

Liquids-Rich Plays, Residual Oil Zone Projects Have Permian Booming

By Al Pickett
Special Correspondent

The Permian Basin is booming—again.

Ironically, the same region in which crude oil has been the lifeblood of local economies for the better part of 80 years has emerged as one of the biggest winners in the U.S. oil and gas industry's push into a new frontier of unconventional liquids plays. Rarely have times been better in the oil fields of West Texas and Southeast New Mexico, with one of the hottest multizone oil resource plays in the nation, high-potential horizontal shale plays with both liquids and gas reserves, and a new era of enhanced recovery projects focused on the residual oil zone (ROZ) below what historically has been perceived as the oil/water contact.

"The variety of opportunities the Permian Basin offers today is almost unbelievable," observes Don DeCarlo, senior vice president of Devon Energy Corporation's western division. "We see myriad opportunities. We are testing so many techniques. We may try three or four to find one that works. But when it does, the results can be very, very good."

The Baker Hughes rig count for the first week of April showed 386 rigs operating in the Permian Basin, with more than 90 percent of them drilling for oil. That is nearly 100 more rigs than only eight months ago, when industry observers were touting a return to pre-2008 economic downturn numbers.



Devon Energy is running four to five rigs in its Wolfberry drilling program, including three rigs in the 17,000-acre Odessa South block. The company expects to drill 127 wells in the Wolfberry play this year, and is extending the depth of its Wolfberry wells into the underlying Strawn, Atoka and Penn formations.

“It is incredible,” says Tim Dove, president and chief operating officer of Pioneer Natural Resources Co., the largest operator in the Spraberry trend with more than 900,000 acres under lease. “Two hundred and six of those 386 rigs were in the Spraberry. That is the highest number since the 1980s. Activity is very fast paced. The number of rigs targeting oil in the United States is a little higher than those targeting gas. That is the first time that has happened in nearly 20 years.”

Companies filed 845 oil and gas drilling permits in February alone—the most recent month for which statistics were available—in the 46 counties of West Texas and four counties in Southeast New Mexico that make up the sprawling Permian Basin, a 102,000 square-mile region that is the largest and most prolific U.S. oil basin, with more than 30 billion barrels of production since the early 1920s.

“It promises to be like this for a long time,” Doug Robison, president of ExL Petroleum and chairman of the Permian Basin Petroleum Association, says of the ramped up activity. “I always get a little nervous when oil prices reach triple figures, because that introduces volatility. But as long as we do not run into regulatory surprises from Washington or Austin, Tx., the foreseeable future looks very bright in the Permian Basin.”

What has fueled this remarkable increase in activity in the Permian Basin, where oil production had been on the decline each

year since the 1970s before making a turnabout this year to put the numbers back on an upward trend? The answer, producers say, is simple: multiple oil targets and new technology that makes those targets accessible and highly economic at today’s commodity price levels.

“This is a fun and exciting time to be in the Permian Basin,” observes Jack Harper, senior vice president and chief of staff at Midland, Tx.-based Concho Resources. “The company is doing well, and we like our position in the basin and the plays we are involved in. Technology and commodity prices have combined to make the Permian Basin the right place to be and this the right time to be here.”

The Permian Basin is also home to nearly 70 percent of the nation’s carbon dioxide floods. Even these enormously successful enhanced oil recovery efforts could get a giant boost as several companies have begun using CO₂ to produce new reserves from residual oil zones below the oil/water contact line that previously was thought to unattainable.

Steve Melzer, owner of Melzer Consulting in Midland, which specializes in helping companies design and execute CO₂ EOR projects, says conservative estimates are that at least 10 billion barrels of oil can be recovered from residual zones. “This is oil that never before has been listed in estimates of the Permian Basin’s potential reserves,” Melzer points out. “It is a huge and viable new resource.”

Wolfberry Play

Much of the surge in Permian Basin activity can be attributed to the Wolfberry play, a commingling of the Spraberry trend and Wolfcamp zones, and everything in between—including the Dean formation. Estimates are that the Wolfberry could easily yield 2 billion barrels of oil, depending on the economics and spacing of wells.

