PS Origin of Supra-Salt Synclines in the "Post Diapiric" Jurassic Morrison Formation, Big Gypsum Valley, Colorado*

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Abstract

The Jurassic Morrison Formation, composed of two members - the Salt Wash and Brushy Basin - can be found surrounding and partially burying the Gypsum Valley diapir in the Paradox Basin, Colorado. The diapir began passively rising during the Late Pennsylvanian/Early Permian and continued to rise differentially along the length of the salt wall until the Late Jurassic, when the Morrison Formation was deposited. The diapir was breached during Neogene erosion of the Colorado Plateau, exposing the diapir caprock. Folds within the Morrison Formation are preserved along the diapir margins where the Morrison overlies the salt. These are best exposed at the southeastern part of Big Gypsum Valley as a series of tight folds that get progressively more open to the northwest. A detailed map along the diapir margin shows synclines and subhorizontal Morrison beds in direct contact with the salt. The lower beds of the Morrison onlap the tilted strata flanking the diapir, indicating continued minibasin subsidence and diapir rise that continued into Salt Wash time. Basal strata of the Morrison contains clasts of diapir and other flanking strata reflecting erosion of the diapir margin by the first channels that flowed across the diapir. These included 1 cm long, ½ cm thick green-gray clay chips and Paradox Formation limestone clasts that can be observed at the base of Morrison sandstone channels ranging in thickness from 0.5 m - 2 m.

Measured sections have been completed on both the northeastern and southwestern part of Big Gypsum Valley. These, along with the tracing of beds along the diapir margin, better displayed a change in bed thickness, which thinned into the axes of synclines and thinned on anticlines. Thus indicating the folds in the Morrison were syndepositional and associated with diapir subsidence or movement during early Morrison deposition. The initial results of this study indicate that diapir and salt movement continued through at least Basal Salt Wash time. The lack of faulting in some areas indicates that much of the Morrison is in place and has not been dropped into its present location through diapir dissolution collapse. Faulting and rotation of the Morrison in other areas indicates that solution collapse may have been locally important. Constraining the mechanisms that formed these structures will help improve our understanding on how salt diapirs function and their impact on the surrounding strata, which could ultimately serve as traps for resources such as oil and gas.

Big Gypsum Valley, Colorado
Background, Stratigraphy, and Significance

Abstact

The Jurassic Morrison Formation, composed of two members - the Salt Wash and Brushy Basin - can be found surrounding and partially burying the Gypsum Valley diapir in the Paradox Basin, Colorado. The diapir began passively rising during the Late Pennsylvanian/Early Permian and continued to rise differentially along the length of the salt wall until the late Jurassic, when the Morrison Formation was deposited. The diapir was breached during Neogene erosion of the Colorado Plateau, exposing the diapir caprock. Folds within the Morrison Formation are preserved along the diapir margins where the Morrison overlies the salt. These are best exposed at the southeastern part of Big Gypsum Valley as a series of tight folds that get progressively more open to the northwest.

A detailed map along the diapir margin shows synclines and subhorizontal Morrison beds in direct contact with the salt. The lower beds of the Morrison onlap the tilted strata flanking the diapir, indicating continued minibasin subsidence and diapir rise that continued into Salt Wash time. Basal strata of the Morrison contains clasts of diapir and other flanking strata reflecting erosion of the diapir margin by the first channels that flowed across the diapir. These included 1 cm long, ½ cm thick green-gray clay chips and Paradox Formation limestone clasts that can be observed at the base of Morrison sandstone channels ranging in thickness from 0.5 m - 2 m. Measured sections have been completed on both the northeastern and southwestern part of Big Gypsum Valley. These, along with the tracing of beds along the diapir margin, better displayed a change in bed thickness, which thinned into the axes of synclines and thinned on anticlines. Thus indicating the folds in the Morrison were syndepositional and associated with diapir subsidence or movement during early Morrison deposition.

The initial results of this study indicate that diapir and salt movement continued through at least Basal Salt wash time. The lack of faulting in some areas indicates that much of the Morrison is in place and has not been dropped into its present location through diapir dissolution collapse. Faulting and rotation of the Morrison in other areas indicates that solution collapse may have been locally important. Constraining the mechanisms that formed these structures will help improve our understanding on how salt diapirs function and their impact on the surrounding strata, which could ultimately serve as traps for resources such as oil and gas.

Regional Map: Gypsum Valley

Figure 1

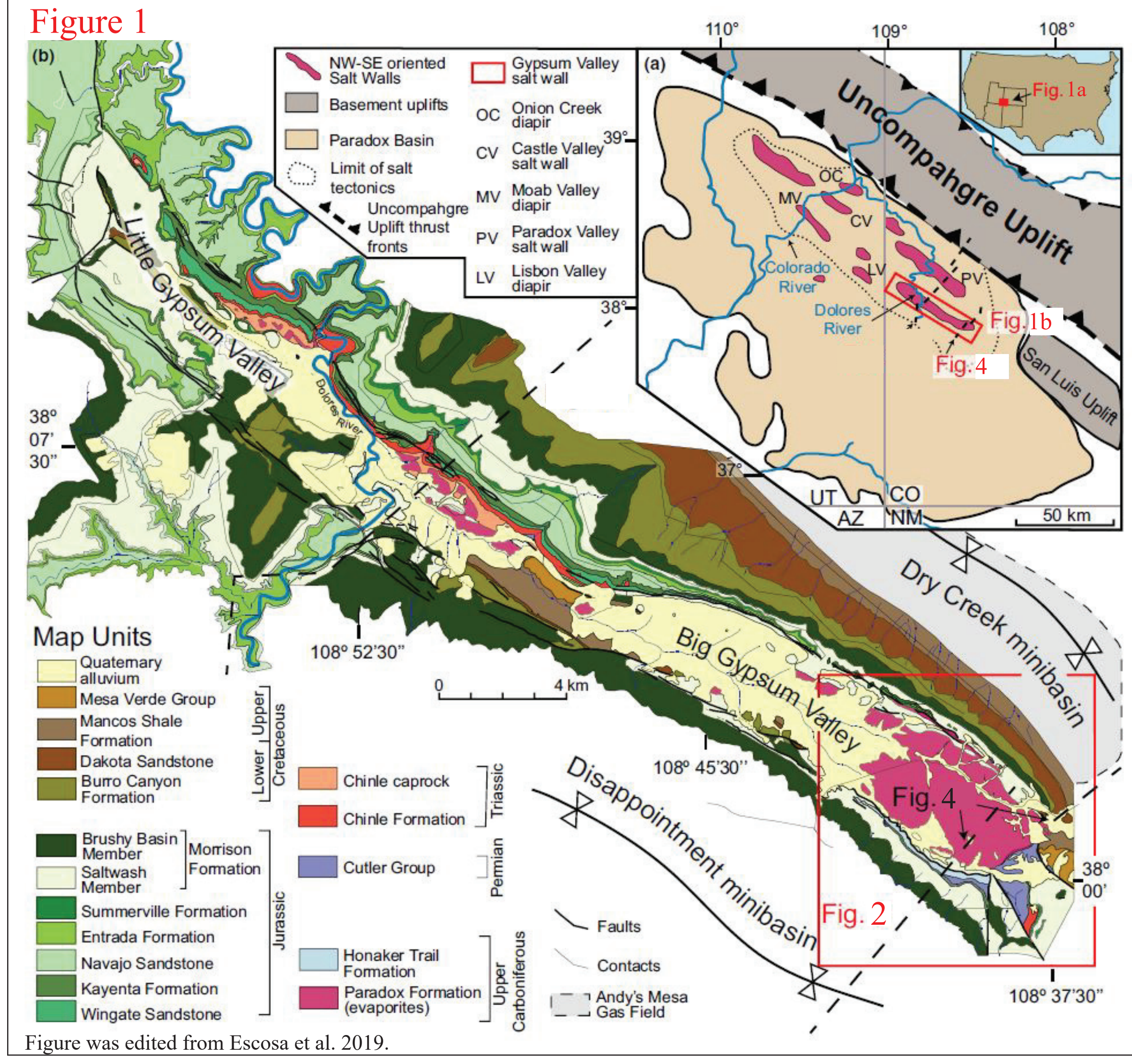

Figure was edited from Escosa et al. 2019.

