# Salt System Evolution of the Northern Paradox Basin*

**Manuel Paz[1], Bruce Trudgill[2] and Chuck Kluth[2]**

Search and Discovery Article #30078 (2009)
Posted March 20, 2009

*Adapted from extended abstract presented at AAPG Convention, San Antonio, TX, April 20-23, 2008

[1]Occidental Petroleum Corporation, Tupman, CA (mailto:Manuel_Paz@oxy.com)
[2]Colorado School of Mines, Golden, CO

## Abstract

The northern Paradox Basin in SE Utah and SW Colorado is characterized by a variety of salt-related structures ranging from deeply buried salt pillows to faulted diapirs and salt walls exposed at the surface (Figure 1).

By restoring a series of 2D structural cross sections, it was determined that the proximal Cutler Group (Permian) is a basinward prograding unit that caused underlying salt within the Paradox Formation (Pennsylvanian) to flow in that same direction, towards the southwest (Figures 2, 3, 4, 5, 6, and 7). Under this scheme, more proximal salt structures evolved earlier than the more distal ones. During the early stages of progradation, there is a nondepositional hiatus in the distal part of the Paradox Basin. Salt withdrawal depended on the amount of mobile salt available and therefore facies within the Paradox Formation.

Depocenters on the east side of the Salt Valley salt wall migrated to the northwest during the early stages of the Cutler Group deposition, and then to the west (Figures 8 and 9). In that same area, welding out of the mobile salt occurred at the end of the Cutler time, although the present-day weld configuration was reached by Chinle time (Triassic).

The highest rates of sediment accumulation, salt wall growth, salt evacuation (in welded areas), salt area decrease and subsidence occurred during Cutler time, when the Uncompahgre Uplift was most active. Under the foreland basin framework, a wedge-top zone was interpreted close or on top of the Uncompahgre Uplift, where post-depositional deformation and cannibalization reincorporated the overlying sediments into the active depositional regime.

This understanding of the salt system evolution in the northern Paradox Basin impacts future oil exploration targets by defining a series of play concepts within the Paradox Formation, Honaker Trail Formation, Cutler Group, and White Rim Sandstone (Figure 10).

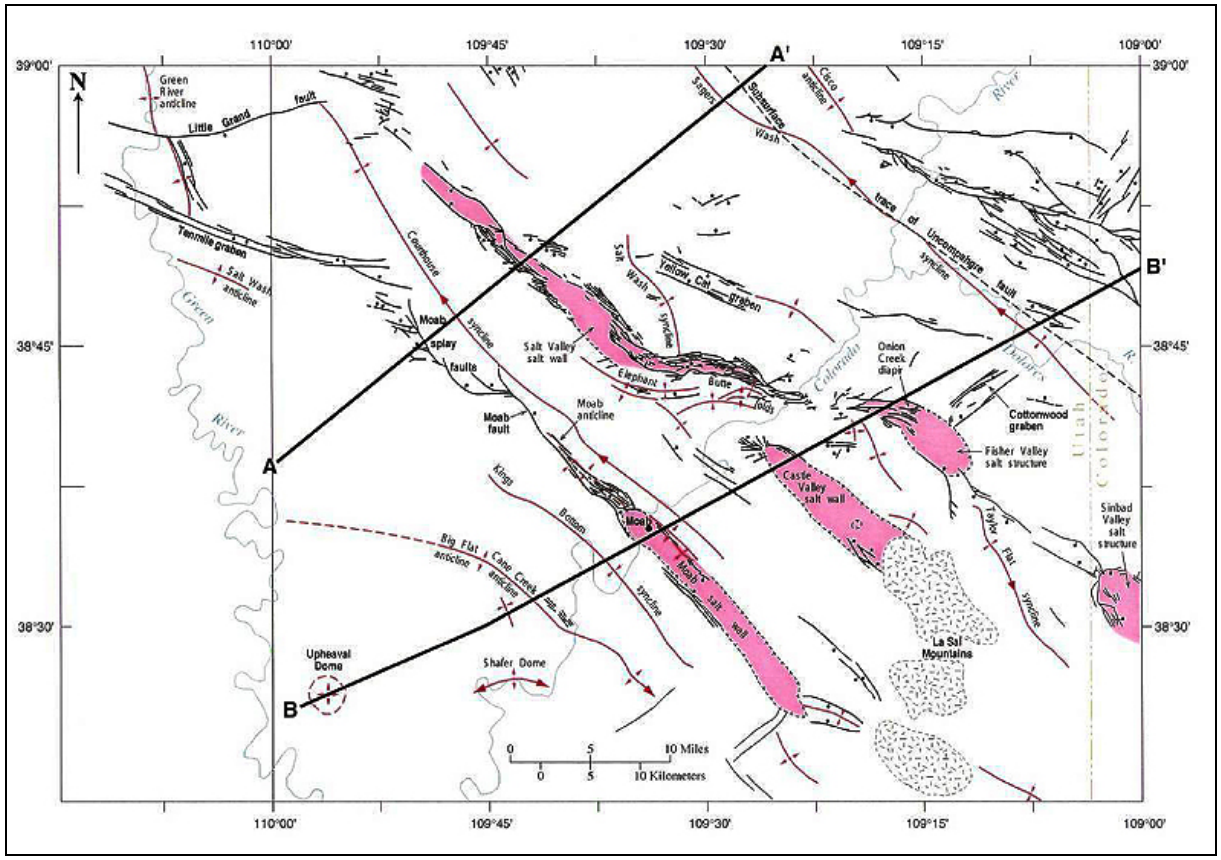


Figure 1. Principal structural features of the northern Paradox Basin. Shallow salt is shown in pink. Also shown are the locations of cross sections (after Trudgill et al., 2004).

