1984 and Beyond: The Advent of Horizontal Wells

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The single most important productivity improvement in the history of the petroleum business may have been the implementation of horizontal wells. The engineering and economic challenges its early innovators faced were steep, but rapid advances between 1984 and 1994 progressively broke down the challenges. A Shell executive once confided to me that, in the early days of that period, one needed permission to plan horizontal wells, but by the late 1990s, one needed permission not to plan one. That is the hallmark of a "disruptive technology"—at first it is viewed with suspicion and elicits risk avoidance, but after industry acceptance, the technology becomes the norm and deviations from it are viewed with disapproval by the very people who questioned the technology in the first place.

In the late 1970s, Teleco perfected the technique to measure well position and direction while drilling. Then it and others added important lithology-marker technology in the form of natural gamma and resistivity measurement. The early days of measurement while drilling (MWD) were marked by low reliability, but the industry persevered because of the cost savings in not having to stop to make openhole position measurements. Positioning in 3D space was now available on the fly.

The First Reports

Horizontal wells were still a curiosity. Then, in the early 1980s, reports started trickling in of directional drillers trying something really different. They were making radical angular changes using a nonrotating drillstring, with a motor for propulsion and a bent sub for angle build. But instead of following convention, which called for pulling the string and drilling the new section without the bent sub and motor, they drilled ahead with the assembly, this time rotating the string and providing motive power by the rotary and the motor. The bent sub in a rotary mode held angle, and the steerable system was born.

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Groundwork for Advancement

I still remember reading the first such report—I thought the authors were nuts! Bent sub flopping around: What would that do to the hole shape, and what about stressing the string? Well, as it turned out, these were tractable issues and one more brick was in the wall to enable efficient angled drilling. Note that, once again, the advance was to eliminate a rig-time hog. The significance was that the early horizontal wells cost roughly 2.7 times as much as conventional wells, and while well productivity was higher, reduction in well cost was an important objective in those days of decision silos that separated drilling and reservoir actions. There are some who believe, and I can be counted among them, that horizontal wells were a trigger for sustained integrated decision making, although clearly the shift to asset units, which occurred during the same time period, was a significant driver. Decisions about wells were made now not by functional units, but by asset teams made up of representatives from the functional units. These events, together with the key advent of formation evaluation while drilling (FEWD), laid the groundwork for this significant advance.

In October 1985, two young Shell petrophysicists, Andy Greif and Craig Koopersmith, published a paper titled "Petrophysical Evaluation of Thinly Bedded Reservoirs in High Angle/Displacement Development Wells with the NL Recorded Lithology Logging System" in a relatively obscure forum (*The Tenth Formation Evaluation Symposium, Canadian Well Logging Society, October 1985*). The impact, however, was far from obscure. An MWD tool had made resistivity measurement of a quality that eliminated openhole wireline logs on the final 12 wells of the 24-well program on the Cougar Platform in the Gulf of Mexico. In this particular case, wireline logs of the time were incapable of detecting and evaluating the thinly bedded turbidite deposits. So, not only were they an effective substitute, but they were better. The previously passed-over B sand was now a prolific producer. The specialized application drove these young men to make the effort to seriously consider the new technology and, ultimately, to take the risk to eliminate the conventional crutch. Today, elimination of wireline logs in favor of FEWD is common.

The success of the electromagnetic wave resistivity sensor spawned concerted activity in the industry, and the first quantitative porosity sensor appeared in 1987. By the end of the decade, the NL Industries (Halliburton today) offering was augmented by Schlumberger, and the FEWD industry

