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Impact of Paleo-Current Analysis on Reservoir Description of Burgan Clastic Reservoirs, North Kuwait

Extended Abstract

The Burgan Formation of Albian age hosts giant hydrocarbon reservoirs in North Kuwait. The Upper Burgan and Lower Burgan are the two dominant clastic reservoirs under production for more than four decades (Figure.1). Most of the remaining reserves are in estuarine channel sequences and shoreface sheet sand bodies (Figure 2). Of late, complex pattern of water movement in different parts of the field with areas of bypassed oil underscored the limitations of conventional reservoir description. An integrated study involving paleo-current analysis with core

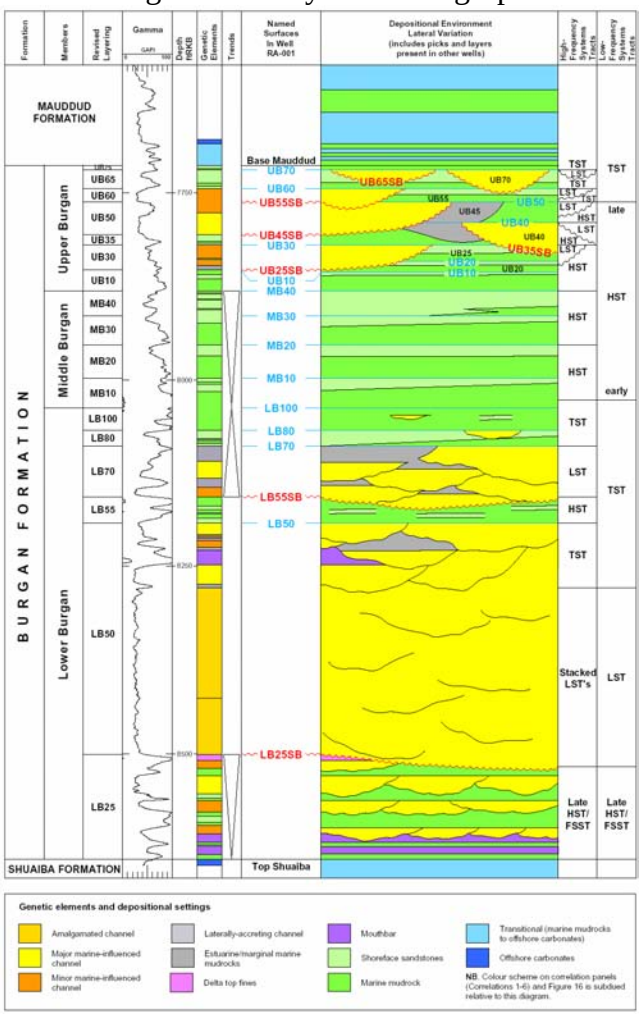

Figure.1 Stratigraphy of Upper and Lower Burgan reservoirs in North Kuwait. Bottom part of Lower Burgan is massive sands from coalesced braided river channels. Upper Parts of Lower Burgan and Upper Burgan are dominantly channel sands.

description, log signature analysis, reservoir pressure and production behavior was carried out to delineate features dominantly controlling reservoir heterogeneity. Imagelogs of 25 wells spread over the Raudhatain field have been specially processed to capture the paleo-current directions in individual channels. The dip magnitudes interpreted from Image logs have been calibrated against cross beddings seen from cores. Image log dips in excess of 10 degrees were most reliable for paleo-current analysis.

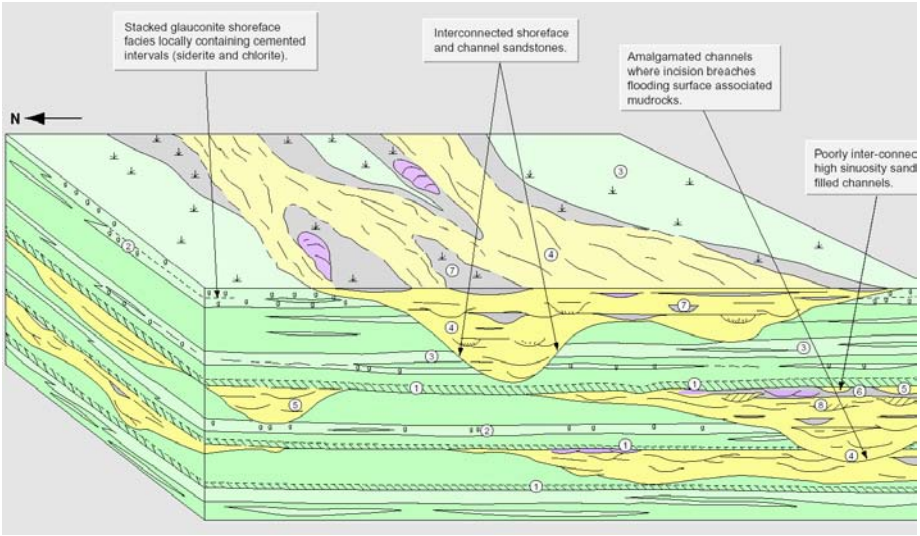

Figure.2 Geometry of Channel and shoreface sands in Upper and Lower Burgan Reservoirs. These sands contain most of the remaining reserves.