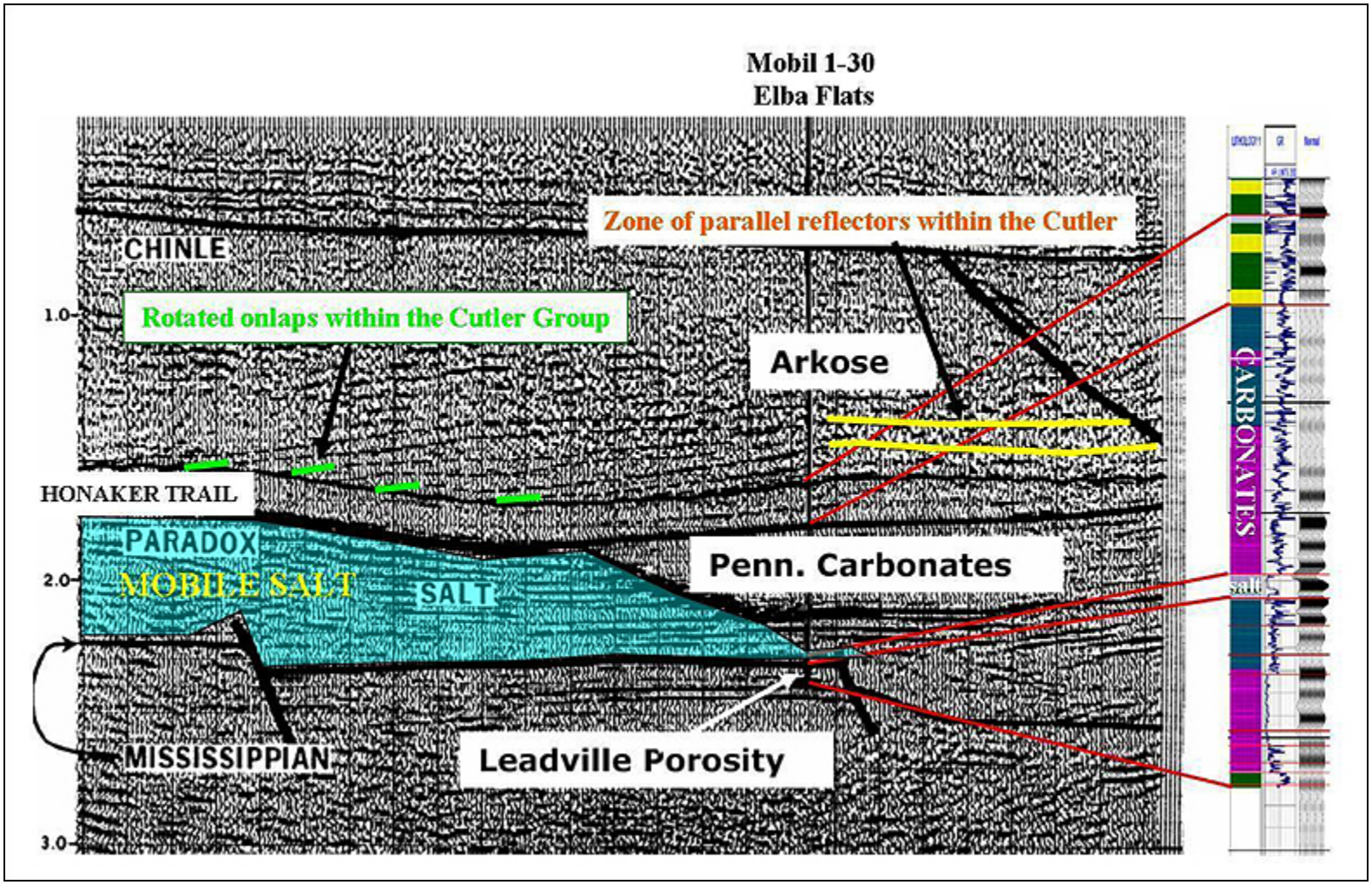


Figure 2. Progradational patterns on seismic. Carbonates wedge within the Paradox Formation. Seismic interpretation by Tidewater Oil and Gas Co., *in* http://energy.ihs.com/NR/rdonlyres/816AB997-C3D0-47BD-B5D7-20DEEAB274D0/0/blott.pdf, and based on Elba Flats drilled section (after Frahme and Vaughn, 1983).

