

## Winning at EOR

*Denbury Resources Inc. shows that enhanced oil recovery (EOR) is a game you can win, not by owning all the assets (though owning some is good) but by owning the CO<sub>2</sub> source.*

By **DONNA MARCOTTE**, Drilling and IT Editor

Carbon dioxide (CO<sub>2</sub>) injection is a common method of enhanced oil recovery, particularly in West Texas and Southern Wyoming, geographical areas with abundant natural CO<sub>2</sub> sources. But it is also the main development strategy for Denbury Resources, Inc., the largest oil and natural gas operator in Mississippi. Yes, Mississippi. The company happened upon, then purchased, Jackson Dome, part of an old volcano structure near Jackson, Miss., and the most reliable strategic source of CO<sub>2</sub> in the eastern United States. Now that it owns this abundant source, its corporate development focus is on exploiting aging plays in its geographic area.

### Why this approach?

According to the company Web site, this play is attractive because: it is lower risk than more traditional exploration and development activities, provides a reasonable rate of return at relatively low oil prices (the upper teens and low twenties), and there is virtually no competition in its geographical area because it owns the only source of CO<sub>2</sub>.

To help Wall Street understand the magnitude of what at first glance seems simplistic, the company developed a board game, the Denbury Resources Oil Game, where the object of the game is to add the most reserves by taking CO<sub>2</sub> from Jackson Dome to old fields (Figure 2). The player who accumulates the most reserves wins. The instructions counsel: Remember that this game differs from the real world because Denbury has the

only carbon dioxide source in the area. Effectively, it's like playing this game with only one player!

### How it happened

Gareth Roberts, president and chief executive officer, admits exploiting old fields with CO<sub>2</sub> was not always their intended strategy and that they hit upon it, as one of their game cards indicates, by a bit of "dumb luck."

In 1996, the company purchased the **Eucutta** field in eastern Mississippi, which was originally developed by Amerada Hess. Initial production of the field by Denbury included some traditional methods such as extending existing wells and drilling new wells deeper, which actually tripled production. However, realizing it was an aging asset, they knew these production levels wouldn't last.

Research showed that in the 1970s, the last time it was thought that depletion of the world's oil reserves was imminent, Amerada Hess had conducted a pilot study of CO<sub>2</sub> injection on the Eucutta field with very good results. It was through the Amerada Hess work that the company also found out about the Jackson Dome CO<sub>2</sub> field.

The company located and purchased another larger field in eastern Mississippi, **Heidelberg**, with similar characteristics as Eucutta. While waiting to develop Heidelberg, their management team thought they had better learn more about CO<sub>2</sub> injection, so they purchased the **Little Creek** field in western Mississippi. Little Creek, originally operated by Shell and sold to a small operator in the mid '90s, had continued CO<sub>2</sub> flooding and was determined to be a good place to continue testing and developing their



Figure 1. Two primary operating areas include Eastern and Western Mississippi, with the 183-mile (295-km) CO<sub>2</sub> pipeline starting at Jackson Dome, extending to White Castle, La. (Image courtesy of Denbury Resources Inc.)

CO<sub>2</sub> expertise. They got very good results on their initial CO<sub>2</sub> testing there, recovering 17% of original oil in place and decided they would get even better results if they doubled their CO<sub>2</sub> injection. The Problem: they did not want to pay double the price. So they decided, if Jackson Dome was not a core asset to its current owner, they would simply purchase it.

### Jackson Dome: The CO<sub>2</sub> source

According to the company Web site, Jackson Dome, an old volcano located near Jackson, Miss., was originally discovered by Shell in the 1960s while drilling for oil and natural gas. At the time, the CO<sub>2</sub> was considered of little use. The CO<sub>2</sub> reserves are located in structural traps in the Buckner, Smackover and Norphlet formations at depths of about 16,000 ft (4,880 m).

In 1996, Airgas, a distributor of



Figure 2. The Denbury Resources game lets players move to different fields and book reserves and shows Wall Street the benefit of the company's strategy. "Dumb Luck" cards may move you ahead or cause you to lose a turn. (Image courtesy of Denbury Resources Inc.)

industrial, medical and specialty gases, purchased Jackson Dome from Shell Energy & Land, along with a 183-mile (295-km), 20-in. diameter, high-pressure pipeline that runs from the Northeast Jackson Dome area to White Castle, La. At time of purchase, CO<sub>2</sub> reserves were estimated at 800 Bcf.

Denbury purchased Jackson Dome and the pipeline from Airgas in 1999 for US \$42 million and still honors existing industrial contracts written by Airgas.

Roberts comments that "everything we've done has worked a lot better than we thought, including Jackson Dome." He explains, that they increased CO<sub>2</sub> production initially by just opening up previously drilled wells, which each produced 20 Mcf/d to 25 Mcf/d. But when they drilled new wells, they were capable of twice that production and, with continued engineering, think they can produce even more. Reserves are now estimated at 2.7 Tcf, with some estimates suggesting there may be 12 Tcf of usable CO<sub>2</sub> in the area, according to the company's Web site.

Tracy Evans, senior vice president, reservoir engineering, explains that the company also had an additional bit of

"dumb luck" in that, back in the 1970s and '80s, both Amerada Hess and Shell had done pilot work on CO<sub>2</sub> injection on some of the fields now owned by Denbury — and documented that work. The company used this research to build their CO<sub>2</sub> knowledge and also read additional literature, hired personnel with CO<sub>2</sub> injection experience, and recently began looking at compositional-based simulations to develop its CO<sub>2</sub> strategy and optimization rates. But when it comes down to it, Evans says the best way to determine optimal CO<sub>2</sub> utilization rates is to look at the results you get in the field.

### And results they got

According to Roberts, after purchase of Jackson Dome, CO<sub>2</sub> injection was doubled at Little Creek and production went from 1300 b/d to 3500 b/d rather quickly with a typical well increasing to over 200 b/d of oil. The company's next purchase was **Mallalieu** field, also in western Mississippi along the newly acquired CO<sub>2</sub> pipeline. When purchased, Mallalieu was producing just 70 b/d. This was the first project the company did from start to finish, designing and developing all wells for production and

injection. Within 2 years the field went from 70 b/d in one well to almost 5,000 gross b/d net production with a typical well increasing to 300 b/d of oil from zero prior to flooding. The company has booked 20 million bbl of reserves to the field. Roberts comments it is almost impossible to find a 20-million-bbl conventional field onshore United States today.

Economics for these projects are based on oil prices at the low- to mid-twenties US dollars for oil and about \$4 MMbtu for natural gas. At current prices, the returns are even better, but Roberts points out that total return on initial investment and longevity of the play provide the really big payoff. Also, the company sold its offshore assets in the Gulf of Mexico in support of its EOR focus and better returns.

In addition to increased production rates and reserves, there are other benefits. Because it works in previously developed fields, a lot of infrastructure exists. In many cases no new footprint is required and sites are being brought up to current environmental standards, pleasing local residents and authorities. Because it re-injects CO<sub>2</sub>, the company receives applicable federal and state tax credits.

### What's in the future?

The company's attention has now turned back to eastern Mississippi and the Eucutta field, the genesis of the idea. Roberts explains, for Phase 2 of their development strategy, the company has evaluated an additional six fields and come up with about 80 million bbl of potential reserves, but knows there are more fields in the area with similar characteristics and thinks there could be three times the potential. Currently the permitting process is underway to extend the existing pipeline some 84 miles (135 km), with hopes to complete construction by the end of this year. Other fields, from East Texas to Florida could be in reach of the company's CO<sub>2</sub> should detail studies, currently underway, prove favorable. **E&P**