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Keynote address: OUTCROP/BEHIND OUTCROP CHARACTERIZATION OF DEEPWATER (TURBIDITE) PETROLEUM RESERVOIR ANALOGS: WHY AND HOW

Increased emphasis on exploration for deepwater (turbidite) reservoirs during the past 25 years has resulted in many discovered fields. The current trend is for companies to fast-track field development, with minimum drilling, no workovers or intervention, increased use of subsea tiebacks, optimal individual well rates and ultimate recoveries, and expanded perforated intervals. However, only about 25% of discoveries are currently being produced or are under development.

Early reservoir simulation is used to predict production performance for fast-track development planning. Simulation. requires a good 3D geologic reservoir input model. Such models are often built using a limited number of appraisal wells, which may hinder accurate bed correlations, and 3D seismic, which may not resolve sub-seismic scale geologic features that control production, and thus the economic viability of the project.

During the past few years, quantitative characterization of outcrops has supplemented subsurface data in the model-building process. However, to adequately document important reservoir properties at the wellbore, interwell and reservoir scales requires studying large, continuous outcrops, preferably in 3D. Though rare, there are some good outcrops that provide information on shale- and sandstone-bed continuity, vertical connectivity, internal geometry and stratigraphic variations in permeability. These are all important input parameters for geological modeling, upscaling geologic parameters, and providing well log recognition criteria for predicting continuity away from a wellbore.

Several tools and techniques are now used to characterize outcrops. Photomosaics and 3D visualization photoimaging provide a means of capturing architectural information in an electronic format amenable to overlay onto seismic volumes or between wells. Logging, coring, and collecting seismic reflection data behind outcrops, as well as collecting gamma ray, sonic velocity, and permeability profiles along outcrop faces provide data that can be directly compared with subsurface well logs and seismic. Ground-penetrating radar (GPR) provides a means for continuously imaging bed-scale features behind an outcrop face.

These techniques have been successfully applied to outcrops of three deepwater (turbidite) deposits. Outcrop studies of the Mt. Messenger Formation (New Zealand) have provided: (a) dipmeter criteria to distinguish channnel, proximal- and distal-levee deposits and (b) internal architecture of levee and channel-fill strata. This information was applied to drilling a successful horizontal well in the Gulf of Mexico, and for improved interpretation of deepwater reservoir characteristics from well data.

Outcrop studies of the Lewis Shale (Wyoming) have provided: (a) borehole image criteria to distinguish sheet from leveed-channel sandstones, (b) quantitative 2D and partial-3D bed continuity and connectivity information, and (c) GPR images of the complex nature of the critical boundary between channel and levee/overbank deposits. This information is useful for more accurate volumetric calculations, for determining drilling directions, and for predicting well performance.

Studies of the Lower Pennsylvanian Jackfork Group (Arkansas and Oklahoma) have provided: (a) a interwell-scale 3D geologic model of a sheet/ channel-fill sandstone complex which has been subjected to 'reservoir' simulation for demonstrating---on the outcrop---geologic heterogeneities that will affect reservoir performance. This approach provides an inexpensive alternative to an immersive visualization theater for addressing drilling and production issues in this type of reservoir.

Although complete 3D outcrop geologic models of these deepwater (turbidite) deposits at reservoir scale are still elusive, the results provide important information that is directly applicable to interpreting and predicting performance of analog reservoirs. Characterization of outcrops using the combination of tools and techniques described here should continue with the ultimate goal of providing the necessary quantitative information to help guide fast-track development of deepwater (turbidite) reservoirs.