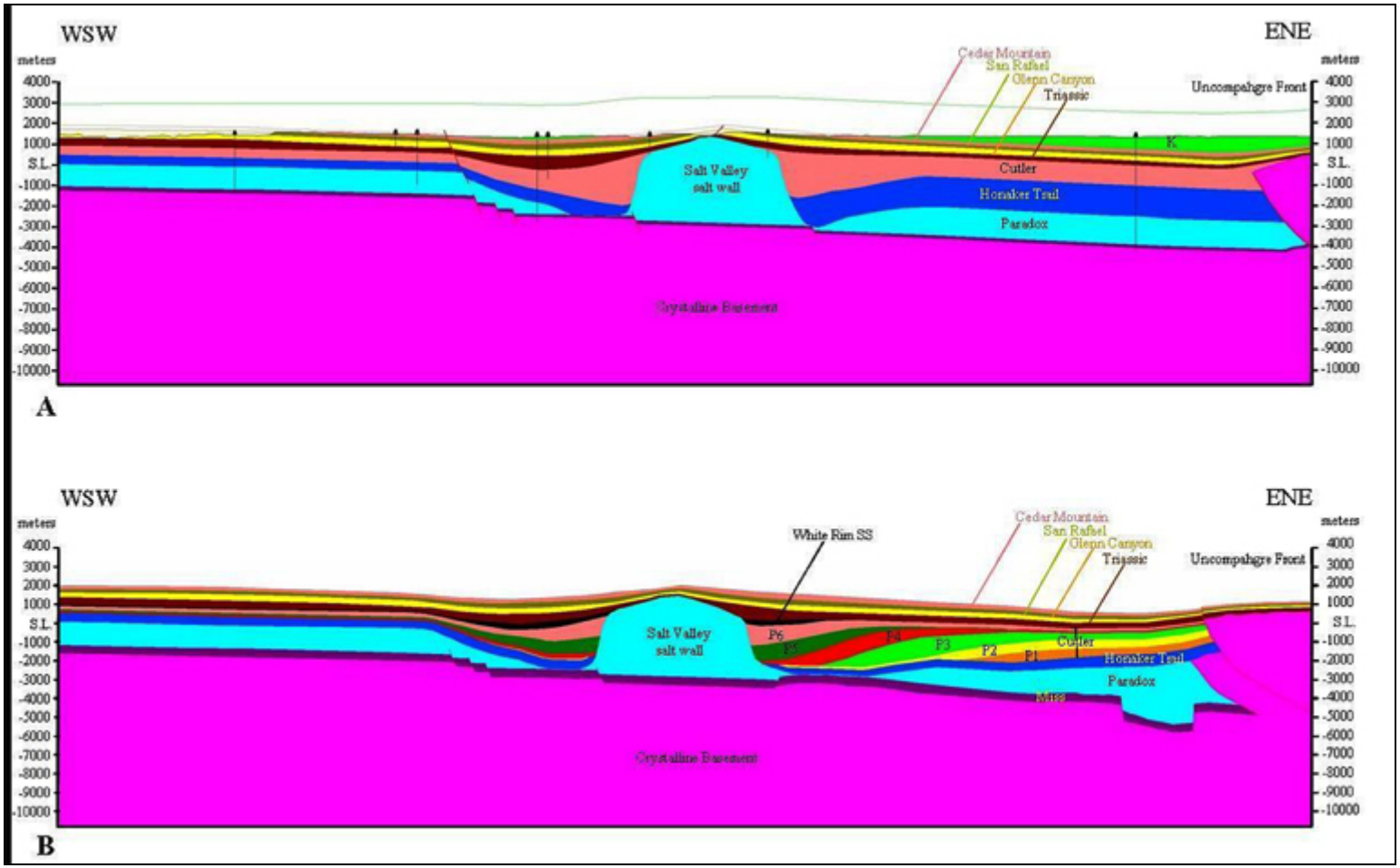


Figure 3. A) Structural cross section A based on the original Doelling's (2001) model (after Trudgill et al., 2004). Present-day topography and wells included. B) Modified section after integrating seismic data and Ge's (1996) physical model.

