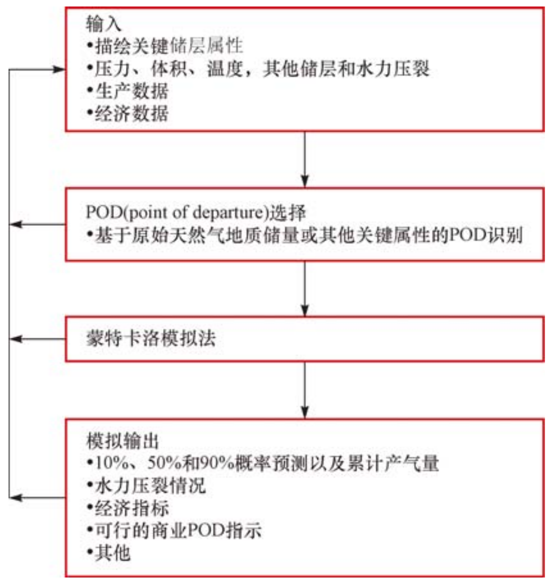

图 4　页岩气勘探开发油藏模拟流程

Fig. 4　Workflow for reservoir simulation of Shale gas development

3　结论与展望

在页岩区带商业化过程的第二阶段中,技术策略主要集中在储层优化上面。毫无疑问,将来在储

层描述、甜点识别、钻井完井和增产措施优化方面会有重大进步。

可能出现一些重大的技术突破：目前钻井方式的改变，以及出现可被称作“随钻增产”（或形成一个新名词：增产式钻井）的钻井与酸化过程的结合，能够使储层伤害最小化并极大地降低成本和缩短钻井完井时间。最终的结果是降低了成本，并实现了更高的最终采收率。

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[编辑 陈会年]

附 录

独立石油天然气生产商的页岩区块技术策略[1]

2014 年 4 月，美国独立石油公司协会年度分析师会议在纽约召开，各公司对其页岩气开发技术策略进行了交流，这对于未来页岩气的高效开发、各公司的股价必将带来积极的影响。各独立石油公司中最具代表性的技术策略如下（公司没有先后之分）。

1 大陆石油公司

巴肯页岩的开发重点是提高钻井效率，以推动增长。该公司在巴肯和斯里福克斯使用了 191 台钻机，采取大型丛式井井场控制成本，保证了高利润。

2014 年计划钻 290 口新井（总计 870 口）。

增大先导井密度：水平段间距 100 m（以及水平段间距 200 m）；同区块的新井井距为 200 m（采用了微地震监测，共 31 口新井）。

2 怀廷(Whiting)公司

2.1 巴肯页岩

该公司在巴肯页岩区块拥有密苏里大峡谷（Missouri Breaks）、卡桑德拉（Cassandra）、萨尼斯（Sanish）、希登本奇（Hidden Bench）等 6 个气田，致力于技术策略优化和中游效率的提高。

新目标:斯里福克斯页岩储层上部。

技术策略为:

1) 识别巴肯页岩成熟度边界/巴肯尖灭(或"死油气线");

2) 推广水力压裂,包括 40 级水力压裂设计、每级 3 个射孔组、120 个可能的进入点;

3) 新型固井尾管(及滑套)。

2.2 奈厄布拉勒(Niobrara)页岩

技术策略为:

1) 中游一体化;

2) 高密度先导性试验:50 m 的井距,3.9 km^2 的钻井单元空间。

3 阿布拉克萨斯(Abraxas)公司

总体技术策略重点为"执行力"。

3.1 伊格福特页岩

1) 甜点识别,获得 100%的经营权益;

2) 均衡投资组合;

3) 油/干气/凝析液,与套期保值相结合;

4) "隐藏"的天然气资源,天然气价格上涨后,额外生产的天然气。

3.2 巴肯页岩

1) 增加井网密度;

2) 在斯里福克斯区域加密钻井。

4 萨姆森(Samson)公司

在巴肯页岩获得的经验——2008 年开始于北畜牧场(North Stockyard)气田——为"越多越好",即更多压裂级数、更长水平段及更多支撑剂。目前,在斯里福克斯页岩区块计划进行加密钻井、边角井和增加开发井数量。

5 西南能源公司(Southwestern Energy):

马塞勒斯页岩:位于宾夕法尼亚州东北部,目前已经加密井网。

费耶特维尔页岩:处于区带的核心部分,进驻早,租金为 320 美元/英亩,矿区使用费为 15%,获得了 74%的经营权益,2014 年计划钻 460~470 口水平井。

新风投区块:位于加拿大新不伦瑞克省,面积 1×10^4 km^2。

总体技术策略为:

1) 增大水平段长度;

2) 降低单井成本;

3) 层系纵向组合生产;

4) 获取邻近矿区。

6 美国能源公司(怀俄明分公司):

"叠加区带"的策略为:

1) 巴肯页岩/斯里福克斯;

2) 奥斯汀白垩岩(Austin Chalk)/伊格福特/布达(Buda);

3) 目前尽量避免涉足国有土地(需要 307 d 处理钻井许可);

4) 拥有斯里福克斯 12.5%的股份;

5) 扩边钻井。

7 Denbury 公司

应对大多数第一年产量递减率高达 80%的页岩和非常规区块的策略为:

1) 提高目标区块采收率;

