Role of Relative Sea Level Change on Geometric Characteristics of Submarine Fans (Onlapping versus Non-Onlapping)*

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Abstract

Deepwater sediments hold a significant amount of hydrocarbon reserves and have always been the most challenging reservoirs to explore and produce. Conventional sequence stratigraphic model for deepwater clastic system consider that deposition and growth of submarine-fan mostly occurs during relative sea-level fall or lowstand. However, recent studies by various workers have shown that sediments can be supplied to deep water even during rising sea level if the sediment supply is high enough to prograde the entire shelf-edge. In order to apply the concepts of sequence stratigraphy for deep-water clastic systems, it is important to understand the various factors other than relative sea-level change, which controls the deep-water clastic sedimentation. Various outcrop, subsurface and modern examples have been reviewed to show how factors like rate of sediment supply, shelf-edge width, and gradient along the relative sea level change are significant for developing the sequence stratigraphic model of a deep-water system. Deepwater sediments can either onlap to underlying unconformable surfaces or form a linked shelf-slope-basin system. Brushy Canyon Formation in the Permian Basin is a classic example, which has deposition of carbonates during highstand and deposition of deepwater clastic submarine fans and slope channels onlapping against the underlying sequence boundary during lowstand. A linked lowstand shelf-slope-basin system is found in the Kuitei Basin (East Kalimantan) during Pleistocene. This study also concludes that deepwater submarine fans are not uniquely related to relative sea-level fall/lowstand. Examples were found in Lewis Shale Formation in the Washakie Basin, Oceanside and Carlsbad canyon-channel system in the California Boarderland Basin, and Upper Sobrarbe Formation in the Ainsa Basin (Northern Spain). Results show that submarine fans and channel-levee systems can develop at any relative sea level, lowstand, highstand or standstill. Shelf-edge delta acts as the sediment source and progradation of these deltas are able to transport coarse sediments to deep water during highstand. The development of highstand submarine fans requires a strong fluvial drive on the deltas. Lowstand submarine fans tend to be bigger thicker and laterally extensive while the highstand submarine fans tend to be smaller and less laterally extensive. Therefore, lowstand deepwater fans are expected to hold more hydrocarbon reserves than highstand fans.
Deepwater submarine fans: a review of conceptual and industrial significance

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BACKGROUND

Deepwater submarine fans are significant depositional systems that form in environments characterized by low energy and high water depth. These fans are critical to understanding the depositional history of sedimentary basins. The formation and development of submarine fans are influenced by various factors, including tectonic activity, sea level changes, and sediment supply. Understanding these factors is crucial for the exploration and development of deepwater fields, as the fans act as reservoirs for hydrocarbons. This review provides an overview of the concepts and models used to describe the formation and evolution of submarine fans, with a focus on deepwater environments.

OBJECTIVES

- Summarize different types of deep water depositional models, particularly focusing on geometric relationships and relative sea level change.
- Understand the combined role of relative sea level change, sediment supply, and shelf width in the formation of deep-water systems.

METHODOLOGY

Detailed literature review and analysis of existing models and data sets were conducted to understand the formation and evolution of submarine fans. The methodology includes a review of field data, stratigraphic and sedimentologic studies, and numerical modeling of submarine fan systems.

APPROACH

- Deep water submarine fans and channel levee systems can develop at different sea levels and have high potential for hydrocarbon accumulation.
- An analysis of the role of relative sea level change on submarine fan deposition is discussed, including the influence of tectonics, climate change, and sediment supply.

SIGNIFICANCE

Onlapping and non-onlapping submarine fans are critical for understanding the geometry of reservoirs and the potential for hydrocarbon accumulation. The significance of this study lies in the understanding of the role of relative sea level change in the formation and evolution of submarine fans, which has implications for exploration and development of deepwater fields.

NON-ONLAPPING (Lowstand)

- During Plesietocene, Kuitei Basin in East Kalimantan (fig. 7) has been subjected to three sea-level lowstand cycles.
- Seismo反射ors which correspond to the first sea-level lowstand can be traced down-slope from a prograding lowstand delta at shelf edge continuously to basin floor fan in the central part of the Indonesian shelf (Saller et al., 2004).
- Oxygen isotope data collected from these sediments matches the Plesietocene sea level curve and it indicates falling sea level during the deposition of such a linked lowstand delta and submarine fan.
- During the first sea-level lowstand that ended at about 240 ka, a shelf-edge delta prograded over the previous shelf edge, and sand-rich sediments spilled onto the slope. Amalgamated and unconfined channel levee systems developed along the slope and correlative deepwater submarine fans developed in the basin floor (fig. 9). It has been interpreted that high sediment influx from the paleo-Mahakam delta which prograded along the shelf edge resulted in the formation of this linked system (fig. 9).

