Deltaic Reservoir Partitions and Connectivity

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Introduction

A major part of the oil in the world produced from sandstone reservoirs has been from ancient delta systems. In general deltaic sands occur farther down dip than any other type of sand and they have relatively high recovery efficiency (Tyler & Finley, 1991). Detail depositional environment study on deltaic reservoirs is important to create a model showing the distribution of reservoir properties that affect fluid flow. This article discussed the geometry and connectivity of deltaic reservoirs

Depositional environment control on reservoir characteristics

The diversity of deltaic depositional systems leads to complex sandstone deposits and reservoir types. Two major types of sandstone deposits, however, form the bulk of reservoirs in deltaic settings: distributary channels and distributary (river) mouth bars. (Fig. 1). The depositional environments control the reservoir characteristics. In distributary channels, sandstones are not commonly reworked by marine currents, and have the coarsest material at the base and finer sand, silt, and clays toward the top. At the channel mouth and near shore, sands are reworked and moved by tides or waves forming bar deposits that generally run parallel to the shoreline. The bars have the coarsest material at their tops.

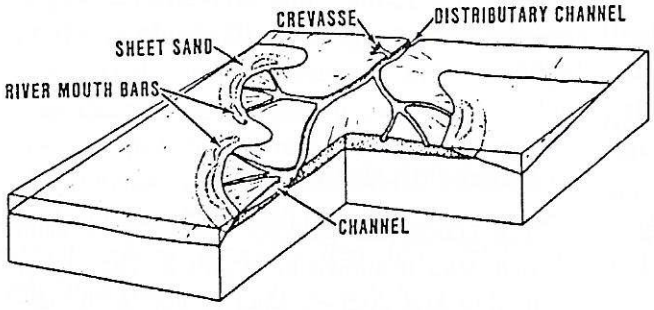


Fig. 1. Sand bodies deposited in a delta.

Distributary channels generally form narrow, bifurcating ribbon-like sandstone deposits which branch out from the main fluvial axis whereas mouth bars form finer-grained sand deposits which tend to be thinner but more widespread (Galloway, 1975).

Farther offshore, sands are spread out and deposited in thin sheets by currents that fan out from a channel mouth. These thin sheets of sand are usually interspersed with thin layers of shale that settle in the water and drape over the sands during periods of lower river flow rates. During floods, larger volumes of sediments flow into delta systems. During those times, new sediments may erode previous deposits. Bars deposited during floods may divert the channels, causing them to cut their banks and to shift the delta building processes to new areas. Waters that spill over channel banks during floods spread silts and clays over the adjacent marsh floor, called as crevasse splays, or on tidal flats. These areas and the mud-rich areas in the front of the delta tend to subside later as the clays compact, which allows re-entry of the sea over the deltaic deposits. (Richardson et al., 1989a).

Because of their prograding nature, deltas tend to form multi-story reservoirs, with distributary channels superimposing onto and eroding into mouth bars. Depending on the nature of the depositional processes, other types of sand deposits such as crevasse splays, tidal bars, etc. can form secondary reservoirs, frequently in horizontal or lateral communication with distributary channels and mouth bars.

In most cases, wells penetrating distributary-channel fill and point-bar reservoirs are much more productive then wells penetrating distributary-mouth bar reservoirs. This is partially due to less reservoir heterogeneity within channel fill compared to the mouth bar deposits. Distributary-mouth bar reservoirs with upward-coarsening log signatures and elongate isopach patterns are relatively thinner compare to distributary-channel fill and point-bar reservoirs. This type of reservoirs generally is isolated within muddy environment with low connectivity (Fig. 2)

Meander point-bar reservoirs with fining upward log signature is generally thicker and have better production (Fig. 2). A comparison of oil cut vs.

oil recover of a typical channel and barrier sand indicates that water breakthrough can be expected earlier in the channel sandstone since the bouyancy of oil over water induces the water in the high permeable bottom of the sand (Graaff & Ealey, 1989).