2) 尝试在巴奈特页岩使用二氧化碳驱;

3) 二氧化碳驱的采收率预测为气田总储量的 17%。

8 Unit 公司

该公司拥有钻机、中游处理设备和管线,主要业务有集气、加工厂及管线建设,还参与工程作业。其开发技术策略为:

1) 在最佳位置钻丛式井;

2) 井场之间的快速转移;

3) 更大的钻井泵;

4) 环境友好;

5) 利用现场天然气作为发动机的燃料;

6) 在常规、成熟油田及非常规储层中钻水平井。

已投产井技术策略:主要为 5—7 层合采。

9 阿特拉斯能源合作公司(Atlas Energy Partners)

通过收购和地域多元化实现公司的成长,其收购和感兴趣的公司有卡里索(Carrizo)公司、泰坦(Titan)公司、匹敌能源(Equal Energy)公司、勘探开发能源(EP Energy)公司等。

该公司在密西西比灰岩区带中心找到了甜点,即根据生产状况决定租期长短的亨顿(Hunton)区块。

10 中州(Midstates)公司

该公司将密西西比灰岩储层的开发经验用于位于俄克拉荷马州和德克萨斯州狭长区域内的宾夕法尼亚砂岩——克利夫兰(Cleveland)和卡蒂奇格罗夫(Cottage Grove)——开发中,并将三维地震技术充分应用于以下情况:储量级别高的地区、布井及完井方式优化、研究密西西比狭长区域是否适合加密钻井、扩展矿区的范围。

11 西马莱克斯(Cimarex)公司

11.1 特拉华(Delaware)盆地阿瓦隆(Avalon)页岩

叠加的区域包括第二博恩斯普林(Second Bone

Spring)、第三博恩斯普林(Third Bone Spring)、沃尔夫坎普(Wolfcamp)和阿瓦隆(Avalon)。

目前其技术策略为:

1) 使先导井交错/堆叠;

2) 进行额外的先导钻井(井距为每 0.32 km^2 4 口井);

3) 扩大压裂规模(如 TimTam24 Fee#1H 井,在原来的 12 级基础上增加到了 20 级)。

其原来的技术策略为:

1) 12 级压裂,初始产量为 175 m^3/d,24 个月后降低到 32 m^3/d;

2) 20 级压裂,初始产量为 239 m^3/d,24 个月后降低到 60 m^3/d(预测值)。

11.2 沃尔夫坎普页岩

该区块的压裂规模不断扩大,其过去的策略为:水平段长度为 1 524 m,压裂级数为 12 级,使用 100 目砂粒 180 t,注入速度为 15.9 m^3/min。

目前的技术策略为:水平段长度为 1 524 m,压裂级数为 20 级,使用 100 目砂粒 2 720 t 或 906 t,注入速度为 6.3~9.5 m^3/min。

12 开拓者(Pioneer)公司

12.1 米德兰(Midland)盆地页岩层段

主要为沃尔夫坎普和斯普里贝里(Sprayberry)页岩/粉砂岩,其技术策略为:

1) 利用古生态模型和生物地层学,完成精细地质建模;

2) 增大井网密度,单井间距为 0.4 km^2;

3) 加密钻井。

12.2 叠合产层

主要包括克里尔福克(Clearfork)、中斯普里贝里页岩、阿托卡(Atoka)及伍德福德,其技术关键是更好地压裂或酸化。

13 哈康(Halcon)公司

13.1 巴肯/斯里福克斯

主要为伊格福特外围区块(扩展了伊格福特的产层),其技术策略为:

1) 开发区带的甜点区;

2) 1 000 个井位,水平段长 2 400 m;

3) 缩短钻井时间,降低压裂成本;

4) 人工举升方式优选;

5) 水平段长度为 2 100~2 700 m;

6) 井距为 300 或 240 m;

7) 增大射孔组密度,试验不同类型的支撑剂。

13.2 塔斯卡卢萨(Tuscaloosa)海相页岩

密西西比页岩的 TMS 井,其技术策略为:

1) 使用 Passey 法,利用测井数据识别甜点(根据声波测井和电阻率测井资料,确定总有机碳含量和成熟度);

2) 高泥质含量-低膨胀系数(蒙脱石含量低),指导钻井和压裂设计;

3) 增加水平段长度,超过 2 195 m;

4) 使用三维地震和新兴的随钻测井技术,精确定位水平段位置;

5) 混合压裂液(不仅有滑溜水);

6) 支撑剂密度大于 2 383 kg/m;

7) 射孔组距离为 15 m;

8) 优化分段的大小;

9) 使用氯化胆碱提高黏土稳定性;

10) 使用更多的抗研磨钻头。

14 马格南亨特(Magnum Hunter)公司

该公司的主要技术策略为:

1) 基于试验井全面搜集信息;

2) 重点区域为尤蒂卡波因特普莱森(Utica Point Pleasant);

3) 投资管线和集输系统。

15 卡里索(Carrizo)公司

该公司主要在尤蒂卡页岩、伊格福特页岩、奈厄布拉勒页岩及宾夕法尼亚马塞勒斯页岩东北部进行作业,2014 年开展加密钻井经济可行性研究,钻 1 000 口补偿井后,估算的最终储量为"母井"的 80%(原因可能是压裂的影响)。