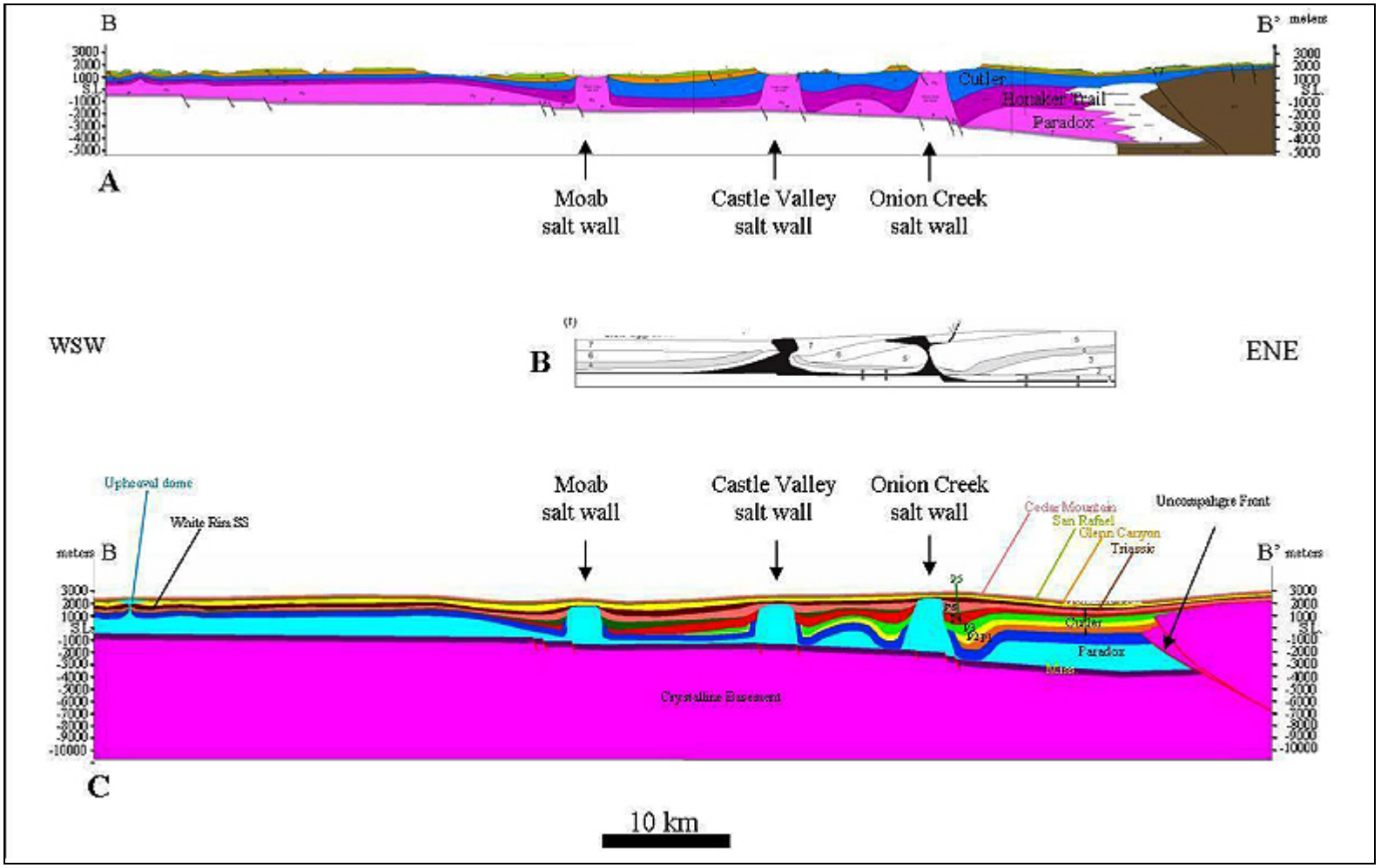


Figure 4. (A) Original cross section B by Doelling (2001). (B) Ge's (1996) final stage of physical model. (C) Modified cross section B after incorporating seismic data and Ge's (1996) physical model.

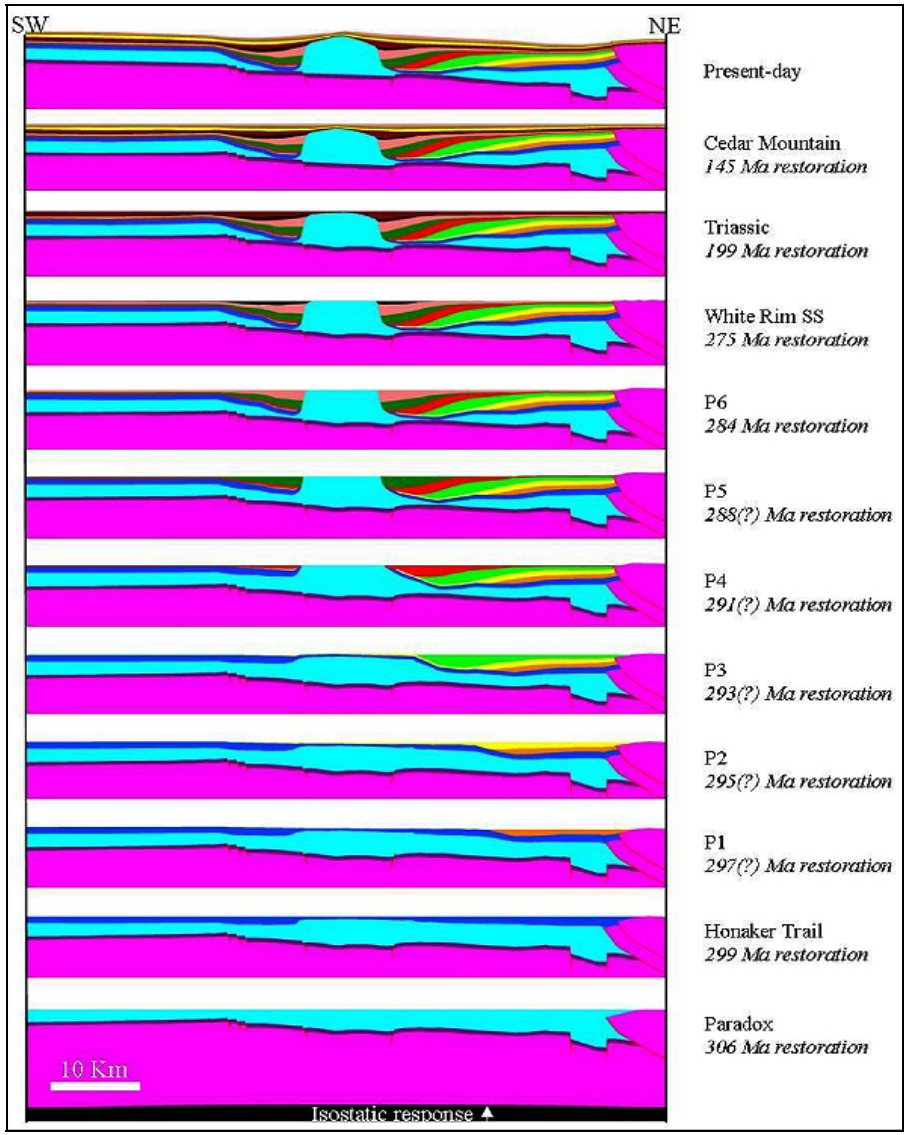


Figure 5. Reconstruction of regional cross section A. No vertical exaggeration.

