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Multiscale analysis of sedimentological heterogeneities in fluvial tight-gas sandstones and its impact on reservoir properties: a case study from the Mulichinco Formation, Neuquén Basin, Argentina

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Sedimentological heterogeneities in fluvial reservoir constitute significant flow barriers, which can be unfolded on a variety of scales. Disparities in stratigraphic distribution, nature of bounding surfaces, spatial changes in facies associations and lithofacies have been indicated as main elements to consider for an integrated evaluation of multiscale heterogeneities in fluvial successions. In fact, the impact of multiscale heterogeneities on the reservoir properties are usually underestimated during modelling workflows, which eventually may affect the recovery of hydrocarbons.

In this study we analyzed sedimentological heterogeneities from fluvial deposits in the Mulichinco Formation, exposed in the southern-margin of the Neuquén Basin (Sierra de la Vaca Muerta Anticline and Cerro Mesa), Argentina. Although these fluvial deposits are included among the main tight-gas reservoirs of the basin, variations between large- to small-scale sedimentary elements and its potential role as flow barriers were not studied in an integrated analysis. The studied interval includes five main sedimentary units (U): gravelly-sand braided channels (U1), sandy braided channels (U2), meandering channels (U3), terminal channels (U4) and floodplain deposits (U5). The sedimentary units represent the deposition in a proximal coarse-load (U1, U2, U5 (restricted)) to distal mixed-load (U2, U3, U4, U5) fluvial system. The channel units vary according to width/thickness ratios, scale of bounding erosive surfaces (small- to large-scale), storey amalgamation, typical in-channel accretion style (downstream or laterally accreting bars), dominant lithofacies and petrophysical properties. U1 and U2 show width/thickness ratios between 25 and 240 (narrow to wide sheets) and a complex architecture defined by medium- to large-scale bounding erosive surfaces and a variable degree of amalgamation. These units are dominated by coarse-grained textures (cobbles to medium-grained sandstones) and downstream-inclined stratasets. Distinctly, U3 and U4 show lower width/thickness ratios, with values of 18 to 161 (narrow sheets) and exhibit a more simple internal architecture represented by medium-scale erosive surfaces. Internally, these units show a finer grain size (medium- to fine-grained sandtones) and even the alternation of sandy and heterolithic facies related to large-scale inclined strata dominated by lateral accretion components.

Four potential scales of sedimentological heterogeneities were identified: stratigraphic distribution of channel bodies, facies association, lithofacies and lamina. The spatial distribution of the different channel-body types shows proximal coarse fluvial deposits pass vertical and laterally to distal mixed-load fluvial units. Moreover, a vertical decrease in net to gross ratios and the amalgamation degree of channel bodies are also recorded, indicating channel body connectivity would be sensitive to channel-body type. Facies associations and lithofacies scale seem to have a reduced influence on porosity and permeability distributions, whereas at the lamina scale, grain size, matrix proportion and cement composition represent the main controls on the reservoir properties.

Qualitative and quantitative data of channel body types and their spatial distribution allow developing a conceptual depositional model, which provide an invaluable basis for updating potential 3D geological models. This work shows that multiscale characterization approach should be implemented to evaluate possible carrier and barrier distributions in fluvial reservoir type, allowing prioritize which scale of heterogeneity requires to be focused on subsurface reservoir modelling.