## PSSequential Structural Restoration of the Lisbon Valley Anticline, Paradox Basin, Utah\*

### Steven Lingrey<sup>1</sup>

Search and Discovery Article #30633 (2019)\*\*
Posted September 30, 2019

\*Adapted from poster presentation given at 2019 AAPG Annual Convention and Exhibition, San Antonio, Texas, May 19-22, 2019

#### **Abstract**

Salt deposition and subsequent diapiric deformation into salt walls/anticlines occurred in the Paradox Basin associated with the Late Pennsylvanian-Permian uplift of the Uncompahgre contractional fault block (Ancestral Rocky Mountains). Recent workers (Paz Cuellar, Trudgill, Fleming, Hearon, Thompson) have used structural restoration to document the sequential growth of the salt diapirs. Current preservation of stratigraphic horizons upon which to construct restoration datums emphasizes Jurassic and older units. Permian datums (Cutler Group) show that a majority of the diapiric structural relief developed during and immediately following ARM tectonism (Trudgill, 2011). Structural restoration of the Lisbon Valley salt anticline, however, shows a majority of diapiric growth that is younger than Jurassic (Fleming, 2015).

In order to capture and visualize the sequential development, Cretaceous and Tertiary datums are necessary. This effort requires an estimated reconstruction of sedimentary units lost during Laramide contractional uplift (minor) and Late Tertiary uplift of the Colorado Plateau (major). To that end, I have created a sequential restoration of the Lisbon Valley anticline that includes: (1) a mid-Jurassic datum, (2) a Mid-Cretaceous datum, (3) a Mid-Eocene datum, (4) an inferred, pre-Colorado Plateau exhumation, Miocene (?) topography, and (5) present-day structural profile beneath current topography. If my stratigraphic reconstructions are correct, a majority of the salt-cored structural relief at Lisbon Valley must have occurred during Mid-Tertiary extensional reactive diapirism on the Lisbon Valley normal fault (D<sub>max</sub> ~ 1500 m).

<sup>\*\*</sup>Datapages © 2019 Serial rights given by author. For all other rights contact author directly. DOI:10.1306/30633Lingrey2019

<sup>&</sup>lt;sup>1</sup>University of Arizona, Tucson, Arizona (shlingr@email.arizona.edu)

# Sequential Structural Restoration of Lisbon Valley Anticline, Paradox Basin, Utah



# Steven Lingrey

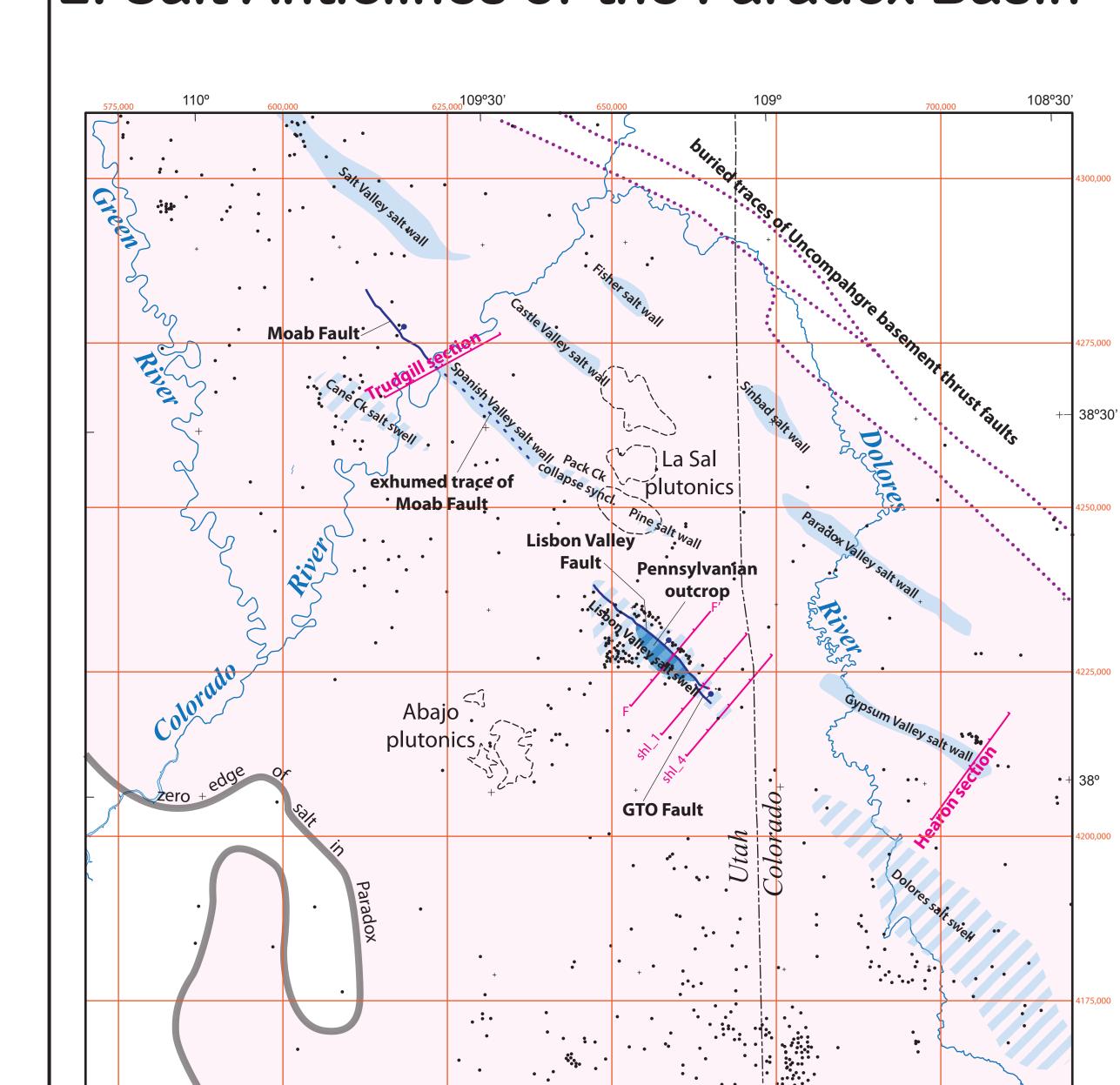
Department of Geosciences, University of Arizona, 1040 E. 4th Street, Tucson, AZ, U.S.A.