The study area is located in the southernmost part of Gypsum Valley, one of the salt structures found within the Paradox Basin (**Figs. 1, 2**).

The Paradox Basin;

- Formed during the Ancestral Rocky Mountains orogeny
- Is flanked on the northeast by the Uncompahgre uplift and on the southeast by the Four Corners platform (**Fig. 1a**)
- Salt was deposited during the Pennsylvanian in the Paradox Formation
- It was during the mid-Jurassic that cessation of diapirism is thought to have occurred and the Morrison Formation was deposited (**Fig. 3**).

Objective

To document the geometries and distribution of the folds found within the Morrison Formation, which run parallel to the diapir margins.

Define the mechanisms that formed these folds in order to improve our knowledge on how salt diapirs function and their impact on the surrounding strata.

The findings will also contribute to creating models that try to define the resulting stratigraphy when salt is the main driver of sedimentation patterns.

Methods

High definition aerial imagery from Google Earth was merged using PhotoShop and then imported onto QGIS. These were combined with topographic maps to be used in the field.

6-12 stratigraphic sections were measured on each of the areas of interest using a Jacob's Staff for bed thickness and Brunton Compass for bed orientation. These were georeferenced using a handheld GPS.

Lastly, the measured sections were digitized using PowerPoint and then correlated in Illustrator for further interpretation.

A 3D outcrop model of the study area was created using photogrammetry on a drone camera with the help of David F. Lankford.

Samples were gathered so diapir derived clasts could be point counted in thin section using carbonate and feldspar stains.

Study Area: Big Gypsum Valley

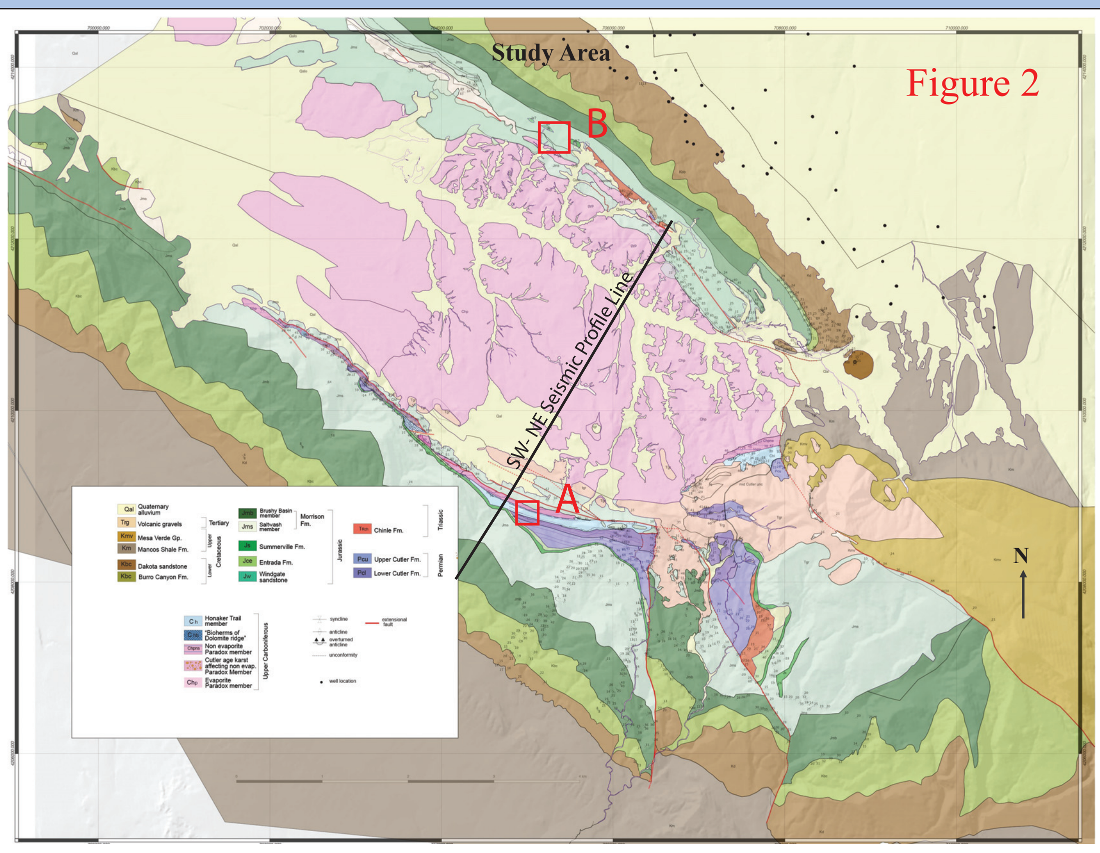

Figure 2 shows the area of focus for this study, the southeastern end of Big Gypsum Valley.

The two red squares, labeled A and B, outline the two key sites of exploration for this study where stratigraphic correlations were made.

The black line represents the SW-NE Seismic Profile Line made by Rowan et al. (2016).

Stratigraphy

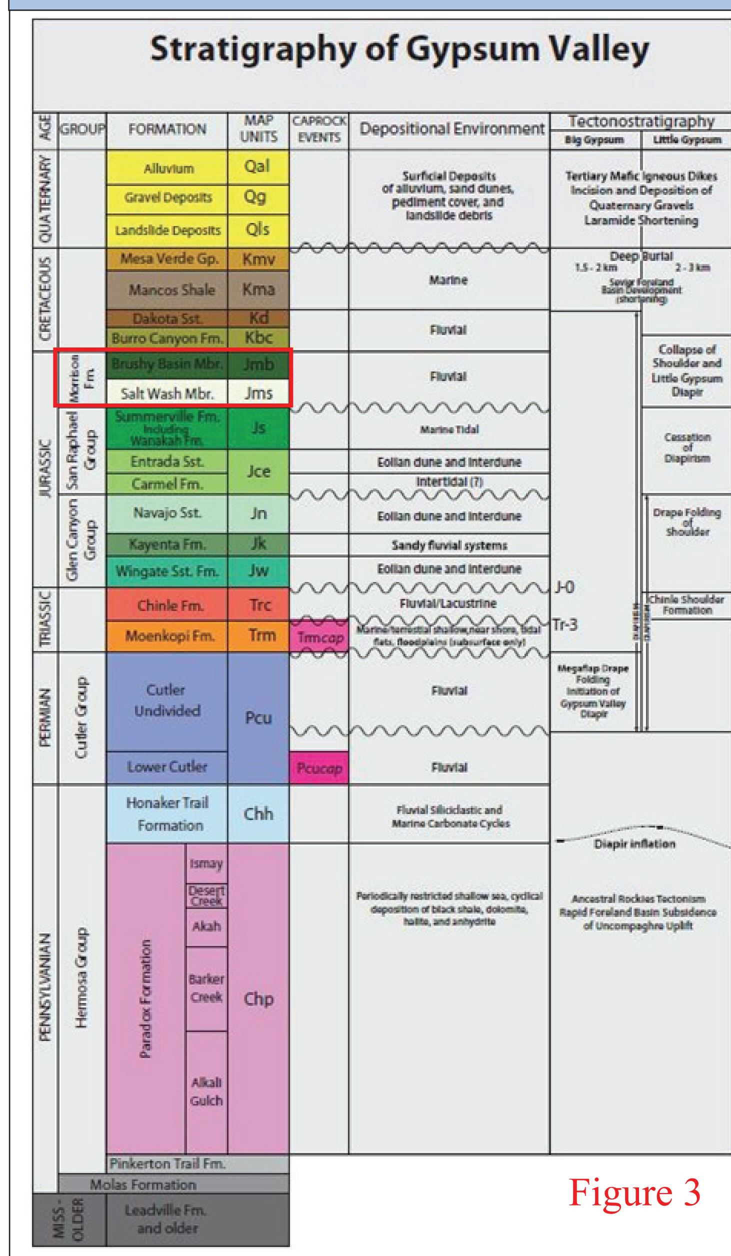

Figure 3

Figure 3 shows the stratigraphic units found in the Paradox Basin at the Gypsum Valley area.