16 兰格能源(Range Resources)公司

该公司的主要技术策略为:根据影响天然气地质储量(GIP)的主要因素(压力、温度、孔隙度、油气饱和度、热成熟度、产层厚度等),对所有区带的天然气地质储量进行分析,包括尤蒂卡波因特普莱森、马塞勒斯、上泥盆系等叠置的产层或区块。

17 斯威福特(Swift)能源公司

该公司的主要技术策略为:

1) 关键是井筒位置的精确定位,包括地质导向/储层中延伸钻井、更好的探测/更好的传感器以及三维地震与钻井结合。

2) 水平段测井,可在品质最好的岩石处选择完井增产,包括优化压裂级数布置、提高压裂液性能、减少为了有效完井所需的压裂级数(注:这与通常所认为的"越多越好"是相悖的)。

3) 压力梯度正常的地段,每个压裂分级内射孔分组,以实现更高的压裂效率。

An Analysis and Outlook of Technology Strategy for Shale Plays: Independents vs. Majors[1]

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Abstract: The early influencers and leaders in shale plays were, most notably, medium-sized independents, Consequently, the majors who participated relatively early in the development of shale plays had very mixed results. This report examines the strategies for exploring for and developing shale plays as implemented by independents and by major oil and gas companies. It finds explanations for comparative success and failure, and charts and ideal strategy for both established and new / frontier shale plays. There will undoubtedly be improvements in the characterization of reservoirs, identification of sweet spots, as well as optimized drilling, completion, and stimulation.

Key words: shale; exploration and development; technology strategy; oil & gas company

In the 80s and 90s, despite the limitations of technology, companies such as Mitchell Energy persisted in their quest to extract hydrocarbons from ultra low-permeability fine-grained formations, which are called “shale” for the purposes of this report, but which in reality cover a wide spectrum of siliciclastic and carbonate fine-grained rocks.

The early shale play companies applied the horizontal drilling techniques which were being pioneered in the Austin Chalk. They moved them north to the Fort Worth Basin, where they started to horizontally drill the Barnett Shale. They also began to experiment with new completion and stimulation techniques, namely multi-staged hydraulic fracturing, and the use of slickwater fracturing fluid (as well as linear and crosslinked gel), and different sizes of proppants.

Because the price of natural gas was high in the early 2000s, success in drilling, completing, and producing the horizontal wells in the Barnett shale was also economically viable. The high initial production levels of gas combined with high prices worked as a powerful stimulus. The notion that shale plays were homogeneous, laterally extensive “resource plays” with productive extent of hundreds of thousands of acres was a paradigm shift which set off a boom and a new direction that continues to shape oil and gas exploration and production today.

1 Phase I: Developing a Business and Technology Strategy for Shale Plays

The early influencers and leaders in shale plays were, most notably, medium-sized independents, some of which soon became large independents.

With a large-scale model that was highly attractive to Wall Street, many companies were able to move past proof of concept to drilling, completing, and producing large plays. Majors did not necessarily do well in the early development of shale plays for several reasons: late to the party (the independents had the sweet spots already leased); were not able to take advantage of the key elements of the independents’ strategy; participated in plays that were not yet tested and/or optimized; acquired leases in unproductive parts of the play; slow to respond to new developments;

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high operating costs; implemented all technologies on large scale, with poor results; teams lacked experience in shale plays or unconventional.

Consequently, the majors who participated relatively early in the development of shale plays had very mixed results. Shell entered the Mississippian Lime play in Oklahoma and Kansas, but decided to sell the play after only a few years, due to disappointing results and high costs.BP partnered with Lewis Energy in the Eagle Ford and while BP seemed to be satisfied with the results, they also announced a desire to contain costs.Like BP, other majors seemed to succeed when they either partnered with an early-entry, experienced independent shale operator. Statoil purchased Brigham Energy (and retained much of the talent) in the Bakken, BHP Billiton purchased Petrohawk, and retained their CEO for a period of time for knowledge transfer, and other companies likewise entered via acquisition rather than simply leasing prospects.

These examples are not to suggest that all independents experienced success, nor that all majors experienced disappointing results; it is just that scope, breadth and scale of majors' involvement made their entrance (and exit) of shale plays all the more dramatic.

1.1 Effective and Efficient Land Positioning

Independent operators tended to specialize in one or two shale plays which they had carefully studied for years. They either owned producing fields where the shale play was a "bypassed pay" zone and consequently held by production, or they were able to swiftly lease vast expanses of a new play without perturbing the market, at least at first.

Barnett Shale The land situation was something of an exception to the rule, given that so much of the land was under the city of Fort Worth, and it was necessary to include a number of public hearings, which loudly publicized the endeavor. The play had a large number of operating companies, and the experiences of each varied widely as the technology was very much in the experimental stage [1].

Marcellus Shale Much of the Marcellus production lies in an area that has long produced from other formations. The Marcellus was, in essence, a bypassed pay zone. Companies such as Range and Cabot, with operations in the area as well as control or access to existing infrastructure had a great initial advantage [1].

Eagle Ford This is an example of a very large play which contained areas that were not commonly leased. It was possible to lease entire ranches, which helped a great deal with respect to efficiency. It also required the operating company to have a very good and trusting relationship with the ranch owner, which is something not easily accomplished by a stranger or large, distant, super-major [1].

