AAPG Datapages/Search and Discovery Article #90310 ©2017 AAPG/SEG International Conference and Exhibition, London, England, October 15-18, 2017

Rank Reduction Processing of 3-D Prestack Seismic Data for the Geomechanical Inversion of an Unconventional Reservoir and its Caprock, Moncton Basin, Canada

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ABSTRACT

When a P-wave hits an interface at a non-normal angle of incidence, P- and S-waves are reflected. The Aki-Richards approximation of the Zoeppritz equations shows that relatively small variations in P-impedance, S-impedance and density at the interface of two geological media can be recorded at different angles of incidence. It is well accepted among practitioners that P-impedance is captured at low angles (<15°), S-impedance at mid-angles (15-30°) and density at high angles (>30°). Prestack amplitude inversion provides an estimation of both types of impedance as well as density. Data acquisition and processing, seismic-to-well ties and the complexity of the subsurface geometry all introduce uncertainty to this estimation. This contribution focuses on a seismic processing method, namely rank reduction that is applied on prestack 3-D land seismic data for decreasing uncertainty. In this method, data are first rearranged into a Hankel matrix. Then, singular value decomposition of the Hankel matrix is used to eliminate irrelevant ranks corresponding to random noise and coherent dipping events that obscure reflections on prestack time migrated (PSTM) AVO gathers to be inverted for recovering P-impedance, S-impedance and density. The values recovered will be used to derive geomechanical properties (i.e. Poisson’s Ratio, Young’s Modulus and brittleness) of an unconventional shale reservoir and its caprock hosted in the highly deformed terrestrial Carboniferous strata of the Moncton Basin, Canada. On PSTM AVO gathers lower-ranks correspond to random noise whereas mid-ranks correspond to dipping events attributed to out-of-plane reflections coming from the complex subsurface structure and higher ranks correspond to flat events having the maximum energy, i.e. the events to be inverted. The rank-reduction method applied in a cascade mode has proven to be efficient for removing lower and mid ranks that contaminated all offsets. The rank reduction scheme has increased the signal-to-noise ratio of near-offset (0-1600m) traces by 35%, by 50% for mid-offset (1600-3200m) traces and by 55% for far-offset (3200-4800m) traces. The enhancement of the events on the far offsets or at higher angles is of critical importance as the density term of the inversion recovered on those angles, is very sensitive to noise but essential for the estimation of Young’s Modulus and brittleness.