TG06

Anatomy of Depositional Sweet Spots in a Tight Gas Sand Reservoir: Examples from the Ordovician Sarah Formation, Kingdom of Saudi Arabia

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SUMMARY

During the late Ordovician, a short-lived period of glaciation affected many parts of the former Gondwanan continent, centred over central Africa. The palaeogeography at this time indicates that a large grounded ice sheet was located on and around the Arabian Shield. Subglacial and proglacial settings can be identified, relative to the proximity of the ice sheet. In proximal settings subglacial channel complexes (“tunnel valleys”) can be identified. Studies indicate that these tunnel valley complexes have extremely heterogeneous fills and complex architectures, reflecting multiple phases of ice advance and retreat, complex patterns of glacio-tectonism and a variety of depositional processes (e.g. tractional and gravity driven processes). Tunnel valleys formed conduits for high-pressure, subglacial meltwater flows that fed sediment onto the continental shelf to the north-east. These proglacial shelf environments are characterized by extensive sheets of sand dominated by submarine gravity flow deposits. These deposits typically lack the extensive suite of soft-sediment deformation features present in the tunnel valleys.

In Saudi Arabia these glaciogenic facies are referred to as the Sarah Formation. A number of recent wells have targeted Sarah channels, with their thick, heterogeneous accumulations of sand, silt and diamictite. The Sarah is subjacent to Silurian source rock facies known as the Qusaiba Shale. In places these Sarah sands are tight, with low porosity and permeability characteristics, as a result of complex diagenesis linked to deep burial. What make these sands interesting are the high porosity-permeability sand units (depositional sweet spots) present within overall tight reservoir zones. This presentation will focus on two depositional sweet spots within the Sarah Formation in the Kingdom of Saudi Arabia. Both examples have been extensively cored and provide an excellent opportunity to unravel the complex sedimentology and diagenetic history that combine to create both tight sands and contiguous sweet spot sands.

In the first example, a well intersected tunnel valley complex, this complex had an extremely heterogeneous fill of tight sands, ice-contact deformed sands and silts containing reworked older Qasim Formation material, and a basal unit of cross-bedded conglomerates and coarse-pebbly sands. In a nearby well this entire Sarah succession was absent, with the Qusaiba Shale resting directly on older sands and silts of the Qasim Formation. This observation suggests that the Sarah Formation has a lenticular, erosively-based geometry which supports the tunnel valley interpretation. Within the well of interest, test data indicates a dual porosity system including a depositional sweet spot within an overall tight sand reservoir.

Away from the tunnel valleys the geology is complex and variable. Some areas are marked by the complete absence of Sarah Formation facies, with other areas having deposits of extremely tight sandy diamictites (probably rain-out till deposits). In a second sweet spot example a well intersected an interbedded Sarah Formation sand and shale succession, deposited in a distal proglacial marine setting, in an area where flows become less confined close to the mouth of a tunnel valley. The majority of the facies comprise stacked low density turbidites, which show Bouma-like divisions of fine-grained, laminated and rippled sands in upward-fining bedsets. Reservoir quality of these sands is poor, with low ambient porosities and permeabilities, related to extensive quartz overgrowth cements. Interbedded with these sands is a thick bed of sand, distinctly different in its grain size (typically medium to coarse-grained) to the surrounding sands. This sand is internally structureless except for a pebbly cross-bedded base and rippled top. Sedimentologically this sand represents deposition from a sustained, high concentration sediment gravity flow, fed from the nearby ice sheet. Routine core analysis indicates that this is excellent reservoir, with good porosities and permeabilities which, like the first example, can be considered a depositional sweet spot. Preliminary diagenetic studies indicate that the detrital grains have a clay (illite) and oil coating (early oil charge), which combined to prevent later quartz overgrowth cementation and would appear to be the main mechanism for porosity preservation.

Primary sedimentology (facies and grain size distributions) and the diagenetic history will be discussed and related to the preservation of reservoir quality. It is anticipated that understanding these controls will impact on regional play concepts and hence benefit future exploration of the Sarah Formation.