Core sedimentology and Log motifs have been used to distinguish channel sands from Shoreface sands. Stratigraphic dips were analysed from image logs (Figure. 3). The dips were discriminated on the basis of angle. Dips of less than 10 degrees showed less spread than all dips taken together. On further filtering of the higher dips on the basis of sand type more consistent directions were observed. Thus, in Upper Burgan sands (Figure. 4), a dominant trend was seen for channel sands with dip in excess of 10 degrees.

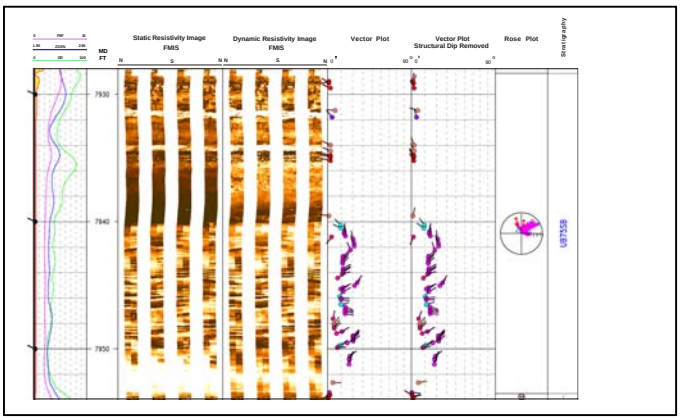

Figure 3. Stratigraphic dip from imagelogs in the Upper Layer of Upper Burgan. A dominant Northeast trend is observed.

The Lower Burgan reservoir consists of coalesced braided channels in the lower

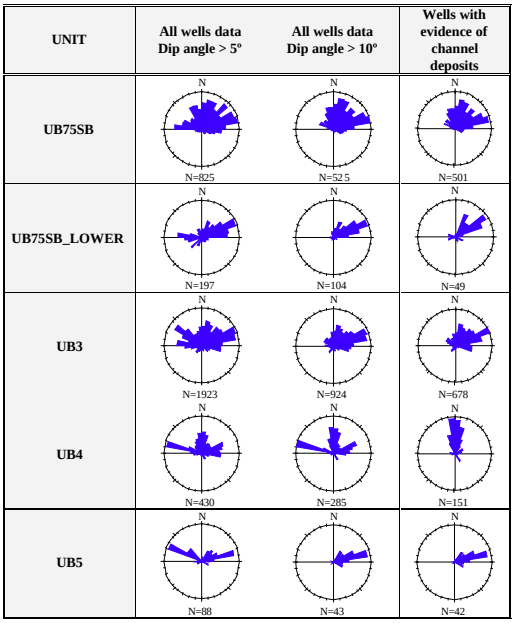

Figure 4. Paleotransport analysis results for the Upper Burgan reservoirs (All wells data included and structural dip removal were applied). Dominant plaeocurrent trends were observed for channel sands with dip more than 10 degrees

part. Individual channels are about 40 feet thick and have amalgamated to a single hydrodynamic unit of about 400 ft thick. The sand bodies are either massive or exhibit very low dips in crossbedded units. No significant direction of channel orientation is observed. Some channels were oriented to Northeast while others show multiple directions of transport. These channels sands don't exhibit significant directional water encroachment and there is regular bottom water sweep instead. The Upper part show dominantly north to northeast trend of paleo-currents in well-defined and thick estuarine-channels. Analysis of water movement shows the directional encroachments along the major channel directions. Pressure depletion is the minimum along major channels in the western part of the field. The reservoir quality deteriorates towards basin in the northeast. This area shows the maximum depletion with very little edge water support. The estuarine channel sands of Upper Burgan reservoir show more variable directions of channels- in addition to dominantly northeast trend; northern and eastern trends follow sand isopachs. A highly variable individual channel orientation is a rule after this study than was ever thought of.

