PS Stratigraphic Architecture of Turbidite and Mass-Transport Deposits in the Outcropping Bone Spring Formation, Delaware Basin, Texas*

Wylie Walker[1] and Zane Jobe[1]

Search and Discovery Article #11107 (2018)**
Posted August 13, 2018

*Adapted from poster presentation given at 2018 AAPG Annual Convention & Exhibition, Salt Lake City, Utah, May 20-23, 2018

[1]Chevron Center of Research Excellence, Colorado School of Mines, Golden, Colorado (wyliewalker@mymail.mines.edu)

Abstract

The dynamics of sediment delivery and partitioning of mixed carbonate-siliciclastic sediment routing systems are poorly understood but impact the spatial and temporal distribution of reservoir-forming elements. The Bone Spring Formation of the Delaware Basin in west Texas is a prolific mixed carbonate and clastic turbidite reservoir, with stacked pay zones and relatively low operation costs. The Bone Spring Fm. consists of shelf-to-basin sandy turbidites and carbonate mass-transport deposits that were sourced from the north and northeastern shelf margins during Leonardian time (~275 Ma). Much research has focused on the more distal (subsurface) deposits of the Bone Spring Fm., but there has been little research on the staging area (i.e., the proximal part of the system) that outcrops in the Guadalupe Mountains National Park. Our research aims to describe the stratigraphic architecture of the proximal Bone Spring Fm. in order to delineate the staging area and the dynamics of carbonate and siliciclastic sediment delivery to the basin.

Using photogrammetric 3D outcrop models and measured stratigraphic sections, we identify and quantify large-scale architectural elements, including slope orientations taken from mass-wasting scars and deformed bedding. We also delineate the mixing of sandy turbidites and carbonate mass-wasting deposits within the proximal Bone Spring Fm., which are likely a primary control on the stacking patterns and sediment partitioning in the distal portion of the reservoir. Using this data, we suggest that variations in mechanical properties, porosity and permeability values, and lateral variability of the distal reservoirs can be traced back to the proximal architecture of the Bone Spring Fm. Additionally, understanding the architecture of the Bone Spring staging area has implications for deposition of the overlying units that have hydrocarbon prospectivity such as the Victorio Peak, Cutoff, and Brushy Canyon formations. Our results help to define the staging area and the morphometric parameters of the Bone Spring Fm. to improve prediction for future development in the Delaware Basin. Our work will also help to constrain sediment delivery and partitioning in other mixed carbonate-siliciclastic sediment routing systems, which form active exploration targets around the world.

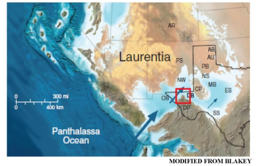
Stratigraphic Architecture of Turbidite and Mass-Transport Deposits in the Outcropping Bone Spring Formation, Delaware Basin, Texas

Wylie Walker[1], Zane Jobe[1] - [1]Chevron Center of Research Excellence (CoRE), Colorado School of Mines, Golden, CO

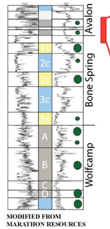
1 Minute Poster - The Bone Spring Formation of the Delaware Basin is a mixed siliciclastic-carbonate shelf-to-basin system. The Bone Spring Fm. shows large-scale cyclicity between siliciclastic-rich intervals (Bone Spring sands) and carbonate-rich intervals (Bone Spring carbonates). However, within these intervals there is significant variability in composition and depositional process. This study focuses on the Bone Spring 1st Carbonate shelf-margin to upper-slope setting that outcrops in Guadalupe Mountains National Park. This outcrop shows the variability in depositional processes and composition that can be seen in the basin. By building the large-scale architectural setting and constraining the compositional facies variabilities, we hope to better understand the connection from the shelf to the basin floor.