The Wolfberry play runs through the heart of the Permian Basin. The western flank, which has produced most of the sweet spots, extends about 100 miles long and 15-20 miles wide from Upton County south of Midland all the way to the east of Andrews, Tx. Wolfberry wells are producing in Upton, Midland, Ector, Crane, and Andrews counties on the western flank. There is also an eastern flank to the play that includes portions of Reagan, Glasscock, Sterling, Martin and Howard counties, Tx.

Henry Petroleum is credited with perfecting the technique of drilling through the Spraberry trend, historically considered the bread-and-butter of oil explorers in the Permian Basin, into the deeper Wolfcamp formation, which long was believed to be nonproductive because of poor permeability, and then using massive multi-stage fracs and commingling production from the multiple zones (as many as eight zones produce hydrocarbons).

In 2008, Concho Resources made a \$565 million acquisition of Henry Petroleum’s Wolfberry’s holdings, which at the time totaled 163 billion cubic feet equivalent of proved reserves (70 percent oil, 62 percent proved, developed) as well as production of 33 million cubic feet equivalent a day and 282 Bcfe of identified unproved reserves.

“Since Henry Petroleum’s team came to Concho, our people have the experience of drilling more than 1,000 wells in the Wolfberry,” says Harper. “That gives us a nice advantage in terms of cost and the ability to leverage into other opportunities.”

Almost all of Concho’s Wolfberry activity is in Upton and Midland counties. Harper says Concho continues to drill on 40-acre spacing, but is experimenting with 20-acre spacing. He adds that Concho is running 13-14 rigs in the play.

“We are still doing eight to 10 frac stages over multiple zones in a 3,500-foot column (from the top of the Spraberry to the bottom of the Wolfcamp),” he



Pioneer Natural Resources expects to have 35 rigs running in the Wolfberry trend by mid-summer, drilling into the deepest part of the Wolfcamp as well as the Strawn and Atoka formations below the Wolfcamp. Drilling deeper and commingling the Wolfcamp and underlying zones with the Spraberry allows Pioneer's Wolfberry wells to produce 30 percent higher rates and recover an additional 30,000 boe of reserves at an average cost of only \$7/boe. One of the 14 rigs the company owns in the Permian Basin is shown here on location.

relates. "The completion technique has evolved over time. We have drilled to deeper zones as well, and we are encouraged by the results. Last year, we drilled more than 300 wells, and we are planning to drill 220 wells this year."

Below The Wolfcamp

Pioneer Natural Resources is running 32 rigs in the Wolfberry, according to Dove, and expects to increase that to 35 rigs by midsummer. Although he says all of Pioneer's rigs are drilling into the deepest part of the Wolfcamp, the company now is targeting formations that lie below the Wolfcamp play.

"In about 50 percent of this year's

drilling program, we are drilling into the Strawn," he explains. "We log it and see if we have adequate porosity. We will complete the well in the Strawn and produce it in about half the wells drilled to the Strawn, equating to 25 percent of the total program. In some areas, we have begun drilling into the Atoka formation (which lies below the Strawn), and we may try to go even deeper into the Mississippian. Big fields are getting bigger."

Dove says going deeper and commingling multiple zones with the Spraberry trend only makes sense economically. "In the first several months after we drilled into the Wolfcamp, our wells were producing 30 percent more than Spraberry trend

wells," he contends. "We have increased reserves for our type well from 110,000 boe to 140,000 boe. We are adding 30,000 boe of reserves per well at a cost of only \$200,000. That averages only \$7 per boe, which is highly economic at current oil prices."

Dove says three-fourths of Pioneer's 900,000 net acres in the Spraberry are held by production. "This is the quintessential oil 'manufacturing' play," he holds.

Pioneer drilled 340 wells last year, and is targeting drilling 700 this year and 1,000 in 2012, according to Dove. "We went from one rig to 30 as we came out of the economic downturn," he adds. "Now we are increasing to 35-45 rigs. The Spraberry is 50 percent of our company's proved reserves and 30-40 percent of our production. That will go up as we lower our reserves-to-production ratio by accelerating drilling."

Pioneer is drilling on 40-acre spacing, but Dove says the next big step will be to reduce that to 20 acres. "We have 15,000 locations ready to drill on 20-acre spacing," he states. "It may be 10-acre spacing some day; we could be drilling here for decades."

Although vertical wells have been used primarily to commingle the Spraberry, Wolfcamp and other formations, Pioneer is experimenting with horizontal drilling in the Wolfcamp zone on the southern outskirts of the Spraberry trend.