The depositional environment, depositional events, and controls are after Stokes and Pheonix (1948), Doelling and Ross (1998), and Trudgill (2011).

Key unconformities are also annotated (Shawe, 1970).

The Morrison Formation, outlined in red, is the unit of focus for this study.

SW-NE Seismic Profile Line

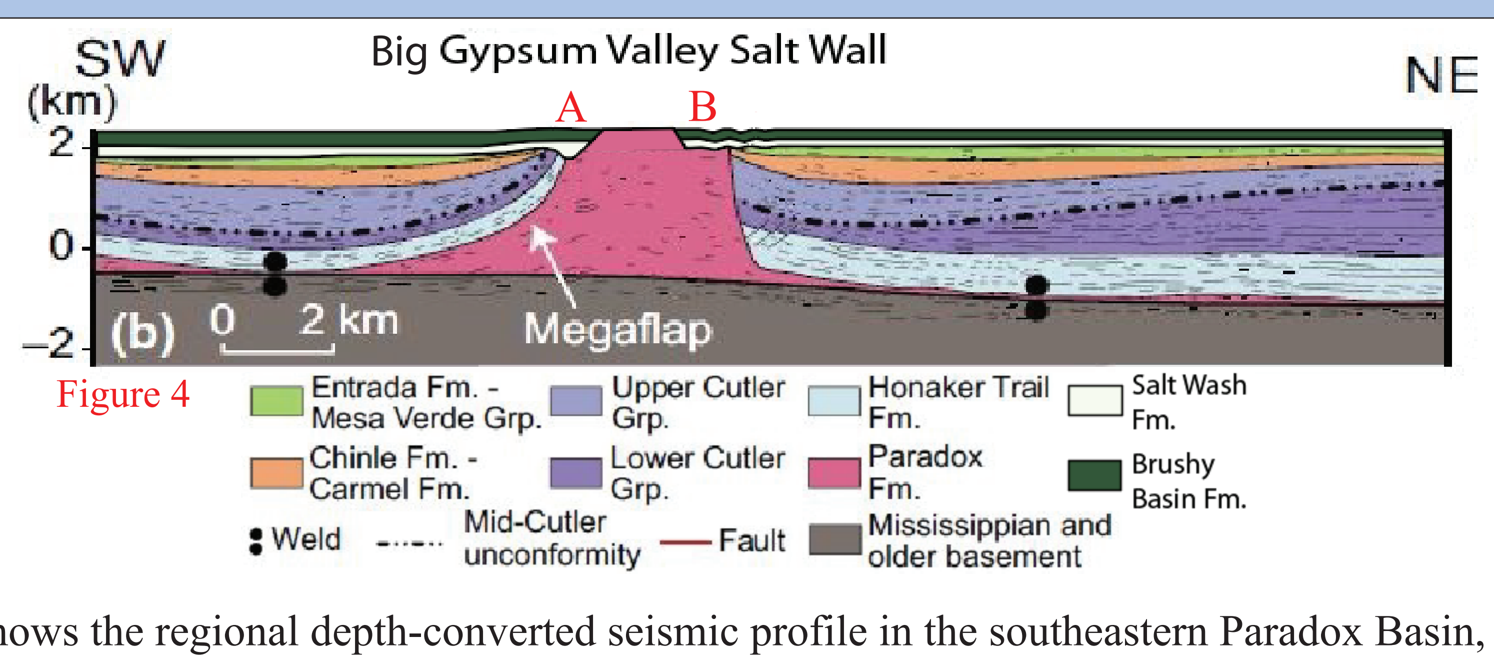

Figure 4

Figure 4 shows the regional depth-converted seismic profile in the southeastern Paradox Basin, as shown in the Study Area map (Figure 2). The figure was modified from Rowan et al. (2016) and Escosa et al. (2019).

The two sites of interest, A and B, are also shown above. At site A, the Morrison Formation incised into the older units as it was deposited and now onlaps the salt. At site B, the Morrison Formation is found folded and in direct contact with the salt diapir.

Salt Shoulders

Salt behaves in a ductile fashion when responding to regional tectonic stresses and differential loading.

Salt shoulders – low angle segments of the salt-sediment interface where the margin of a passive diapir steps abruptly inboard

Divided into;

- inboard margin
- outboard margin

In the southern end of Big Gypsum Valley, the Morrison Formation forms a salt shoulder that wraps around the southeastern end of the diapir.

Figure 5 shows the formation of a salt shoulder and the resulting stratigraphic geometries.

