The Heterogeneities and Reservoirs Characterization of Shahezi Formation Tight Gas in Xujiaweizi Fault Depression

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The tight sandstone gas prospecting is a key area of unconventional oil and gas exploration. The source rock of Shahezi Formation indicates adequate source condition for gas, which shows features of great thickness, wide distribution, high organic content and remaining high and overmature stages. Meantime, it possesses a reservoir condition with low porosity and low permeability, a conservation condition with good sealing, a well-matched migration condition, a favourable trap and good source reservoir caprock assemblage. It has qualifications for large-area tight gas reservoir.

The Shahezi Formation develops in faulted basin. It is close to the source, with a feature of fast phase transformation, and indicates a strong heterogeneity. It specifies as follows: (1) It is close to source, with a coarse and fine lithology hybrid and sorting difference. The Shahezi Formation developed in the strongly-faulted period. The provenance mainly came from the west-east direction of short axis. The sediment unloaded quickly, which led to poor sorting and rounding. It mainly developed feldspar debris sandstone with low composition and structure maturities, which forms the objective basis of strong heterogeneity. (2) The facies changes fast and the gas layer show a horizontal discontinuity. Fan delta develops in western steep slope zone. The braided river delta develops in eastern gentle slope zone. The gravel rock mass shows a skirt zonal distribution. The fast change and narrowness of facies zone lead to great difference of physical features of gas layers. Meantime, the differences of conglomerate sorting, rounding and supporting feature cause the great differences of lithologies. It results in that the same gas layer in the same facies zone show different lithology feature, which bring about the different physical properties of reservoirs, the worse discontinuities of gas layer and stronger heterogeneity. (3) The single layer is thin and gas layers don’t concentrate vertically. The single gas layer of Shahezi Formation is thin, mainly 5-20 m, average 10.3 m. Different gas layers are cut apart by mudstones, whose vertical concentration ratio are low and present a dispersive distribution feature. (4) The buried depth is large and the pore structure shows inhomogeneity. The buried depth of Shahezi Formation is large. And the reservoirs remain in B period of middle diagenetic stage and the late diagenetic stage. The types of pores are mainly secondary porosity such as dissolution hole of the particles, interparticle dissolution pore and gravel seam. The pore structure presents the features of small hole throat, poor sorting, skew negative, high replacement pressure and unapparent platform. Poor pore-throat structure is the root cause for strong heterogeneity.

The core analysis of Shahezi Formation indicates that the porosity mainly distributes from 2% to 6%, average 4.3%, among which greater than 4% accounts for 53%. The permeability is mainly less than 0.1mD, average 0.3mD, among which less than 0.1mD accounts for 61.6%. The physical properties of fine sandstone and conglomerate of delta front zone are the best, which of delta plain comes second. The underwater distributary channel sand body and sheet sand of fan delta front, and the underwater distributary channel and channel mouth bar of braided delta front possess the best porosity. As the buried depth grows, the reservoir’s physical property becomes worse gradually. The dissolution which produces all kinds of secondary pore improves the reservoir properties, which is important for the development of relatively-high pores. At the same time, in order to analyze the microcosmic feature of the tight reservoir in Shahezi Formation, microcosmic experiments are designed to characterize them, such as CT, NMR, constant velocity mercury, low temperature nitrogen adsorption, rock wettability, gas phase infiltration and displacement and so on.

The analysis shows that: (1) The porosity of sandy conglomerate reservoir distributes from 2 nm to100 μm,
mainly nanometer scale porosity. The average aperture shows a feature: that of the tuff sandstone is larger than that of grit stone, and that of conglomerate rock, middle fine sandstone and argillaceous sandstone in return. The conglomerate develops with low porosity and large hole, and grit stone (with gravel in it) with large porosity and hole. (2) The throat of sandy conglomerate is mainly microcapillary tube and capillary. As the supercapillary and capillary become more and more, the permeabilities improve obviously. The aperture of throat is the key point to control permeability. (3) Reservoirs mainly develop micropore and microthroat and most of the throat’s aperture is less than 0.5 μm. The grit sandstone (with gravel in it) possesses larger throat aperture and that of the silly and fine stone the least. Domestic part of conglomerate develops large throat. The pore-throat structure is the best with assembly of interparticle fracture and dissolution pore in (sandy) pebble conglomerate. The conglomerate with matrix fracture or little dissolution pore owns poor pore-throat aperture, and the saturation of mercury invading is low. The middle pore-throat structure of grit stone (with gravel in it) is the best with assembly of primary residual pore and dissolution pore, or that of intergranular pore and dissolution pore.

The micropore-throat feature of reservoirs is an important factor that affects the physical properties of reservoirs, and also the key content of tight gas characterization. The study of microstructure characterization of tight gas reservoir in Shahezi formation remains in the exploration stage. With the study deepening, a distinctive characterization method for multiscale pore-throat in Shahezi formation must be able to form. It can provide basis for understanding the microfeature of tight sandy conglomerate in Shahezi formation correctly. Also, it can form a basis for the specification of tight gas formation mechanism and the enrichment region prediction.

References