"We have drilled two horizontal wells in the Wolfcamp and they are being tested," Dove states. "We plan to drill up to eight horizontal wells, and that will determine whether we will drill future horizontal wells on our acreage."

Dove notes that Pioneer's efforts to become a vertically integrated operator in the Permian Basin provide benefits across its entire operations. "We are now 30-60 percent vertically integrated. We



As part of its effort to become a vertically integrated operator in the Permian Basin, Pioneer Natural Resources owns five frac fleets, 14 drilling rigs and 25 pulling units. The company says its vertical integration strategy allows it to better control costs and



meet its operating goals. Shown here are a company-owned frac pump truck as well as a hydraulic fracturing operation using Pioneer's equipment and employees.

peak rates of 200 boe/d or less.”

Enviably Position

Midland-based Fasken Oil & Ranch Ltd. has a history that dates to 1913, according to Mark Merritt, oil and gas manager and senior vice president for the company, when David Fasken Sr. bought the C Ranch in Andrews County and portions of Midland and Ector counties.

It just so happens that much of the ranch that the Fasken family has owned for nearly 100 years is in the western flank of the Wolfberry play, which puts it in the enviable position of being the land owner, mineral owner and operator. Merritt says Fasken drilled 53 wells last year and plans to drill nearly 100 more this year, with five rigs operating on the ranch.

“We are drilling primarily on 40-acre spacing, although we have a couple of pilot projects testing 25-acre and 19-acre spacing,” he relates. “It is too early to tell the outcome of that work.”

Merritt admits he is amazed by the success of the Wolfberry. “We have been drilling through the Wolfcamp since the 1950s, looking for conventional pay zones in the Devonian and Ellenberger,” he says. “We drilled through the Spraberry and Wolfcamp. We saw shows, but we never thought it was commercial. Technology, namely multistage massive fracs, made this possible. We have been pleasantly surprised by the resource potential.”

He points out that the Wolfberry has a 3,500-foot gross interval, and Fasken is completing multiple zones with multiple fracs on each zone, with a total of eight to 10 stages per well. Like other companies, Fasken now is drilling deeper (to 11,000-



In the Bone Spring play in the Delaware Basin in New Mexico, Devon is drilling horizontal wells with multistage completions that are yielding initial daily rates as high as 800 barrels of oil equivalent. On the Texas side of the basin, Devon’s most recent Bone Spring horizontal well in Reeves County came in at 900 bbl/d and still was producing at that rate two months later. Operating 18 rigs in the basin, Devon also is drilling horizontally in the Avalon Shale play.

own five frac fleets, 14 drilling rigs and 25 pulling units,” he explains. “Not only is that a way to control costs, but it also allows us to meet our operating goals.”

Pioneer also is conducting a waterflood in the 7,000-acre Sherrod Unit, south of Midland. “We have seen positive results,” Dove comments. “Our objective is to stem production declines. The issue with a waterflood is that it takes a large contiguous acreage position. You do not want to spend the money doing a waterflood to improve the production in your neighbor’s wells.”

Looking To Score

ExL Petroleum’s Robison uses a baseball analogy to describe his company’s strategy to “prove up” acreage before selling it. “We move runners around the baseball diamond, and we score when we sell the property,” he says. “We have done it multiple times. We put together prospects and then partner when we get the right ratio of proven developed producing and proven undeveloped producing reserves.”