the surface (~250 m of lower Hoanker Trail cover). Initial collapse into the near surface salt manifest in a) sub-vertical

normal fault and b) northeastward tilt to form the Lisbon Valley anticline of Doelling (2002).

liapiric deformation into salt walls/anticlines occurred in the Paradox Basin associated with the Late Pennsylvanian-Permian uplift o ontractional fault block (Ancestral Rocky Mountains). Recent workers (Paz Cuellar, Trudgill, Fleming, Hearon, Thompson) have used structural oration to document the sequential growth of the salt diapirs. Current preservation of stratigraphic horizons upon which to construct restoration datums emph Jurassic and older units. Permian datums (Cutler Group) show that a majority of the diapiric structural relief developed during and immediately following AR tectonism (Trudgill, 2011). Structural restoration of the Lisbon Valley salt anticline, however, shows a majority of diapiric growth that is younger than Jurassic (Fleming, 2015). In order to capture and visualize full sequential development Cretaceous and Tertiary datums are necessary. This effort requires an estimated reconstruction of sedimentary units lost during Laramide contractional uplift (minor) and Late Tertiary uplift of the Colorado Plateau (major). To that end, I have created a ential restoration of the Lisbon Valley anticline that includes: 1) a mid-Jurassic datum, 2) a mid-Cretaceous datum, 3) a mid-Eocene datum, 4) an inferred, pre-Colorado Plateau exhumation, Oligocene-Miocene (?) topography, and 5) vthe present-day structural profile beneath current topography. If my stratigraphic ctions are correct, a majority of the salt-cored structural relief at Lisbon Valley must have occurred during mid-Tertiary extensional reactive diapirism on the Lisbon Valley normal fault ( $D_{max} \sim 1200 \text{ m}$ ).

