**Solving the Mystery of Low Rate of Penetration in Deep Wells**

**L.W. (Roy)Ledgerwood III**

**Abstract**

Rocks deep in the earth have unique and enigmatic material properties due to the confining pressures in the earth. Confining pressure increases rock strength and changes rock from a brittle to a ductile material. Humans tend to think of rock as brittle, since all of our direct experience with rock is at atmospheric pressure. But as wells were drilled deeper into the earth, it became apparent that the rock being drilled in oilfield wells yielded much lower penetration rates than rocks of the same composition near the surface. About seventy years ago, researchers in drilling mechanics began to study this by building high-pressure test facilities in which rock could be confined and drilled. Even with these new test machines, researchers had to hypothesize what was happening to the rock at the bottom of the borehole because they could not observe the drilling process first-hand. Though they understood that rocks under confining pressure become ductile, they continued to form hypotheses based on brittle failure mechanics. This presentation reviews the detective-story history of model development to explain low rate of penetration in deep boreholes. It then describes our current industry understanding of rock failure under a bit, which includes a significant role played by crushed rock detritus. Current challenges facing the drilling mechanics community are identified. This presentation constitutes a plea for continued research in this area.

**Biography**

Roy Ledgerwood earned a BS in Mechanical Engineering from Texas Tech University in 1975 and began working for Hughes Tool Company Research. Bob Cunningham, one of the pioneers in oil-field drilling mechanics, mentored him. In 1987, Ledgerwood earned an MS in Mechanical Engineering from Rice University where he studied drilling mechanics with Dr. John Cheatham, another pioneer in the field. When Hughes Tool Company built its Full-scale High Pressure Drilling Simulator—a test facility in which may stress rock rock up to 15,000 psi and test bits as large as 12 ¼”—Ledgerwood was the first supervisor of the facility. He designed and performed unique tests to show that crushed rock detritus in a borehole has a strength on the same order of magnitude as the original rock at the instant it is created. Ledgerwood has collaborated with other similar laboratories in Salt Lake City, Tulsa, and Pau, France in joint-industry and proprietary tests. In addition to testing, Ledgerwood has modeled the drilling process with both Finite Element Analysis and Discrete Element Analysis. These mathematical models show that most of the energy expended while drilling a deep well is dissipated not in failing the rock, but in extruding crushed rock detritus. He holds 14 patents and is the author of 23 techincal papers.