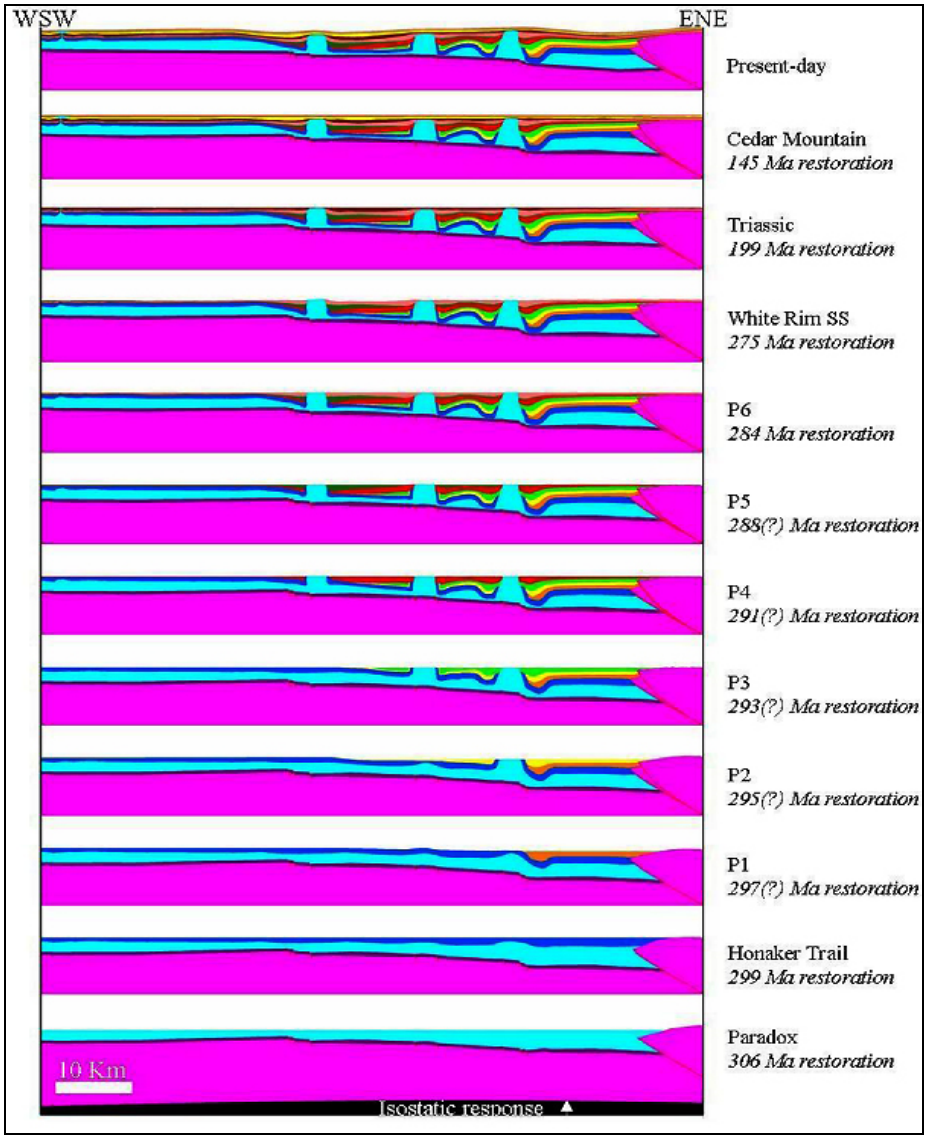


Figure 6. Reconstruction of regional cross section B. No vertical exaggeration.

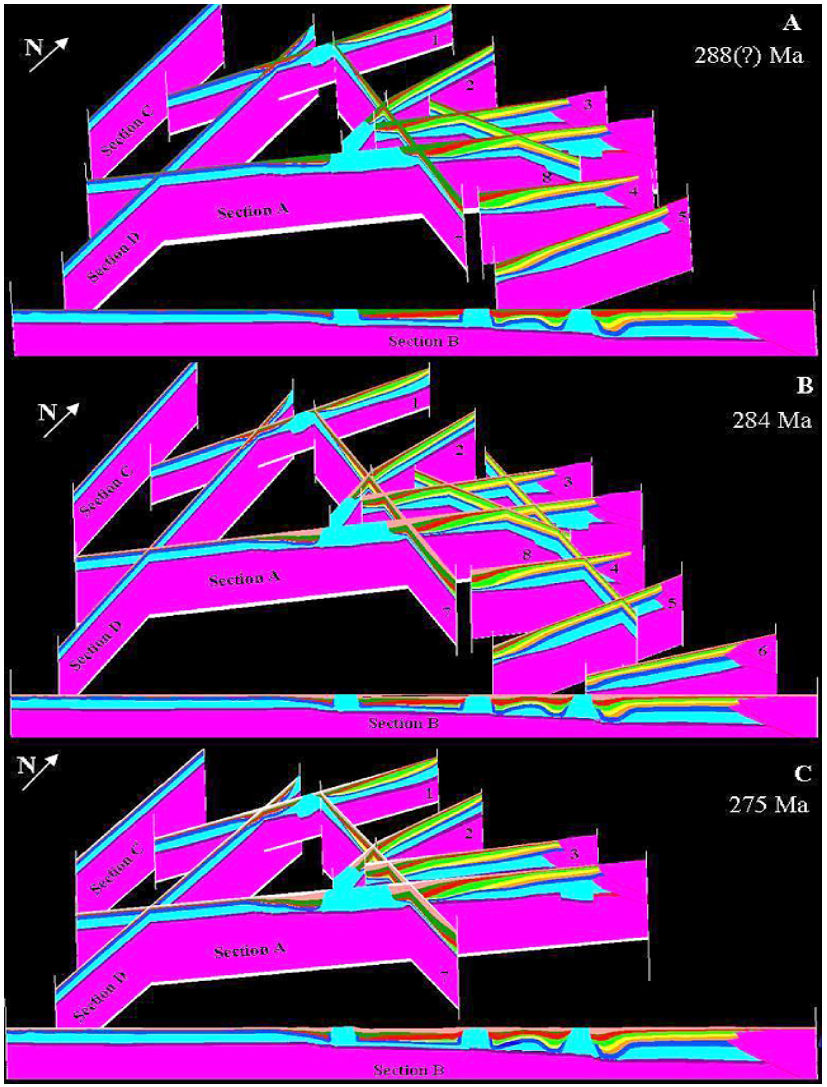


Figure 7. Structural restorations at the top of: A) Intra Cutler Unit P5 B) Cutler Group C) White Rim SS.