Bakken Companies such as Brigham and Continental were able to obtain leases in the early stages of the play before the true potential was recognized. They were helped in their leasing (while perhaps hampered in obtaining public financing) by the persistently low United States Geological Survey estimates of recoverable reserves, which were, for many years, officially announced to be 4 BBO, while, given the new technologies and new zones such as the Three Forks, they are commonly held to be as high as 48 BBO [1].

1.2 New Financing Approaches

Because of the sheer magnitude of the plays and the potential for vast reserves produced in horizontal wells drilled as parallel laterals, and which could be "mined" for uniform results across the entire play (at least that was the early thinking) [2-3], the estimates of ultimate reserves and for cash flow were highly attractive to Wall Street. Most independents, however, could not hope to drill this highly capital-intensive play without obtaining funding in innovative ways.

"Aggressive" Means Risk-Tolerant Investors The super-majors are often constrained by the fact that their major shareholders are large institutional investors who have traditionally looked at companies as capable of producing profits, which translate into dividends and predictable rise in price. On the other hand, the small-cap small companies have been considered very aggressive, which means that the investors are less risk-averse, and welcome the possibility of high returns [1-3]. That said, the "high-risk / high-reward" approach sometimes hits a snag when shareholder activists gain control of a company. Sometimes it seems to be the only solution to high debt and low natural gas prices. However, it often results in the ejection of the original visionary leader. The argument is that the visionary leader was good for a "proof of concept" notion and the shareholder activists need to come in and establish a kind of prudent order which means cost-control and uniform operations. This may be a good idea, but, it may not always work. Much depends on the culture of the organization.

Chesapeake Energy Developed new, aggressive approaches to public financing via equity financing, debt financing, and even financing future production. The prevailing belief was that the high capital costs were well worth the risk, thanks to very attractive projected returns on investment, and also potential returns on stock. Not all financing options rewarded their investors with the hoped-for returns, but that is a different story.

SandRidge Energy Developed their "Mississippian Trusts" in order to develop the Mississippian Lime play, which is not a shale but a limestone, but considered an "unconventional" in the sense that was viewed as massive, laterally extensive, and ideal for high-density multi-stage laterals. The Trust instruments were securities sold separately from the regular stock, and functioned as effective financial vehicles for.

Devon Partnered with international national companies in order to obtain needed capital to develop plays such as the Woodford Shale. The companies investing were not necessarily hoping for a quick return on their investment in terms of selling stock, but were more desirous of obtaining technology exchange and knowledge transfer for developing their own country's shale resources.

PetroHawk Obtained initial investment funding from various sources in order to develop first "proof of concept" Eagle Ford wells in what was identified as a fairway or sweetspot in the Eagle Ford.

Continental Resources An innovator in multi-staged hydraulic fracturing and obtaining very high initial production rates in the Bakken, Continental Resources leveraged revenues derived from their oil production (while the oil prices were high) to purchase leases in what was considered a gas-rich area, in their Woodford "SCOOP" play in southern Oklahoma.

The development phase of unconventionals is proving to be just as innovation-dependent as the exploration phase [4-5]. One can argue that the companies that acquire assets from distressed companies that are suffering from the dual onus/burden of high debt and low natural gas prices tend to be too cautious because their investors expect a steady rate of growth as if achieving "proof of concept" meant smooth sailing. Unfortunately, in the case of unconventionals, a high degree of innovation is necessary as more information is gained about the reservoir.

1.3 Implementing New Technology

A quick overview of the new technologies in Phase I, which resulted in the mainstreaming of shale plays can narrow a potentially very long list to that of several "make or break" new technologies, many of which were developed quickly by the independents in conjunction with service companies. Independents tended to use the field as a "living laboratory" and were able to test and evaluate the results of individual wells in early stages[6-7], before the operations tempo had to accelerate dramatically as companies sought to drill as quickly as possible to make sure the leases were held by production (HBP) for the leases expired.

Independents had the ability to revise and even completely overhaul their drilling programs and drilling plans if the results of one or two wells indicated that the approach they were using would result in large problems.

Geochemistry to Determine Productive Limits Direct methods were used to determine TOC and thermal maturity to identify productive limits. In addition, new methods of indirectly calculating/estimating TOC using existing logs (the Passey Method) were used with some degree of success[5, 8-9] .

Horizontal Drilling / Flexible Geosteering Being able to drilling horizontally, and to steer the well while drilling required new kinds of bits, drillpipe, and pumps. Small companies were able to experiment on a few wells at the beginning and work out critical issues, rather than having to roll out with a drilling plan involving 50 or 60 simultaneous wells[10].

Imaging for Proper Identification of Sweet Spots and Staying in the Zone Mitchell Energy and others developed an approach that integrated geological and geophysical information, and to generate and interpret 3D seismic images that would both reveal zones of enrichment ("sweet spots") both before drilling, and in conjunction with geosteering. Being able to stay in the zone was most critical for formations containing geohazards, including water zones and abnormal pressure[6-7].

New Fluids that Minimized Formation Damage Understanding the behaviors of the clay minerals as well as the other elements of the well were very important in developing fluids that did not clog fractures / fracture zones[6,10-11].

Tools for Real-time Temperature and Pressure Monitoring Logging While Drilling (LWD) represented a huge breakthrough. High temperature-resistant sensors that transmit real-time information made a great deal of difference[12].

