QuantumRD®

QuantumRD® deploys ViaLogy's Quantum Resonance Interferometry (QRI®) for computational weak signal processing and has been developed to bring new capabilities to the upstream oil and gas industry. As a ViaLogy service, QuantumRD is applied to detect, characterize and size reservoirs:

- ☐ at intervals where reservoir and non-reservoir lithologies could not be previously differentiated using 3-D seismic data;
- ☐ achieving areal and depth resolution where reservoir features could be given geological or geomorphological significance; and
- ☐ mapping physical properties (porosity, fluid distribution and lithology) based on new reservoir attribute markers

The best of today's migration, seismic inversion, and stacking algorithms narrow-out the acquired spectral bandwidth to cancel or to average out seismic noise. Their purpose is to extract sound-reflecting boundaries in order to correlate the strength of boundary reflections with the lithological properties of rock within the layer above and below a given boundaries. The discerned lithologies are then interpreted within different geological contexts to infer hydrocarbon presence. While subsurface structure can be accurately mapped using current techniques, these reflection- based methods are challenged in accurately discerning subtle changes in rock, fluid distribution and porosity in complex stratigraphies.

QuantumRD attacks the subsurface imaging and reservoir de-risking problem at three levels to derive more value from 3-D seismic than available techniques:

(a) In order to derive reservoir attributes QuantumRD assesses how coherent and random noise within the full seismic acquisition spectrum is differentially and directly modulated by subtle changes in porosity, fluids and lithology. There are signal changes buried in the noise that, if detectable, are very valuable. They reflect physical properties, something that has been known for years, but has not been exploited due to algorithmic limitations. The ability to exploit subtle disturbances in noise for the purpose of actually characterizing signals or events of interest is a core QuantumRD feature.

(b) ViaLogy's patented interferometric signal processing protocol - in software - determines how noise within the seismic data has been impacted by changing reservoir properties of interest, without the need for either explicitly defining signal or precisely isolating it from noise. QuantumRD uses a synthetic noise source, using rock-

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physics and well-control data to probe the acquired seismic data and to detect, characterize and amplify changes in seismic noise. This process of excitation of conventionally acquired seismic data using synthetic noise in software, determines attributes of interest, such as presence of prespecified levels of porosity, as emergent resonances.

(c) The implementation of a new workflow sequence relies upon the deconstruction of conventionally processed complex seismic datasets into optimal voxels (or smaller volume cells) over the formation of interest to immunize against errors in velocity estimation and gather conditioning over the entire dataset. Individual voxels analyzed for porosity, fluid and other rock properties are recombined to build net-pay reservoir models or "resource models" from bottom-up. QuantumRD achieves higher precision and accuracy by using excitation at the individual voxel level.

QuantumRD's key constituents summarized above provide actionable information, significant scale and business leverage. Since mid-2008, QuantumRD has allowed ViaLogy to assist our exploration and production (E&P) clients in addressing a broad spectrum of operating challenges and priorities ranging from how to lease prospects; detect, delineate and characterize reservoirs on their prospects; develop optimal offsets; how to stimulate and fracture them; and understanding reservoir compartmentalization for enhanced recovery.

Recent project execution allowed us to demonstrate our value-proposition in some of the most complex but prolific formations with tremendous opportunity for future growth.

Carbonate Reservoirs

Recognizing that more than 60% of world's oil and 40% of world's remaining gas reserves are in carbonates, ViaLogy has devoted substantial effort in focusing QuantumRD capability to de-risk and characterize complex stratigraphic carbonates, their stacking, continuity, fracture density and spacing prediction. Porosity prediction is at the heart of discriminating potentially productive carbonate bodies. Carbonate reservoirs continue to be difficult to characterize using 3-D seismic due to their greater heterogeneity from rapid vertical and lateral facies variation, lower seismic resolution due to higher velocities, and inherent inability to directly image fracturing. Basin geology models provide limited insight to positioning of individual wells and offsets, as formation properties change unpredictably. Because of the broad-spectrum of diagenesis (chemical, physical, or biological change undergone by sediment in its initial deposition) that affects carbonate rocks, the final porosity in these carbonates may or may not be related to the depositional environment. Also, unlike other lithologies, the original primary porosity in carbonates may be totally destroyed during diagenesis and significant new secondary porosity may be created. So to get a successful well, it is important to find certain patterns of natural fracturing and high continuous porosities from 3-D seismic.