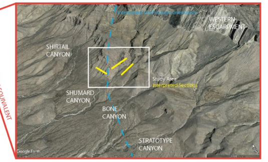
CHEVRON CENTER OF RESEARCH EXCELLENCE
COLORADO SCHOOL OF MINES
EARTH • ENERGY • ENVIRONMENT

STUDY AREA AND GEOLOGIC SETTING



Early-Permian, Leonardian-aged (~275Ma) Bone Spring Formation





Outcrop below the Western Escarpment in Guadalupe Mountains National Park, Texas

SHELF MARGIN AND SLOPE FACIES

FACIES 1: laminated carbonate mudstone
hemipelagic slope deposits

Thin section and SEM show siliciclastic-carbonate compositional mixing, along with early dolomitization

FACIES 2: internally deformed carbonate mudstone
hemipelagic slope deposits that have undergone deformation from high slope angles or high sediment supply

FACIES 3: thick-bedded bioclastic-rich carbonate mudstone
hemipelagic slope deposits that are proximal to the shelf margin relative to Facies 1 and 2

FACIES 4: thin-bedded bioclastic packstone
sheet deposits that represent pulses of coarse-grained material coming off the shelf

FACIES 5: thick-bedded bioclastic packstone
calci-turbidites or debrites

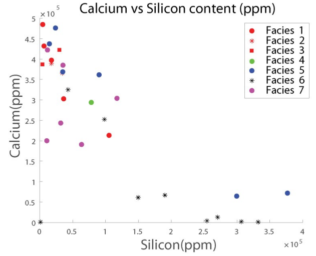
Thin section view with XPL on; large carbonate fossils with silicate cement likely sourced from silicious fossils

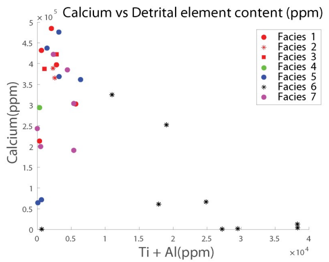
FACIES 6: siliciclastic-carbonate siltstone
silicate rich slope deposits representing a change in sediment supply or a RSL fall

Thin section and SEM analysis show the siliciclastic-carbonate compositional mixing

FACIES 7: bioclastic wackestone
outer shelf margin to upper slope deposits; represents continuum of Facies 1, 2, and 3 moving shelfward. Considered Lower Victorio Peak

