Migration of Dynamic Subsidence Across the Late Cretaceous U.S. Western Interior Basin in Response to Farallon Plate Subduction*

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Abstract

The Cretaceous Western Interior Basin is generally thought of as a foreland basin because of the asymmetric westward-thickening sediment wedge and its relationship to the Sevier thrust belt along its western margin. However, flexural backstripping results document clearly that only along a narrow band, about 120 - 180 km wide, directly in front of the thrust belt, was the subsidence driven by the load of the Sevier thrust belt. Backstripped and decompacted cross sections of the Upper Cretaceous succession across central Utah and Colorado and southern Wyoming reveal a component of continuously evolving long-wavelength residual subsidence, characterized by an initial maximum subsidence in the west and transforming into a subsiding “trough” that migrated eastward over time in perfect synchrony with the west-to-east passage of the Farallon slab, as reconstructed from tomography based on quantitative inverse models. This subsidence component is additive to well-understood subsidence driven by the thrust belt and associated sediment and water loads.

The new residual subsidence data permit rigorous testing of existing geodynamic models, and reveals that the residual subsidence is of dynamic topographic nature and that the major driver behind the Western Interior Basin was subduction of the Farallon plate. The subduction created buoyancy-induced mantle flow with a downward drag on the crust. Moreover, regional variations in subsidence rates suggest a possible deficit of negative buoyancy (mantle loading) inside the slab beneath Colorado, supporting the hypothesis that a thick flat slab beneath Colorado represents a subducted oceanic plateau. Outside this plateau, as for example in Wyoming, the normal thickness of the subducted plate would cause greater subsidence.

Reconstructed subsidence profiles across Utah, Colorado and Wyoming all demonstrate variations in subsidence on a spatial scale of about 100 km after about 80 Ma. This spacing is the typical length scale of the subsequent Laramide basins and ranges. These short wavelength 'spikes' in the broad dynamic subsidence profiles, therefore, are thought to reflect the onset of Laramide-style uplifts at depth.

Overall, this paper documents how the Cretaceous stratigraphy records the timing, patterns and position of underlying mantle processes during Farallon slab subduction.

Selected References

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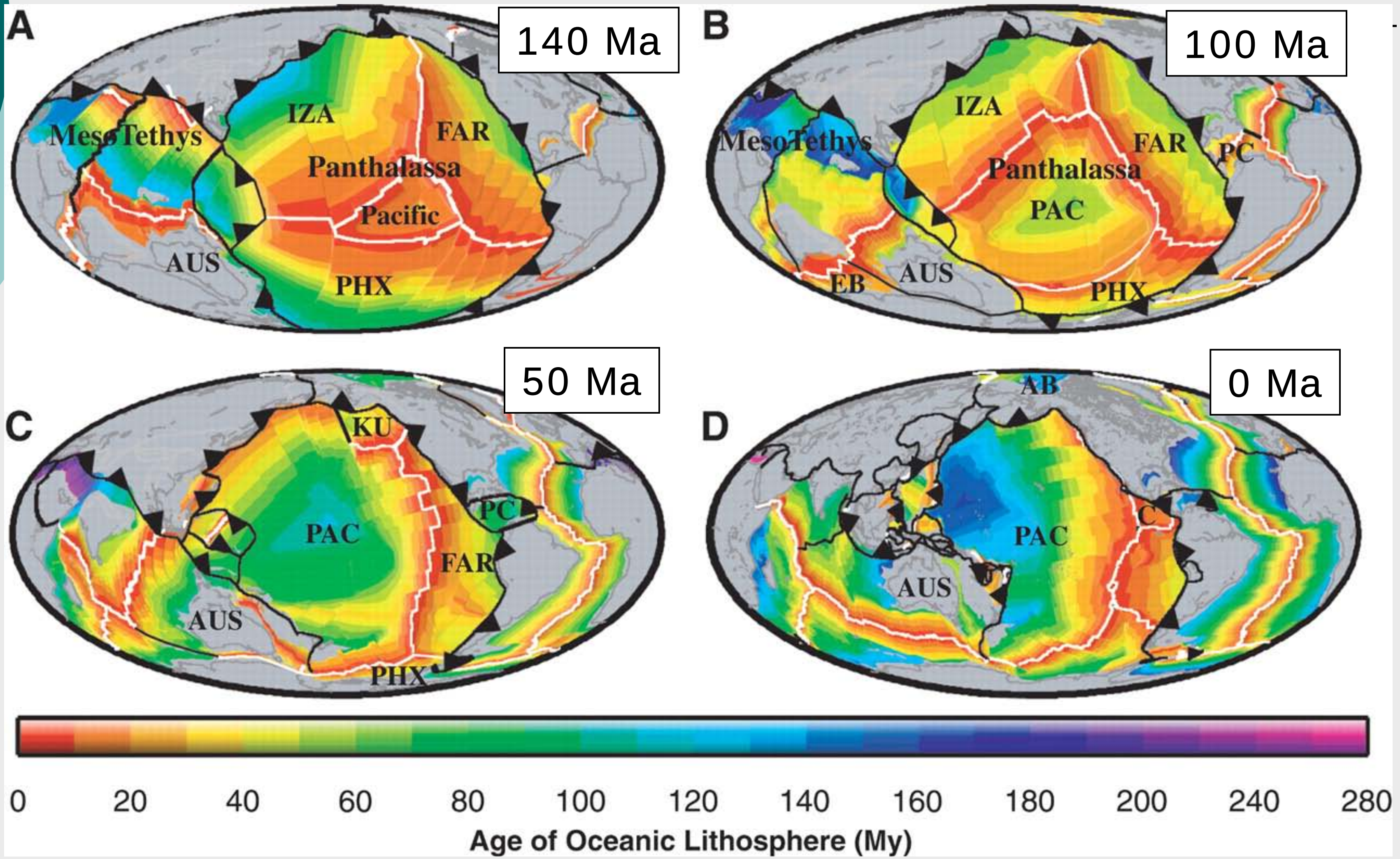
The Main Points