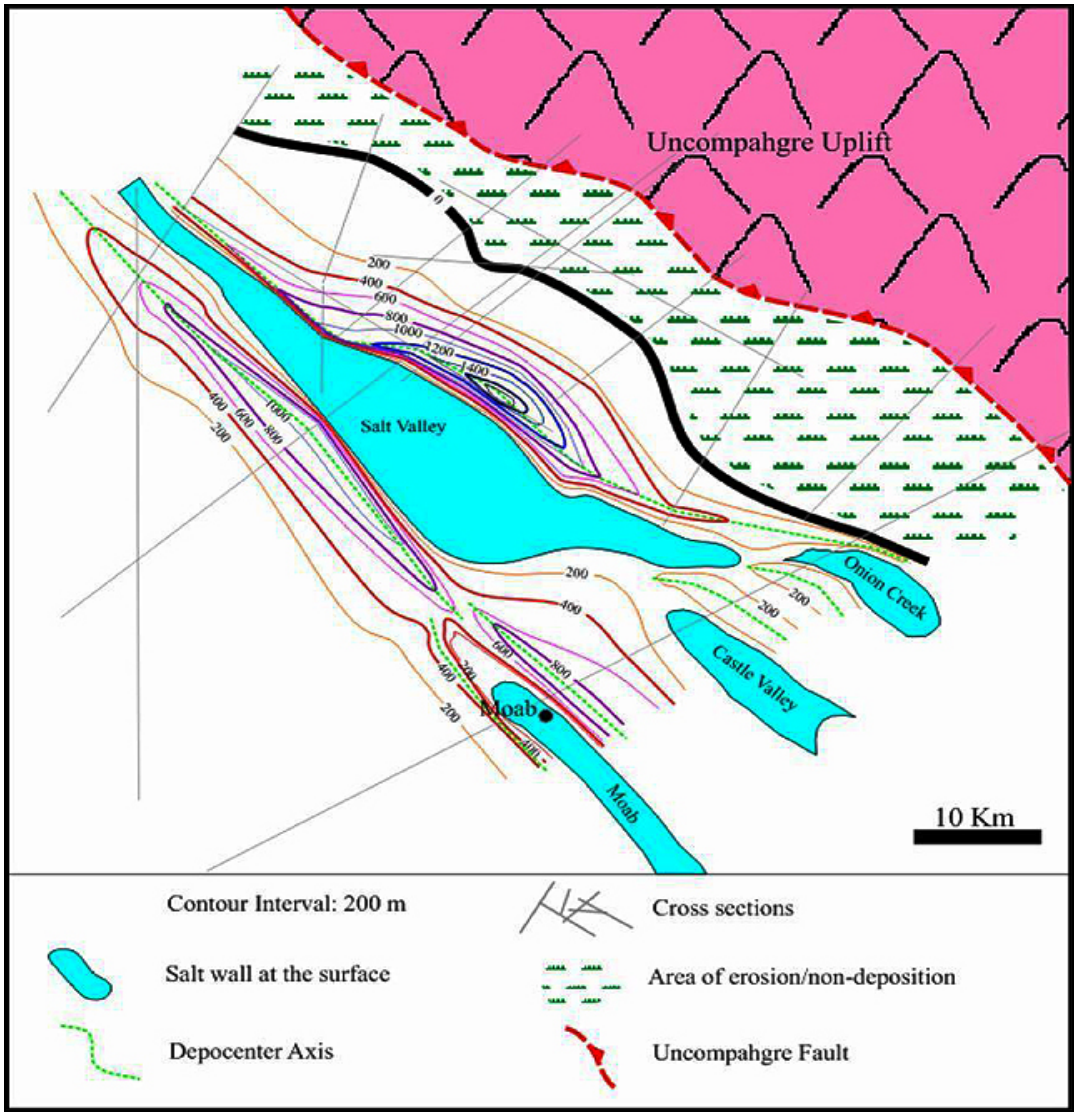


Figure 8. Paleogeographic and isopach map of the P5 Unit (Intra Cutler).

