FORMATION AND PRESERVATION OF A LARGE, SUPER-DEEP ANCIENT CARBONATE RESERVOIR IN THE TARIM BASIN

G. Y. Zhu[1], Z. Y. Zhang[1], A. V. Milkov[2]

[1] Research Institute of Petroleum Exploration and Development, Petrochina, Beijing, China,
[2] Murphy Oil Corporation

Introduction

Deep and super-deep reservoirs have become increasingly important oil and gas exploration targets in recent years. To date, however, all super-deep oil and gas fields that have been discovered are concentrated in Cenozoic-aged strata. Indeed, when paleo-reservoirs are deeply-buried, oil-cracking can occur as a result of high temperature, leading to the significant generation of natural gas. Deeply-buried oil deposits can also often be damaged by thermochemical sulfate reduction (TSR) reactions between oil and sulfate at high temperatures, and so carbonate reservoirs are often transformed over time into hydrogen sulfide-rich gas fields. Thus, as time since formation increases, the preservation of deep liquid petroleum become less-and-less likely as the result of destructive factors. This explains why super-deep ancient carbonate reservoirs are rare, while gas or condensate reservoirs are relatively common.

Recently, a large oilfield buried to depths between 7,000 m and 8,000 m was identified in the southern Halahatang region of the northern Tarim uplift, Tarim Basin (i.e., Fuyuan, Jinyue, Yueman, Guole blocks etc.). This discovery is the deepest carbonate oilfield yet identified in Lower Paleozoic strata, further confirming the huge oil potential of western China, and providing a new research opportunity for work on the accumulation and preservation of paleo-reservoirs. The study of this example of a Karst fracture-cavity carbonate reservoir will provide an important new data for deep marine carbonate oil and gas exploration.

Results

This oilfield has the Ordovician Yijianfang and Yingshan formations as reservoirs, a lower Paleozoic formation as its source, and contains a reserve of more than 1 billion tons. Because this oilfield consists of an ancient and giant carbonate reservoir, the deepest yet discovered anywhere in the world, it opens up new avenues of petroleum exploration in deep ancient marine settings. This oilfield is dominated by structural-lithological karst fracture-cave reservoirs that are covered by middle and upper Ordovician limestones and mudstones, has a reservoir pressure between75 MPa and 85 MPa, pressure coefficients between 1.2 and 1.7, and temperatures that range between 140°C and 160°C. This study suggests that charging and accumulation of hydrocarbons into this field occurred in during the late Hercynian period of the Permian, followed by subsequent gradual deep burial, before the basin began to rapidly subside 5 million years (Ma) ago. Following subsidence, the thickness of overlying strata increased by more than 2,000 m before finally attaining current burial depth now; as a result, this oilfield represents an example of a well-preserved ancient petroleum system. On the basis of this study of the geochemical features of oil and gas preserved in this system, crude oil can be classified as mature, while the latter is considered to be an associated gas. In addition, no crude oil-cracking has occurred in this oilfield.

Conclusion

The discovery of this oilfield opens a new wave of possibilities for hydrocarbon exploration in deep marine carbonate paleo-reservoirs.

As the degree of reservoir development is mainly dominated by karstification, the amount and development of fractures, and local sedimentary facies, hydrocarbon accumulations will be horizontally distributed in bands and not vertically restricted by burial depth. Clearly, super-deep strata hold massive exploration value.

The deficiencies in the time-temperature compensation effect in late stage rapid and deep burial at low geothermal gradients are key factors controlling the preservation of super-deep paleo-reservoirs. The liquid petroleum exploration potential of strata buried deeper than 8,000 m is thus huge.

Petroleum accumulation within this oilfield was controlled by reservoirs and fractures, while karst reservoirs also tended to develop with favorable fracture-cave connectivity. High-quality reservoirs within the Tarim Basin exhibit strong beads-like amplitudes in seismic sections and are thus easy to identify. Oil and gas enrichment in these reservoirs is concentrated along fault belts, and so wells that will have high and stable yields should be distributed within fracture-cavern aggregations adjacent to large fault belts.