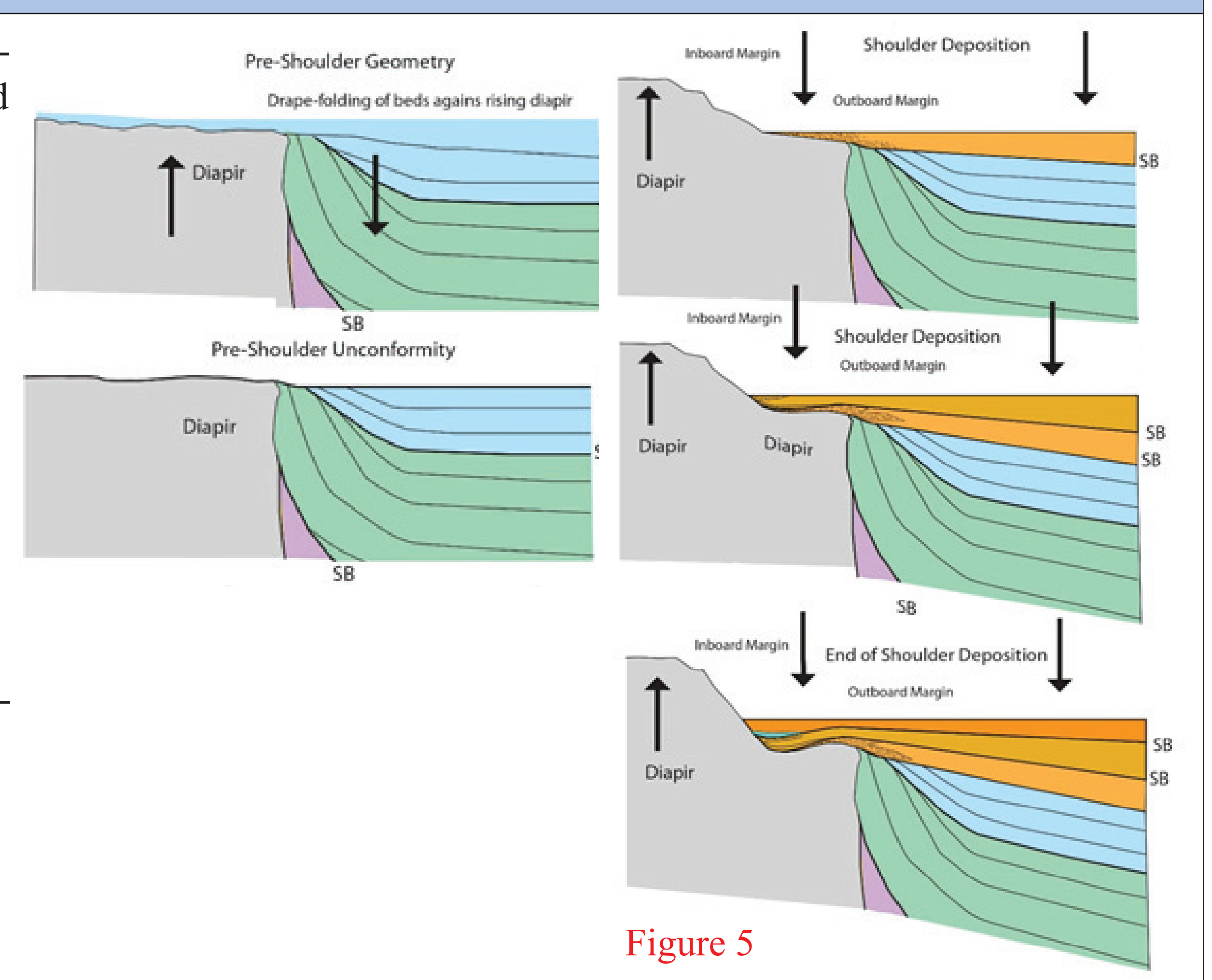

Figure 5

Origin of Supra-Salt Synclines in the "Post Diapiric" Jurassic Morrison Formation, Big Gypsum Valley, Colorado

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The University of Texas at El Paso
Department of Geological Sciences

The Morrison Formation

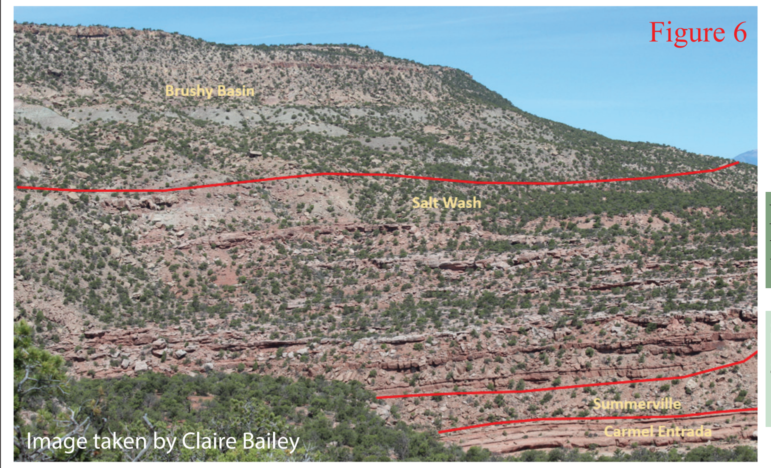


Figure 6

In this study, our focus is on the Jurassic Morrison Formation. The primary members in the region include the upper Brushy Basin and Salt Wash Members (**Figure 6**).

Brushy Basin Member: Multi-colored shale and thinly laminated mudstones with lenses of brown chert-pebble conglomeratic sandstones.

Salt Wash Member: White to rusty red lenticular sandstones that show scour and fill features and crossbedding intercalated with mudstones.

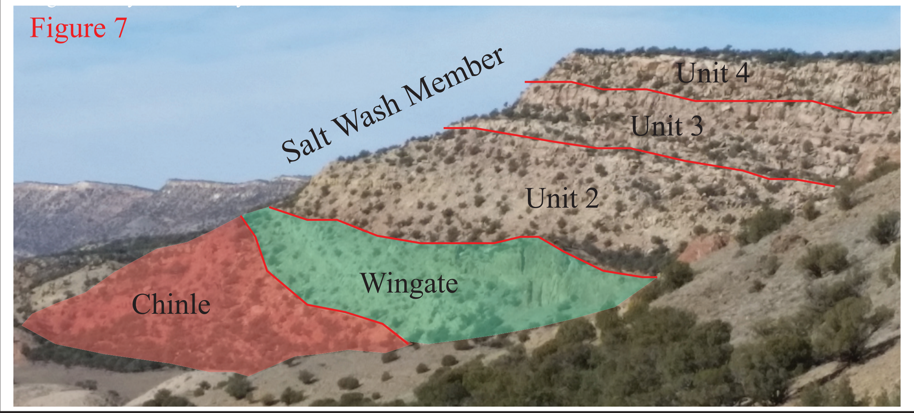


Figure 7

The Salt Wash member can be broken up into four seperate units (**Figure 7**):

1. Floodplain mudstones with sandy crevasse splays
2. Amalgamated braided channels
3. Isolated meandering channels
4. Laterally stacked meandering channels

Stratigraphic Sections Locations

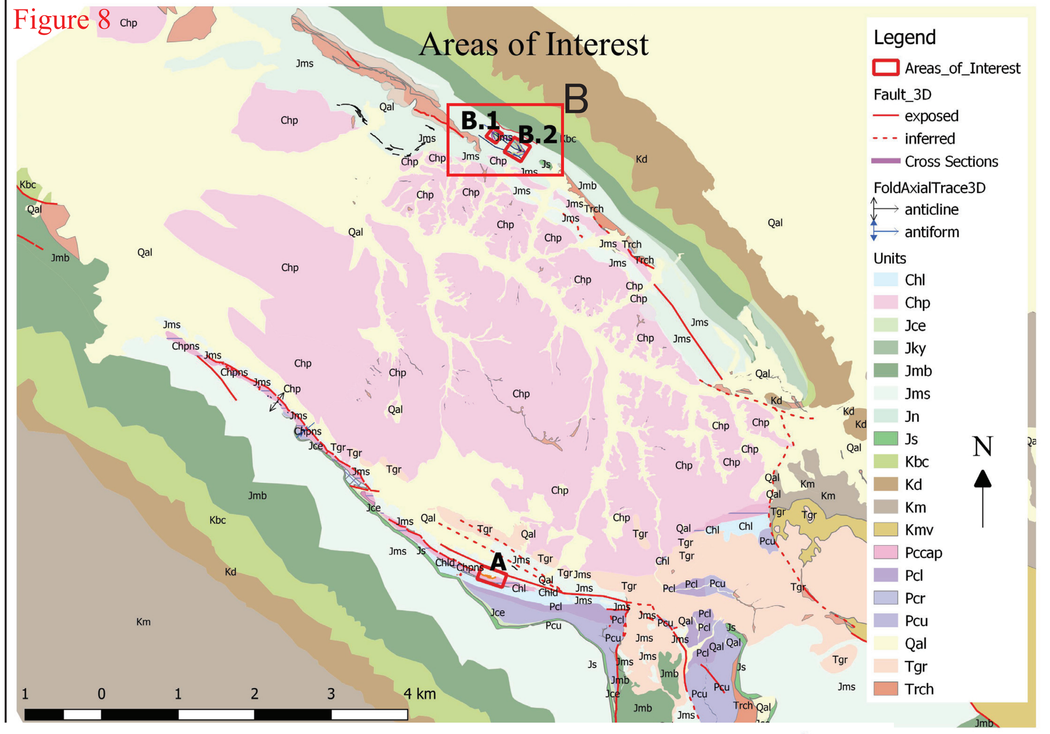


Figure 8

Figure 8 outlines the three areas of interest where stratigraphic sections and correlations were made.