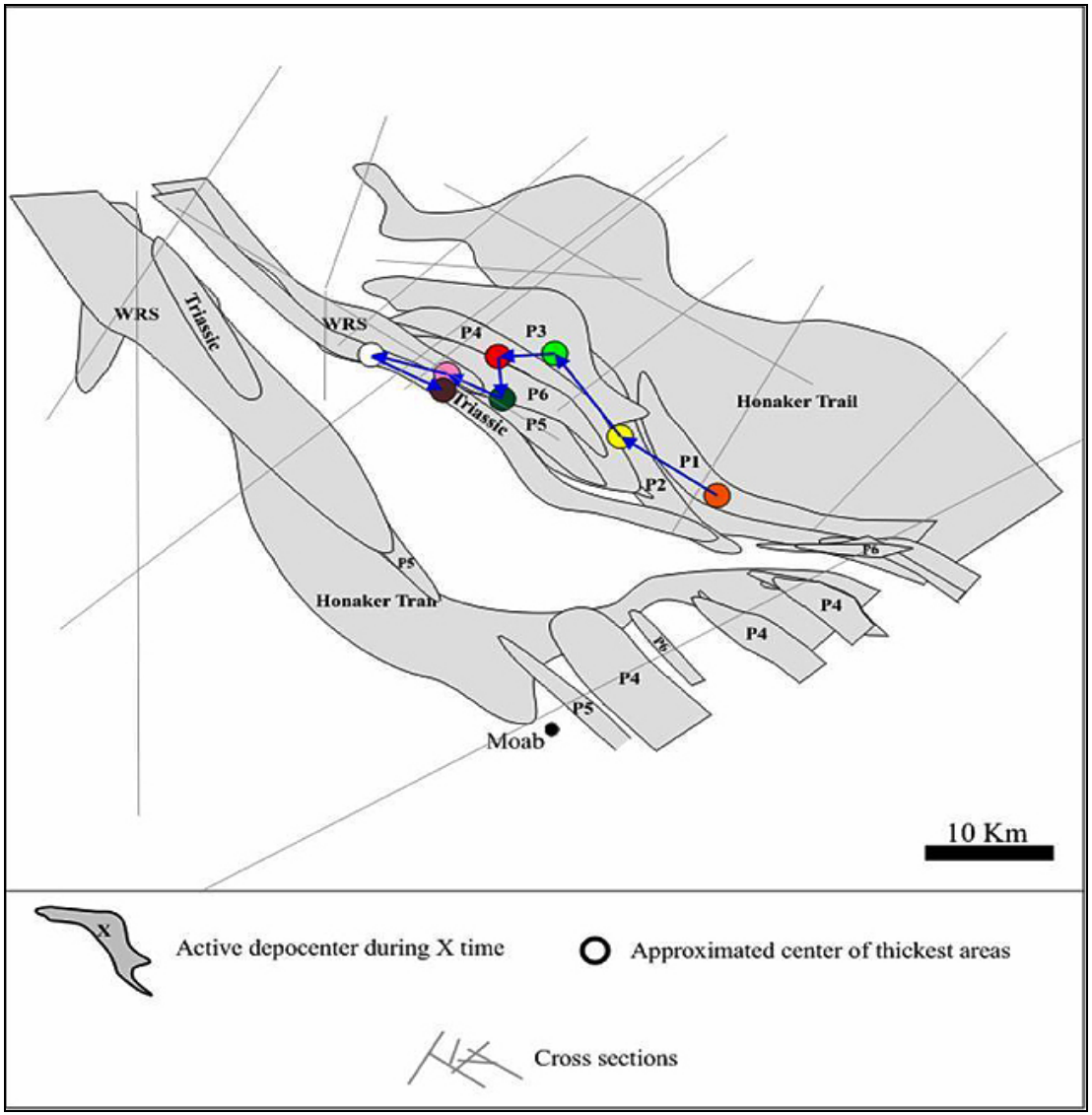


Figure 9. Depocenter migration along the east side of the Salt Valley anticline.