Induced vs. Natural Fracture Systems Being able to drill in the zones containing high degrees of natural fracturing could have a significant impact, particularly in gas-productive formation such as the Marcellus and the Haynesville[13]. A better understanding of fracture pathways (Fig.1, Figure a shows effective connectivity and conductivity of fractures after stimulation, Figure b shows limited connectivity and conductivity after fracturing[12]) has allowed optimization of proppants, hydraulic fracturing fluids, and pressure / techniques.

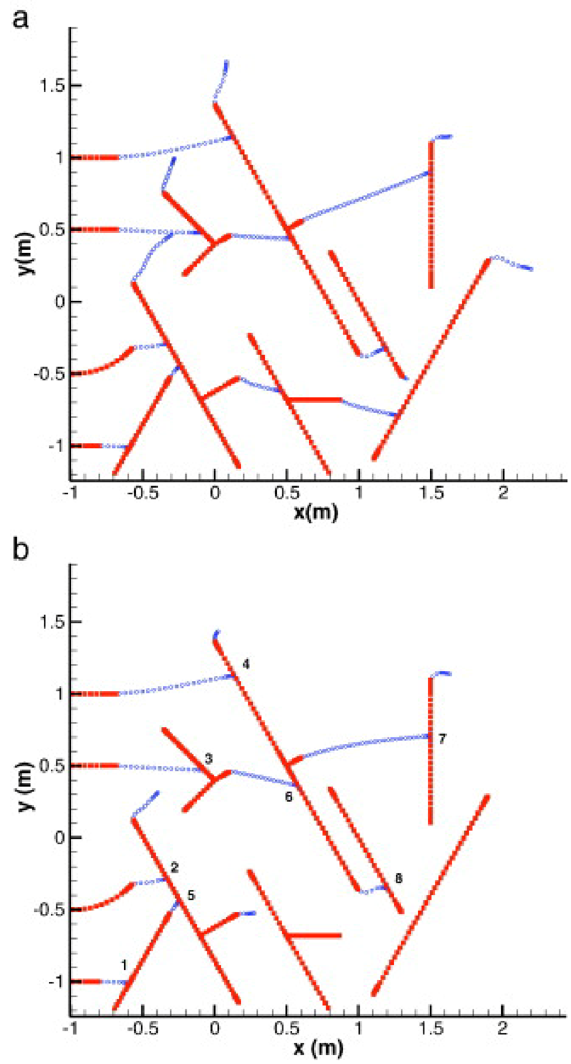

Fig. 1 Mapping fracture pathways

Hydraulic Fracturing Fluids and the Hydraulic Fracture Design Understanding the behaviors of fracturing fluid, and recognizing that while there are some common elements, all plays are different, is a key issue. For example, guar gum was a key additive in early hydraulic fracturing programs in the Barnett. However, how much was enough? And, it was necessary in some cases to add a stabilizer such as zirconium to "cross-link" the gel and create a polymer that could withstand more pressure, and work better with the proppants[6].

Better Understanding of Rock Behavior Understanding how a rock will behave, particularly as it applies to pore architecture, conduits, and fractures was the difference between a good flowing well, and on that never flowed, or had a very precipitous decline. Independents made sure that they understood to the best of their ability what was happening to the rocks while drilling, while completing, and also while producing[12].

XRD for Identifying Mineralogy New technologies such as XRD are being used to identify clay minerals to model and predict behavior during drilling, completion, and stimulation[8]. Fig. 2 shows the minerals from XRD analysis for N. American shales.

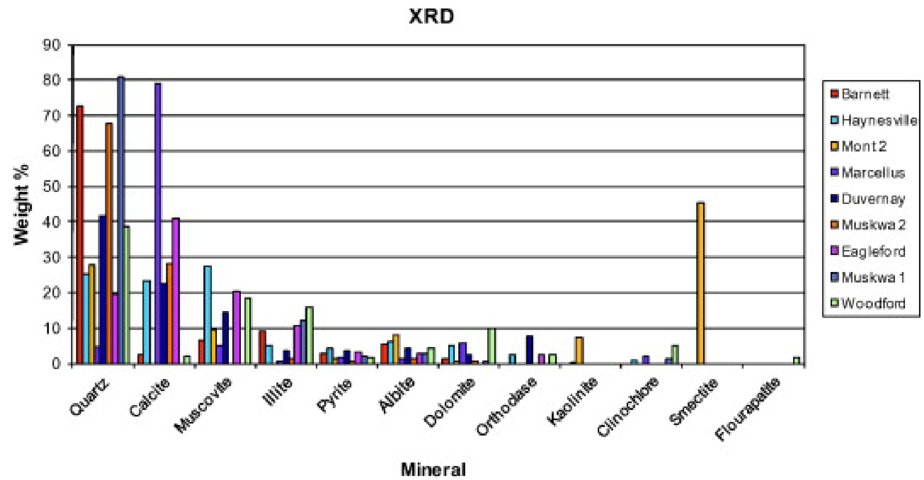

Fig. 2 Minerals from XRD analysis for N. American shales

The "Living Laboratory" Approach Instead of adhering to the "factory" model that some operators claim to be following, in reality, they're highly innovative, and they are willing to experiment with different drilling and completion techniques, along with treatments. It means that they will have highly variable results in the early stages because some techniques will be more effective than others. Nevertheless, the lessons learned will be used profitably later[14-15].

