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Factors Controlling Reservoir Properties of Lacustrine Turbidites in Intracratonic Rift Basins: A Case Study from Barmer Basin, Northwest India*

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Abstract

Lacustrine deep-water turbidite plays are potential areas for future exploration and exploitation in NW-SE trending 200 km long and 25 km wide Barmer Basin located in Northwest India. Sediment gravity flow deposits in the form of turbidite sand and heterolith enclosed within a background of lacustrine muds - in the Palaeocene Barmer Hill Formation of the Vijaya & Vandana (V&V) Field, in the basin, provide an excellent opportunity to study the factors controlling the reservoir properties and consequent hydrocarbon accumulations in these reservoirs.

In the V&V core area the entire sedimentary column is divided into seven packages, inferred to be deposited as sediment gravity flows in a mud dominated slope channel environment, downslope from a fan delta system. The top 3 packages - the subject of the present study - are composed of slope channel system, which at the seismic scale has an overall linear shape and oriented in ENE-WSW direction with lateral extent variations controlled by changes in sediment input and basin slope/topography. The associated smaller scale elements – resolved from 261 m of core data from key wells – can be divided into four broad lithofacies: sandstone, heteroliths, mudstone, and porcellanite.

Sandstone lithofacies – the principal reservoir in the V&V Field - is quartz to sub-litharenite in composition and is characterized by a wide variation in grain size, matrix content and cement type. Most of the sandstones cored in the study area are silty to highly silty which explains their low reservoir quality, with relative abundances of coarse to fine being guided by the distance of transport and associated subenvironments.

It is, however, the burial diagenesis (involving clay mineral authigenesis and cementation, under the influence of evolving pore water at elevated pressure and temperature) that exerted primary control on reservoir quality in terms of porosity and permeability. Based on the results of thin section photomicrographs and mercury porosimetry data, three distinct sand sub classes have been identified, reflecting variation in pore throat size - tight sandstone (~0.01-0.1 mD), moderately tight sandstone (~0.1-10 mD), and sandstone with cement dissolution (~10-200 mD)

(Figure 1). This classification can be correlated to the interplay of pore reduction and pore enhancement which is controlled by cementation clay authigenesis and grain dissolution respectively.

Low pressure and low temperature 'Early' diagenesis commenced with grain re-organization and mechanical compaction followed by dissolution of unstable grains. This is followed by precipitation of framboidal pyrite (due to consumption of organic matter by sulphate-reducing bacteria) and replacement of unstable volcanic fragments by chlorite. A period of methanogenesis ensures precipitation of intergranular, siderite crystals by reaction with available ferrous iron in the system. Increased alkalinity and consequent carbonate cementation is attributed to anaerobic or less commonly aerobic degradation of oil by deeply infiltrating meteoric water during the hyperpycnal flow (Morad et al., 2002, Mansurbeg, 2017, Mansurbeg et al., 2006), the fluid mechanism believed to be responsible for the deposition of V&V sands. All these processes lead to degradation of reservoir characteristics by porosity destruction. Siderite is the most widespread cement and occurs most commonly as anhedral finely crystalline siderite partially replacing the detrital clay matrix and locally forming micronodules (Figure 2).

Onset of high pressure and high temperature 'Late' diagenesis is marked by grain dissolution (mainly Kfeldspar grains and volcanic rock fragments) enhancing the reservoir properties. Pore fluids were acidic at the start of later diagenesis with the onset of the main phase of post-compactional grain dissolution and subsequent blocky kaolinite and quartz overgrowth development. Liberated silica and alumina ions helped in crystallization of kaolinite. Quartz overgrowths are seen to have precipitated after the main period of burial-related diagenesis from excess silica generated from unstable grain dissolution. Resulting alkaline pore water deposited ferroan calcite and ferroan dolomite. Finally minor pyrite associated with replacement gets precipitated as pore water becomes acidic at the end of diagenesis (Figure 2).

This study helps in understanding the variation in reservoir quality which is mainly controlled by the relative abundance of detrital clay content (matrix) and their diagenetic derivatives (cement). This is critical in explaining the well test results and in selection of key candidate wells for an early development wherein the flow rate potential will be principally predicted through free available pore spaces.

Selected References

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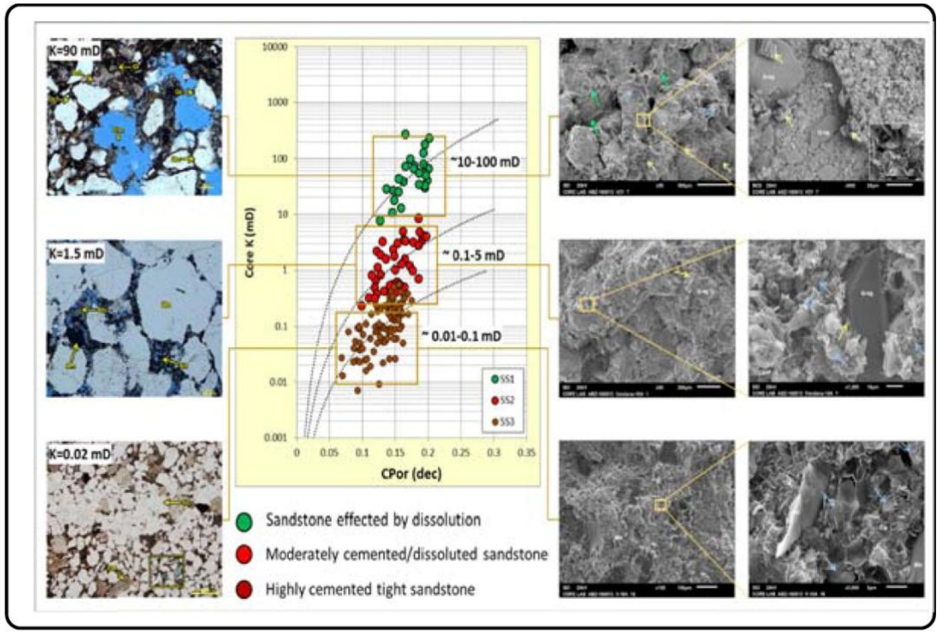

Figure 1. Based on the results of thin section photomicrographs and mercury porosimetry data, three distinct sand sub classes have been identified, reflecting variation in pore throat size - tight sandstone (~0.01-0.1 mD), moderately tight sandstone (~0.1-10 mD), and sandstone with cement dissolution (~10-200 mD).

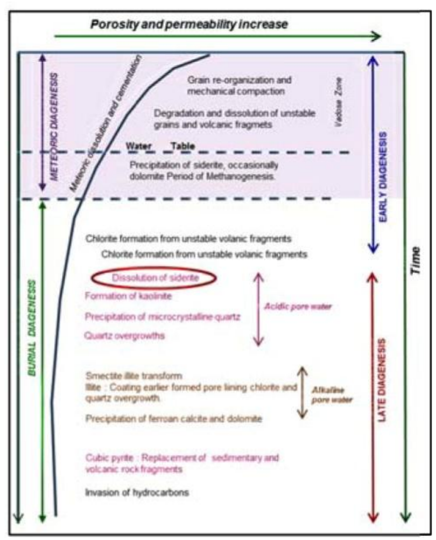

Figure 2. Diagenetic pathways in V & V sandstones.

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