QuantumRD's high vertical and areal resolution and sensitivity in assessing fine-scale lithological variations and heterogeneities to find porous and permeable lenses within carbonate bodies was validated in positioning the successful onshore Strawn well in the Midland Basin after a string of 15 previous failures using conventional seismic processing. ViaLogy continues to develop new capabilities to recognize and identify characteristic abrupt changes in rock type distribution to discriminate between local regions of macro porosity (e.g., vugs) and large aperture fractures for exploration, field redevelopment and enhanced recovery. In addition to de-risking new drilling locations, ViaLogy is working on developing a systematic, automated approach to redevelop under-performing or abandoned wells that could be sitting near near-pay zones that may have just been missed.

Clastic Reservoirs

On-shore and deep-water clastic reservoirs are among the world's largest, most explored, and most productive hydrocarbon plays. These include a variety of turbidite sand-body geometries such as channels, lobes, sheets and levees in complex down slope settings. Post-depositional stresses modify primary sedimentary structures changing pore size distribution and permeability characteristics challenging interpretation of pay and saturation distribution in otherwise sand-prone reservoirs. Exploration success, and subsequent appraisal and development of these highly productive reservoirs depend upon accurately mapping the interplay of sediment dispersal within reservoir-scale or basin-scale geometry to delineate source, seal, and reservoir geologies. Conventional de-risking has relied on acquiring large offsets and higher frequency data. While this has advanced structural interpretation, success has been spotty due to lack of fluid imaging capability. QuantumRD's ability to exploit noise within seismic data and increase resolution for jointly assessing sand-stacking along with in-place fluid saturation could be significant in de-risking and finding net pay. QuantumRD Clastic application, on a New Mexico, US 3-D seismic survey explained distribution of producers and dry-holes, de-risked and significantly altered the existing reservoir model delivering drilling targets with potential for multiple large gas wells.

Shale Gas Resource Plays

Unconventional shale gas resource development is rapidly becoming a dominant global trend in onshore exploration. As this hydrocarbon resource is pervasive in the formations, efforts over the past few years focused on grid-based drilling that made extensive use of horizontal drilling and high volume fracturing. But that is changing. The wells produce from low permeability shale formations that are also the source rock for the oil and natural gas. As the larger hydrocarbon volumes are restricted to fracture porosity within the shale, or within micropores, or adsorbed onto the minerals and organic matter within the shale, subtle changes in lithology produce dramatic changes in production outcomes and economics even in closely space wells. However, these lithology changes register only as weak changes in conventional 3-D seismic signal; that has been designed to primarily image large impedance contrasts across lithologies. As the changes in impedance contrast within shales formations are very subtle, geophysicists struggle to add value by using the signal measured by conventional seismic in unconventional reservoirs. Other influences on shale productivity include the "brittleness" or ability to

fracture the reservoir, and the accurate identification of thin stringers embedded with the shales from which they can be produced.

Combining the sensitivity and enhanced resolutions payoffs demonstrated for carbonates and clastic reservoirs to refine seismic derived brittleness and porosity volumes, shale gas and oil resource plays are becoming a major focus area for QuantumRD.

QuantumRD is being developed as a transferable, licensable product, and we are assessing new opportunities in improving signal-to-noise in onshore and offshore seismic and electromagnetic acquisitions, microseismic for hydraulic fracture monitoring and optimization, and interferometric acquisition protocol for direct hydrocarbon imaging using conventional 3-D vibration sources.

