Abstract

The Tocito Sandstone (TS) has been long proven to be a highly prolific reservoir system in the largest domestic onshore conventional gas basin in the U.S., the San Juan Basin (SJB). Similar shelf sand types associated with the pre-Tocito Gallup Sands and the more transgressive post-Tocito El Vado Sandstones have proven equally productive in recent wells resulting in a mini-boom of sorts in the SJB. Studies of the nature of all these shelf sand systems from outcrop, core, logs and seismic reveal thick (1-2 m) cycles of heterolithic wave-rippled, moderately to intensely bioturbated marine sands stacked in 8-12 m thick shelf sequences that are spatially extensive throughout the eastern as well as western SJB. Tocito sands in the western SJB outcrop are much more proximal in nature with tidal channel and bar facies associations predominate. Tocito intervals in the southeastern SJB outcrop show at least six sanding and thickening upward cycles composed of thinly-laminated, wave-rippled sands (Facies 3) interbedded with marine shales (Facies 1) progressing upward to moderately bioturbated, sand-rich parasequences (Facies 4). Shelf parasequences compensationally stack in near paleoshoreline regions around Cabazon Peak northward to subsurface localities at least 140 km north of the paleoshoreline. Near-shore cycles near Cabazon Peak transition just 8 kilometers northward to contain extensive mega-hummocks (Facies 2). Analysis of hummocks in the Tocito sands suggest mega-swell waves up to 9 m high may have affected the paleo-shelf distributing sands widely across the region, and possibly contributed to the submarine erosion of up to 60 meters of material from the paleo-shelf. This regional study of SJB shelf reservoir sands is the first to quantify the regional nature of sand distribution, link super-greenhouse processes to potential shelfal submarine erosion and redistribution of sediments, and to examine prograding versus transgressive shelf reservoir systems.
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Problem

The Tocito Sandstones and the El Vado Sandstones of the San Juan Basin, New Mexico are two of the most prolific units in one of the most prolific onshore hydrocarbon basins in the U.S., however their nature west to east across the basin is very poorly understood.

- Huge amounts of submarine erosion post-date deposition of the Gallup. The origin and implications of this erosion are poorly understood.
- Some of the largest hummocks in the world outcrop in the Tocito and El Vado intervals and can be used to discern the scale of wave processes that have affected the super-Greenhouse shelf of the Cenomanian-Turonian boundary time in the basin.
- How does the Tocito and El Vado vary lithologically across the basin and what are the implications for fracturability and production in these units?

Key Questions

1. How are the Tocito and El Vado intervals distributed basin-wide, especially on the extreme margin? Where are the sands in these intervals coming from on the eastern basin margin and could the submarine forebulge influence deposition?

2. What are the temporal relationships between proximal and distal outcrops of the Tocito/Lower and Upper El Vado and Gallup sandstones?

3. Are large scale hummocks, documented in eastern Tocito outcrops, also present to the northwest and could the submarine forebulge influence deposition?

4. Can greenhouse climate storm systems help explain far-field deposition of Tocito sands?

5. Why do far northwestern Tocito outcrops lack distal (usually interbedded with shales) when Tocito outcrops at Hogback and Rattlesnake find more proximal facies?

6. What are the controls on reservoir quality and distribution of porosity and permeability, and fracture properties in the Tocito/El Vado interval?

Western Interior Seaway Paleogeography

Outcrop Image of Isolated Sands

Many of these distal sand bodies have a highly heterolithic nature. They are often composed of multiple cycles of sanding up stratigraphy and are all deposited in dominantly subaqueous positions, sometime very long distances from the shoreline. The El Vado Sandstone, New Mexico is located some 120 km from its shoreline.
Bioturbation, natural frac-

Abundant oyster hash occurs on bedding surfaces throughout the El Vado. The hash is likely the source of carbonate cements in the outcrop and subsurface.
Erosion and truncation play a significant role in the stratigraphic relationships of the Tocito. It rests unconformably on the Torrivio, Gallup, Juana Lopez and Mancos and younger Tocito sequences incise older, producing stratigraphic pinch outs and stacked reservoirs. Several hypotheses try to account for the nearly 120m of missing section. Transgressive erosion would not have the erosive power to remove that much section. Regressive erosion related to subaerial exposure is a possibility, although evidence for exposure includes only carbonate nodules. Jenette and Jones (1991) and Nummedal and R flea (1991) suggested it was primarily regressive erosion and later transgressive erosion that erased evidence of subaerial exposure. This hypothesis involves local uplift that would not have persisted through all four Tocito sequences and would not have been basin-wide.

Abundant and large-scale hummocks occur in shelf deposited sands throughout the Cretaceous Eocene super Greenhouse deposits of the Western Interior Seaway. The preservation of such abundance of hummocks may be due to increased storm wave base and deeper development of hummocks than are other times in the rock record (Arora et al, in prep). Gentle slopes on ramp shelves make it difficult to sustain shelf turbidity. However, storm generated waves such as those indicated by the mega-hummocks of the Tocito and El Vado intervals suggest the possibility of combined flow with hyperpycnal plugging plumes formed by storms associated Rools interacting with distal shelf waves that are extremely large in size. These combined processes may explain why sand beds are found on ramp shelves (Nummedal, 1996) and why Arora et al (in prep) prove the impact of such combined processes.

The Correlation Problem

Nummedal and Mckenna (1994) published an attempt to integrate various outcrop locations into a west to east correlation using ammonite zonations. Notice the large amounts of apparent submarine erosion from Plunge Pool and The Mounds eastward to El Vado Road, Rhyolite and north to Pueblo Colorado.

The Correlation Problem...