- Area A is a Paleo Canyon where the Morrison Formation is seen incising into the underlying units of the Megaflap and the salt diapir.
  - **Figure 9** shows the locations for the 6 stratigraphic sec tions measured in area A.
- Area B shows a series of folds within the Morrison Formation and can be divided into areas B.1 and B.2.
  - **Figure 10** shows the locations for the measured sections on area B
    - 3 on B.1
    - 12 on B.2

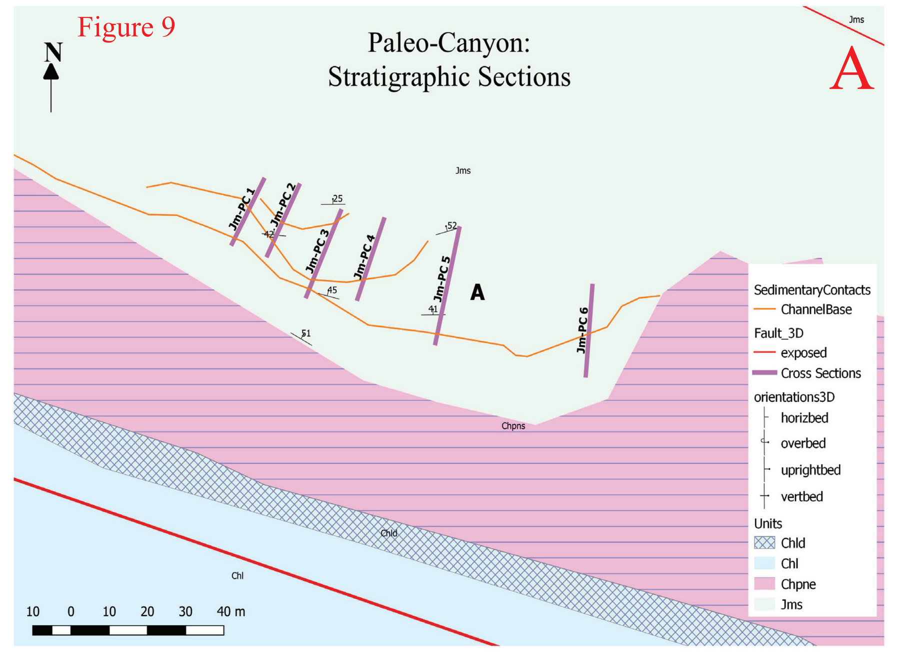


Figure 9

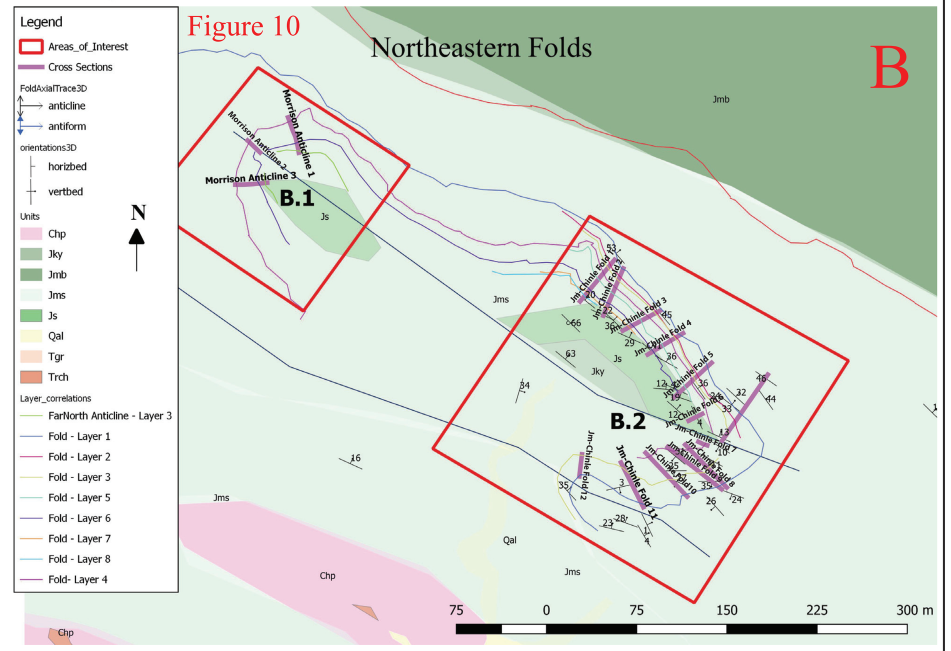
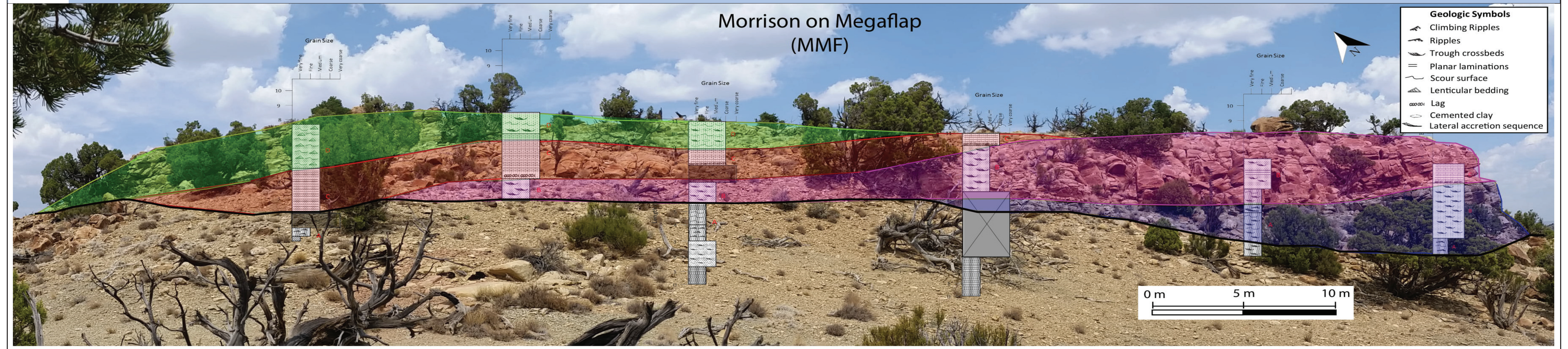