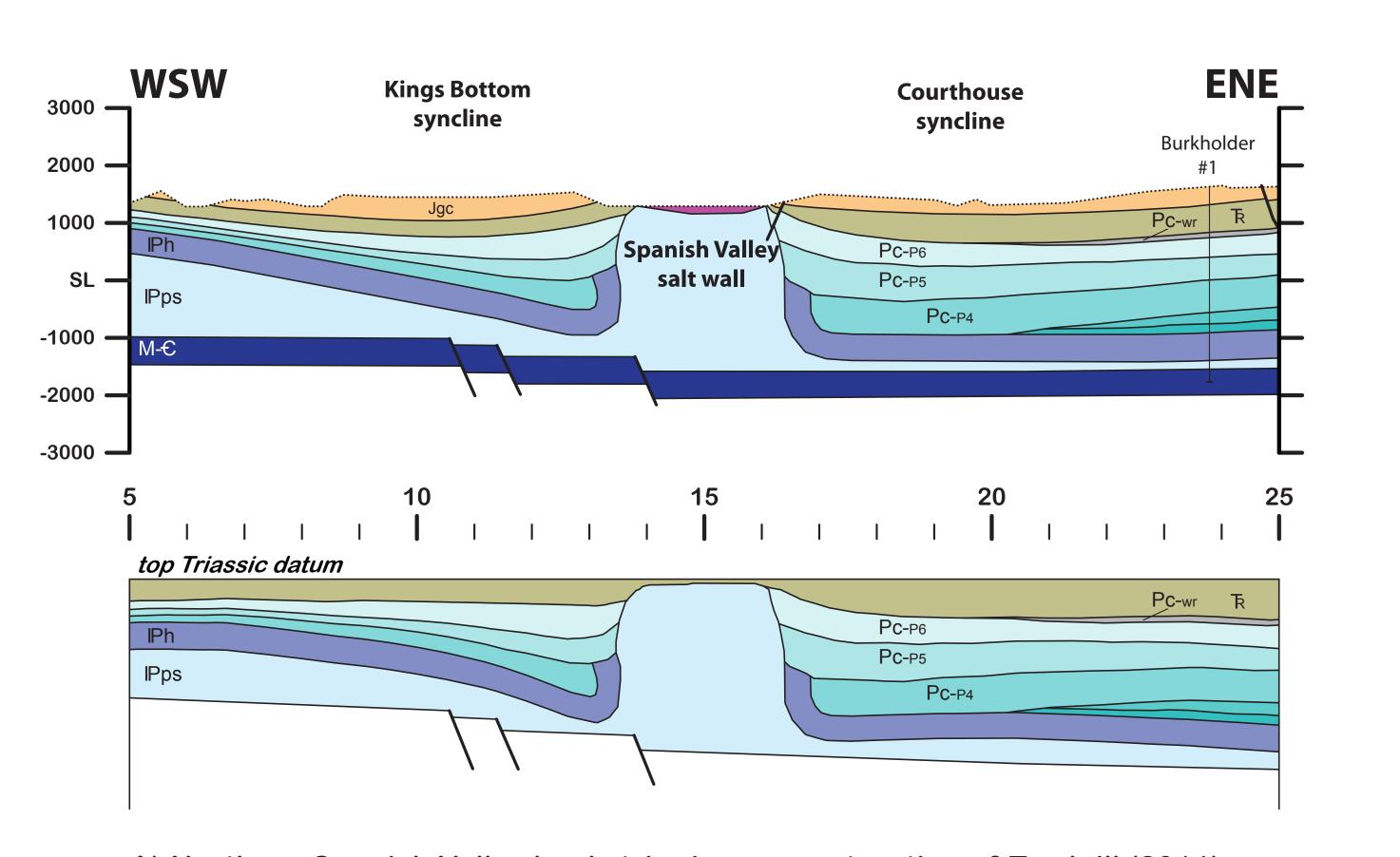
# 2. Salt Anticlines of the Paradox Basin

