Demonstration of Microholes for Oil Production and Emplacement of Subsurface Seismic Instrumentation

ID Number*:* 03FE06-4

Program

The goals of the present Phase II project are (1) to demonstrate the use of microboreholes with 1-in.-diameter, retrievable seismic arrays installed in the bores, to collect high quality seismic data at a substantially reduced cost compared with the use of conventional-sized boreholes, and (2) to determine if higher quality seismic data can be obtained in a microhole well completion that is designed to enhance seismic-data collection. This project evolved from the earlier Phase I project with a goal to demonstrate the use of microboreholes for use as producing oil wells.

Project Goals

The overall objective of the Los Alamos National Laboratory (Los Alamos) Phase II project is to demonstrate the technical and economic feasibility for the development of a highly mobile, self-contained, microhole drilling system as an enabling technology for commercially viable seismic-data acquisition. Succeeding in these objectives will result in reduced access (well) cost and improved quality of data. Air-filled microholes completed with PVC (or other nonmetallic casing) are expected to provide the lowest noise environment possible for retrievable seismic instrumentation.

A second goal of the project is to evaluate new commercial drilling equipment. The Los Alamos microdrilling equipment also serves as a platform to evaluate commercial technology that is, or may be, appropriate for microdrilling and completion service. This will be accomplished by testing and evaluating as many commercial products as possible during field operations in the drilling of micro-instrumentation holes.

Overall, the goal is to show that microholes provide downhole access that is significantly less expensive, and that they also provide superior acoustic performance when compared to the use of temporarily converted production or injection wells.

Performer(s)

The NETL/SCNGO-funded Los Alamos Phase II project is synergistic to the larger Rocky Mountain Oilfield Testing Center (RMOTC) carbon-sequestration project, "CO_2 Geological Storage R&D Project," at NPR3 operated by RMOTC. Up to four microwells will be drilled (and one is presently completed) to monitor the injection, sequestration, and long-term storage of CO_2 in the depleted oil reservoir in the Tensleep formation in the Teapot Dome oilfield in central Wyoming.

The Los Alamos and RMOTC collaboration is drilling Microboreholes into the Steele Shale. The Microdrilling Team from Los Alamos designs the microwells, assembles and operates the drilling and well completion equipment, and documents the results of the field demonstrations. Operational and field support is provided by the RMOTC staff and

field personnel. RMOTC obtains regulatory approvals for the microholes, provides technical input and final approval for drilling and completion plans, constructs the microwell locations, and provides drilling water and field support—including running microcasing strings with a pulling unit or small crane—to the LANL Drilling Team.

The Lawrence Berkeley National Laboratory (LBNL) Team is furnishing and operating seismic arrays and data acquisition system. They will evaluate seismic data obtained from microboreholes as well innovative instrumentation for acquisition of seismic data.

The University of Wyoming is investigating the potential for passive seismic monitoring using microhole-deployed geophones for long-term monitoring, in addition to participating on the team that is developing a geologic description of the reservoir and fault seal, and evaluating the potential for leakage from the proposed CO_2 storage zone(s).

Project Results

Phase I.

The RMOTC Team permitted two microwells in the Teapot Dome Field, constructed two well locations, and provided Los Alamos field support to drill two microholes and run casing. After Los Alamos drilled, cased, and cemented the first micro-production well, the RMOTC Field Team perforated the well and installed a sucker rod pump and pumping unit on the location. Oil production quickly declined and pumping has been suspended while the well is evaluated as a candidate for stimulation. Due to the poor production results the second microwell location was diverted from production evaluation and used to evaluate the well program planned for the Phase II operations.

Phase II.

The RMOTC Team has permitted four microwells in the Teapot Dome Field, constructed four well locations, and provided Los Alamos field support to drill three microholes and run casing on the microhole completions.

The LBNL Team has modeled the acoustic performance of the geologic formations in the CO_2 injection area and sited the four well locations for the monitoring project based on the modeled results. The Team selected the seismic arrays that will be run in the microholes and procured equipment needed to assemble and deploy the arrays. Two complete multi-offset vertical seismic profiling (VSP) surveys (12 shot locations each) with offset distances from 35 feet to 2700 feet (every 250 feet) were completed using a 20-level hydrophone string and a 20-level geophone string. In total, 40 levels were recorded for each set of sensors using 12 different shot locations. A vibroseis was used as a source (Enviroseis from IVI Inc); this source was selected to minimize ground disturbance and for its high frequency content (up to 300 hertz).