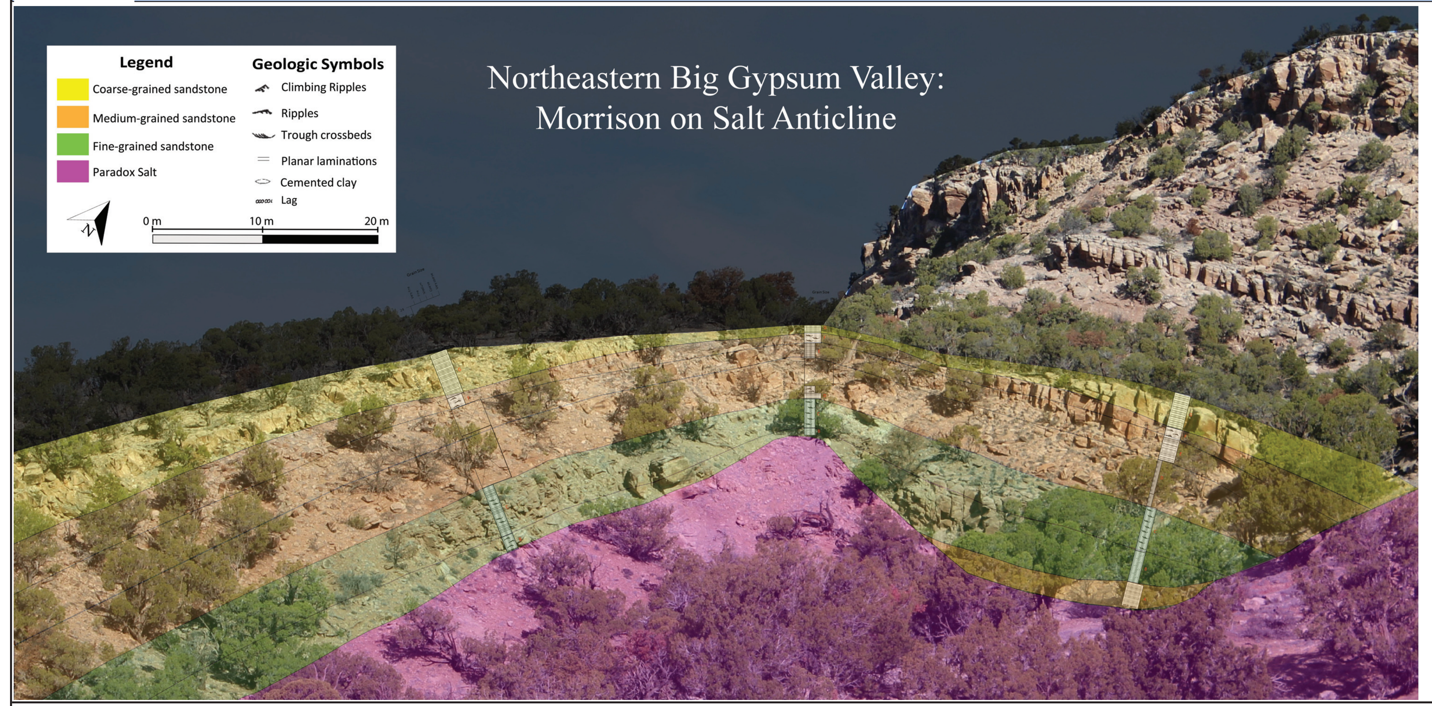
Figure 10

A Southwestern Big Gypsum Valley: Paleo Canyon



The colors shown in the figure above represent the different channels found in the Paleo Canyon to the SW of the salt diapir, where the dark line is the canyon margin.
The Morrison Formation incises at least 4 m into the underlying strata, which could potentially breach traps.
Stratigraphic sections show that 89% of the canyon is composed of sands and 11% is shales. Because the shales are not laterally consistent, there is no effective seal in the canyon.

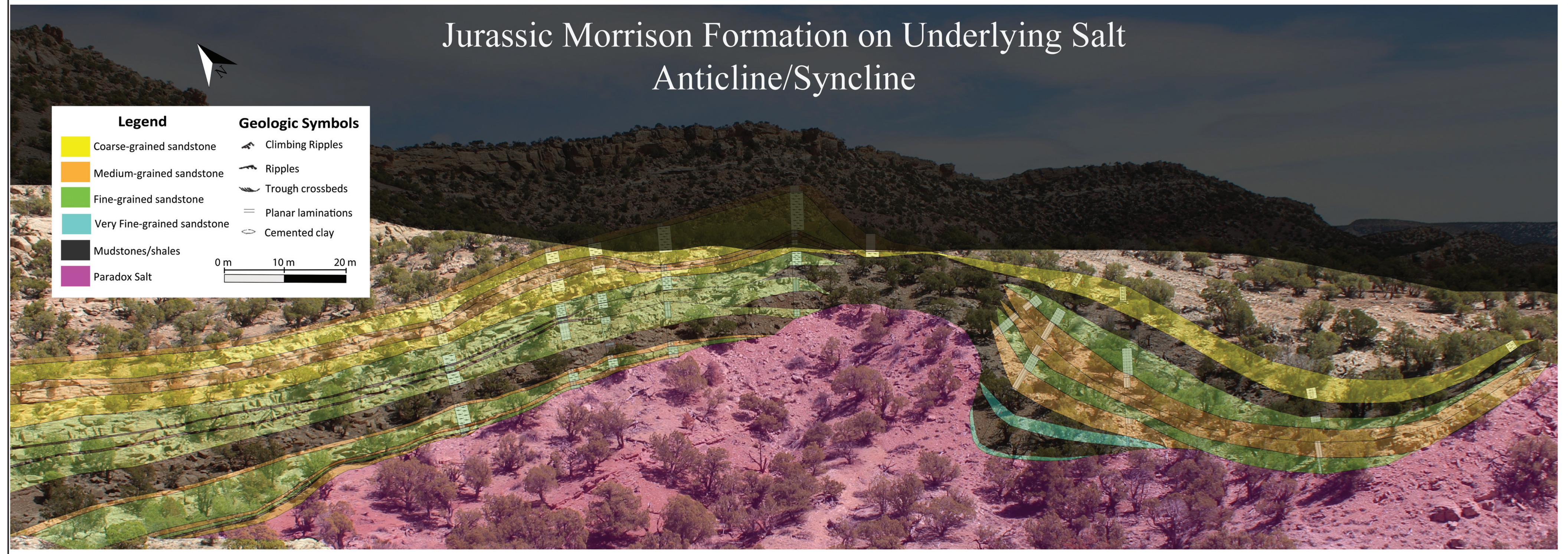
B Northeastern Big Gypsum Valley: Morrison on Salt



B.1

The figure to the left shows three stratigraphic sections measured and coorrelated accross an anticline where the Morrison Formation is found folded and in direct contact with the salt diapir.

- Located at Unit 3 of the Salt Wash Member: isolated sandstone channel deposits
  - Alternate from ripple cross-stratified laminae, trough cross-bedded sandstones, and tabular beds
- Area is composed entirely of sandstone channels that pinch out against the salt
  - Muds and shales pinch out before they get to the surface
- Stratigraphic sections vary in thickness from 10 m (on the anticline axis) to 21 m
  - 52% lateral increase in thickness
- Stratigraphic units thicken outwards from the anticline's axis with a lateral change of 3 m



B.2

The figure to the left shows the stratigraphic correlation of 12 measured sections along an anticline-syncline couple where the Morrison Formation is in direct contact with salt.

- Located at Unit 3 of the Salt Wash Member: isolated channel deposits
- Sediment consists of 67% sandstones and 38% shales/mudstones.
  - Significant amount of porous sand for resources to be stored in and shale to serve as a seal
  - Shales and muds thicken towards the anticline axis
- Stratigraphic sections change in thickness from 1 m (anticline axis) to a maximum of 33 m (syncline axis)
  - 96% lateral increase in thickness
- The stratigraphic units thin onto the anticline and thicken into the syncline with a lateral change of about 4-5 m
- The flow direction is parallel to the fold axes (SE), possibly indicating structural influence on the channels