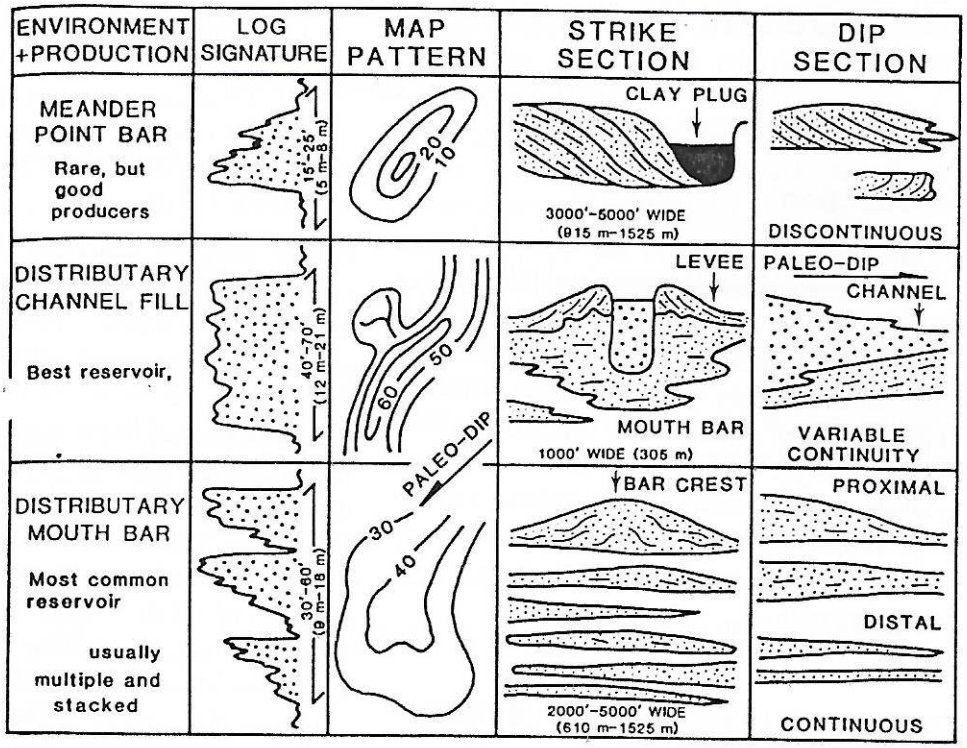


Fig. 2. Depositional environments, gamma-ray log signatures, clean-sandstone isopach map patterns (contours in feet), and strike and dip section model (modified after Keltch et al., 1990)

The size and geometry of each type of reservoir sand deposit in deltas is a function of two fundamental parameters: (1) the depositional processes controlling sand transport and (2) the stratigraphic packaging of the sands, i.e. the degree of amalgamation between individual sand deposits. Although relatively little work has been published on the detailed geometry of sands deposited in different types of deltas, the study of modern deltas has shown that to a large extent, sand geometry is a function of the relative importance of fluvial discharge, waves and tides (Galloway, 1975; Wright, 1977).

Mud-rich delta model

In mud rich deltas, high-quality sands are distributed in the channels and in river-mouth bars, similar to those found in sand-rich deltas. The principle differences between the mud-rich and sand-rich delta models are the lower quality of the bars and sheet sands, the poorer lateral continuity, and the large areas along the shoreline and that are covered by beds of silt and clay (Fig. 3). Oil recoveries and sweep efficiencies in mud-rich deltas are expected to be less than those in sand-rich deltas. Problems in locating wells and developing projects are more critical than in sand-rich deltas because of the poorer communication among sand members. Location of pilot-test areas for evaluation of additional recovery processes requires special studies by all disciplines involved in describing the reservoir and designing the recovery process (Richardson, et al, 1989b).

