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STRATIGRAPHIC CONTROLS ON PETROPHYSICAL ATTRIBUTES AND FLUID-FLOW PATHWAYS IN AN EXHUMED FLUVIAL RESERVOIR; SUNNYSIDE QUARRY, CARBON COUNTY, UTAH

Yohan Kusumanegara*

ABSTRACT

Fluvial, floodplain and lake facies of the Green River Formation (Eocene) occur within an exhumed oil reservoir exposed in a quarry near Sunnyside, Utah. Strata in the quarry highwalls define three, base-level rise asymmetrical genetic sequences arranged in a long-term base-level rise stacking pattern. The basal genetic sequences consists almost entirely of trough cross-stratified sandstones of amalgamated channel fills. The second sequence consists of about 50% amalgamated channel sandstones in the lower half, and a mixture 40% floodplain mudstones and 10% isolated channel sandstones in the upper half. The third sequence consists of about 20% isolated channel sandstones, 50% floodplain mudstones, 20% crevasse splay/crevasse channel complexes, and 10% lacustrine mudstones at the top.

Visual estimates of oil staining intensity, coupled with numerous petrophysical (porosity, permeability, capillary entry pressure, percentage of bitumen weight) and petrographic measurements of the different facies, were the basis for defining fluid-flow compartments and compartment boundaries at the time scale of reservoir charging (millions of years). Variable color intensity of oil staining on the fresh surfaces of sandstones is a qualitative measure of pore volumes, as all sandstones are fully saturated with oil. Strata and facies that functioned as fluid-flow conduits, retardants and barriers were mapped on photomosaics. The major fluid-flow compartments are coincident with genetic sequences. The laterally continuous floodplain and lacustrine mudstones which cap each genetic sequence entirely lack oil in the matrix porosity. They functioned as fluid-flow barriers between the fluid-flow compartments, although numerous fractures in the surface exposures could have permitted fluid migration vertically through the mudstones if they also were present in the subsurface. All fluvial sandstones are fully saturated and functioned as flow conduits with varying degrees of permeability and interconnectedness.

If degrees of measured and visually estimated intensity of oil staining are accurate proxies for fluid-flow pathways, then homogeneity of fluid flow may not be equated directly with facies homogeneity. At one extreme of an apparent continuum, fluid-flow pathways may be tortuous and extremely variable within an entirely homogeneous, high permeability sedimentary facies. Sweep efficiencies may be low in these cases. At an intermediate position in the continuum, increased diversity of sedimentary facies and stratigraphic variability usually cause sufficient stratigraphic separation of permeable and nonpermeable strata such that fluid-flow pathways are more confined and have a reduced tortuosity. Sweep efficiencies may be high in these cases. At the other extreme of the continuum, where diversity of sedimentary facies and stratigraphic variability is very high, stratigraphic units are discontinuous and restricted in area. In such cases, fluid-flow pathways are restricted and not laterally connected.

Facies analysis coupled with the petrophysical and petrographic measurements demonstrated that petrophysical properties are strongly tied to subtle variations in facies, and that both are stratigraphically sensitive. In the amalgamated fluvial channel sandstones, for example, porosity and permeability changes are exactly coincident and monotonic with stratigraphic position. These variations exactly coincide with subtle variations in grain size, sorting and trough cross-stratification set thickness within identical sedimentary facies. Porosity and permeability are highest in trough cross-stratified sandstones immediately above channel scour bases, and decrease upward to the next scour base. Successive channel sandstones within the same

* ARCO Indonesia

genetic sequence have progressively lower porosities and permeabilities. Channel sandstones from one genetic sequence to the next also have progressively lower porosities and permeabilities. Similar types of patterns and monotonic associations between petrophysical attributes and subtle changes in facies are recorded for other sedimentary facies.

Facies and petrophysical variability is most easily explained by the ratio of accommodation:sediment supply which oscillates during stratigraphic base-level cycles. With high accommodation, an increased number and proportion of the original bedforms and macroforms that occupied the fluvial channels and floodplain are preserved in the stratigraphic record. Facies diversity increases, usually with the result of adding more mud-rich and poorly sorted sandstones, as well as mudstones, to channel deposits. With decreasing accommodation, only those bedforms and macroforms which have the highest preservation potential are incorporated into the stratigraphic record.

For floodplain/fluvial channel environments, these are the bedforms that occupy the deepest parts of channel scours. With reduced accommodation, there is a tendency toward increased facies homogeneity and preservation of amalgamated, cannibalized bedforms and macroforms.

These results demonstrate that standard porosity/permeability crossplots of sedimentary facies are unnecessarily broad and imprecise. When such petrophysical data are grouped according to their stratigraphic positions, and not just with respect to sedimentary facies, the porosity/permeability values have significantly reduced scatter. Porosity and permeability measurements and predictions should be made from a stratigraphic perspective.