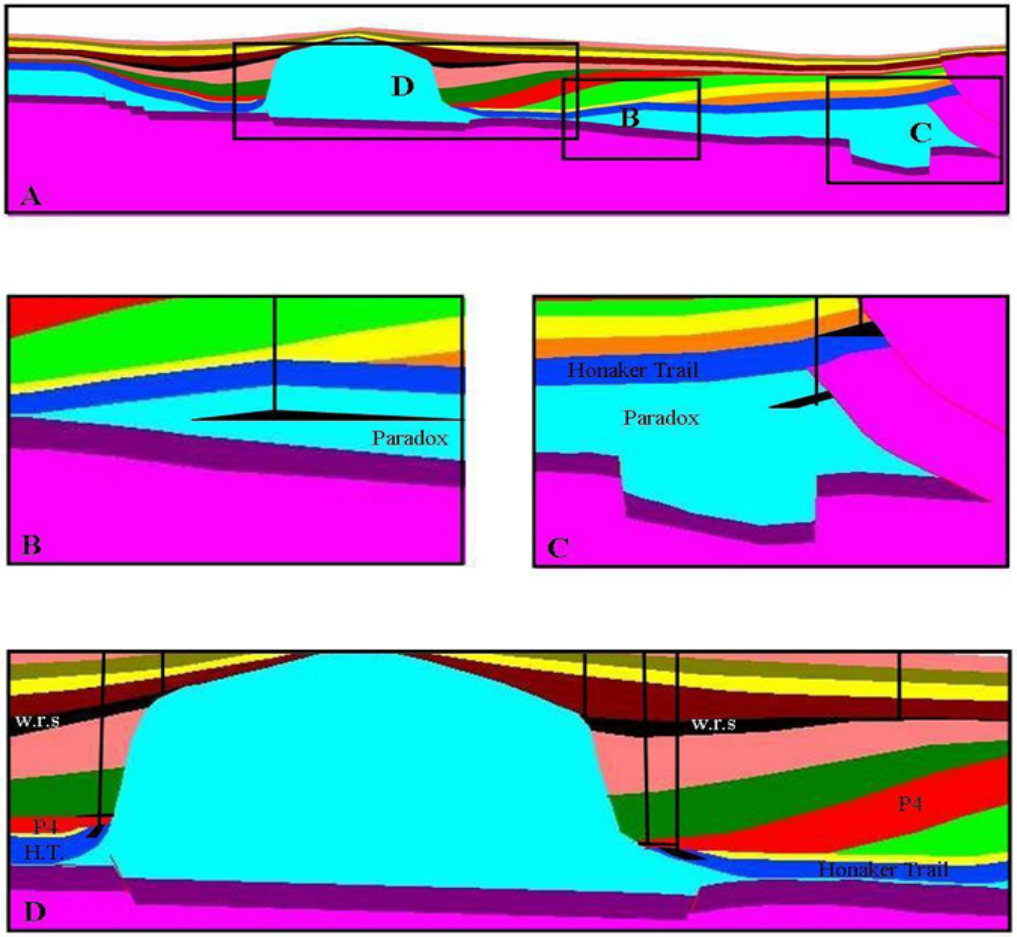


Figure 10. Exploration potential. A) Index section. B) Paradox carbonates. C) Sandstones In Honaker Trail and Paradox, derived from eroded Mississippian previously on top of Uncompahgre. D) Karstified carbonates in Honaker Trail; sandstones in P4 derived from eroded Honaker Trail carbonates; White Rim Sandstone (w.r.s.) onlaps (against salt wall and Cutler).

**Relevant results of the present study include:**

- Based on clinoforms observed in seismic data, the stratigraphic framework of the proximal Cutler Group in the northern Paradox Basin is that of progradational patterns (P1-P6) that progressively onlapped basinward (to the southwest) from the Uncompahgre Uplift, causing the underlying salt to flow in the same direction.

- Under this scenario, the easternmost Onion Creek salt wall was the first structure to start growing, the Castle Valley salt wall was the second, and the Moab salt wall located to the west was the last one.

- By Honaker Trail time (Missourian-Virgilian) the salt system was already active, as indicated by thinning of this unit towards the Salt Valley salt wall. Deposition associated to salt mobilization was active until the end of Chinle time, indicating that the salt system was active during a period of ~100 m.y.

- During the early progradational stages (P1-P3), the distal part of the Paradox Basin was under erosion and/or nondeposition. So, in this part of the basin it is likely that a nondepositional hiatus between the Honaker Trail Formation and the overlying Cutler Group developed.

- Mobilized salt within the Paradox Formation is heterogeneous. To the east of the Onion Creek salt wall, seismic data suggest that there was no salt evacuation at all between the adjacent depocenter and the Uncompahgre Uplift. Meanwhile to the east of the Salt Valley salt wall, the proportion of mobile salt decreased progressively, but not abruptly nor totally, towards the Uncompahgre Uplift.

- The P1 depocenter for the Salt Valley was the same as for the Onion Creek. By P2 time, there were separate depocenters for each salt wall, and after that the Salt Valley depocenters kept migrating initially northwest (P1 to P3) and then west (P3 to P6).

- The Salt Valley and Onion Creek salt walls are linked, as suggested by their surface bending geometries, which were inherited by the geometry of the preexistent adjacent depocenters.

- The first complete evacuation of salt associated with the Salt Valley salt wall occurred at the end of Cutler deposition and to the east of the wall. Later, this weld zone would expand radially, until the end of Chinle time when the present-day configuration of welds was reached on both flanks.

• Salt area, which is equal to the integrated thickness, in regional cross sections diminished by around 30% from the original depositional area. This assumes, as a first approximation, no movement of salt in or out of the plane of the cross sections. It is likely that most of salt area decrease was caused by dissolution, because salt was exposed at the surface for more than 20 million years.

• The highest rates of sediment accumulation, salt wall growth, salt evacuation (in welded areas), salt area decrease, and subsidence occurred during Cutler time, when the Uncompahgre Uplift was most active.

• Depending on the seismic data quality, it is possible to see how locally, the Paradox, Honaker Trail and Cutler units may onlap onto the Uncompahgre Uplift. These areas correspond to the wedge-top zone of the foreland basin, although for most of the Uncompahgre Front, post-depositional deformation and cannibalization reincorporated those sediments into the active depositional regime in the foredeep.

• Based on this study, a number of different kinds of play concepts can be considered for oil exploration: carbonate-derived sandstones within the Paradox and Honaker Trail formations against the Uncompahgre Uplift, karstified carbonates in the Honaker Trail Formation adjacent to the salt walls, carbonate-derived sandstones in basal Cutler, adjacent to salt walls, and onlap of White Rim Sandstone against the Salt Valley salt wall and Cutler Group.

## References


Doelling, H.H., 2001, Geologic map of the Moab and eastern part of the San Rafael Desert 30’ x 60’ Quadrangles, Utah Geological Survey Map 180, scale 1:100,000.

Frahme, C.W. and E.B. Vaughn, 1983, Paleozoic geology and seismic stratigraphy of the northern Uncompahgre Front, Grant County, Utah, *in* J.D. Lowell and R. Gries, eds., Rocky Mountain Foreland Basins and Uplifts: Rocky Mountain Association of Geologists, p. 201-211.

Ge, H., 1996, Kinematics and dynamics of salt tectonics in the Paradox Basin, Utah and Colorado: field observations and scaled modeling: Ph.D. thesis, University of Texas at Austin, Austin, Texas, 317 p.

Trudgill, B.D., N. Banbury and J.R. Underhill, 2004, Salt evolution as a control on structural and stratigraphic systems: northern Paradox foreland basin, SE Utah, USA, in GCSSEPM 24th Annual Research Conference.