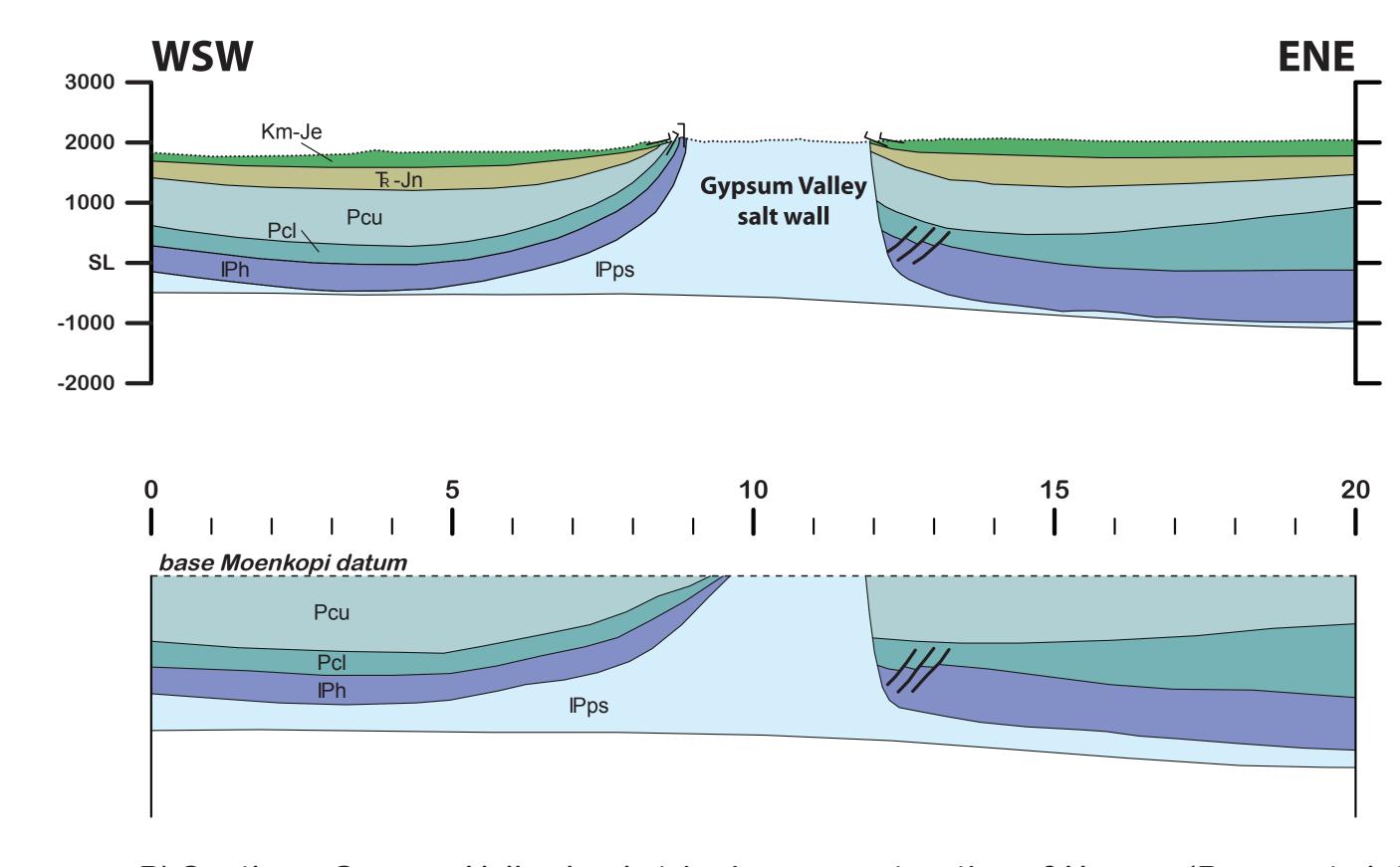


The Paradox Basin is interpreted as a flexural foredeep basin adjacent to the contractional, NW-trending Uncompangre basement-cored uplift that developed during the Late Pennsylvania and Early Permian (Dickinson and Lawton, 2003; Barbeau, 2003). Most of the major salt anticlines (diapiric Pennsylvanian Paradox Formation) in the Paradox Basin are marked by broad, elongate, NW-trending valleys floored with scattered evaporitic exposures.

## **Location Map of central Paradox Basin:**

- 1) exposed crests of salt walls coring salt anticlines shown in solid light blue 2) buried crests of salt swells coring salt anticlines shown in striped light blue
- 3) structural sections are marked in pink
- 4) normal fault traces with displacement > 500 m shown in dark blue (Moab, Lisbon Valley, GTO)



