Facies Variability Within a Single, Deep-Water Basin-Floor, Mixed Carbonate-Siliciclastic Fan
(Upper Wolfcamp Fm., Permian, Delaware Basin, New Mexico)*

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Abstract

Rarely are sea-floor fans containing a significant volume of carbonate detritus documented or discussed. Such fans are common within the lower Permian Wolfcamp Fm. in the Delaware Basin in SE New Mexico and west Texas, U.S.A. Three cores retrieved as part of an unconventional oil/gas exploration and development program in SE New Mexico Wolfcamp preserve interlayered wackestone, packstone, and mixed siliciclastic-carbonate mudstones. Core combined with regional subsurface studies show that the sediments are organized into an approximately 350 ft. thick mixed carbonate-siliciclastic deep-water fan. Carbonate debrites are concentrated in more axial positions and siliciclastic mudstones in more distal areas. Cores collected represent the frontal to distal fringe, off-axis, and lateral fringe portions of the fan. The fan prograded SW. The carbonate dominated portion of the fan trends at least 35 mi. in a NE-SW direction and 11 mi. NW-SE across. It is partially bounded to the east by a fault. Lobe complexes can be recognized which are bounded by regionally correlative horizons (A, B, C, and D, from older to younger). An overall upward fining across B and C horizons records a progressive back-stepping of the fan through time. Unlike siliciclastic fans where axial facies are dominated more by turbulent flow deposits (turbidites), the axis, off-axis, and lateral fringe facies in the Wolfcamp are dominated by laminar flow deposits such as coarse carbonate debrites and mass transport deposits (MTDs). Mixed carbonate siliciclastic hybrid event beds (HEBs) and finer grained background sediments form a minor component in these areas. Coarse carbonate deposition decreases towards the frontal fringe areas where facies are dominated by mixed carbonate-siliciclastic mud-rich HEBs and background sedimentation. The core through the lateral fringe differs from the off-axis core in that the debrites in the lateral fringe are thinner and often rheologically stratified with finer grained debrites sitting directly on top of coarse-grained debrites suggesting a genetic link in their formation. The axial facies appear to be dominated by thick (amalgamated?) ungraded debrites and MTDs. Facies changes from axis to frontal fringe are gradual but facies changes from axis to lateral fringe are rapid and may change significantly over a 2 mi. horizontal well.
Selected References


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Observation: Most of what is known about deep-water fans comes from siliciclastic-dominated systems.

Presentation Outline

• Location of study area, stratigraphy and paleogeography
• Show map and cross-sections through a Permian mixed carbonate-siliciclastic fan in the Delaware Basin, New Mexico and discuss how it was mapped
• Show a technique that allows a decent integration of detailed core facies to petrophysical logs
• Discuss facies and depositional processes
• Show how facies vary across the fan
• Summary
The Delaware Basin is the perfect place to look for mixed carbonate-siliciclastic fans and to begin to put together depositional models.

Over 400,000 wells drilled in the PB in the last 100 years

Blakey, Paleogeography of W. North America
290 Ma Early Permian

Reference Well

*http://fortune.com/longform/permian-basin-oil-fortune-500/*
Reciprocal model of sedimentation in Delaware Basin – Traditionally, carbonate fans are not generally recognized

Paradigm:
2. Mudstones deposited from suspension settling
3. Carbonate-dominated turbidites and debris flows largely restricted to basin margins

Example of upper Wolfcamp mixed carbonate-siliciclastic fan

From Kvale et al., in press, Facies variability within a mixed carbonate-siliciclastic sea-floor fan (upper Wolfcamp Fm., Permian, Delaware Basin, New Mexico). AAPG Bull.
Zonation of Wolfcamp fan and paleotopography

3-D Petrel model derived from gamma-ray logs
Over 100 well logs used to generate map

Net-to-gross map showing percentage of gamma-ray log interval of less than 55 API

From Kvale et al., in press, AAPG Bull.
Just How Big is the Wolfcamp upper A fan?

**SUBMARINE FAN SIZE VARIATION**

*Wide range of size & shape*

Each deepwater fan is unique, with an internal structure, elements, & lithology that vary across a range of scales in response to local processes of the depositional setting, including those tied to physiography, tectonics & source terrain.


Kendall and Haughton, 2006
Scaling core facies to petrophysical logs using facies inventory plots

Facies inventory plots:
- Documents proportions of facies over a 1 m (3ft) moving window
- Minimizes short term facies variability
- Highlights longer-term stratigraphic trend
- Mimics changes in gamma-log response

Inspired by Pierce et al., 2017, Sedimentology, v 65., 952-992

From Kvale et al., in press, AAPG Bull.
Depositional processes – Facies in Wolfcamp mixed carbonate-siliciclastic fan are dominated by sediment gravity flow deposits

Core axis/near-axis facies – dominated by debrites (paraconglomerates *)

* Conglomerate not formed from normal aqueous flow but rather through mass transport or glacial processes – clasts not necessarily in contact

From Kvale et al., in press, AAPG Bull.
Paraconglomerate with mud and carbonate clasts - image logs help to differentiate between clay clasts and background bedding.
Lateral fringe – wackestones (muddy debrites) and some paraconglomerates (fewer than fan axis)
Lateral fringe – wackestones and packstones are commonly stacked and appear to be genetically linked

Suggests rheologically stratified flow

Short red arrows (right-hand figure) point to possible fluid escape structures

From: Sohn et al., 2002, Terra Nova, v. 15, no. 5, 405-415
Frontal to distal fringe – Dominated by mixed carbonate-siliciclastic hybrid event beds (HEBs); exhibit features very similar to siliciclastic HEBs

Red circles indicate carbonate “coatings” that formed around terrestrial plant leaves

From Kvale et al., in press, AAPG Bull.
HEBs vary in completeness of divisions
HEB facies can be recognized on image logs but need core to calibrate initially

- The brighter (more resistive) the image log, the more carbonate within the facies
- At least 4 facies can be distinguished in this image
Wolfcamp fan facies summary

- **Axis to Off-Axis (core A)**
  - Dominated by paraconglomerates (Pc) (debrites)
  - Debrites can be carbonate- or mudstone-clast rich
  - Relatively minor HEBs
  - Turbidites are rare!

- **Lateral Fringe (core B)**
  - Abundant wackestones (Ws) (muddy debrites)
  - Debrites are rheologically stratified (linked Pc and Ws)
  - Fewer beds of Pc
  - Increase in mud-dominated HEBs over Off-axis core

- **Frontal to Distal Fringe**
  - Dominated by HEBs
  - Debrites are thin and uncommon
  - Bioturbation more common

*From Kvale et al., in press, Facies variability within a mixed carbonate-siliciclastic sea-floor fan (upper Wolfcamp Fm., Permian, Delaware Basin, New Mexico). AAPG Bull.*
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- Additional information will be presented Tuesday afternoon 2-5 pm, P92, Pore System Characterization of Wolfcamp Lithofacies, Delaware Basin, J.J. O’Brien et al.

One of two turbidites identified in the three cores used in the study – boundary between HEB and turbidite classification appears to be diffuse...