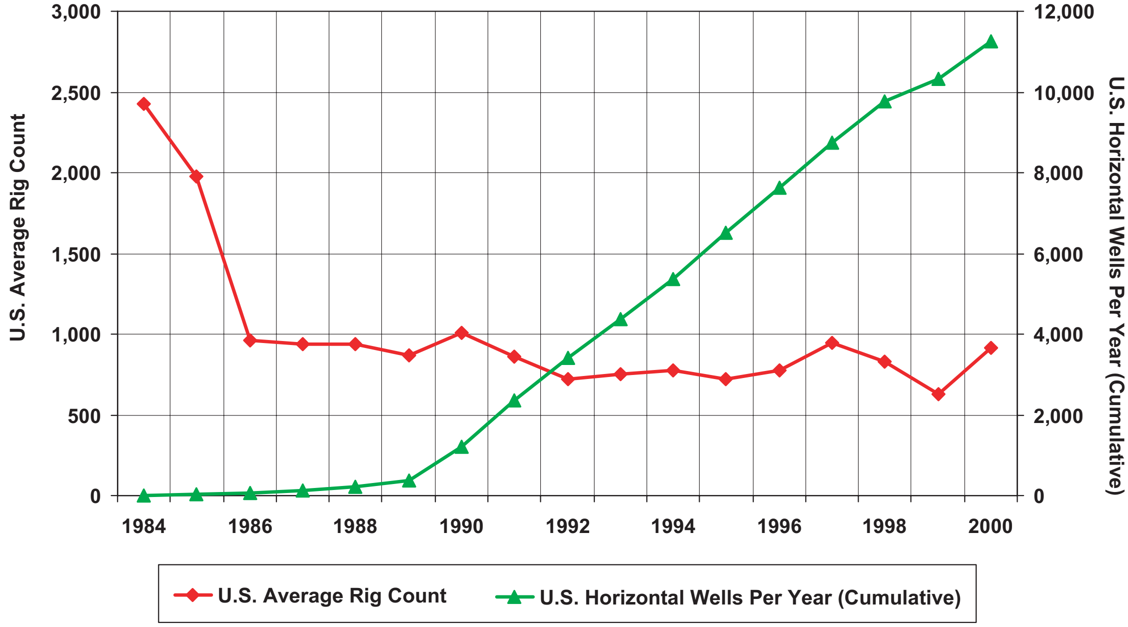

Fig. 1—The explosive growth of horizontal wells.

was now in full stride. A footnote to this episode is that in general, the petrophysical community became progressively comfortable with accepting a lower-quality log and forming new judgments regarding fitness for purpose. With some singular exceptions, such as the EWR application in turbidites, logs in logging while drilling (LWD), as it came to be known, were not as accurate as the wireline. This was particularly the case for porosity and density sensing. But, once again, the elimination of rig time was a key factor in the rationalization, and likely also the asset unit-based "common good" mentality. Also important was the fact that these were early measurements, prior to fluid invasion, and left time to make reservoir decisions. To misquote Mick Jagger, time was on their side.

The Austin Chalk

The technology table had been set. One could now drill a horizontal well using MWD for positioning on the fly, an important attribute for precise placement, a steerable assembly to obtain the needed trajectory and make course corrections on the fly without pulling the string, and then, finally, the ability to evaluate the reservoir adequately without using wireline logs. The logs were especially costly in a high-angle setting because of the nonviability of true wireline-conveyed systems at hole inclinations much greater than 50°.

The first modern horizontal wells are generally credited as being drilled by Elf Aquitane in Lacq Superieur on land and in Rospo Mare offshore during 1980 to 1983. But a basically conservative industry needed one more push to drive wide-scale acceptance. This was the Austin Chalk play. Independent oil companies operating in this Texas area noted that the naturally occurring fractures were particularly amenable to production enhancement by intersection by horizontal wells. The first such well was drilled in 1985, and, over the next decade, there was explosive growth. By 1990, about 1,500 horizontal wells had been drilled; by 2000, there were between 12,000 and 20,000 **(Fig. 1)**, and small companies became big companies in very short time.

In the early 1990s, a US Department of Energy survey showed that costs for horizontal wells were averaging only about 17% more than conventional wells, and that the productivity increases were between two- and seven-fold. Curiously, though, the quantitative formation evaluation impetus was a small factor, although LWD still remained a key enabler for horizontal-well exploitation of more conventional reservoirs. But, unquestionably, the Austin Chalk allowed the industry to cut its teeth on debugging and optimizing the technique of horizontal-well drilling. This factor, of compelling economics of a special kind, was not unlike the situation at Cougar for wireline replacement, and once again underlined one of the litmus tests for disruptive technology: It often finds a foothold in niche situations, but then blossoms to become the norm in other.

An intriguing feature of this period was that at the same time major advances in drilling were being made, the drilling industry itself was under pressure. Massive personnel cutbacks were occurring, and overall drilling activity was in decline. There was a dramatic rise in horizontal-well activity, but a drop in the rig count. Also of interest was the drop in development and lifting costs per BOE in the same period, as cataloged by the Energy Information Administration **(Fig. 2)**. This near-halving of lifting costs is at least partly attributable to horizontal wells, even though they were in the minority of total wells drilled. There is also support for the hypothesis that horizontal wells, together with asset decision making, contributed to a shift from cost/foot thinking in drilling to cost/barrel thinking. This period also saw the practical realization of 3D-seismic interpretation, which increased certainty regarding the location of sweet spots in the reservoir