- Dynamic topography above the subducting Farallon Plate created the Cretaceous Western Interior Seaway, with an overprinting of a thrust-belt flexural foreland basin along its western margin
- The specific Cretaceous ‘sub’-basins migrated eastward tracking the crest of an inferred oceanic plateau slab within this plate
- This is the first time that lateral basin migration related to slab movement has been documented

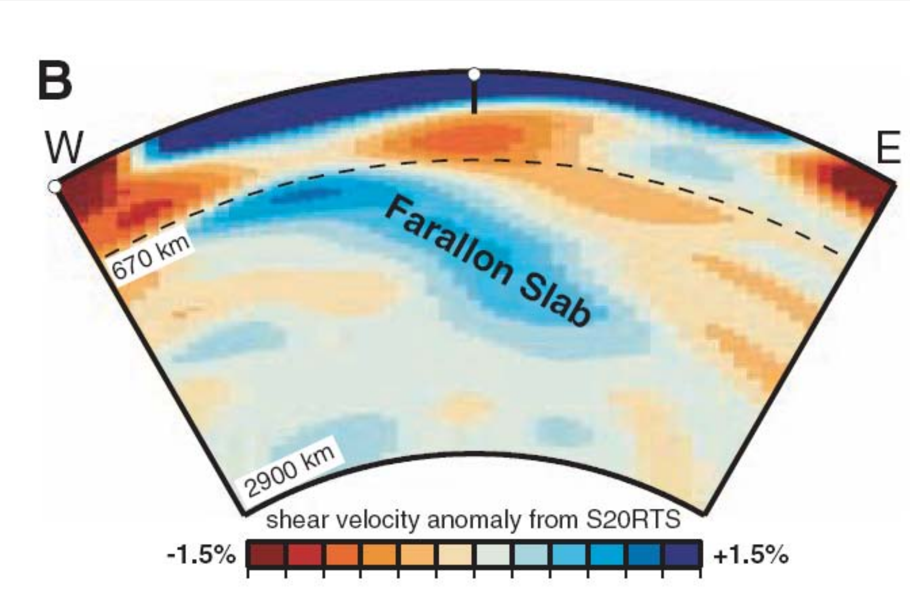
The Migration of the Farallon Plate

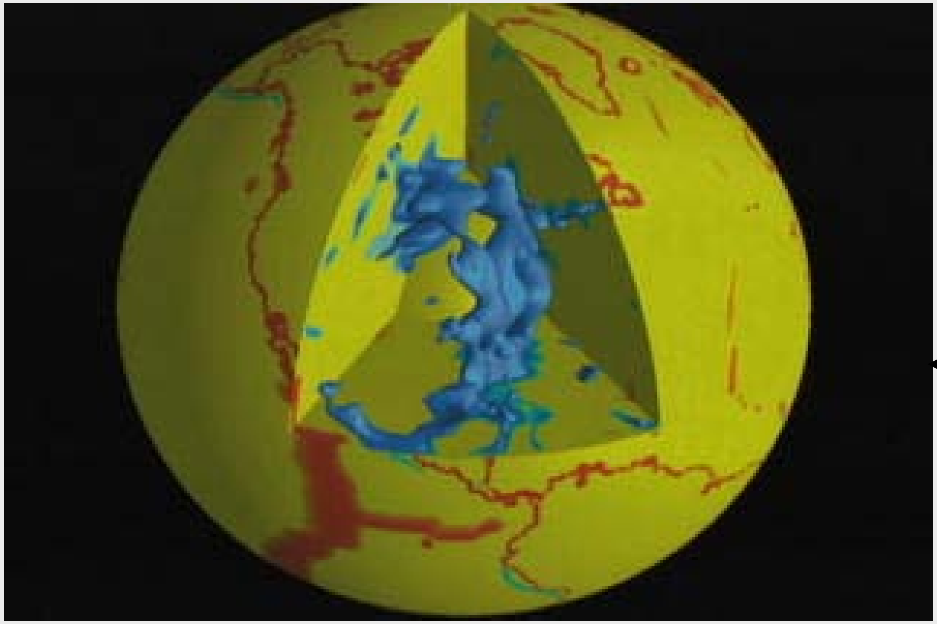


R. D. Muller et al., 2008

The Deep Remnants of the Farallon Plate Today