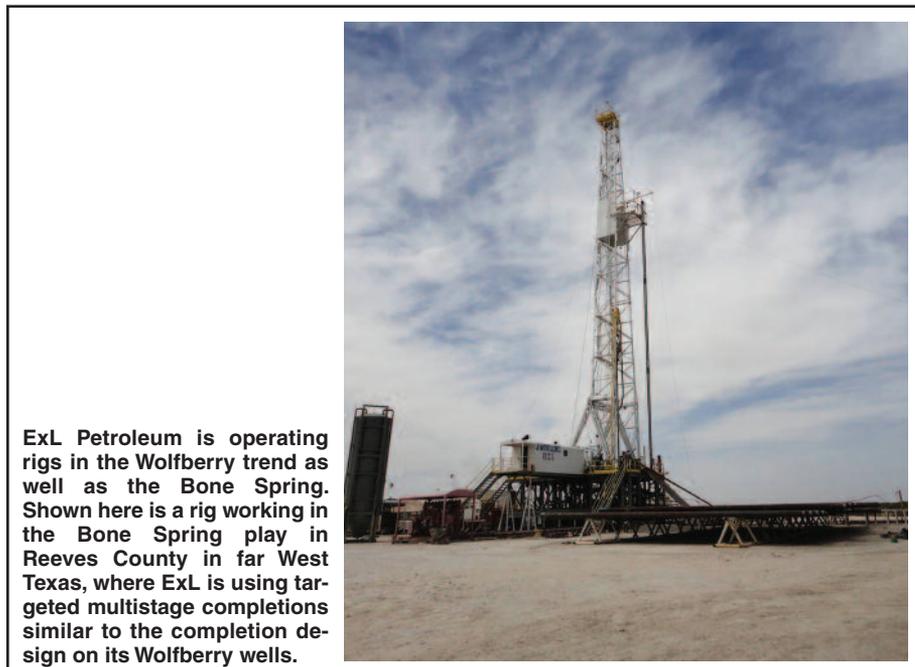
The company has two rigs operating in the Wolfberry, trying to bring prospects to fruition for selling the property, according to Robison. He says ExL also is working in Reeves County in far West Texas, attempting targeted multistage completions in the Bone Spring, similar to the Wolfberry.

“We always are looking for new prospects,” he adds. “These new plays are associated with a fairly rich gas stream. There is a challenge to get the gas sales lines hooked up fast enough.”

Devon Energy also is maintaining an

active drilling program in the Wolfberry, running four to five rigs, including three rigs in the 17,000-acre Odessa South block, according to DeCarlo. “We are working north of there, too, doing a lot of derisking work,” he remarks, adding that Devon plans to drill 127 wells in the Wolfberry in 2011. It also is drilling its Wolfberry wells deeper into the Strawn, Atoka and Penn formations.

Production from the Wolfberry wells varies, depending on location and porosity of the formation, according to DeCarlo. “If we have a well that makes 500 barrels a day, we have a good one,” he adds. “However, the wells generally produce at



ExL Petroleum is operating rigs in the Wolfberry trend as well as the Bone Spring. Shown here is a rig working in the Bone Spring play in Reeves County in far West Texas, where ExL is using targeted multistage completions similar to the completion design on its Wolfberry wells.



Fasken Oil & Ranch Ltd. drilled 53 Wolfberry wells last year and plans to drill nearly 100 more this year with five rigs running on the C Ranch, which David Fasken Sr. purchased in 1913. The ranch is located along the western flank of the Wolfberry play in Andrews, Midland and Ector counties. Fasken also is preparing to launch a horizontal drilling program in the Yeso oil play in New Mexico later this year.

12,000 feet) to the Strawn and “completing everything between the Spraberry and the Strawn.” Merritt says it takes about three months before Fasken’s Wolfberry wells reach peak daily production around 130 barrels of oil.

“These wells definitely have long productive lives, but they go on a steep decline, perhaps a 75 percent decline in the first year,” he adds. “Then they flatten over the years. These wells still may be producing 30 years from now, albeit at low rates.”

He says Fasken always has been “conservative financially to maintain a balance sheet to withstand the ups and the downs” of the cyclical oil and gas business. Merritt admits, however, that being the mineral owner as well as the operator with 100 percent of the royalty has made the Wolfberry play on the C Ranch “very economical” for the company.

Bone Spring/Avalon Shale

The other play that has sparked the resurgence is in the Delaware Basin in southeastern New Mexico and far West Texas on the western side of the Permian Basin. Like the Wolfberry play, the Delaware Basin offers a variety of targets, including the Bone Spring and Avalon Shale. Unlike the Wolfberry, however, operators primarily are drilling horizontal wells, either in the Bone Spring or Avalon,

depending on the location.

“In New Mexico, we are involved in the Second Bone Spring in Lea and Eddy counties,” says Devon’s DeCarlo. “There is a nice trend in the Second Bone Spring. They make nice wells and produce at very commercial rates.”

