Petroleum Technology Transfer Council

APPALACHIAN BASIN

FOCUSED TECHNOLOGY WORKSHOP

HARD ROCK DIRECTIONAL DRILLING:

Technical Challenges and Needs for the Appalachian Basin

PURPOSE OF WORKSHOP

PTTC's Appalachian Basin Regional Lead Organization hosted a Focused Technology Workshop in Pittsburgh, PA on November 20, 1997 to describe directional drilling technology in hard rock formations, to examine how, why, and where directional drilling technology is being used in the Appalachian Basin, to compare the costs of the directional drilling vs conventional drilling, and to examine the effectiveness of directional drilling on production. The workshop was co-sponsored by IOGA-PA and the SPE Stimulation and Storage Group, and was part of their Fall 1997 meeting.

PROBLEMS BEING ADDRESSED

One of the main problems that prevents wider use of directional drilling technology in well-indurated reservoirs in the Appalachian Basin is the increased costs required in equipment and drilling time. Furthermore, although there is much interest in the technology, operators need more exposure to the decision-making process, as well as accurate information on costs, problems, equipment, and how to evaluate their reservoirs as appropriate for a successful directional drilling program.

SELECTION OF TECHNOLOGY SOLUTIONS FOR PRESENTATION

The workshop was designed to present factual information on the directional drilling experience by examining case studies of wells drilled in hard rock lithologies. Additionally, because well control problems and drilling rig systems are different than

those required for conventional drilling, we included a segment on new surface systems that control fluid pressure, and a review of on-going research and development of downhole systems that will improve the efficiency and speed of directional drilling in the future. A panel discussion allowed regional operators to voice their concerns and to discuss in detail special attributes and limitations of current directional drilling methods.

In planning the workshop we chose speakers who had recently been actively involved in drilling deviated wells. Project managers with the Department of Energy, members of the SPE Storage Stimulation Group, and PAG members suggested speakers with recent experience and who understand how the technology actually works in the field. All suggested speakers were contacted.

INFORMATION ON SPEAKERS AND PRESENTERS

Our lead speaker, Jim Ammer, is Project Manager in the Fuels Resource Division, U.S. Department of Energy, Morgantown, WV.

Paul Amick is a Senior Engineer, in Well Services, Gas Storage Department, Columbia Gas Transmission, Charleston, WV. He graduated with a BS in petroleum engineering from West Virginia University in 1982, and completed additional classes in geology and graduate level petroleum engineering. He was previously employed with Reuben Graham, Inc. and has worked and successful petroleum engineering consultant. He has experience as a senior engineer in field operations associated with GRI Devonian Shales research, and with various assignments (design, planning, drilling, completion, testing) throughout the Appalachian Basin and in Italy.

Paul Conti is a District Manager for Wilson Downhole. He has 19 years oilfield experience and 14 years experience in directional drilling. He graduated in Drafting Design Engineering from Pennsylvania State University. During high school and college he worked as a rough neck/roust and a tool pusher. In 1983 he became involved in well service, completions, reworks, and directional drilling. In 1988, while employed for Baker Hughes Drilling Systems, he and his directional team planned and drilled the first Antrim horizontal well for a Michigan independent operator. He has since drilled various medium and long radius wells in all parts of the northeastern United States and has pioneered short radius underbalanced drilling in various formations.

Robert Cuthbertson is an Underbalanced Drilling Manager, Inter-Tech Drilling Solutions, Ltd., Houston, TX.

Bill Murray is in his fifteen year with Belden and Blake, North Canton, OH. He is currently General Manager for northern Ohio and western New York. During his tenure as Drilling Manager, he coordinated several special drilling projects, including projects with GRI and DOE. He is a member of NYIOGA and OOGA, and is a member of the Marietta College Petroleum Advisory Board.

Al Yost is a Project Manager, Fuels Resource Division, U.S. Department of Energy, Morgantown, WV.

Stan Shaw is a Senior Engineer, Reservoir Services, Gas Storage Department, Columbia Gas Transmission, Charleston, WV. Mr Shaw received his BS in Petroleum Engineering from Marietta College in 1985, and his MS in Petroleum Engineering from Texas A&M in 1986. Before joining Columbia Gas he worked for S.A. Holditch and Associates in College Station, TX, Eastern Reservoir Services in Kingsport, TN, and Reuben L. Graham, Inc., in Charleston, WV.