3D Model

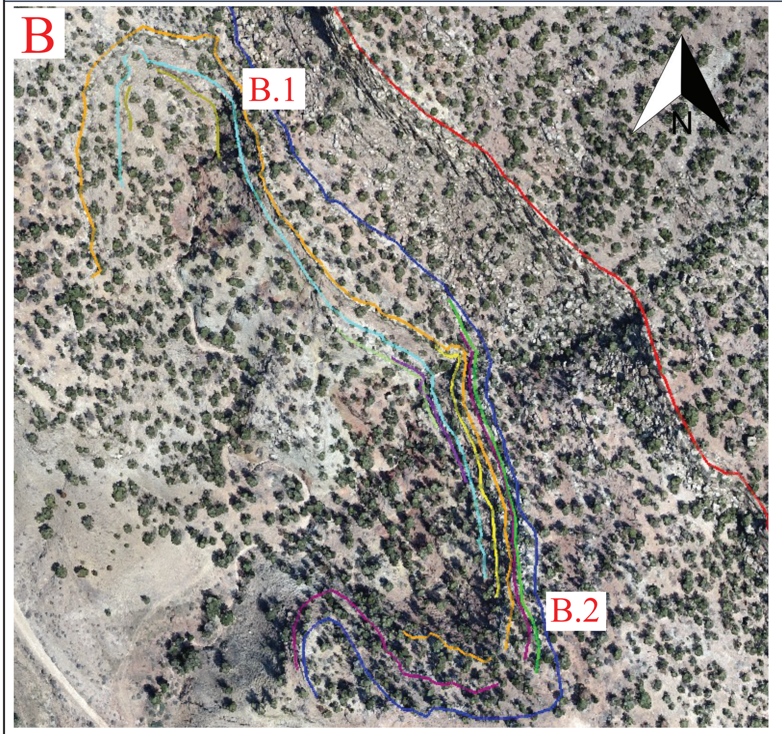


Figure 10

Figure 12

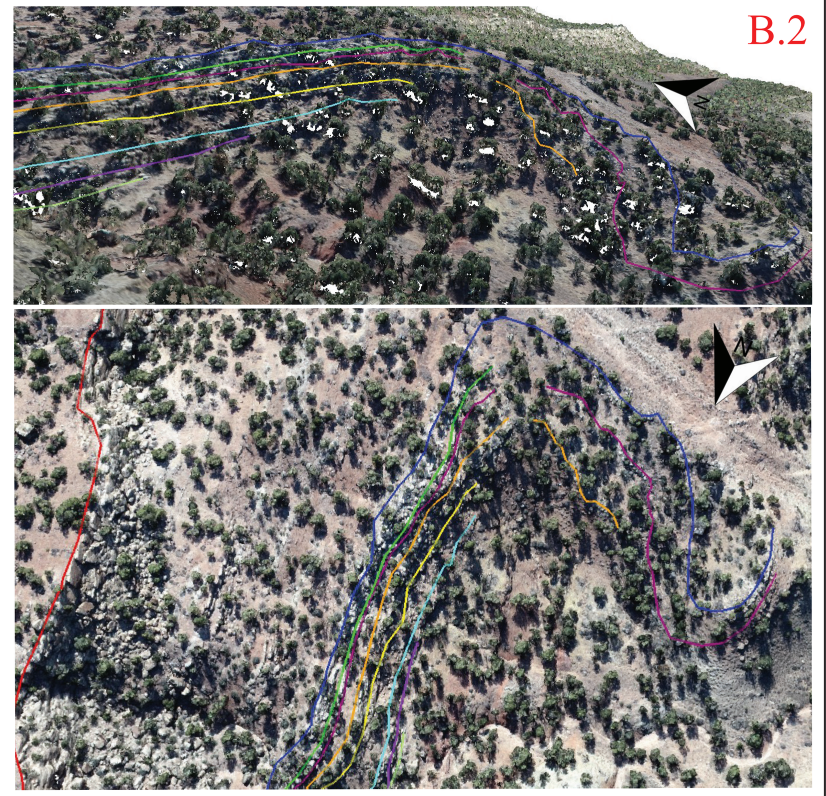


Figure 13

Figure 11 shows the top view of area B, where the Morrison Formation is found folded and in direct contact with the salt diapir.

- The different colors represent the top of sandstone channels that run across this area.
- The Morrison Formation forms an anticline at area B.1 (**Figure 12**) and an anticline/syncline couple at area B.2 (**Figure 13**)
- The sandstone channels pinch out against the salt near the anticline axis and thicken towards the syncline axis

Sample Analysis

Basal strata of the Morrison Formation contain diapir-derived clasts, reflecting erosion of the diapir margin by the first channels that flowed across the diapir;

- Includes
  - 1 cm long, ½ cm thick green-gray clay chips (**Figure 14**)
  - carbonate pebbles (**Figure 15**)
- Indicate that the Morrison Formation was in direct contact with the salt during deposition

These clasts will be point counted in thin section for future analysis in order to better determine whether they are related to the Paradox Formation or caprock.


Figure 14

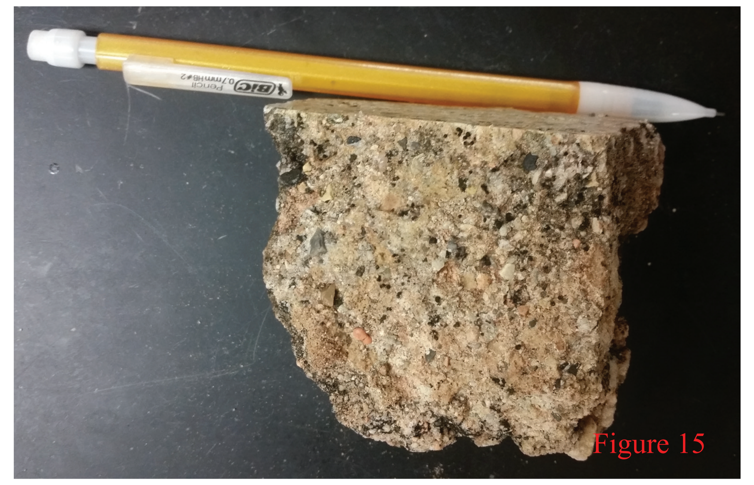


Figure 15

Big Gypsum Valley, Colorado
Results, Conclusions, and Future Work

Results

The lower beds of the Morrison Formation onlap the tilted strata flanking the diapir.
- Indicating continued minibasin subsidence and diapir rise as the Morrison Formation was being deposited.

Basal strata of the Morrison Formation contain diapir-derived detritus, such as green-clay chips and carbonate pebbles.
- Reflecting erosion of the diapir margin by the first channels that flowed across the diapir
- Indicate that the Morrison Formation was deposited directly on top of the diapir rather than faulted against it

There is a lateral change in bed thickness within the Morrison Formation, which thins on anticlines and thickens on synclines. The basal units pinch out against the salt diapir.
- Suggests that the Morrison Formation was being folded as it was being deposited.

On the SE side of the salt diapir, the Morrison Formation incises into the salt diapir and older units of the megaflap to create a Paleo Canyon.
- Shows that the contact between the Morrison Formation and the underlying units isn't a horizontal surface.

Conclusions

The initial results of this study indicate that diapir and salt movement continued through at least Salt Wash time in the late Jurassic.