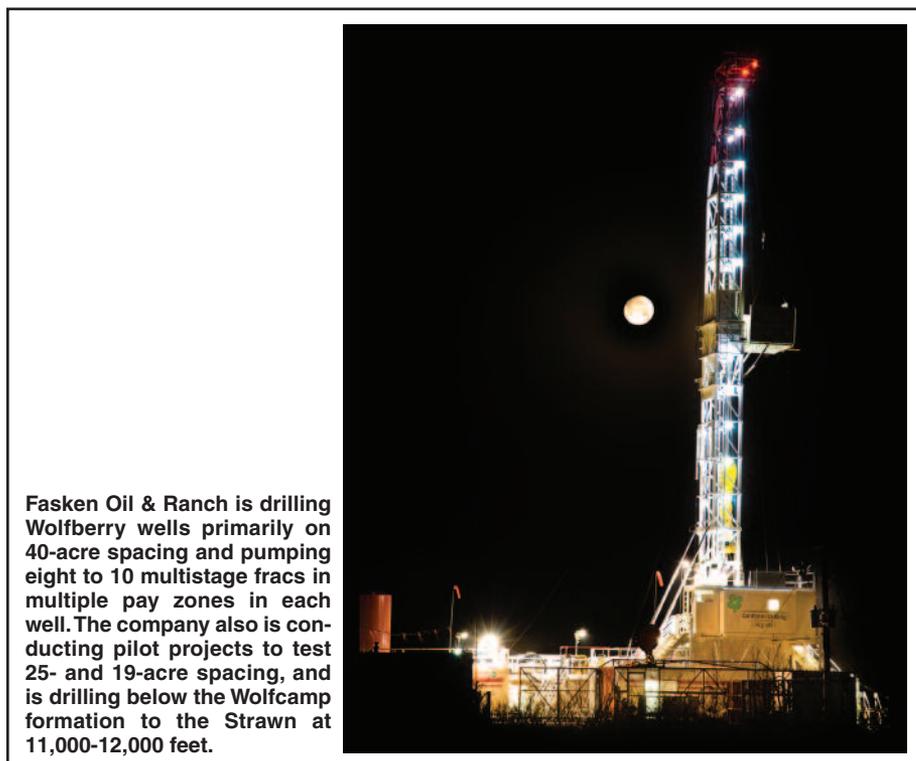
He notes that Devon’s Second Bone Spring horizontal wells are producing anywhere from 200 to more than 800 boe a day. “They are strong wells that produce over an extended period, but they are also expensive to drill and complete at an average per-well cost of \$3.5 million-\$4.0 million.”

He describes Devon’s Second Bone Spring horizontal wells as “mainly oil with casinghead gas” with average production of 500 barrels of oil and 0.5 MMcf of gas a day.

On the Texas side of the border, DeCarlo says Devon has drilled three or four wells in the Third Bone Spring in Ward County. “They are expensive wells, costing \$6 million-\$7 million apiece, but the performance has been outstanding,” he observes. “The first well made 500 bbl/d. Our most recent well came on at 900 bbl/d and still was producing at that rate two months later. Typically, these wells come on at initial daily rates of 500-1,000 barrels of oil and 2 MMcf of gas.”

DeCarlo says Devon continues to do a lot of exploratory work in the Delaware Basin. It has 18 rigs operating, “one-third of which are doing derisking work and testing new ideas and two-thirds that are drilling solid production opportunities,” he states.

In addition to its horizontal wells in



Fasken Oil & Ranch is drilling Wolfberry wells primarily on 40-acre spacing and pumping eight to 10 multistage fracs in multiple pay zones in each well. The company also is conducting pilot projects to test 25- and 19-acre spacing, and is drilling below the Wolfcamp formation to the Strawn at 11,000-12,000 feet.



the Second Bone Spring in Lea and Eddy counties, Devon also has drilled 10-12 wells in the Avalon Shale, according to DeCarlo, including several across the state line in Culberson County, Tx.

“We have had scattered results so far,” he reports. “We have not drilled a dry well, but some wells are definitely better than others. We are trying to unlock the secret to the Avalon Shale. It will get cracked eventually.

“A lot of operators are trying a lot of things,” he continues. “We will drill a pilot hole and then discuss where to take it. There are a lot of ways to exploit the reservoir. It is a very dynamic and still evolving play.”

Active On Three Fronts

Just as Concho Resources entered the Wolfberry through an acquisition, the company jumped into the Bone Spring/Avalon Shale with the largest acquisition in its history. Concho paid \$1.65 billion in 2008 to acquire the oil and gas assets of Marbob Energy Corporation, which included 76 million boe of estimated proved reserves (58 percent oil, 63 percent proved, developed) and 166 million boe of estimated unproven reserves.

