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Waterflood Performance Outcomes across a Set of Deep-water Turbidite Reservoirs

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Summary

Many Angola deep-water reservoirs now have a production history of at least a few years, and up to 15 years. In most cases, reservoir sweep has been tracked with one or more 4D seismic surveys, in addition to pressure and production data. The information has been integrated into reservoir simulation models. A set of waterflooded turbidite reservoirs is discussed, with deposition ranging from well-developed channel complexes to sheet-like sands. Some fields have significant quantities of thin-bedded pay, and there is varying influence from fault baffles. Aquifer strength is another important variable between reservoirs.

Introduction

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Content

This presentation discusses the relationship between waterflood sweep and the geological setting. It presents 4D seismic images and discusses dynamic pressure and watercut data. However, it does not include specific information on named fields, their recovered volumes or recovery factors.

In channelised reservoirs, early well performance is dominated by water sweep in channel axes (Figure 1). 4D seismic and material balance support a view of efficient sweep through high net-to-gross channel axes. However, in lower net-to-gross channel margins and overbank regions, the story is less clear. It is normal to see significant levels of production-influenced pressure depletion in margins, which provides proof of connectivity, but it is much more difficult to demonstrate water sweep (Figure 2). 4D interpretation is more challenging in marginal facies but history-matching allows cases with very limited margin sweep. Understanding recovery with relation to facies becomes an increasingly important issue as the field matures. Sheet-like sands tend to show a high degree of vertical communication and efficient sweep in the absence of structural complexity.

Figure 1 Injector-Producer well pair in the axis of two channel complexes – from a 3D lithology volume (left hand image) and a 4D difference volume (right hand image).

Figure 2 4D anomalies showing water movement in a channelized reservoir – some sweep in the channel margin is evident.

Most of the fields considered have initial pressure and fluid data which suggest lateral and vertical communication on geological timescales, even when major shale intervals are present. However, there are fields or field segments which are dynamically dominated by fault-baffling (Figure 3). In more highly faulted fields, there are some faults which behave dynamically as sealing barriers, while others behave as baffles with varying degrees of transmissibility, and others enable communication between intervals or may even act effectively as conduits. Numerous wells have pressure transient data influenced by seismic or sub-seismic faults in the vicinity of wells, with impacts on performance.

Figure 3 Amplitude map from 3D lithology volume showing main faults and reservoir fairway in a sheet reservoir interval (left hand image). The right hand image is a 4D anomaly map from the same reservoir showing water movement. OWC shown on top and base reservoir.

Major shales commonly act as barriers to vertical communication, though pressure interference and 4D seismic demonstrate communication through some apparently continuous shales. However, sand-to-sand contact does not guarantee good dynamic communication. Stratigraphic features within sands, such as channel interfaces in stacked channel complexes, mud-filled channels, and regions of thin-bedded pay, are responsible for baffles which can have an important influence on well and reservoir performance.

Aquifer strength normally plays a significant dynamic role in these fields, particularly in mitigating pressure decline during periods of low injection. However, there are few fields in which aquifer strength is sufficient to make waterflood redundant. Aquifer strength is a function of rock compressibility and connectivity as well as volume.

Conclusion

- Dynamic data from several years of production allow turbidite reservoirs to be characterised in terms of flow behaviour
- Channel margins have clearly slower sweep than axes and constitute a significant part of the remaining oil habitat
- Presence of thick shales between sand intervals causes dynamic pressure differentials but thinner shales are often not effective barriers
- Fault baffles can dominate both areal sweep and aquifer support
- Opportunities exist to increase recovery by understanding the remaining oil habitat

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