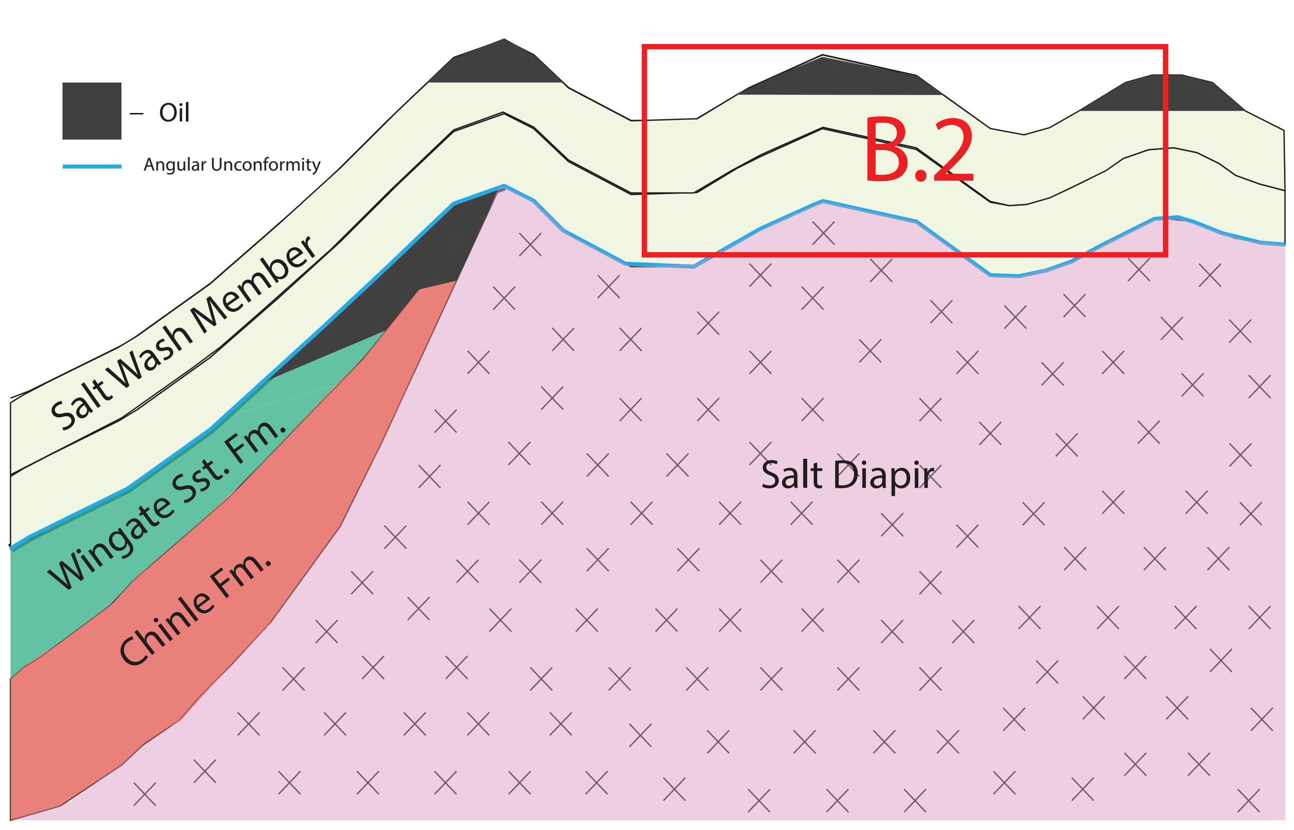
The lack of faulting in some areas indicates that much of the Morrison Formation is in place and has not been dropped into its present location through diapir dissolution collapse as has been previously thought.

Bedding shortening through folding is evident in the Morrison Formation, which could be the result of salt movement during deposition.

Diapir-derived clasts found within the basal units of the Morrison Formation further imply that the it was in direct contact with the salt diapir during deposition.

The pinching out of basal units against the salt diapir indicate that the Morrison Formation was being folded during deposition, thus making the deformation syndepositional.

Possible Reservior and Trap Locations



The schematic to the left shows four sites that are possible outcrop analogues of reservoirs and traps.

Including:
- The crests of anticlines on units deposited on the salt
- Horn traps
- Pinch out traps
- Stratigraphic traps where there is an unconformity between the Morrison and the older Wingate Formation

Future Work

Additional stratigraphic sections will be measured and correlated along the far northeastern Morrison Formation anticline (shown as B.1) in hopes of better portraying the thinning and thickening of the sandstone channels along the fold.

The 3D model created by David F. Lankford will be used to calculate the thicknesses of units in areas that have yet to be explored in the field. The different channels will then be traced using Agisoft Metashape Professional.

Samples gathered from the basal units of the Morrison Formation, which contain diapir-derived clasts (**Figure 16**), will be cut and sent to Spectrum Petrographics Incorporation for thin section preparation.

- Diapir-derived clasts will be point counted in thin section using carbonate and feldspar stains
- Blue dye will be used in hopes of studying the permeability of the gathered samples

Figure 16

Paleocurrent data will be gathered from the study area in hopes of expanding our knowledge on the flow direction for the southeastern end of Big Gypsum Valley.

- This information will be displayed in Rose Diagrams and added on to the regional work done by Claire H. Bailey (**Figure 17**)
- The paleocurrent data will help in determining whether the flow of water had any impact in the observed geometries

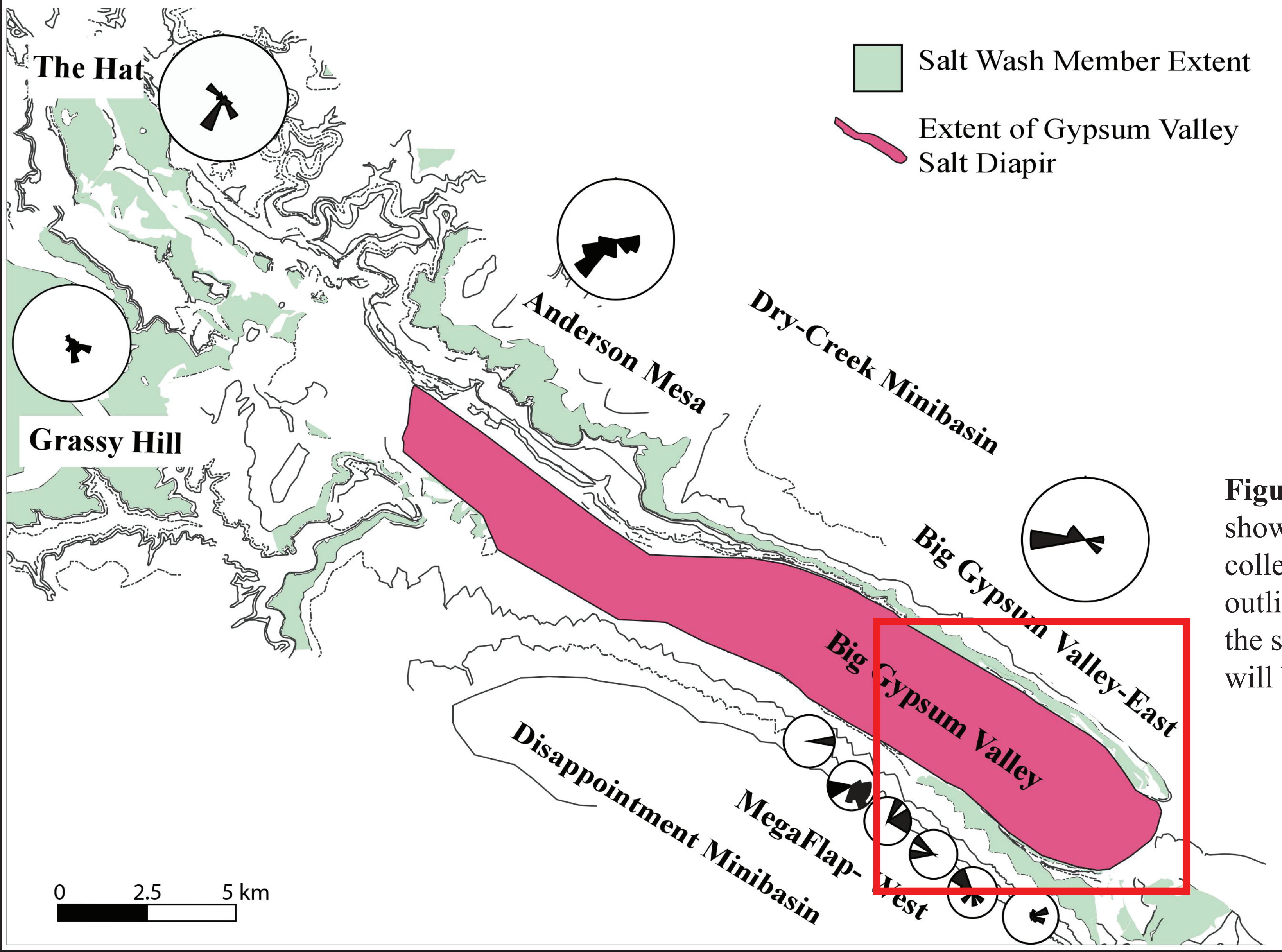


Figure 17: Gypsum Valley map showing the paleocurrent data collected by Claire Bailey. Red outline shows the location of the study area where more data will be collected.

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