Unconventional hydrocarbon prospects: A study of the Cambrian- Eocene rocks of the Salt Range, Upper Indus Basin, Pakistan

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The Salt Range area of the Upper Indus Basin of Pakistan is potentially rich in conventional as well as unconventional hydrocarbon reservoirs but rising prices and declining hydrocarbon production merit paying serious attention to the exploitation of the unconventional reservoirs. In the Salt Range area of the Upper Indus Basin of Pakistan, the Cambrian-Eocene strata are potential candidates for producing unconventional hydrocarbon reservoirs. The previous investigations related to the Cambrian-Eocene stratigraphy, sedimentology and source rock analysis are lacking the detailed analysis of the potential gas reservoirs in the Salt Range area of the Upper Indus Basin. In other parts of the world, particularly in North America, the use of advanced stratigraphic and geochemical techniques in the Barnett Shale has resulted in the exploration of more than 13,500 gas wells. The progression in the US gas industry and substantial investment in shale gas exploration has been noted. We expect that the use of advanced analytical techniques in evaluating unconventional hydrocarbon source rock potential will provide a formidable base for the exploitation of the existing gas reservoir potential of the study area. In this study the Precambrian-Tertiary strata of the Indus Basin, Pakistan is analyzed for their unconventional hydrocarbon prospects. The potential organic-rich shales were collected from five key stratigraphic sections. These rock samples were evaluated through geochemical analyses using Total Organic Content (TOC) and Rock-Eval Pyrolysis techniques, mineralogical analysis using X-ray diffraction (XRD) and nano-porosity evaluation using Scanning Electron Microscopy (SEM). Different geochemical parameters were plotted in different cross-plots to determine the TOC, kerogen type, level of maturity and migration history of the hydrocarbons. The analyzed samples show thermally immature, mature and post-mature organic contents. The organic content found in most organic-rich shales was Type III kerogen, capable of generating gas while the occurrence of rare Type

I kerogen shows oil-bearing organic content. Most of the samples have poor genetic potential and few samples show a very good genetic potential. The integration of source rock geochemistry, mineralogy and SEM data suggests that the Pre-Cambrian Salt Range Formation, Permian Wargal Formation, Cretaceous Lumshiwal Formation, Paleocene Patala Formation and Eocene Nammal Formation are ductile and not suitable for fracking. As the Cambrian Baghanwala Formation, Permian Chhidru Formation, Triassic Mianwali Formation and Jurassic Datta and Shinawari formations are semi ductile, these formations are also not suitable for fracking. Nevertheless, the Permian Sardhai Formation and Triassic Tredian Formation are brittle in nature and suitable for fracking. Finally, the Cambrian Kussak Formation, Permian Tobra, Dandot and Warchha formations, Jurassic Samana Suk Formation and Cretaceous Chichali Formation are brittle in nature and are suitable for fracking.