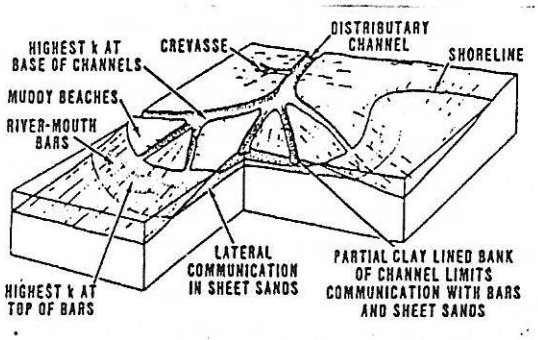


Fig. 3. Conceptual model of a depositional sequence in a mud-rich delta (Richardson et al., 1989)

Sand-rich delta model

The conceptual geologic model of a sand rich delta is shown in Figure 2. The higher quality and thickest sand is left in the upstream part of a distributary channel. The sand body thins and becomes less permeable towards the river mouth. The individual bars deposited farther offshore are thinner and have poor vertical continuity. Lateral continuity is good within both channels and stream mouth bars themselves, but is usually

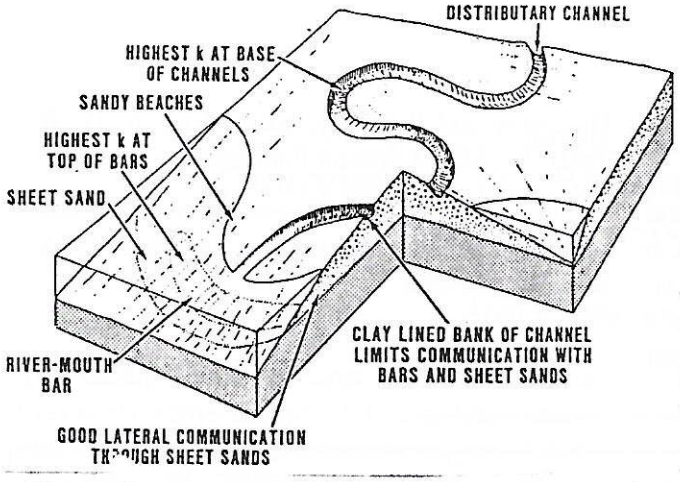


Fig. 4. Conceptual model of a depositional sequence in a sand-rich delta (Richardson et al., 1989)

poor between channels and bars because clays and shale are often left on the banks of the channels. Allen & Chambers (1998) observed that there is no significant sand accumulation occurs in the distal extremity of the distributary channels. This suggests a zone of sand bypass and that there is no systematic sand continuity between a distributary channel sand and its mouth bar on the delta front. Lateral continuity between bars is often fair to good through sheet sands laid down in the same sequence (Richardson et al 1989c).

Vertical and lateral heterogeneity

Vertical and lateral reservoir heterogeneity understanding are important to improve hydrocarbon reservoir accuracy. Tyler & Finley(1991) have made a statistic on vertical to lateral heterogeneity comparison on different depositional system and displayed the result as a heterogeneity matrix (Fig. 3). This table shows that minimal heterogeneity is associated with strong nearshore marine processes including wave-dominated deltas. At the other end of the spectrum is system characterized intense internal heterogeneity. These deposits are typically characterized by well-developed channel networks, such as in fluvial dominated deltas and flood-tidal deltas. Vertical heterogeneity of deltaic reservoirs are considered low as generally they have relatively wide distribution of shale layers compare to other system (Haldorsen et al., 1987; Fig. 4). Low vertical heterogeneity will enhance vertical seals for hydrocarbon traps.

Conclusion

Within deltaic system, hydrocarbons are produced from multistoried and laterally discontinuous sandstone bodies deposited as distributary-mouth bars, distributary-channel fills, and delta-plain point bars. These reservoir types are interrelated in a predictable manner, each having a unique isopach pattern, log signature, relative abundance and, most importantly production history. It is important to define and to understand the characteristics of each reservoir type because reservoir type has a dramatic influence on production.

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