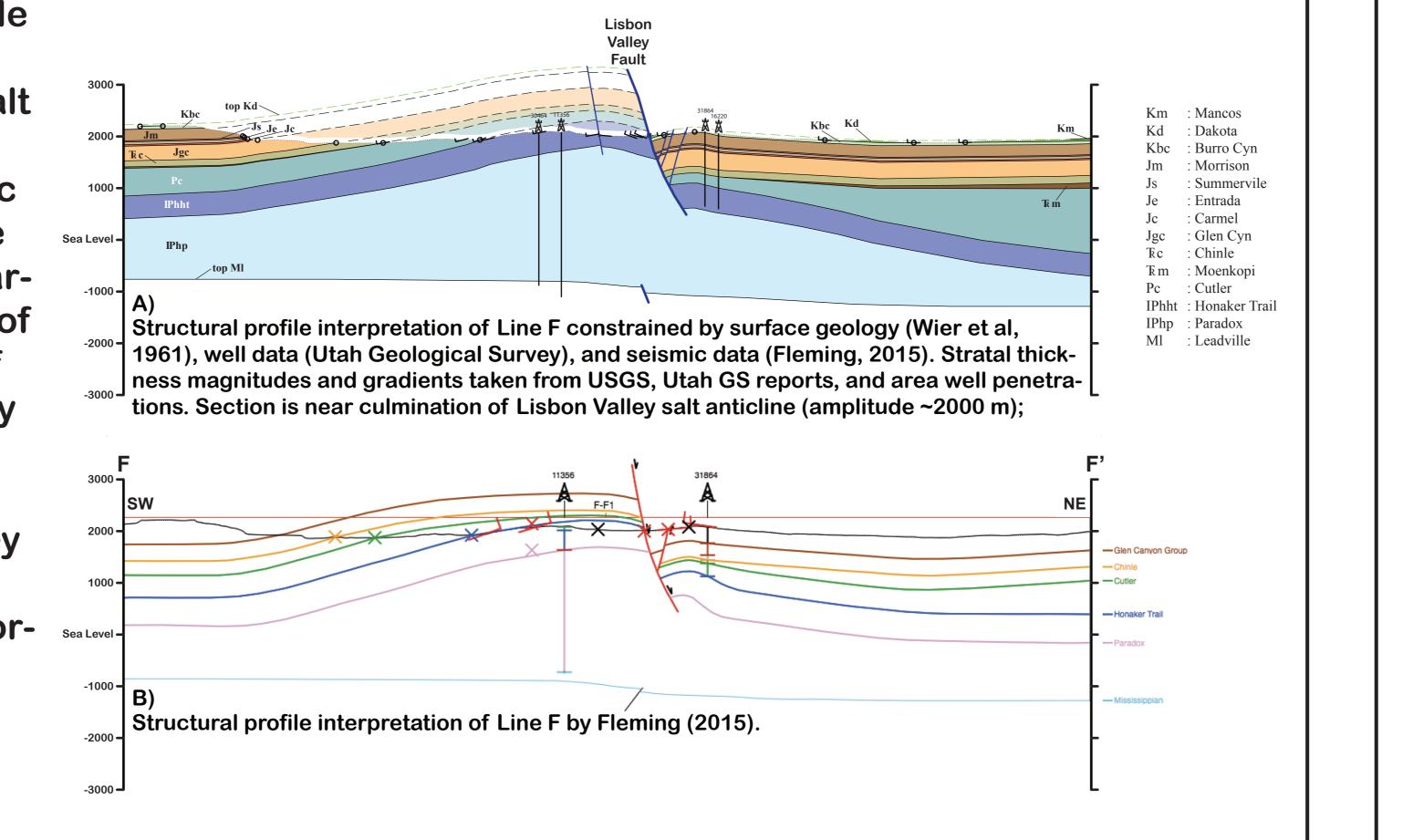


B) Southern Gypsum Valley backstripping reconstruction of Hearon (Rowan et al, 2016) A) Northern Spanish Valley backstripping reconstruction of Trudgill (2011)

Comparison between present-day structural profiles (top) and Triassic age restorations (bottom) show that the large amplitude salt wall development occurred by the end of the Permian. Restorations of Trudgill and Hearon imply no significant post-Triassic contraction or extension.

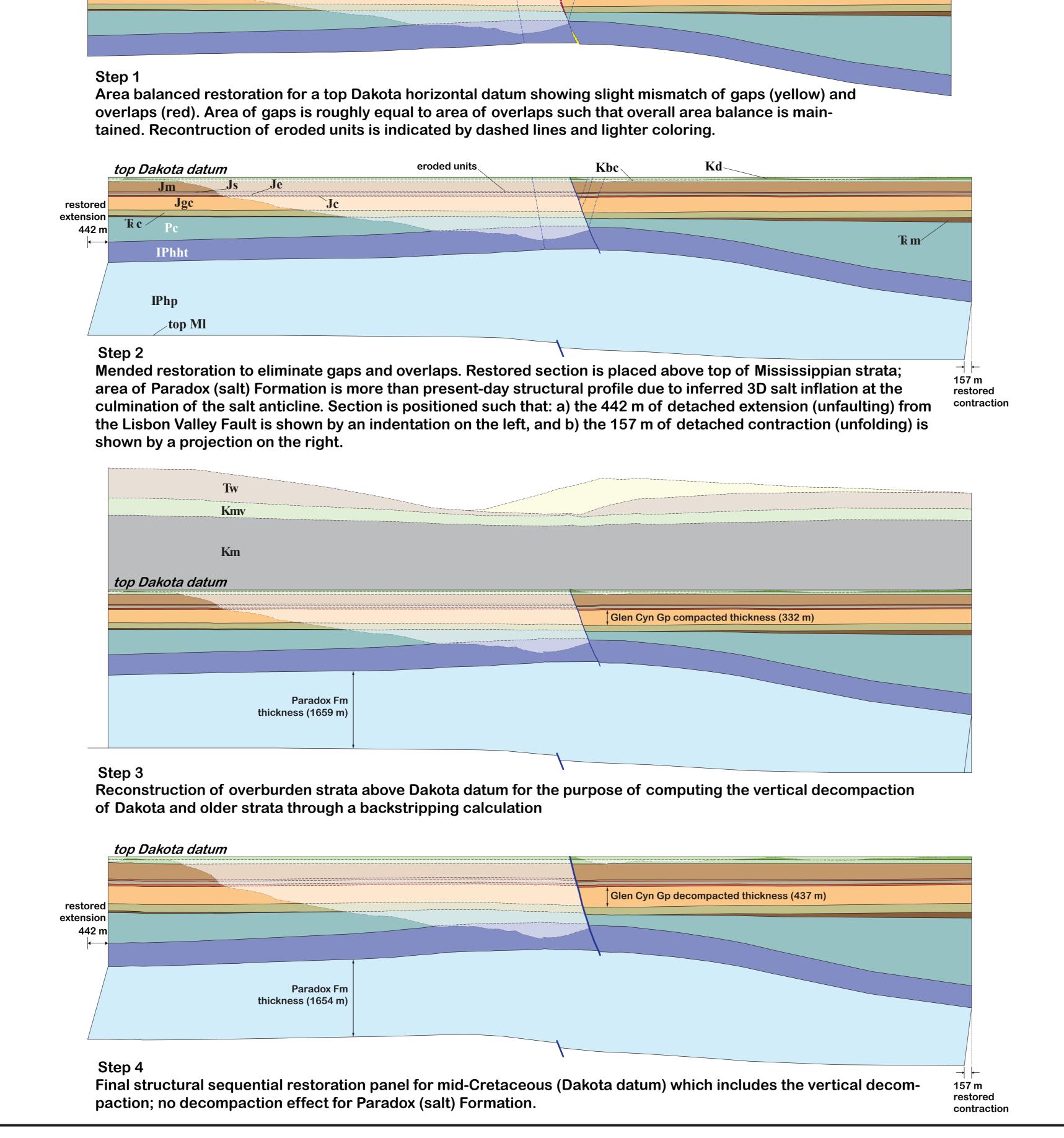
## 3. Profile Interpretation of the Lisbon Valley Salt Anticline ine F is a re-interpretation of a profile