Team-Based Operations Structure(Distributed Leadership) Teams can be quite small and are interdisciplinary, typically with engineers, geologists, geotechs, and a geophysicist working together. Decisions can be made rapidly, and the team leader has the authority to make a decision quickly without lengthy approval processes.

1.4 Emerging Challenges

The first phase of exploration of shale plays resulted in great technological success in determining that it is possible to drill and complete shales so that they produce very high volumes of oil, gas, and liquid-rich gas. The problem is that of decline rates, however, and according to a report by Credit Suisse, the first year decline rates can range from a high of almost 80% in the Mississippian Lime, to around 65% in the Bakken Three Forks. To combat steep decline rates, and to better drain the reservoir, the focus started to turn to the viability of increased density or infill drilling (horizontal wells)[2-3].

In addition to steep decline rates, other challenges emerged, including escalating costs of massive hydraulic fracturing jobs, the need to optimize drilling pads and infrastructure, a need to better pinpoint sweet spots, and to determine ideal well spacing and cluster density. Determining the productive limits of a play (a "line of death") and also identifying new zones, especial in multiple pays or "stacked" zones[10, 16].

2 Phase II: Optimizing Shale Plays

Companies are now in a new phase of developing shale plays, which involves optimizing operations in order to achieve higher initial production rates and to reduce decline rates, and increase recoverable reserves. The key concerns in the second phase, for majors as well as independents involve achieving efficiency and improving the quality of the portfolio of properties. Goals include: retaining acreage; rapid cash flow from production; learning from experience;

implementing "game-changer" technology; optimize infrastructure; reduce the steep curve associated with decline rates; explore new ways to increase density in shale plays to increase ultimate recovery rates.

2.1 General Approach

A general workflow has been developed by Williams-Kovacs & Clarkson (2014) that provides an overview of the shale gas development process at the play level(Fig.3)[13].

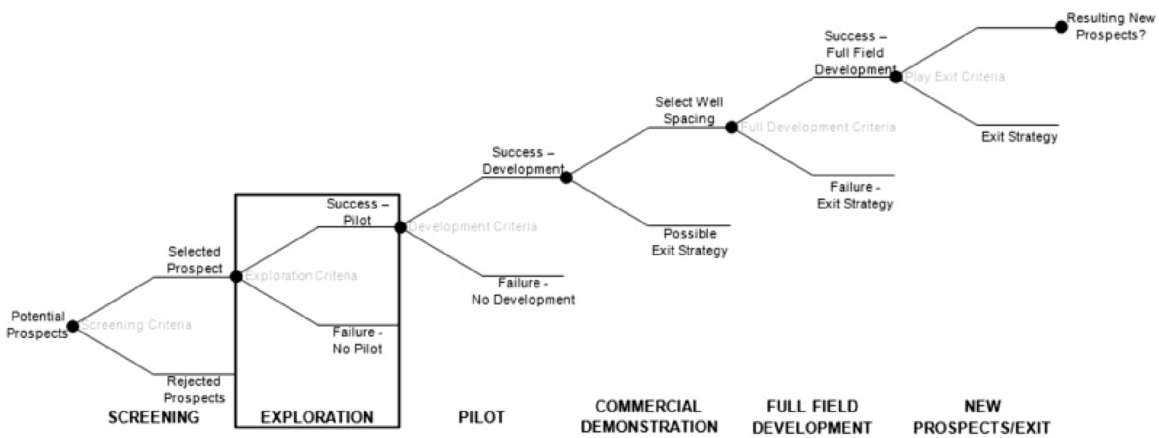

Fig. 3 Workflow of the shale gas development process

2.2 More Specific Approach

The process of shale play development can be summarized in the following way.

2.2.1 Exploration

Identifying the most productive parts of the play (the "sweet spots"):

1) Obtain Acreage (lease or acquire);

2) Large-scale basin analysis studies;

3) Type sections, logs, seismic, petrophysics, etc.

2.2.2 Appraisal

Plan for both pilot tests and horizontal production wells.

Pilot Design Maximize the science, gather data for ongoing lab studies:

1) Pressure monitoring;

2) Instrumented wells;

3) Logging and coring;

4) Prestimulation pilots/ post-stimulation pilots.

Horizontal Wells Optimize stimulation design, operations:

1) Higher density cluster spacing;

2) Optimizing proppant density;

3) Increase cluster density, add more proppant[17].

2.2.3 Development

Keeping capital costs and production optimization balanced[1].

Capital costs Efficient use of capital, hedging, good contracts for midstream,Multi-pad drilling operations.

New zones in "stacked" plays Multiple wells from each location; Acreage "multiplier"; Reduced risk and cost.

Well placement Optimizing spacing and siting (includes stacked and infill).

Operations efficiencies Infrastructure, midstream, water /fluids treatment.

Well-density optimization (infill drilling / "downspacing") 660' between one-mile long wells (80-acre spacing); 330' between one-mile long wells (40-acre spacing); Determining performance (80% of parent? 60%?);Determining fracture interference / fluid behavior / flow paths.

As the field is developed, optimization is important[18]. In order to develop an optimization approach, it is important to use effective models / modeling which takes into account variables that include the physical performance as well as financial and economic variables(Fig.4)[13].