Harper says Marbob’s operations were located in southeastern New Mexico, including a large acreage position contiguous to Concho’s core Yeso oil play on the New Mexico Shelf, or the western shelf of the Delaware Basin, as well as a significant acreage position in the emerging Bone Spring play.

“With the Marbob acquisition, Concho became active on three fronts in New Mexico and West Texas: the Yeso, the Bone Spring/Avalon Shale, and the Wolfberry,” he relates. “We feel very fortunate to be so well positioned in all three areas.”

With the Marbob acquisition and additional acreage the company has since acquired, Concho now has 150,000 net acres in the Bone Spring/Avalon play, with two-thirds of it in Eddy and Lea counties in New Mexico and the rest in Reeves and Pecos counties in Texas, according to Harper.

He says Concho is running five rigs in its Avalon Shale/Bone Spring play area, with two drilling horizontal wells in the Avalon Shale, two drilling horizontals in the First and Second Bone Spring, and a fifth drilling vertical oil wells in the Wolfcamp and Bone Spring formations.

The Avalon Shale wells are producing

equal parts of oil, dry gas, and natural gas liquids, while the Bone Spring wells typically produce two-thirds oil and one-third gas. “All have high-Btu, liquid-rich gas,” Harper states.

Harper says 20 percent of Concho’s drilling budget is earmarked for the Bone Spring/Avalon Shale, and that the company has identified almost 1,000 drilling locations on its acreage. “We plan to drill about 60 Bone Spring/Avalon wells this year. We would like to increase that, but first we want to fully understand the play,” he remarks. “I hope it can become another manufacturing process to maximize production.”

Meanwhile, Concho has 12 rigs drilling vertical oil wells to 5,000-7,000 feet in the Yeso play, where the company has more than 50,000 net acres. “These are very economic wells, and we have a lot of running room for future drilling,” Harper concludes.

While Merritt says the Wolfberry is keeping Fasken busy, his company also has prospective Yeso acreage in Eddy County, where it is planning to drill horizontally into the oil-bearing zone.

“We have not drilled a Yeso prospect yet, but we are preparing to drill two horizontal wells in the Yeso later this year,” Merritt reports, adding that the company also has some deep Morrow production in the area. “The Yeso play is moving our direction. Wells have been drilled next to our

leasehold, and we are working with other operators to get the production infrastructure in place. You need to know where your saltwater disposal will be, and you have to have drilling rigs under contract and frac services line up. Logistics have become more difficult as activity has picked up.”

Rewriting The Textbook

Fort Worth-based Approach Resources has coined the term “Wolffork” in its operations on the southeastern side of the Permian Basin in Crockett County, Tx. “It is similar lithology as the Wolfberry,” explains Ross Craft, president and chief executive officer of Approach Resources.

The difference is the Clearfork, which Craft says is the time equivalent to the Spraberry in this part of the basin. Approach is doing multistage fracs and commingling the Clearfork, Dean and Wolfcamp formations.

“We have rewritten the textbook for the southern Midland Basin,” he contends. “It was thought that the Midland Basin did not extend into northern Crockett County, in part because of the Ozona Arch and the Big Lake Fault. If this was true, one would expect the Wolfcamp to be thin or absent.”

Approach has proven the conventional thinking on the southern Midland Basin to be wrong. Craft explains, “The Ozona Arch is present, but not at the Wolfcamp time,



In the southeastern Permian Basin, Approach Resources has established a play it dubs the “Wolffork” in Crockett County, drilling horizontally and pumping multistage fracs to commingle production from the Wolfcamp formation and the Clearfork fractured gas and oil interval above the Wolfcamp. Approach plans to drill 11 horizontal Wolffork wells this year.



and the Big Lake Fault does not significantly affect the Wolfcamp's thickness."

