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The Next Wave: Three-Dimensional, Three-Component Technology

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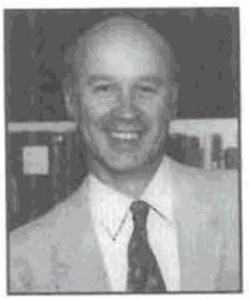
Three-dimensional (3-D), three-component (3-C) technology provides significantly more information about reservoir properties than can be obtained with conventional compressional 3-D surveys. 3-D, 3-C seismology involves the acquisition of seismic data in three orientations at each receiver location: two orthogonal and one vertical. The horizontal components of source and receiver displacements enable the recording of shear (S) waves, which are a powerful complement to P-waves. When three components of source are used, nine times the data of a conventional (P) wave 3-D can be recorded at approximately one-third more cost, thanks to advancements in today's acquisition and processing systems. The cost effectiveness and power of 3-D, 3-C will increase as new systems are developed. Acquisition and processing of 3-D, 3-C will increase the fidelity of seismic data to determine structure, lithology, and reservoir porosity, permeability, and fluid properties.

Examples from Cedar Hill Field, San Juan Basin, New Mexico, show the use of 3-D, 3-C in defining sealing faults, zones of lower in situ stress, and higher fracture density, overpressures, and zones of free gas. This technology can reduce risk and uncertainty in exploration and development of naturally fractured reservoirs.

A 3-D, 3-C seismic survey was made over the northeastern limit of Joffre Field, Alberta, to detect porosity within two complex Upper Devonian carbonate reservoirs (Nisku and Leduc). The compressional 3-D seismic data show several key structural and stratigraphic features along the northeastern updip edge of Joffre Field, but do not directly detect porosity within these dolomite reservoirs. The shear wave data image both Nisku and Leduc reservoirs. Combined P-wave and S-wave velocity ratio (Vp/Vs) mapping of the Leduc and Nisku intervals discriminates between porous and tight carbonates. This technology characterizes significant spatial variability of reservoir properties within these reservoirs. By integrating the 3-D, 3-C seismic results with geologic and reservoir production data into a reservoir model, new Nisku Field extension and field redevelopment targets are identified, and improved reservoir exploitation can be achieved.

Morrow valley-fill sandstone deposits in southeastern Colorado are prolific oil reservoirs that are not commonly detected with compressional seismic data. A 3-D, 3-C seismic survey acquired over a portion of the Sorrento Field, Cheyenne County, Colorado identifies the reservoir sandstone and its spatial variability. Velocity ratio (Vp/Vs), anisotropy, and shear wave amplitude mapping of the multicomponent seismic survey reveal reservoir sandstone distribution and discontinuities, and a local gas cap. Sandstone deposition and reservoir compartmentalization are influenced by faults and recurrent fault block movement.

The greatest advancement in geophysical technology is yet to come as we introduce the four-dimensional, three-component (4-D, 3-C) seismology. Time-lapse 3-D, 3-C surveys will produce "snapshot" images that can be analyzed and compared. These can be used to monitor the fluid property changes over time as the reservoir is produced. 4-D, 3-C geophysical technology will provide the most complete information currently available for economically efficient hydrocarbon exploitation. ■



Thomas L. Davis received his B.E. degree in Geological Engineering–Geophysics in 1969 from the University of Saskatchewan, his M.S. degree in Geophysics from the University of Calgary in 1971, and his Ph.D. from the Colorado School of Mines in 1974. He is currently Professor of Geophysics at the Colorado School of Mines and Director of the Reservoir Characterization Project. Except for a 3-1/2 year sojourn to the University of Calgary from 1977 to 1979, Tom has been a faculty member of the Department of Geophysics at CSM since 1974. He currently teaches courses on seismic interpretation and integrated exploration and development.