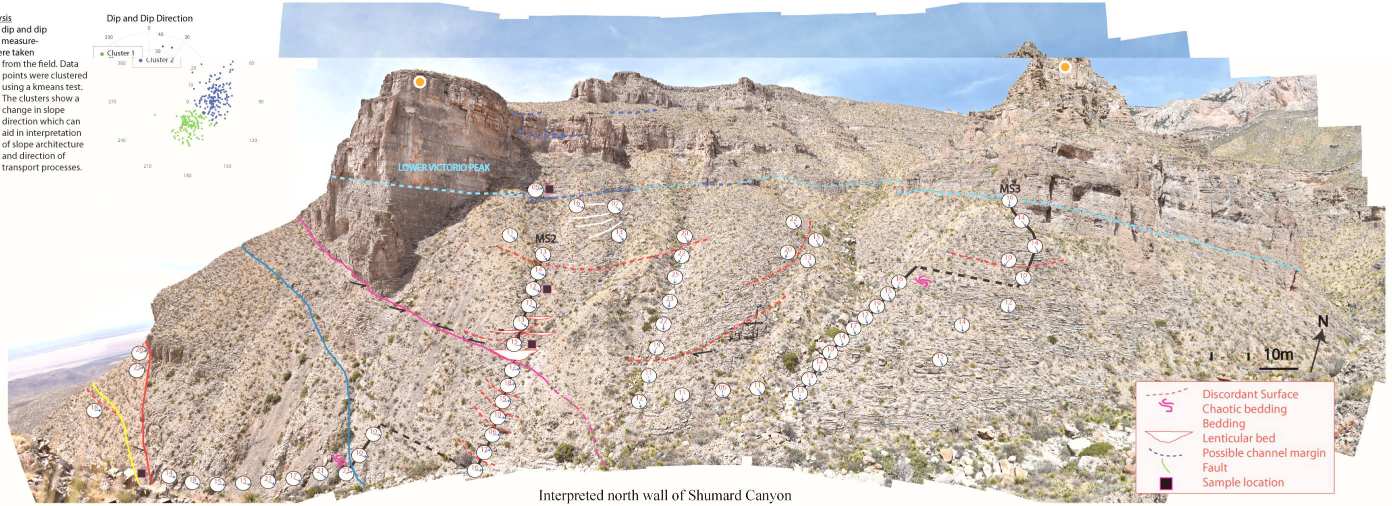
XRF DERIVED FACIES COMPOSITION



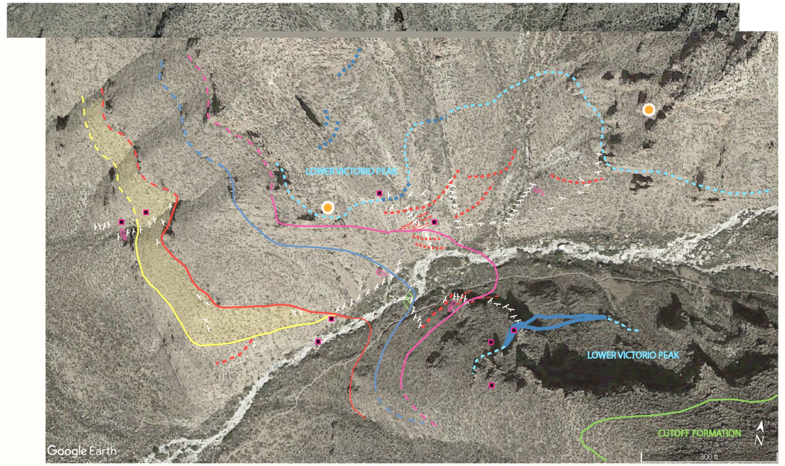


XRF Analysis
33 hand samples were taken from the field and analyzed with a handheld XRF machine. A pca analysis indicates that Si and Ca describe 99% of the variability in the rock. Plotting all of the data on a Ca vs Si plot shows the mixed composition, as well as diagenetic features that are hard to distinguish with the naked eye.

Dip Analysis
Over 300 dip and dip direction measurements were taken from the field. Data points were clustered using a kmeans test. The clusters show a change in slope direction which can aid in interpretation of slope architecture and direction of transport processes.

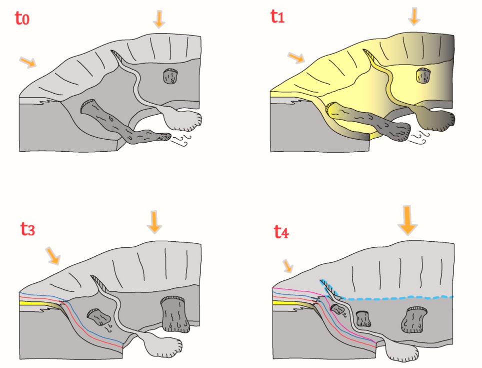


Interpreted north wall of Shumard Canyon



Interpreted aerial view of Shumard Canyon

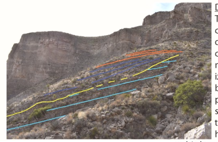
SLOPE ARCHITECTURE AND EVOLUTION



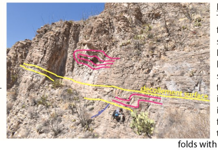
Slope Architecture and Evolution
The outcropping Bone Spring shelf and slope shows an initial carbonate-rich mudstone facies followed by a package of siltstone. This siltstone package is interpreted as a brief period of high siliciclastic input, either through aggradation of the shelf to sea-level or RSL drop or a change in sediment input conditions. Following, the shelf-slope continues to prograde and aggrade in an eastward direction. There is evidence at each time-stage of mass-wasting, but there is not always evidence of channels. At the last stage of exposed time, the shelf-slope has prograded from the north. This view shows a complex architecture where the two slopes meet, with multiple discordant surfaces and channel features. The high frequency of features in this area may be a result of oversteepening and subsequent failure which in turn resulted in topographically low areas that channels preferred.