TECHNOLOGY SOLUTIONS PRESENTED

Mr. Jim Ammer began the workshop with an overview of the estimated reserves (proved, probable, and possible) in the common "hard rock" reservoirs in the Appalachian Basin: the Tuscarora Sandstone, Clinton Sandstone, Oriskany Sandstone, Huntersville Chert, and Berea Sandstone. Citing figures from numerous sources, approximately 15 TCF of gas remains in these reservoirs. These reservoirs are an excellent resource in which very large amounts of recoverable gas remain. In order to profit from the production of this resource, we need to find out how to drill faster, cheaper, and better. One of the problems with directional drilling in these rocks is the slow rate of penetration: generally less than 6 feet per hour using air.

Mr. Paul Amick and Mr. Stan Shaw walked the audience through the planning, drilling and testing of a short radius horizontal well drilled in the Oriskany Sandstone in south central West Virginia. The criteria for well selection was an existing well bore in one of their gas storage fields. The well was cased with 7" casing above the Oriskany, the Oriskany was completed open hole, had been fracture stimulated, but had not been reworked for 15 years. After evaluating several design options, they selected a short radius deviation in order to penetrate an 8' sweet spot in the formation. Drilling fluid options included freshwater gel, polymers and 3% calcium chloride. They presented their pre-drilling plan, and compared it with the actual drilling process which included day vs. depth graphs and drilling statistics. Well test figures after drilling compared favorably with predictions based on flow rate, length, pressures, permeability, drainage area, and thickness. The well continued to improve with time. Their advice to operators drilling in Oriskany: 1) expect a high fluid loss, 2) gauge problems accurately (such as the recognition that the Oriskany is a very abrasive rock, thus a compatible drilling fluid must be selected), and 3) it takes some time to see improvements.

Mr. Bill Murray presented a case study of a deviated well drilled in the Clinton Sandstone in northeast Ohio. The well was a joint project with Belden and Blake and DOE. Two previous attempts at drilling deviated wells in the region had failed. The drilling plan for this well, in Mahoning County, was to kick off below the Salina salt horizon, attain 70o at the top of the Clinton, and increase to angle to 90o in the red Clinton for a distance of 1900'. The most illustrative part of this presentation was the accounting of technological problems that had to be overcome. Equipment failure was a problem: MWD flow

restrictor broke, orienting sleeve rotated, air motors broke; in general there was a hard fight with motors, steering tools, and bits. These problems added nine days to the project; 34% of the time was spent drilling, 26% of the time was spent in tripping. The well deviation exposed 1400' of the Clinton, which was subsequently stimulated by fracturing 2' intervals at 3 different depths. The fracturing jobs were successful, and there were no problems with cementing and completion. The well was budgeted at $1.55 million dollars in which 80% was spent on drilling and stimulation. The cost for this well did not favorably compare with the costs for vertically drilled wells in the Clinton which run approximately $170,000. Mr. Murray suggested that directional drilling may not be economical for primary recovery in the Clinton at this time, but may be better suited to EDR. However, the major accomplishment of the project was an increase in reserves 2.5 times that of conventionally drilled wells in the Clinton.

Mr. Al Yost presented a review of the newest downhole drilling systems that are being developed to address the technical challenges that directional drilling presents. Novatek Engineering, Inc. and DOE-FETC are involved in the development of a mud-activated down-hole hammer for water-mud applications. The construction is simple: a rotary bit combined with a percussion drill. The prototype consists of a high-blow, low frequency, 8.5" bit. The major improvement that this system will offer is a projected 80% increase in the rate of penetration over conventional tri-core drilling. Another system under development by Smith International, Houston TX, is a steerable air drilling system consisting of a diamond-enhanced hammer bit and an air driven self-rotating hammer. The third system under development is an integrated underbalanced directional drilling system using a steerable positive displacive motor. An EMT downhole repeater unit will improve pressure well drilling capabilities, and motors will be able to handle water, air, and mixed fluids. The system is being developed by Sperry-Sun in cooperation with DOE. The amount allotted to research and development projects for advanced downhole systems is in the range of $5 - 8 million.

