Biosteering the Upper Permian Khuff Reservoirs in Saudi Arabia

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Abstract

Biosteering to assist coiled-tube underbalance drilling has been successfully applied, and is now a routine practice, to improve gas and condensate recovery from development wells at depths in excess of 12,000 ft in the Late Permian Khuff C carbonate reservoir of Saudi Arabia. Multilaterals are drilled by re-entry of the motherbore with the objective to maintain multilateral drilling within selected porous layers over distances in excess of 4000 ft. The coiled-tube drilling process has the advantage of rapid adjustment to the inclination and trajectory as well as enabling continued gas and condensate production while drilling. As logging, during narrow-bore coiled-tube drilling, is confined to the gamma tool which follows the bit by approximately 30 ft, the only "real-time" source of stratigraphic control is provided by micropalaeontological analysis, up to two hours ahead of the gamma data. Controlled drilling prohibits the use of rate of penetration to be used as an accessory stratigraphic guide. The use of water as a drilling medium enables cuttings to be received with a lag time of between 10 and 20 minutes from 12,000 ft, depending on the degree of gas contribution. Stratigraphic position is achieved by reference to a local biozonation based on closely-spaced comprehensive micropalaeontology of core samples from the motherbore or a nearby offset well. Although of shallow marine origin, the Khuff C depositional environments are highly variable laterally over short distances so that it is necessary to establish reference biofacies-based biozonation schemes to support each well to be biosteered. The Late Permian biofacies include a variety of benthonic foraminifera together with fragments of associated microfossils that include brachiopods, calcareous algae, bivalves, gastropods and bryozoa. By comparing the micropalaeontology of cuttings samples with those recorded in a cored offset well, stratigraphic position can be determined within 2 ft vertical thickness. Caving is minimal due to the sliding and non-rotational drilling methodology. This information enables the drill trajectory can be monitored as it approaches the planned reservoir layer and real-time adjustment instructions provided to the directional driller whenever deviation from the plan is detected. As the "eyes" of the drill, this technique has resulted in excess of a sevenfold increase in gas production for each well and a significant increase in gas and condensate production. The highly diverse microfossils of the Jurassic to Neogene formations of Saudi Arabia provide the potential for this high-resolution biostratigraphic technique to be applied to coiled-tube underbalanced development drilling of all carbonate reservoirs.