ONLAPPING (Hightstand & Sealevel standstill)

- During the Plio-Pleistocene, the Kuitei Basin in East Kalimantan has experienced highstand and sealevel standstill conditions.
- During the highstand, the Mahakam delta was the principal sediment supply source and the submarine fan system was active. The submarine fan migrated upslope and deposited in the basin interior. This resulted in the formation of a submarine fan system that extended from the shelf edge to the basin floor.
- During the sealevel standstill, the submarine fan system remained active and continued to extend upward into the basin. This resulted in the formation of a submarine fan system that extended from the shelf edge to the basin floor.

This study also concludes that deepwater submarine fans are not uniquely related to relative sea level fall/lowstand. Examples were found in Lewis Shale Formation in the Washakie Basin, Oceanside and Carlsbad Canyon channel systems in the California Basin, and Upper Sattbarie Formation in the Ainsa Basin. Examples include: Brushy Canyon Formation in the Permian Basin, Pleisocene deposits in the Kuitei Basin, Lewis Shale Formation in the Washakie Basin, Oceanside and Carlsbad Canyon-channel system in the California Borderland Basin, and Upper Sattbarie Formation in the Ainsa Basin.
Role of Relative Sea Level Change on Geometric Characteristics of Submarine Fans
(Onlapping versus Non-Onlapping)

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California Borderland

Background
The California borderland basins have been fed by submarine canyons since the Late Quaternary till recent. Sediment has been supplied to the southeastern Santa Catalina and San Diego Trough in the borderland area mainly by three submarine canyon-channel system since at least oxygen isotope stage (OIS) 3 (younger than 58 ka).

From north to south, these canyon-channel systems are the borderland, Carlsbad, and La Jolla systems (fig. 10).

Highbank fans
At present sea level highstand condition, deposition of thick submarine fan at La Jolla canyon system has been reported from interpretation of two-dimensional seismic reflection profiles (WesternGeco and USGS).

Shelf width control (between the canyon head and the shelf-slope break)
During the latest Pleistocene interval of sea level (var. 20 ka)
- Oceanside and Carlsbad canyons: received sediment from fluvial systems.
- La Jolla canyon: no sediments were finally deposited at during sea level lowstand due to absence of any fluvial source and sediments laden submarine fans from nearshore to shelf break currents.

At recent sea level highstand
- Oceanside and Carlsbad canyons: head fans cannot capture the sediments being supplied by their respective fluvial sources as the sea level rises and the shoreline moves further landward. So, the bulk of the sediments get transported by the longshore drift and deposited as submarine fans (fig. 10).

Leash Shale, Washakie Basin, WY

Background
The Big Horn-Box Elder depositional system (fig. 1) was deposited on continental crust during the mid- to upper Pleistocene regression of the Cretaceous Western Interior Seaway.

High sediment supply essentially led to the generation of large, sand-rich submarine fans during relative sea level rising, as well as falling (Carvajal and Steel, 2006; Pyles et al., 2010).

Characteristics of highbank fans
Highbank fans are relatively thinner, and smaller in dimensions. It lacks the onlapping relationship with the underlying sequence boundary as lowstand fans does. More aggradation signature than propagation is revealed in highstand shelf edge deltas, therefore, it is defined as high sediment supply drive, rather than sea level drive.

Quantitative data:
- Well log correlation and outcrop data help tracing and quantifying shoreline trajectory across the profile (fig. 12 and 13).
- 14 documented channels
- shelf-edge trajectory
- fan thickness and area
- the character and/or geometry of the sand accumulated on the slope

Sobrarbe Deltaic Complex, Ainsa, Northern Spain

- The youngest marine outcrop (the sy-n-tectonic Sobrarbe Formation) records the progradation of a linked shelf-slope-basin system across the basin (fig. 14).
- Shell edge is located where transgressive surface starts dipping 2 degree northward.
- Local erosional surfaces (fig. 15) are correlated landward to delta plain.
- The topsets of the three erosional surfaces-bound units are at almost the same elevation. It indicates sea level did not change measurably during the late Pleistocene.
- This example suggests that deep marine fans deposits are not uniquely related to relative sea level rise or fall (Kim et al., 2013).

CONCLUSION
- Deepwater submarine fans are not uniquely related to relative sea-level fall/washdown.
- Submarine fans and channel-levée systems can develop at any relative sea level change, lowstand, highstand or stillstand.
- Factors like sediment supply and shelf-edge width and gradient and reservoir geomechanics play a major role in combination controls the formation of deepwater deposits.
- Progradation of shelf-edge delta plays a major role in formation of Highstand deepwater deposits.
- Deltas that prograde to the shelf edge are able to transport coarse sediment to deep water either with or without sea level change.
- The development of highstand fans requires a strong fluvial drive on the deltas.
- Deepwater sediments can either onlap or form a linked shelf-slope-basin system.

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REFERENCES