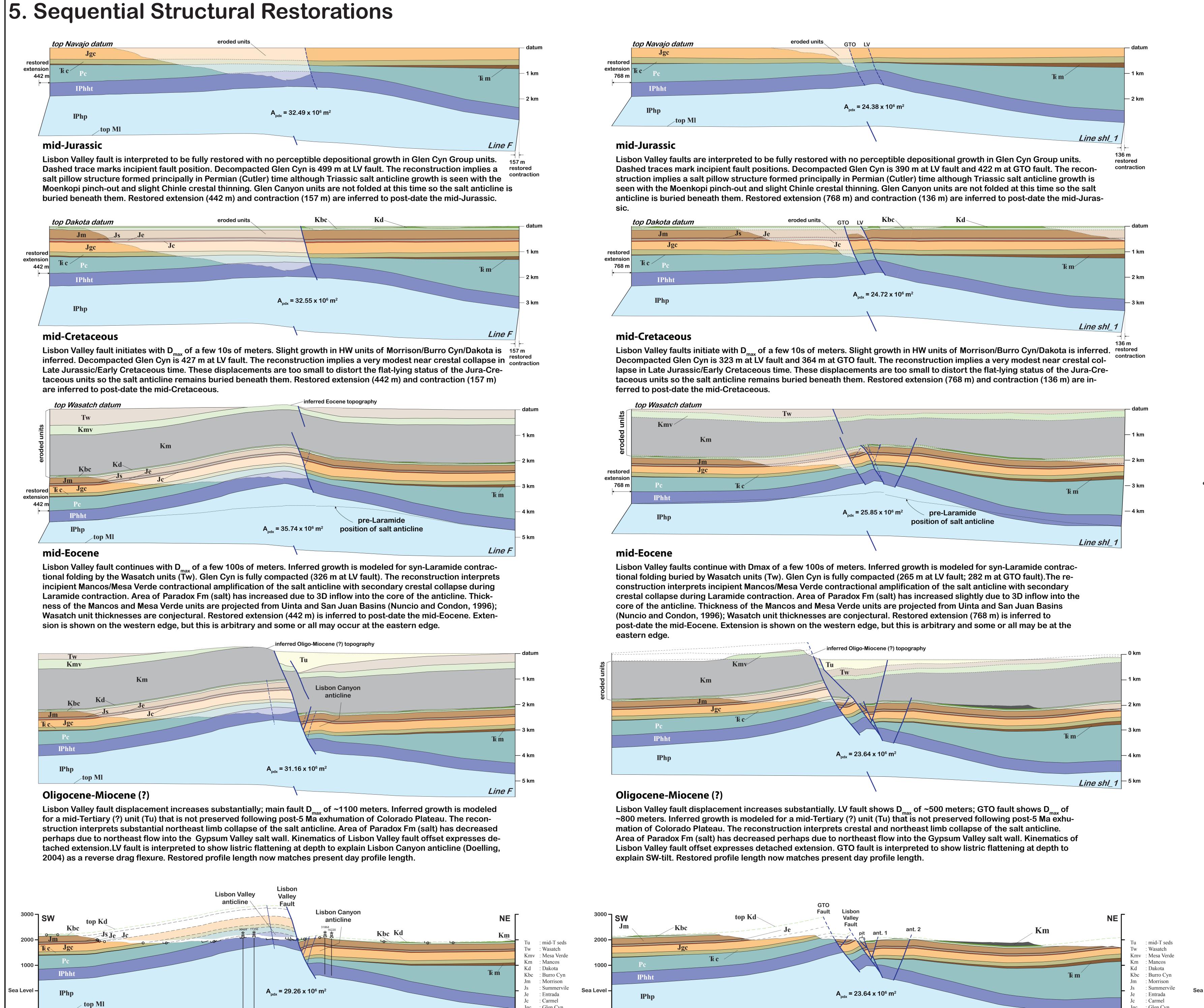
tude ~2000 m) of the Lisbon Valley salt Fleming (2015) with the aid of seismic Idata. The anticline is detached above the salt swell in the Pennsylvanian Paradox Formation. The northeast flank of normal slip offset by the Lisbon Valley fault. Restoration of a nearby profile y Fleming (2015) to a top Navajo datum indicated that the Lisbon Valley fault is post-mid-Jurassic. Sequential restoration in panel 5 shows the majority of Lisbon Valley fault offset to be



# 4. Method of Restoration

Restoration of structural profiles was made using LithoTect software. Step 1: areal balance restoration with areal misfits (gaps and overlaps) shown across Lisbon Valley fault. Step 2: mended restoration with interpreted detached shortening (on NE) and detached extension (on SW). Step 3: reconstruction of depth of maximum burial. Step 4: computed decompaction.