The channel orientations mapped from paleo-currents are immensely helpful in understanding fluid movements, especially edge water, in the Upper Burgan and Lower Burgan formations. Further delineation of major channels, identification of areas of bypassed oil and orientation of horizontal wells are being pursued on the basis of the study. The channel orientations are the key inputs in detailed reservoir descriptions for Static and dynamic model build. In channel sequences, Acoustic Impedance volume from inversion of 3D seismic data was supplemented with paleocurrent data to delineate the channels (Figure.5). The sand bodies

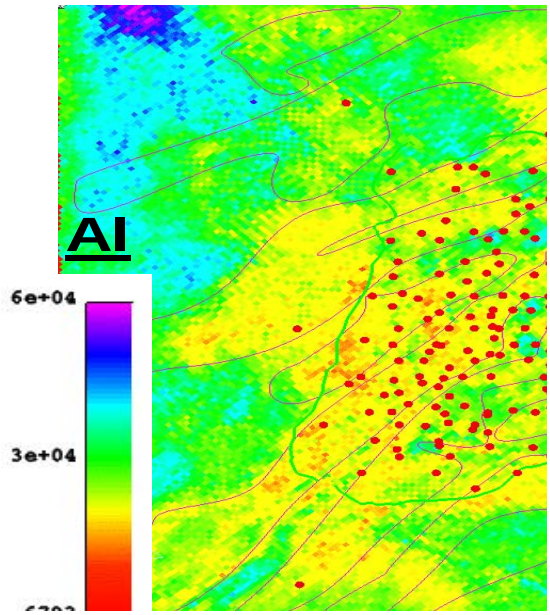

Figure: 5 Acoustic Impedance of an Upper Burgan layer with channels carved in it. The Channels orientations were derived from AI and paleocurrent at different locations.

were divided into 4 types depending upon their log signatures (Gammaray and PEF), porosity and permeability after calibrating against core. Type-I and Type-II sands were high quality sands deposited in major and minor marine influenced channels respectively. Type-III and Type-IV sands were the product of shoreface environment. These lithotypes were predicted in uncored wells using fuzzylogic.

Type-I and Type-II sand bodies were stochastically populated within the channels, delineated from inversion seismic, paleocurrent analysis and core sedimentology using object modeling (Figure.6). Shale (Non Reservoir) and other sands were populated with more affinity away from channel areas. Stochastic petrophysical models, such as porosity and permeability were created using the facies model. The spatial distributions indicate a clear trend along the channels influencing directional heterogeneity (Figure.7).

Static model built from the improved reservoir descriptions integrating paleo-current study was fed to a full field dynamic model. The dynamic model has been successfully history matched and is currently used for prediction cases.

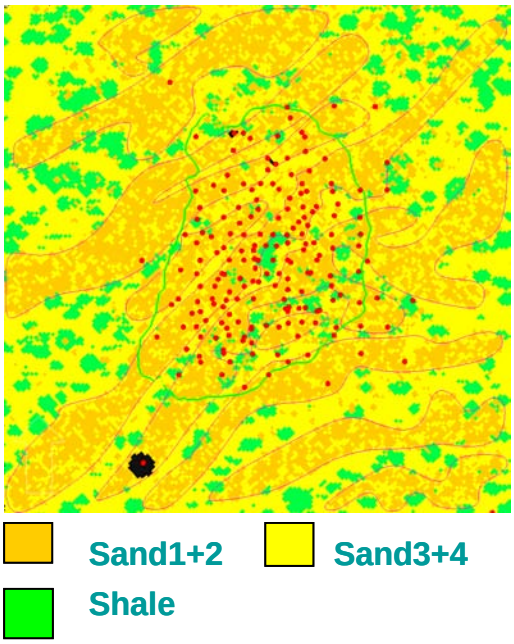

Figure: 6 Stochastic facies model of two main reservoir types (Sand1+2 and Sand3+4) and non-reservoir. Sand1+2 were distributed within channels while Shale was populated away from channels. Poor quality sands (Sand3+4) had higher affinity of being away from channels too.

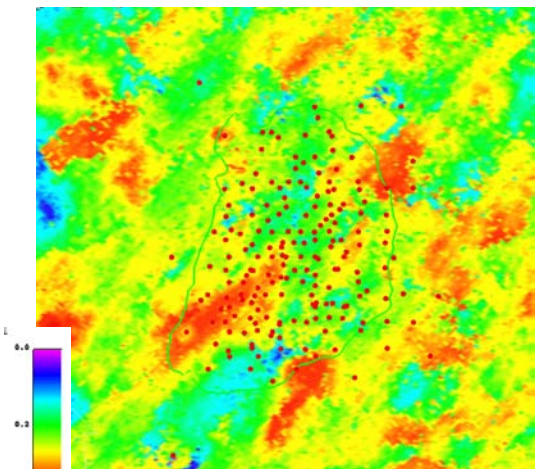

Figure: 6 Porosity model influenced by channel orientation. Sequential Gaussian Simulation with spatial statistics was used to co-simulate porosity and permeability.

Orientation of channels is a major issue in development planning and reservoir management of the channel units. Paleo current analysis has been found to be a useful tool to address the issues with improved reservoir descriptions.

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