The Los Alamos Team designed the microhole completions and evaluated the drilling and completion procedures on the previously permitted production microhole location that was not properly sited to support the monitoring of the proposed CO_2 sequestration site. In June 2004 the Los Alamos team drilled the evaluation well. This demonstration included: (1) drilling a 2-5/8-in. hole from the bottom of a 3-in. conductor pipe at 43 ft to

just below the Shannon formation at 500 ft, (2) installing and cementing a 2-3/8-in.-OD steel, flush joint tubing string as an intermediate microcasing that would isolate the Shannon formation from the well bore, and (3) drilling a 1-7/8-in. hole to 800 ft, and installing a 1.66-in., OD-flush joint PVC casing that was sealed to the well bore with bentonite grout. The bentonite grout was treated with soda ash to delay the thickening of the grout; despite that the pumping and displacement pressure was much higher than the calculated working pressure of the PVC casing by the end of the placement. There was no indication of a failure of the PVC pipe. Based on these results, Los Alamos decided to eliminate bentonite grout and use cement to seal the PVC casing on the remaining micro-instrumentation holes.

Los Alamos deployed to drill the microholes that were sited to support the CO_2 sequestration project in late September 2004, and the first micro-instrumentation CO_2-monitoring hole was drilled and completed in October 2004. The 808-ft well was completed with 800 ft of PVC casing to serve as a completion casing set below 587 ft, where a steel intermediate casing was cemented to isolate the Shannon formation. The displacement pressure for the cement slurry was much lower than the displacement pressure observed when grout was used, but was higher than desired for the PVC flush joint casing.

One point of concern regarding the use of PVC pipe is the flush joint connections. The concern arises because of the lack of an industry dimensional specification and performance standard for these joints. In this particular case the pipe we procured from a local vendor at a substantial savings over previous sources had many pins and boxes that were cut off-center, and therefore the joints didn't align well. We are reevaluating the continued use of PVC pipe as well as alternate sources of PVC pipe.

The second micro-instrumentation hole was drilled to 407 ft, and cased with a steel intermediate casing which was cemented to isolate the Shannon reservoir. Operations were suspended because a suitable alternative to the low-cost PVC casing was not identified, and winter weather was beginning to impact drilling operations unfavorably.

Benefits

We intend to show that micro-instrumentation holes can be drilled for between 1/4th and 1/10th the cost of conventional-sized holes, and that they will provide a suitable environment for seismic instrumentation placement. We will also evaluate the use of a nonmetallic casing, PVC line pipe, as a method to reduce noise and improve the performance of a micro-instrumentation hole dedicated to reservoir-monitoring service. With these demonstrations, we expect to show that microholes provide downhole access that is significantly less expensive, and that they provide superior acoustic performance when compared to the use of temporarily converted production or injection wells.

Background

Providers of geophysical data to the oil and gas industries seek low-cost access to the subsurface for the emplacement of seismic instrumentation for a variety of purposes. This need motivated our efforts to evaluate microholes for seismic-data acquisition. The use of microholes expressly designed for deployment of seismic sensors can enhance conventional reflection surveying, locating sources of natural and induced seismicity, VSP, and crosswell imaging capabilities. Of these applications it is expected that VSP capabilities will most benefit from microhole technology because of the unusually high noise conditions in which commercial VSP surveys are now made. Emplacement of seismic instrumentation in the subsurface results in (1) reduced natural surface and cultural noise, (2) reduced or eliminated seismic signal travel paths through highly attenuating surface layers, and (3) a greatly improved signal-to-noise ratio. While conventional wells can often provide the same function, drilling conventional wells is far too costly. Access to the existing wells appropriately sited for installation of seismic instruments is often not feasible due to lost production or unacceptable well preparation costs. Existing wells may not provide a quiet environment for the sensors unless potential gas evolution from production zones is isolated, and surface piping is disconnected from the well. Microholes have the advantage of being a low-cost alternative to conventional wells, and can be designed to specifically support subsurface deployment of instrumentation in the desired location, and with a well completion chosen for optimal acquisition of seismic data rather than production or injection service.