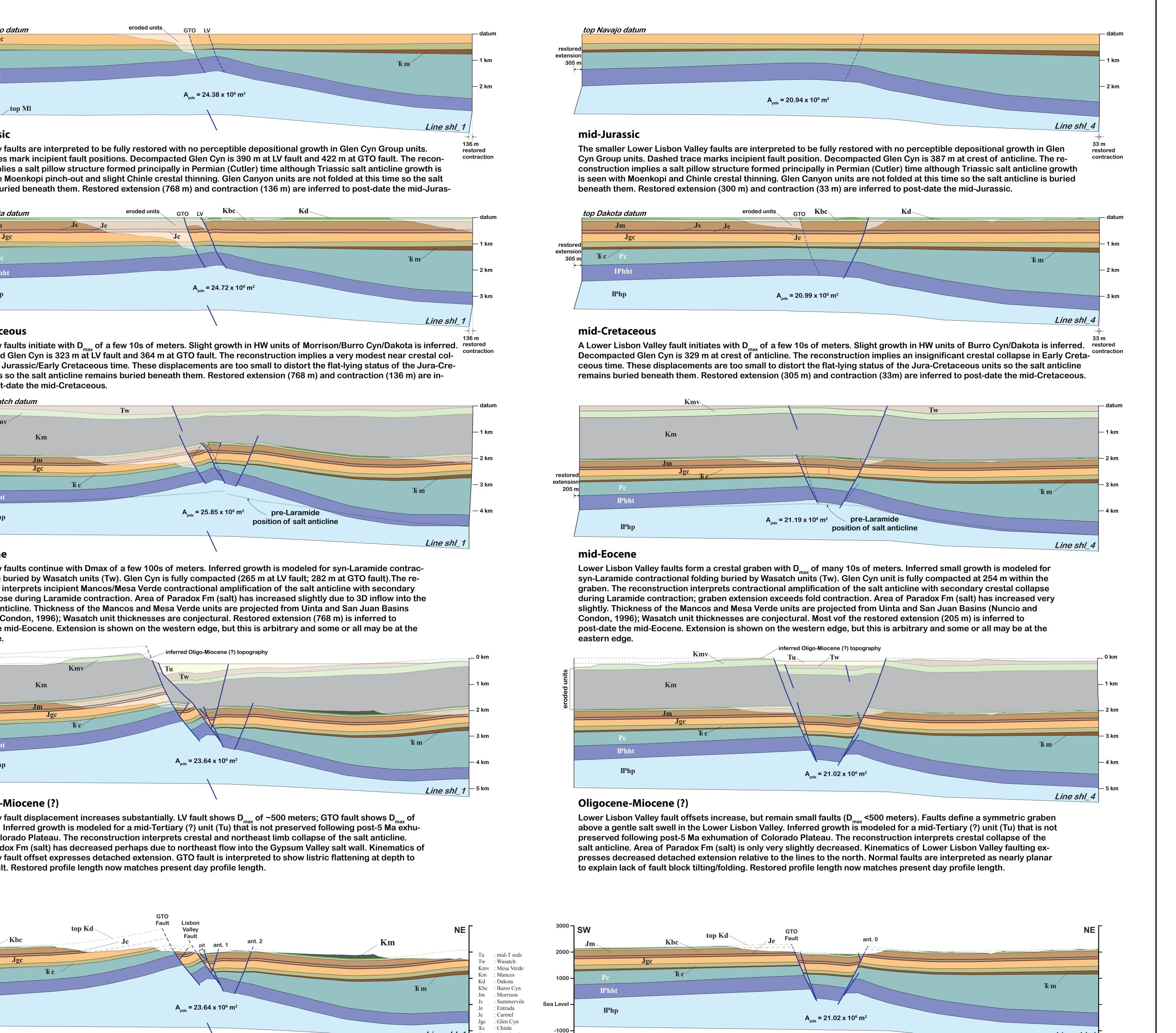




ward GTO displacement increases and LV displacement decreases. The fault block between shows significant south-

vation (Lisbon Valley Mining Company); LV fault surface exposed in SW corner of the pit.

ward dip and constitutes a breached relay ramp. Pit demarcates the location of the Centennial Pit copper mining exca-



Colorado Plateau down to Upper Jurassic/Lower Cretaceous units. Paradox salt lies beneath 1500 m of overburden. A

southern strand of the GTO fault shows <500 m offset. A similar offset antithetic fault (ant. 0) creates a symmetrical

<sup>00 I</sup> graben block that drops into the salt crest.