The Wolfcamp Shale has four members: the D, C, B and A from bottom to top. The Dean and Clearfork are located above the Wolfcamp. The Dean and Clearfork are fractured oil and gas sections, and the Wolfcamp, also a fractured oil and gas section, is the generating rock. The combined thickness of the Wolfcamp Shale is 2,500 feet of gross oil and gas potential, Craft states. "The A and B members of the Wolfcamp comprise a 200-foot thick section of organic-rich source rock that is thermally mature and located in the peak oil and wet gas generating window," he says

The company has drilled more than 500 wells in Crockett County since 2004, targeting the deeper zones, Ellenberger, Strawn and Canyon formations, Craft continues. "Many times when we drilled through the Wolfcamp, we saw strong shows of oil and gas. We thought it was only shale and the shows were coming from isolated open fractures," he states.

But Approach then hired Qingming Yang as vice president of exploration, who pulled data from the past three or four years of drilling and created a plan to determine whether the Wolfcamp could indeed produce at commercial rates.

"We went through a tedious process to disprove it," Craft says. "But every data point came back positive. We evaluated whole core, log data and drilling show data. All the data came back that it had sufficient thermal maturity, porosity and size to be commercially productive."

Approach first conducted a three-well recompletion pilot program targeting the Wolfcamp only, and then a five-well pilot targeting a combination of Wolfcamp, Wolfcamp and Wolfcamp and Canyon, with the emphasis centered on increased frac stages. All the while, Approach was acquiring more lease acreage.

Craft says the company's acreage in northern Crockett County now is flanked by a number of large independents and even a major, all of whom paid as much as \$3,500 an acre in the latest university lease sales. "We have one rig drilling horizontally in the Wolfcamp B zone, right under the organic bench," he imparts. "We expect our lateral lengths to range from 4,000 to 8,000 feet and our frac stages to range from 14 to potentially 24. We believe there could be as much as 180 million boe of original oil and gas in place per 640 acres. Our internal recovery assumption is 3

percent oil and 10 percent gas."

Craft says Approach plans to drill 11 horizontal wells this year. He adds that the company will drill 26 vertical wells in the Canyon formation and then will recomplete the Wolfcamp zones approximately one year later. It also plans to drill 19 vertical wells in which it will commingle the Canyon with the Wolfcamp.

Approach's horizontal wells are expected to produce anywhere from 47 to 77 percent oil and NGLs, according to Craft. "The Btu value of the gas is high," he notes. "The Canyon/Wolfcamp wells are expected to produce 40-70 percent oil and NGLs. One of the beauties of our acreage position is that we have more than 200 miles of company-owned gathering infrastructure in place across a large portion of our 140,000 net acres. In addition, there are several processing plants in the area with capacity."

Infrastructure Expansions

The ramped up activity with the development of the Wolfberry, Wolfcamp and Avalon Shale/Bone Spring, all of which are producing oil, gas and NGLs, has in some cases, stretched the region's service industry and midstream providers to the limit, especially the capacity to take the NGLs to market.

"We have more crude oil than takeaway capacity," says Fasken's Merritt. "The pipeline to Cushing, Ok., is maxed out. Even crude oil trucks are in short supply. We are seeing limitations on stimulation services and drilling crews. There are limitations everywhere you look. I never thought that would happen in the Permian Basin, but it is a good problem to have."

Craft reports that DCP Midstream is holding an open season on a proposed 180,000 bbl/d NGL pipeline that it plans to build from the Delaware Basin in New Mexico through the Permian Basin to west of San Antonio, the Eagle Ford Shale, and eventually, to Mont Belvieu, Tx., NGL storage facilities and chemical plants along the Texas and Louisiana Gulf Coast.

Nuevo Midstream LLC, a startup midstream company based in Houston, announced in April that it had secured a \$65 million equity commitment to help it develop and operate midstream infrastructure for gas producers in the Permian Basin, with specific emphasis on the Bone Spring, Wolfcamp and Avalon Shale.

Equity backing for the new company

comes from the EnCap Flatrock Midstream's Energy Infrastructure Fund, Torch Energy Advisors Incorporated and Petroleum Fuels Company Inc. Jay Lendrum, president of Torch Energy, is serving as chief executive officer for Nuevo Midstream.

Lendrum says Nuevo Midstream will center its early operations on upgrading the Ramsey gas gathering lines and processing plant in Reeves County near Orla, Tx. The company expects to have initial processing capacity of 10 MMcf/d on line by midsummer.

"As demand increases, we will expand and bring on additional gathering, processing and treating capacity," he reveals. "Our plans call for a second cryogenic processing plant at the Ramsey location with capacity of 50 MMcf/d. The Avalon Shale and Bone Spring really have kicked off."