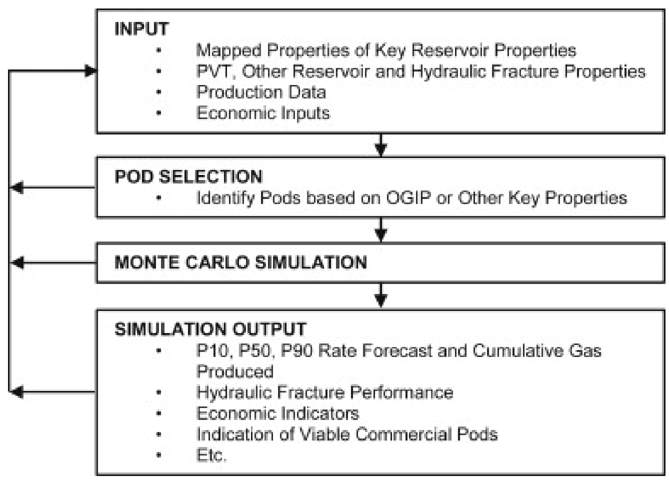

Fig. 4 Workflow for reservoir simulation

3 Conclusion and a Potential Future

Technology strategies in use in Phase II of the commercialization of shale plays focus on optimizing the reservoir. There will undoubtedly be improvements in the characterization of reservoirs, identification of sweet spots, as well as optimized drilling, completion, and stimulation.

Sea changes could involve changing the way we currently drill, and merging the acidizing and drilling phases for something that could be considered "stimulating while drilling" (or "Stimu-Drill," to coin a phrase), to minimize formation damage and to dramatically reduce costs and also the time to drill and complete a well. The results would be cost savings and higher ultimate recoveries.

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[Editor: Chen Huinian]

APPENDIX

Shale Play Technology Strategy of Independent Oil and Gas Producers A Brief Sample Based on Analyst Day Presentations, April 2014 [1]

A close evaluation of the presentations made by U.S. independent oil and gas producers at the annual IPAA analyst meetings held in April 2014 in New York reveal what companies view as their most important strategies, most likely to have a positive impact on company and play valuation, as well as their stock prices.The technology strategies of a representative sampling of independents described above appears here. The companies in this section are not listed in any particular order:

1 Continental Resources

Bakken Focus on drilling efficiencies in order to drive growth.

191 rigs drilling in the Bakken and Three Forks;

2014 plan: 290 net wells (870 gross);

Increased density pilot wells: 330' between laterals (vs. 660 ft between laterals);660-ft same-zone spacing – use microseismic monitory, 31 new wells.

Question: is there interference in the natural and induced fractures?

Question: what is the ultimate recovery of wells drilled in the tighter pattern? Can they recover as much as the original "parent" well?

Mega-pads: "Cost discipline drives excellent margins".

Woodford SCOOP play.

2 Whiting

2.1 Bakken

With six fields in the Bakken (Missouri Breaks, Cassandra, Sanish, Hidden Bench, and others), Whiting has focused on a technology strategy of optimization and also efficiency in midstream.

New objective: Upper Three Forks.

Technology Strategy:

1) Identify the Bakken maturity limit / Bakken pinchout (or "line of death");

2) Improve hydraulic fracturing distribution: 40-stage hydraulic fracturing design;3 perf clusters per stage; 120 potential entry points;

3) New style of cemented liner (vs. sliding sleeve).

2.2 Niobrara

Integrated midstream;

High-density pilots: 165-ft spacing; 960 acre DSU.

3 Abraxas

Abraxas opened their 2014 Analyst Day report with a statement that their overall strategy is "focused in execution."

3.1 Eagle Ford

1) Pinpoint sweet spots and acquire 100% working interest;

2) Balanced portfolio;

3) Oil / dry gas / condensate – coupled with hedging;

4) "hidden" gas portfolio: affiliated gas that can be produced when the price warrants it.

3.2 Bakken

1) Increased density;

2) Infill drilling with Three Forks zone.

4 Samson:

Bakken experience (North Stockyard field since 2008): "More Is Better" , more stages, more lateral length and more proppant.

Now, planning:

Three Forks: infill drilling; corner wells; additional developmental wells.

5 Southwestern Energy

Marcellus experience: NE Pennsylvania position – now increased density.

Fayetteville experience: In the heart of the play, early entry ($320 / acre, 15% royalty, 74% working interest), planning 460 – 470 horizontal wells in 2014.

New Ventures: New Brunswick – 2.5 million acres.

Overall strategy includes:

1) Longer laterals;
2) Reducing well costs;
3) Vertical integration of production ;
4) Contiguous acreage position.

6 U.S. Energy (Wyoming)

"Stacked Play" Strategy:

1) Bakken / Three Forks;
2) Austin Chalk / Eagle Ford / Buda;
3) Now avoiding Federal lands (takes 307 to process permit to drill);
4) Participate 12.5% in Three Forks;
5) Step-out wells.

7 Denbury

Response to the 80% first year decline rates of most shale and unconventional plays:

1) Targets enhanced recovery;
2) Trying CO_2 flood in Barnett;
3) Estimated recovery with CO_2 flood: 17% of total field reserves.

8 Unit

Owns drill rigs, plus midstream processing + pipelines: gas gathering, processing plants, pipelines.They operate as well. Operating strategy:

1) Pad drilling for optimized locations;
2) Fast movement between locations;
3) Bigger mud pumps;
4) Environmentally friendly;
5) Natural gas-utilization for engines on site;
6) Drilling horizontal wells in conventional, mature fields as well as unconventional.

