4-D Stratigraphic Architecture and 3-D Reservoir Fluid-Flow Model of the Mirador Formation, Cusiana Field, Foothills Area of the Cordillera Oriental, Colombia

by

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ABSTRACT

A high resolution sequence stratigraphic study using 2300 feet of core calibrated with geophysical logs from 14 wells and 1800 measurements of porosity and permeability established the 4-D stratigraphic architecture and facies distribution and the 3-D reservoir zonation of the Mirador Formation in the Cusiana Field area. The most common reservoir-quality rocks are trough cross-stratified sandstones and pebbly sandstones of channel facies successions in the lower Mirador and of channel and bay-head delta facies successions in the upper Mirador. The geometry, continuity, volume and petrophysical properties of facies and facies successions change regularly as a function of their stratigraphic position.

Two long-term stratigraphic cycles constitute the Mirador Formation in the Cusiana Field area. The lower long-term cycle comprises three intermediate-term, landward-stepping stratigraphic cycles. Cycles I and II are base-level rise asymmetrical, whereas cycle III is more symmetrical. These intermediate-term cycles are composed of, in stratigraphic order, channel, crevasse splay and lake facies successions of the coastal plain facies tract. This trend of facies indicates base-level rise or increasing accommodation-to-sediment supply (A/S) ratio. The change in symmetry, the increasing ratio of lake and crevasse splay to channel facies successions and the continuous onlap of the intermediate-term cycles record base-level rise of the lower long-term cycle. Strata representing base-level fall time of the lower long-term cycle are continuous lake and floodplain mudstones in the Cusiana field, and are known as the Middle Mirador Mudstone. The lower long-term cycle ended with a time of subaerial exposure and valley incision that creates an erosional relief of at least 50 feet in the Cusiana field area.

The upper long-term cycle comprises four intermediate-term, landward-stepping approximately symmetrical stratigraphic cycles. These intermediate-term cycles are composed of, in stratigraphic order, channel, bay-head delta and bay-fill facies successions of the bay facies tract. This facies succession indicates a base-level rise, whereas the reverse transition represents a base-level fall.

Trough cross-stratified facies of channel facies successions in the lower long-term cycle and of channel and bay-head delta facies successions in the upper long-term cycle are the main reservoir rocks in the Mirador Formation. Crevasse splay, lake and floodplain facies successions in the lower long-term cycle and bay-fill facies successions in the upper long-term cycle constitute fluid-flow retardants or barriers at the time scale of reservoir production. Petrophysical data establish that permeability of good reservoir rocks is, at least, two orders in magnitude higher than of poor reservoir rocks, and that porosity in good reservoir rocks is 2 to 3% higher than in poor reservoir rocks.

Sixteen reservoir zones were defined in the Mirador Formation. Reservoirs within the upper and lower long-term cycles are separated by the continuous Middle Mirador Mudstone which creates two large reservoir divisions. At the second level of zonation, the reservoir compartments and fluid-flow retardants or barriers coincide with the intermediate-term stratigraphic cycles. A third level of reservoir compartmentalization follows the distribution of facies successions within the intermediate-term cycles. A strong stratigraphic control of porosity and permeability was identified at three scales of stratigraphic cyclicity. In all cases as accommodation-to-sediment supply ratio increases porosity and permeability decrease, whereas porosity and permeability increase as this ratio decreases.

Zones Ia, IIa, IIIa, Va, and Vc are fluid-flow compartments. Zones Ib, IIb, IIIb, Vb, VI a, VIb and VIc are fluid-flow retardants or barriers at the time scale of reservoir production. Zones Ic and IV are barriers. And finally zones VId and VII are retardants in some areas of the Cusiana Field and fluid-flow compartments in other areas.

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