Mr. Robert Cuthbertson provided the audience with information about and manufacturers of specialized equipment needed at the surface to efficiently and safely handle well effluent and contain pressures, yet still be able to access cuttings and fluid samples, during underbalanced drilling. In addition to a well designed engineering plan, proper surface equipment is required to ensure safe results. Depending on the case, the following equipment is necessary:

1) wellhead diverters a) rotating control head relies on changes in wellbore pressure to seal, and b) rotating blowout preventer which supplies an externally hydraulic pressure to seal. Rubber is the primary sealing element, and current rubber technology limits drilling pressures to 1500 psi. As better rubber goods become available higher pressures applications can be used.

2) emergency shut down valves installed immediately downstream of the rotating diverters. These can be automatic, manual, or remotely controlled; a redundant system is safest.

3) underbalanced drilling choke manifold to properly control the well. This should not replace the rig manifold whose primary function is emergency well control. Multiple chokes are recommended in order to eliminate shut down in the event a choke is plugged by cuttings or cut-out due to erosion.

4) pressurized sample catcher used to obtain samples, because in UBD samples cannot be taken from the shale shaker.

5) chemical injection pumps are used in cases where it becomes necessary to inject chemicals in order to offset problems associated with corrosion of gases, and to change to pH of drilling fluids so that they can be recovered and reused.

6) UBD production separators used to separate different fluids and to separate solids from fluids. These range from basic 2-phase systems to more sophisticated 4-phase separators with automated electronic data gathering systems that record temperature, gas volumes, pressures, volume of drilling fluids pumped and returned, and production, as well as high-low pressure alarms that provide an extra margin of safety.

7) flare systems that must be designed to handle BTU heating value and total daily volume so excessive ground heat does not occur.

Mr. Paul Conti related his experiences in drilling nearly 80 short radius underbalanced wells in the Niagaran reef trend. The reef trend, in Michigan, is considered to be a mature oil horizon.

The goal was to develop a low-cost drilling program using horizontal drilling technology to re-enter existing wellbores. The horizontal portions of the wells were drilled with nitrogen. A team approach to well planning, which included multidisciplined engineers, experienced production and drilling operators, and quality service company support, resulted in a successful program. A simple well design based on production test data and minimal evaluation logging helped lower cost while maximizing the number of candidate wells. Mr. Conti discussed specific remedial drilling and completion procedures that were foreseen and unforseen in the program. The drilling program resulted in greater than three-fold increases in production and approximately a ten-fold reduction in gas-oil ratio, as well as decreased water production. Additionally, as more wells were drilled, and the staff gained more experience, the price of drilling the horizontal wells decreased significantly. Mr. Conti also presented the results of a successful horizontal drilling program in the shallow Antrium Shale gas zone, also in Michigan. Horizontal drilling was the preferred technology based on the assumption that if more of the pay zone was penetrated, and more of the vertical fractures were intersected, then increased production would result. In concluding, he said that one of the major problems he has experienced is that, although the inner workings of tools work adequately, it is commonly the connections that fail; for instance, sealed bearings burn up by spinning too fast, thus burning the oil within the seal.

OPERATORS REACTION TO AND RECEPTION OF TECHNICAL INFORMATION

The question and answer portion of the program went well. Audience participation was excellent and there was lively discussion on a number of topics. Much of the discussion was about specific experiences or the use and merit of, or problems associated with specific types of equipment.

The panel discussion focused on:

1) the economics of directional drilling - the economics of a project should not be based on the cost of the first well. In many cases, the first well will be the most expensive; however, the learning curve is very steep, and as the specific requirements of drilling a particular formation are discovered, the cost generally decreases.

2) limitations of electronic monitoring tools and measurement while drilling tools when used in directional drilling projects.

3) the use of pre-existing wells to save money

4) new mud technologies - such as adding hollow glass spheres or using 7.5# muds to decrease the cost of drilling with nitrogen.

5) discussion of the attributes of drilling with air vs. nitrogen - nitrogen acts as a membrane gas which eliminates much of the problem associated with fines and corrosion.

The symposium provided drillers, operators, and engineers with accurate and realistic information on planning, drilling, and completing horizontal wells; what equipment is used, what happens to equipment, types of muds and fluids, safety issues. One of the major insights is that the cost of drilling can be competitive with conventional techniques, but probably not on the first well. New drilling equipment, appropriate drilling fluid mixtures for specific formations, and better adapted monitoring, steering, and logging equipment should be able to reduce the costs of drilling horizontal wells in the future.

K. R. Bruner