Project Summary

Los Alamos has demonstrated that its present-day microdrilling system can be adapted to produce both a micro-production well in Phase I, and a micro-instrumentation well in Phase II. In order to improve microdrilling performance on the remaining wells, Los Alamos is now evaluating the drilling and completion results from the first two completed micro-instrumentation wells. LBNL is preparing to conduct background monitoring for the proposed Teapot Dome field CO_2 sequestration program in the recently completed microhole.

Los Alamos has begun the evaluation of two new commercial subcomponents in the microdrilling platform:

(1) 900-ft of Quality Tubing QT-16Cr™ (a corrosion resistant alloy coiled-tubing product) was installed on the coiled-tubing microdrill rig. The material is designed for long term direct exposure to wet CO_2 and air environments. It may also have advantages in drilling service including improved fatigue life, increased abrasion resistance, and may also reduce pressure losses inside the tubing during mud circulation. Large pressure losses in the circulation system are believed to be a primary constraint on the maximum feasible depth of the present microdrilling concept.
(2) A Dennis Tool Company pilot bit and reamer were run on an atypical Los Alamos microdrilling assembly: Dennis Tool 1-3/4-in. pilot bit, 1-7/16-in. OD single-lobe drilling motor, Dennis Tool 1-11/16-in. OD stabilizer integral to 2-3/8-in. reamer,

1-11/16-in. OD, 5:6-lobe drilling motor, 2-1/4-in. OD stabilizer, and coiled-tubing connector sub. A 2-3/8-in. hole was drilled from 47 ft to 129 ft at an average penetration rate of 30-ft per hour before the penetration rate dropped from 50-ft per hour to less than 12-ft per hour.

Current Status

Los Alamos has suspended operations for the winter, and is preparing to complete the second monitoring well, and to drill and complete up to two additional microwells next spring. CO_2 injection is presently planned to begin in 2006. LBNL will return after the remaining microholes are drilled and perform multi-offset VSP surveys in the additional holes.

Microdrilling Operations at Tea Pot Dome Field

Figure 1. Microdrilling Site at RMOTC operated Tea Pot Dome Field: From left to right: the Los Alamos drilling mud cleaning system, the Los Alamos coiled tubing drilling rig, and two pickup trucks. In the foreground is the reserve pit and flush-joint tubing that will be run as a production casing for a Shannon oil well.

Figure 2. Microwell at RMOTC operated Tea Pot Dome Field: The Los Alamos coiled-tubing drilling rig with 1-in. coiled tubing running through the stuffing-box drilling-mud diverter that conducts high pressure drilling mud to a hydraulic motor and bit on the bottom of the coiled tubing. The hose in the foreground is the flow line that conducts the drilling mud returns from the well annulus to the mud cleaning unit.

Figure 3. Microdrilling Site at RMOTC operated Tea Pot Dome Field: From left to right: two pickup trucks, the Los Alamos coiled-tubing drilling rig and drilling-mud cleaning system, a RMOTC water truck, and a Tea Pot Dome field pump jack.

Figure 4. Los Alamos Microdrilling Field Team and coiled tubing unit. From left to right: Jim Thomson and Dave Anderson.

Figure 5. Mud cleaning unit with suction strainer assembly in the foreground.

Figure 6. A RMOTC pulling unit and Los Alamos coiled tubing unit rigged up simultaneously over a well drilled in September 2003. The pulling unit was used to run a string of steel flush joint casing; the coiled-tubing unit made a clean-out run following cementing.

Figure 7. Foreground. LBNL Microgeophone array sonde between sections of the deployment cable. Backgound. Contract **vibroseis** unit with a 16000 lb amplitude and a sweep range of 10 to 200 Hz.

Figure 8. Dennis Tool Company equipment being tested on the Los Alamos coiled-tubing microdrilling rig. From left to right: 1-3/4-in. pilot bit, 2-3/8-in. reamer, and cross-over sub to mate equipment to Los Alamos drilling assembly.

Figure 9. Dennis Tool Company equipment assembled on an atypical Los Alamos microdrilling drilling assembly. From bottom to top: Dennis Tool 1-3/4-in. pilot bit, 1-7/16-in. single-lobe OD drilling motor, Dennis Tool 1-11/16-in. OD stabilizer integral to 2-3/8-in. reamer, and 2-1/4-in. OD stabilizer.