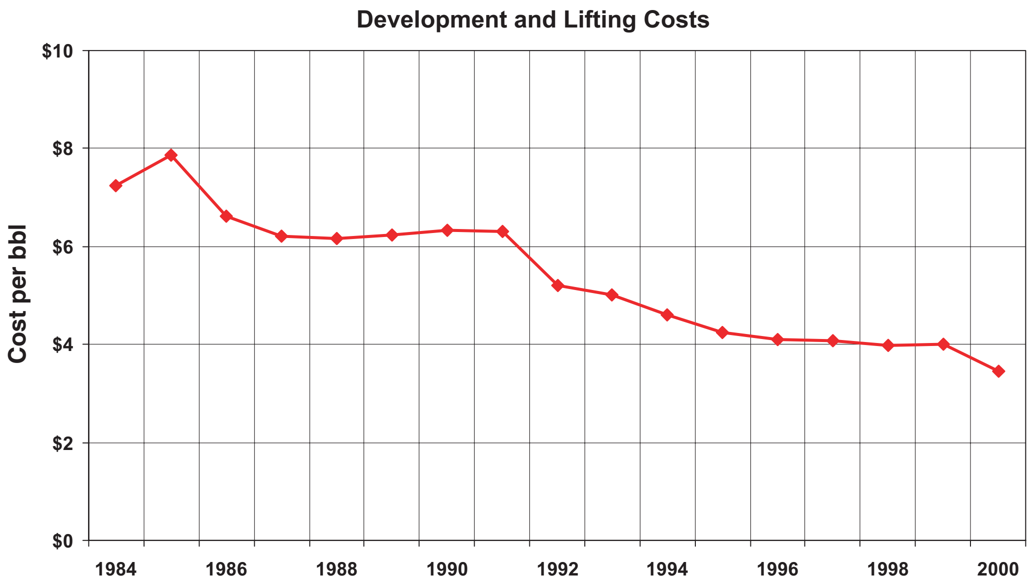

Fig. 2—Developing and lifting costs fell sharply during the period.

and provided a firmer basis for the increased productivity likely from a horizontal well.

Decisions Closer to the Field

Major changes also occurred in the industry during this time. Oil companies underwent restructuring, in many cases with the formation of asset units, as noted earlier, thus shifting decisions closer to the field. Most firms drastically reduced R&D spending, and the onus for development activity progressively shifted to the service companies, which did not materially pick up the R&D spending slack until the mid-1990s **(Fig. 3).** This eventually led to an exacerbation of an industry problem: the slow uptake of technology compared with other industries.

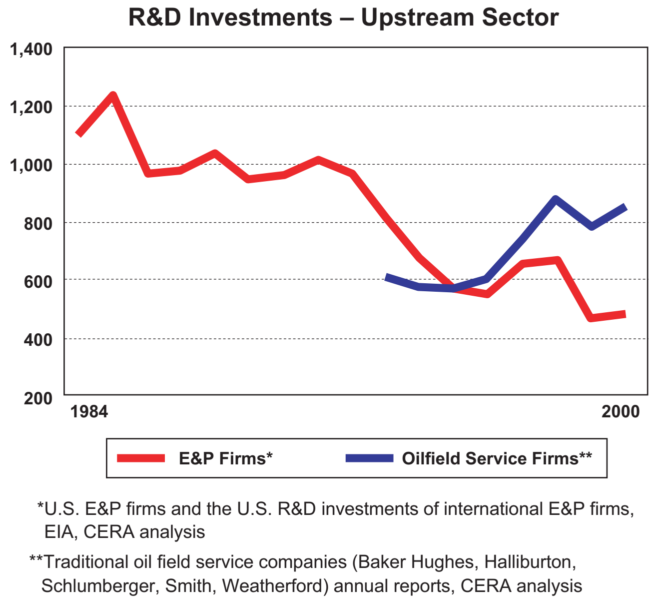

Fig. 3—The shift in R&D spending.

Some have theorized that the shift resulted in "information asymmetry." In the original concept in economics, theorized by Nobel Laureate George Ackerlof, this results when the buyer has less information or understanding than the seller and, as a consequence, devalues the offering. An everyday example is the "lemon discount." If the seller of a used car shares little information about the car, the buyer will assume it is a "lemon" and discount its value. In our industry, the most manifest result is likely risk aversion—the developers having less understanding of the precise need and the user less proficiency in the technology. This hypothesis was discussed and developed at an Applied Technology Workshop (SPE 98511, Rao and Rodriguez).

Causality is difficult to establish in most walks of life. The circumstantial evidence supports the theory that horizontal wells, arguably the single biggest productivity-enhancing technique in the business of developing and lifting hydrocarbons, were enabled by a series of events acting in concert between the mid-1980s and mid-1990s. It began with 3D-seismic interpretation coming into its own, with associated reservoir simulations identifying the high potential of horizontal wells. Steerable drilling systems, enabled by improved motors and the advent of MWD, reduced the cost of horizontal wells. Quantitative LWD permitted hydrocarbon saturations to be estimated in time for completion decisions. These were the technology underpinnings to change.

Asset-decision-making framework, introduced at the same time, was a significant factor at a behavioral level. Finally, compelling economics were a driver for risk taking. This could lead one to conclude that disruptive technologies require a convergence of three factors: the right combination of enabling technologies, compelling economics that highlighted a niche play at first, and industry risk takers and/or a new organizational dynamic. This period that began in 1984 seems to have experienced this unique combination of circumstances, ushering in a brave new world of lower lifting costs. **JPT**

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