Strategy for operated wells: focus on stacked plays with 5 – 7 zones.

9 Atlas Energy Partners

Growth by acquisition and geographic diversification, acquisitions and working interest: Carrizo, Titan, Equal Energy, EP Energy.

Hedge fund.

Mississippi Lime play: acquired sweet spots in play core, Hunton held by production.

10 Midstates

Pennsylvanian sands in Oklahoma and Texas Panhandle (Cleveland and Cottage Grove). Apply lessons learned in the Mississippian Lime to Cleveland / Marmaton.

Use 3D seismic to: high-grade locations; optimize well placement and completion techniques; investigating Mississippian benches to infill drill for increased density; expand acreage position.

11 Cimarex

11.1 Avalon Shale (Delaware Basin)

Stacked zones: Second Bone Springs; Third Bone Springs; Wolfcamp; Avalon.
Strategy:
1) Stagger / Stack the pilot wells;
2) Do extra pilot drilling (4 wells / 80-acre spacing);
3) Upsize fracs (example: TimTam 24 Fee # 1H - 20 stages vs old 12).
Old strategy:
1) 12-stage / 1100 BOPD IP → 200 BOPD after 24 months;
2) 20-stage / 1500 BOPD IP → 375 BOPD after 24 months (projected).

11.2 Upsized Wolfcamp frac

Old strategy: 5,000 ft lateral / 12 stages / 400,000 lbs sand / 100 mesh / 100 b/min.
New strategy: 5,000 ft lateral / 20 stages / 6,000,000 lbs of sand / 2,000,000 lbs at 100 mesh / 40-60 b/min.

12 Pioneer

12.1 Shale intervals in Midland Basin

Wolfcamp and Sprayberry Shales / silts, strategy:
1) Careful geological modeling using paleoecological models & biostratigraphy;
2) Increased density: 100-acre spacing;
3) Infill drilling.

12.2 Stacked pay

Clearfork;
Middle Spraberry Shale;
Atoka;
Woodford.
Key? Better fracs / better acidizing .

13 Halcon

13.1 Bakken / Three Forks

Eagle Ford stepout (extending the productive read of the Eagle Ford), strategy for Bakken / Eagle Ford:
1) Develop sweet spot of play;
2) 1,000 locations, 8,000 ft laterals;
3) Reduce drilling days / lower fracturing cost;
4) Optimizing artificial lift;
5) 7,000 – 9,000 foot laterals;
6) 1,000 or 800 ft spacing;
7)Increase perf cluster density and test proppant types.

13.2 Tuscaloosa Marine Shale

TMS Well in Mississippi, TMS Strategy:

1) Identify sweet spots on log using Passey Method(Determine TOC and maturation by measuring separation on sonic log & resistivity log);

2) High clay – low swelling factor (low smectite) – design drilling and stim plan;

3) Longer lats: 7,200 ft +;

4) Lateral placement well-defined using 3D seismic and innovative LWD;

5) Hybrid frac (not just slickwater);

6) 1,600+ lbs proppant / foot;

7) 50 ft cluster spacing;

8) Optimize stage size;

9) Stabilize clay using choline chloride;

10) More abrasion-resistant bits;

11) Multi-well pads.

14 Magnum Hunter

1) Extreme information gathering on pilots;

2) Utica Point Pleasant focus;

3) Investing in pipeline / gathering system.

15 Carrizo

Utica;

Eagle Ford;

Niobrara;

NE Pennsylvania Marcellus;

Testing infill economics in 2014;

Base on EUR that is 80% of "parent" using 1,000 offsets (frac interference?).

16 Range Resources

Gas In Place (GIP):

1) Pressure;

2) Temperature;

3) Porosity;

4) HC Saturation;

5) Thermal maturity;

6) Net thickness.

Strategy: GIP Analysis on all plays.

Stacked pay or new plays: Utica Point Pleasant, Marcellus, Upper Devonian.

17 Linn Energy

Granite Wash;

Uinta;

Jonah Field (Green River) – evaluating new processes for kerogen oil;

California;

Permian – Midland;

Permian Basin;
Hugoton Embayment;
Salt Creek;
Williston Basin.

18 Vanguard

Strategy: Geographically diversified.
Jonah Field: Ultra Petroleum ,QEP Resources.
Shale Play Diversification:
1) Bossier;
2) Haynesville;
3) Marcellus;
4) Utica;
5) Eagle Ford;
6) Fayetteville (core);
7) Woodford;
8) Barnett (core);
9) Bakken.

19 Gulfport

Utica / Point Pleasant.
Strategy for siting wells:
1) Thickness;
2) TOC;
3) Thermal Maturity;
4) Overlapping Sweet Spots.

20 Swift Energy

Strategy:

1) Wellbore placement critical for success: geosteering / staying in the zone, better detection / better sensors, 3D seismic integration with process.

2) Logging horizontal laterals: allows selective stimulation of highest quality rock.

3)Grouping clusters within each stage around common fracture gradients: results in more efficient fracs.

4) Continuous optimization by assertively pushing engineering and technical limits.

5) 3D seismic / proper placement of laterals.

6) Logging well laterals: optimized placement of frac stages, improved frac performance, reduces number of frac stages needed to efficiently complete a well (note – this counters the conventional wisdom of “more is better”).