Lendrum notes that Clayton Williams Energy's announcement of a joint venture with Chesapeake Energy Corporation, as well as involvement in the area by independents Concho, Cimarex, Anadarko Petroleum and Devon, is proof of the enormous potential of the Wolfcamp/Avalon Shale/Bone Spring play.

"It is producing both oil and gas," Lendrum says. "It is 50-55 percent oil, but the economic value is 75-25. But you have to gather, process and treat the gas. It is a perfect situation for a midstream company."

The Ramsey system consists of approximately 130 miles of gas gathering lines, compressor and measurement stations, and processing, fractionation, storage and loading facilities. The gathering system crosses through Eddy County in southeast New Mexico and Culberson, Loving and Reeves counties in West Texas.

"The biggest issue facing the market is liquids takeaway capacity, because these plays are yielding so many liquids," Lendrum adds. "The question is how to get it to Mont Belvieu. Until the DCP line is built, some are looking at a rail system to get the NGLs out of the Permian Basin to Mont Belvieu or the Gulf Coast."

CO₂ EOR, ROZ Projects

Enhanced oil recovery projects using carbon dioxide continue to play a major role in the Permian Basin production picture. Melzer says 64 EOR projects are active in the Permian Basin, injecting nearly 2 Bcf/d of CO₂. He claims that 5 percent of domestic production and almost



20 percent of oil production in Texas is the result of CO₂ EOR efforts.

"The big issue in the Permian Basin is not having enough CO₂ supply for the number of pent-up projects," he says, adding that proposed coal-fired power plants in the Permian Basin will employ new carbon capture technology that should eventually provide additional carbon dioxide for EOR projects.

Fasken's Hanford Field in Gaines County north of Seminole is a shining example of what a CO₂ flood can mean for a mature, declining field, and how the residual oil zone is the next step to using carbon dioxide injection to further boost oil recovery.

"We started CO₂ injection in the field in 1986," recalls Merritt. "Cumulatively, we have had more than 50 percent recovery. It has been a really successful project."

The Hanford Field has 26 producing wells and 26 injectors. Merritt says Fasken has begun injecting below the pay zone into the ROZ. "The oil is coating the rock and the oil saturation is such that it is not mobile with water," he states. "It is too early to evaluate results and we are limited on our CO₂ source. We need more carbon dioxide. However, it opens new possibil-

ities. The residual oil zones are more widespread than the main pay. It is costly because you have to displace the water with CO₂ to make the oil mobile and flow it from the injector to the producing well. It is a slower response than a water-flood."

Merritt says Fasken has patterned its CO₂ residual oil zone project after the success that Hess Corporation has had in the nearby Seminole Field, which was one of the pioneering projects in using carbon dioxide to sweep the oil from below the oil/water contact line.

Legado Resources, based in The Woodlands, Tx., also is conducting a CO₂ flood in the residual oil zone in the 6,000-acre Goldsmith-Landreth-San Andres Unit, a field west of Odessa, Tx., that began producing in the 1940s. "We have deepened the wells and injected the CO₂ into both the ROZ and the main pay," says Dane Cantwell, Legado's senior vice president of development. "We are treating it as one zone."

He says the company initially conducted a four-well pilot and ramped production from 170 to 650 bbl/d. Legado now is injecting 50 MMcf/d of carbon dioxide in the first phase of the project, according to

Cantwell. The second phase will be completed by the end of the year.

"This field will have six phases, so it will take a while to put together," Cantwell adds. "It looks like the oil in place in the residual oil zones is similar to the original oil in place in the San Andres."

As exciting as the new technology-driven developments are in plays such as the Wolfberry, Wolffork and Avalon Shale/Bone Spring formations, Melzer says it is astonishing to consider that residual oil zones will have more oil in place than the total cumulative volume that has been produced since the Permian Basin discovery well was drilled eight decades ago.

"The Permian Basin has produced so much oil over the years, but the good news is that 20-35 percent of what was left behind is recoverable," Melzer emphasizes. "I know it must seem inconceivable, but I believe ROZs could hold as much as 30 billion barrels of recoverable oil, which would be equal to the amount the basin has produced to date. We have to find a way to get more carbon dioxide supply, but the Permian Basin has a wonderful future. It will be producing oil for generations to come." □