# 6. Is the Lisbon Valley Fault Contemporaneous with the Moab Fault?

Lisbon Valley fault (Hodson et al. 2016; Solum et al. 2010; Eichhubl et al. 2009; Davatzes et al, 2005; Solum et al, 2005; Foxford et al, 1996). The cross sectional profile of these faults is similar, although the exposed Moab fault lies above northwest plunge end of the prominent Spanish Valley salt wall. While initial fault motion may have been Jurassic, dating of clays (Solum) indicates ~60 Ma timing of fault displacement to acrue >1000 m offset. This has been interpreted as Laramide age salt reactivation. The Lisbon Valley restorations as interpreted show modest Laramide age offset, but show significantly more offset with post-Laramide timing. Given the extent of stratigraphic reconstruction, it may be possi ble to entertain a hypothesis of greater offset in the Laramide. The detached extension, however, is constrained by more complete Jura-Cre tacous strata. This extensional stretching is far greater than the contrac tional shortening inferred as Laramide. As such, the mid-Tertiary extension contemporaneous with the western Colorado Plateau and Ric Grande Rift normal faulting seems a better hypothesis for the Lisbon

# 7. Conclusions

Restoration of Paradox Basin profiles by others and in this poster show that a large majority of the structural amplitude of salt walls and salt swells in the Paradox Basin formed in the Permian contemporaneous wi the deposition of the Cutler Formation during the waning stages of Ancestral Rocky Mountain tectonism (contractional uplift of Uncompan basement fault block). Restoration at Lisbon Valley, however, shows some slight salt anticline amplification during Laramide deformation and signi icant amplification during mid-Tertiary detached extension. Recognition of these effects needs structural restoration using younger datums (mid-Eocene and Oligocene-Miocene (?)) than has heretofore been used. To accomplish this requires reconstruction of ~1500 m of eroded stratigraphy. If my stratigraphic reconstructions are correct, the salt-cored structural relief at Lisbon Vallev must have occurred during mid-Tertiary extensional reactive diapirism on the Lisbon Valley normal fault.

## 3. Acknowledgements and References

Structural geology research in the Paradox Basin have been supported by a Keck Foundation grant to the University of Arizona (Peter Reiners, principal investigator). Lantz Indergard and Brian Sparks are geologists with the Lisbon Valley Mining Company who provid ed access to their copper mining pits near Line shl\_1. Bob Krantz, George Davis, and Amanda Hughes are colleagues also studying Paradox Basin structural geology that have helped develop my understanding. Mark Fisher of Northern Illinois University gave me access to a full copy of Matthew Fleming's MS thesis. Halliburton provides an academic license of the LithoTect™ restoration analysis software at the University of Arizona.

Barbeau, D.L. 2003. A flexural model for the Paradox Basin: implications for the tectonics of the Ancestral Rock Mountains. Basin Research, 15, 97-115. Davatzes, N. C. and Avdin, A. 2005. Distribution and nature of fault architecture in a layered sandstone and shall

sequence: An example from the Moab fault, Utah. in R. Sorkhabi and Y. Tsuji, eds., Faults, fluid flow, and petroleum traps: AAPG Memoir 85, 153–180. Dickinson, W.R. and Lawton, T.F. 2003. Sequential intercontinental suturing as the ultimate control for Pennsylvania Ancestral Rocky Mountains deformation. Geology, 32, 609-612.

Doelling, H.H., Ross, M.L., and Mulvey, W.E. 2002. Geologic map of the Moab 7.5' quadrangle. Utah Geological Su Eichhubl, P., Davatz, N.C., and Becker, S.P. 2009. Structure and diagenetic control of fluid migration and cementatio along the Moab fault, Utah. AAPG Bull. 93, 653-681.

Fleming, M.W. 2015a. Integrated structural and fracture analysis of Lisbon Valley salt anticline, Utah. Northern Illinois Fleming, M.W. 2015b. 3-D structural evolution of the Lisbon Valley salt anticline, Paradox Basin, Utah. (abs) AAPG Bull. Hodson, K.R., Crider, J.G., and Huntington, K.W. 2016. The role of fluids in faulting and fracturing in carbonates and

other upper crustal rocks. Tectonophys., 690, pt. A, 240-252. Nuncio, V.F. and Condon, S.M., 1996. Burial and thermal history of the Paradox Basin, Utah and Colorado, and petroleun potential of the Middle Pennsylvanian Paradox Formation. USGS Bull. 2000-O, 41p. Rowan, M.G., Giles, K.A., Hearon IV, T.E., and Fiduk, J.C. 2016. Megaflaps adjacent to salt diapirs. AAPG Bull., 100,

Solum, J.G., van der Pluijm, B.A., and Peacor, D.R. 2005. Neocrystallization, fabrics and age of clay minerals from an ex posure of the Moab Fault, Utah. Jour. Struc. Geology, 27, 1563-1576. Solum, J.G., Davatzes, N.C., and Lockner, D.A. 2010. Fault-related clay authigenesis along the Moab Fault: Implications

Trudgill, B.D. 2011. Evolution of salt structures in the northern Paradox Basin: controls on evaporite deposition, salt wall growth and supra-salt stratigraphic architecture. Basin Research, 23, 208-238. Trudgill, B.D. & Paz, M. (2009) Restoration of mountain front and salt structures in the northern Paradox Basin, SEUtah. in: The Paradox Basin Revisited-new developments in petroleum systems and basin analysis, Houston, W.S., Wray, L.L. and Moreland, P.G. (eds), RMAG Sp. Publ., 132-177.

for calculations of fault rock composition and mechanical and hydrologic fault zone properties. Jour. Struc. Geology,