SEQUENCE STRATIGRAPHIC CONTROL OF SEISMIC PROPERTIES AND FACIES VARIATION IN DEEPWATER SHALES, OUTCROP AND SUBSURFACE EXAMPLES

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Effective evaluation of seal quality, in an exploration setting, requires a predictive model to estimate the distribution, sealing capacity and petrophysical properties of shale seals and flow barriers. Such a sequence stratigraphy-based predictive model must be grounded in outcrop and field analogs and then extrapolated into seismic data space. This study examines the sealing capacity, petrophysical properties and distribution of Upper Cretaceous Lewis marine shales in two wells from south-central Wyoming and compares them to some recent deepwater drilling results. In both outcrop and subsurface, measured sealing capacity of shales varies with textural and compositional factors that allow the recognition of specific shale rocktypes. Each type of shale displays distinctive compositional and petrophysical properties and occupies a well-defined sequence stratigraphic position including transgressive, highstand, and condensed section deposits, with characteristic seal and seismic properties. The shale types, in order of greatest seal capacity to least, are phosphatic shales, pyritic fissile shales, silty shales, silty calcareous shales, silty calcareous mudstones, and bioturbated argillaceous siltstones. The most promising seals, the phosphatic and pyritic shales, belong to the condensed section and uppermost transgressive systems tract. The phosphatic shale is also characterized by the highest content of both total organic carbon (TOC) and authigenic minerals. Interestingly, neither of these two high sealing capacity microfacies shows more detrital clay than other microfacies. The shale types with lower sealing capacities belong to the highstand systems tract and are generally poorer in iron-rich minerals than the better sealing microfacies. Petrophysical properties, including high bulk density, shear velocity, Young’s modulus and shear modulus, distinguish the best seals from highstand systems tract shale types with poorer seal capacity. This correspondence between sealing capacity and seismic properties suggests that seismic data may have good potential as a tool for seal evaluation. Stratigraphic stacking patterns that emplace a low-velocity and low-density zone immediately above a high velocity, high-density shale type produces a very strong positive acoustic impedance contrast in the vicinity of the maximum flooding surface. This contrast in acoustic properties, at a shale-on-shale contact, will generate a strong seismic reflection. The arrangement of slow shale types rocks above fast rocks can generate an AVO anomaly similar to those generated by hydrocarbon filled sandstones and probably accounts for the false sand anomalies seen in some recent wells.