CONNECTIONS TO THE BASIN

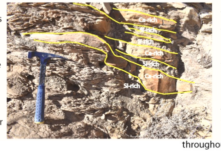
Calci-turbidites or debrites
At the upper slope-shelf margin interface there is a prominent bioclastic packstone with interpreted amalgamation surfaces. The feature shown here is on the scale of 100m wide by 15m thick and is interpreted as a carbonate channel. This channel likely fed the toe-of-slope and basin with carbonate turbidity flows or debrites. This facies can also be found on the outcrop at a mid-slope stage and are much thinner with silicious diagenetic features.



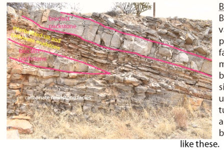
Discordant Surface
The most prominent features in the outcropping Bone Spring are the large discordant surfaces. These surfaces show significant dip and dip direction variation. In most cases, these surfaces are chracterized by Facies 1 and 2 both above and below the surface. These surfaces are interpreted as either failure scarps or erosional surfaces and fill in with a wedge architectural pattern. The scarp shown here would have supplied approximately 1,000-1,500 cubic km of material down-slope.



Folds
Throughout the slope setting are numerous folded surfaces. Folds range from meter-scale to mm-scale internal folding (i.e. Facies 2). The folds like the one pictured here are likely end-members to some of the scarp surfaces nearby. Presumably, some failures large enough would have made it into the basin and potentially transformed into fine-grained calciturbidites. All folds found on the outcrop were originally similar to Facies 1 and 2, although there are likely folds with mixed composition.



Mixed facies
Mixing of silica-rich and carbonate-rich facies can be found on the upper slope as pictured here. This lithofacies mixing is not prominent on the outcrop and is primarily found in one location, indicating that the presence of silicate-dominant beds was likely a result of temporary sediment supply changes or RSL change. In addition to bed-scale mixing, compositional mixing within facies is wide-scale, indicating Si and Ca sources were present and mixing throughout Leonardian time.



Basin deposits
Basin-floor deposits show significant variability in both composition and interpreted depositional process. Many of the facies found at the upper-slope to shelf-margin can be found here in the basin but have undergone changes in grain size and cementation. Understanding the upper-slope and shelf-margin architecture, compositional stacking behavior, and depositional processes will help better understand basin floor deposits like these.

PRELIMINARY OBSERVATIONS AND INTERPRETATIONS

• The outcrop exposes a region of the slope where two slope directions interact. This inflection point shows a high frequency of failure and is where all of the channel deposits were found. The inflection in the slope may have created a region of high sediment accumulation leading to a higher frequency of failure that further led to a low topographic point that the channel preferred.

• Compositional mixing within Bone Spring facies indicate a consistent presence of siliciclastic in the system. However, the siliciclastic-dominant lithofacies of the Bone Spring Carbonate are not temporally widespread, indicating a sediment supply change or RSL fall. This suggests that siliciclastic-rich intervals in the basin floor may be linked to temporally constrained sources.

• Discordant surfaces and abundance of folds and chaotic bedding on the upper-slope point to a very unstable environment that led to many of the slope deposits being transported to the basin via debris flows. These flows may have transformed into fine-grained calci-turbidity currents that are common further out in the basin.

• There are large-scale carbonate channels at the shelf-margin, implying that there were point-sources for large calci-turbidite deposits. In addition, smaller, less confined channels are found on the outcrop that are likely an additional source of coarse-grained deposits to the basin.