2D Tomographic Expression of the Farallon Plate Today →

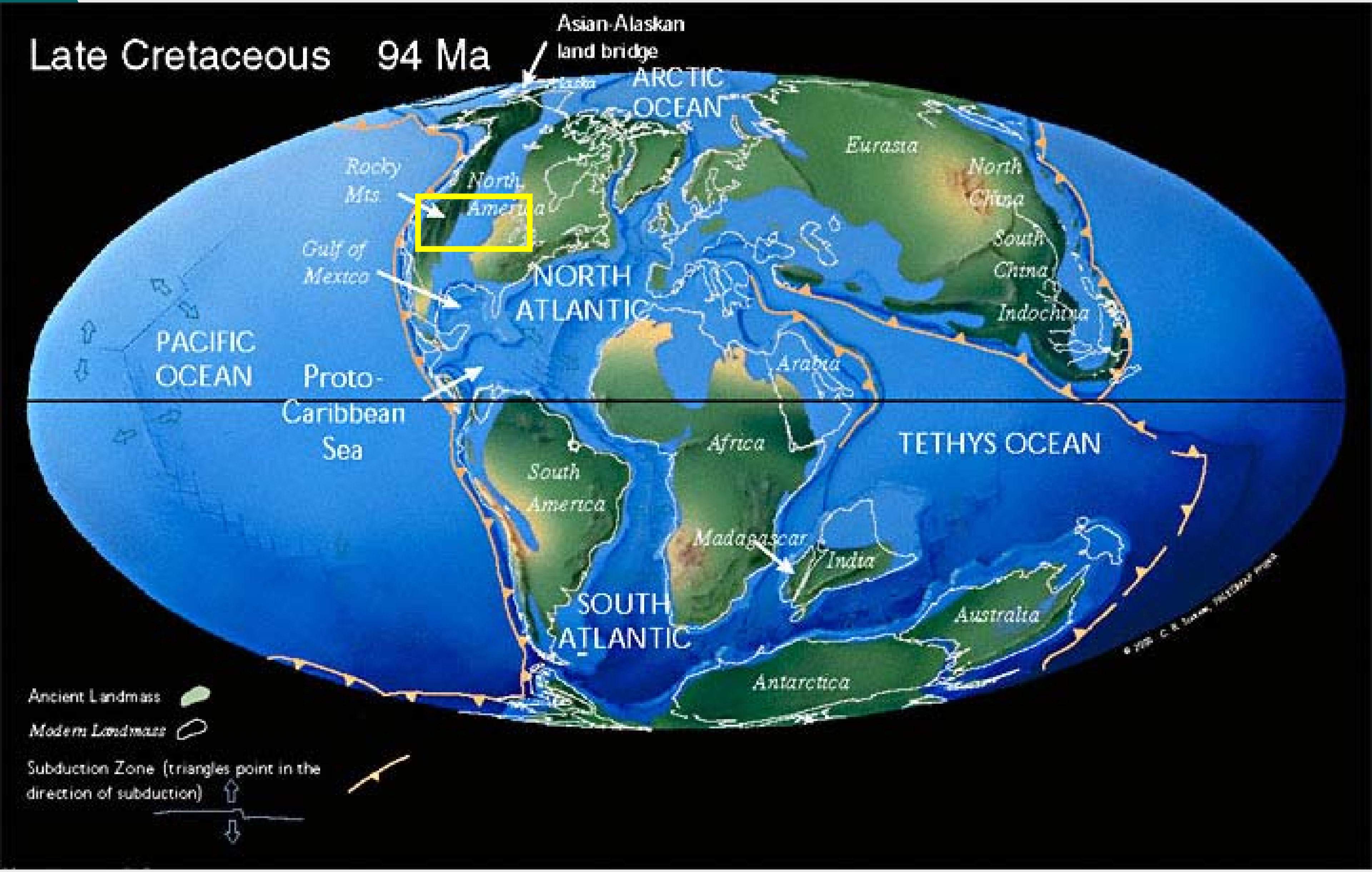




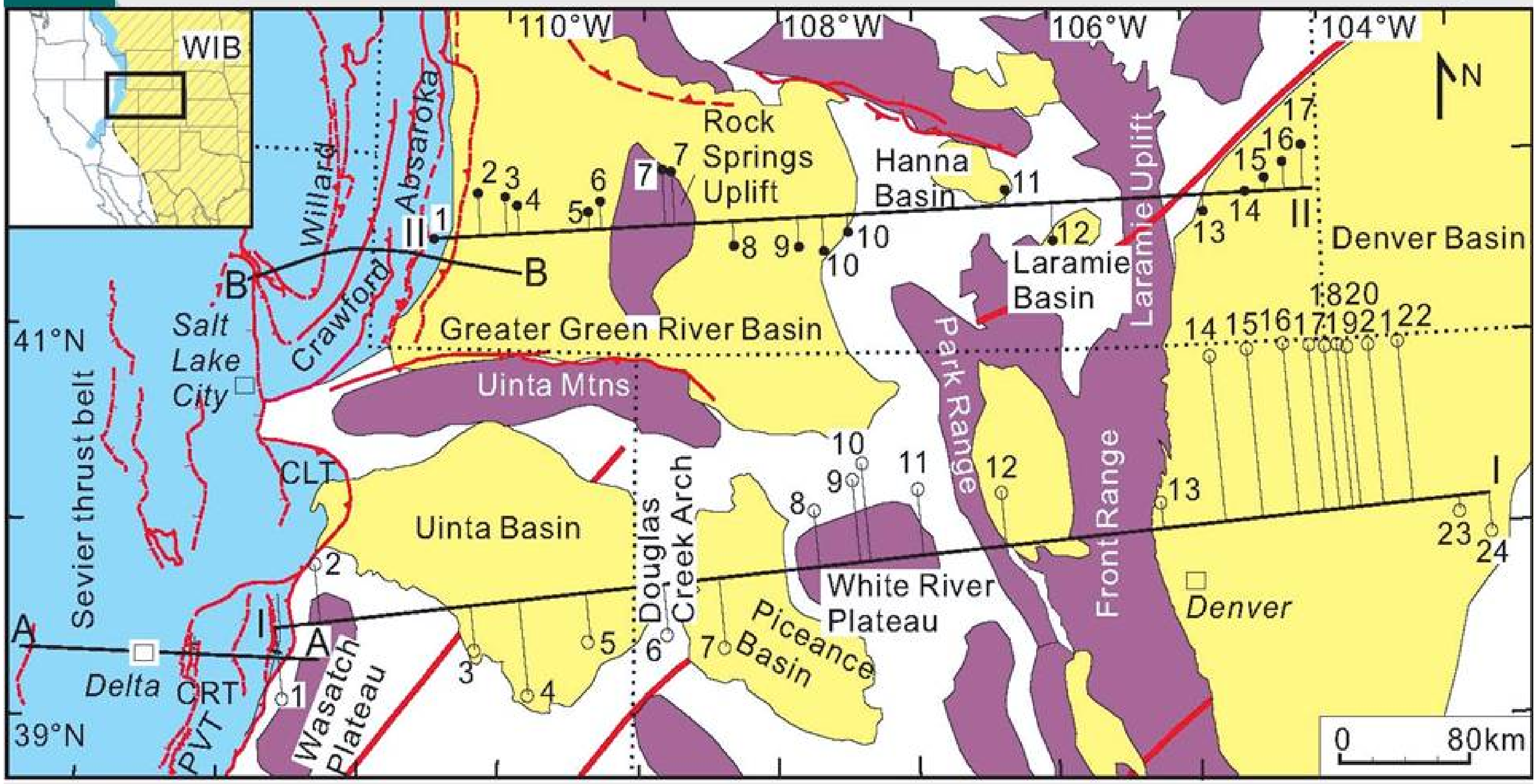
← Model of Farallon Plate Today – from 3D Tomography

Web site of Hans-Peter Bunge, Ludwig Maximilian University, Munich

Cenomanian Global Paleogeography

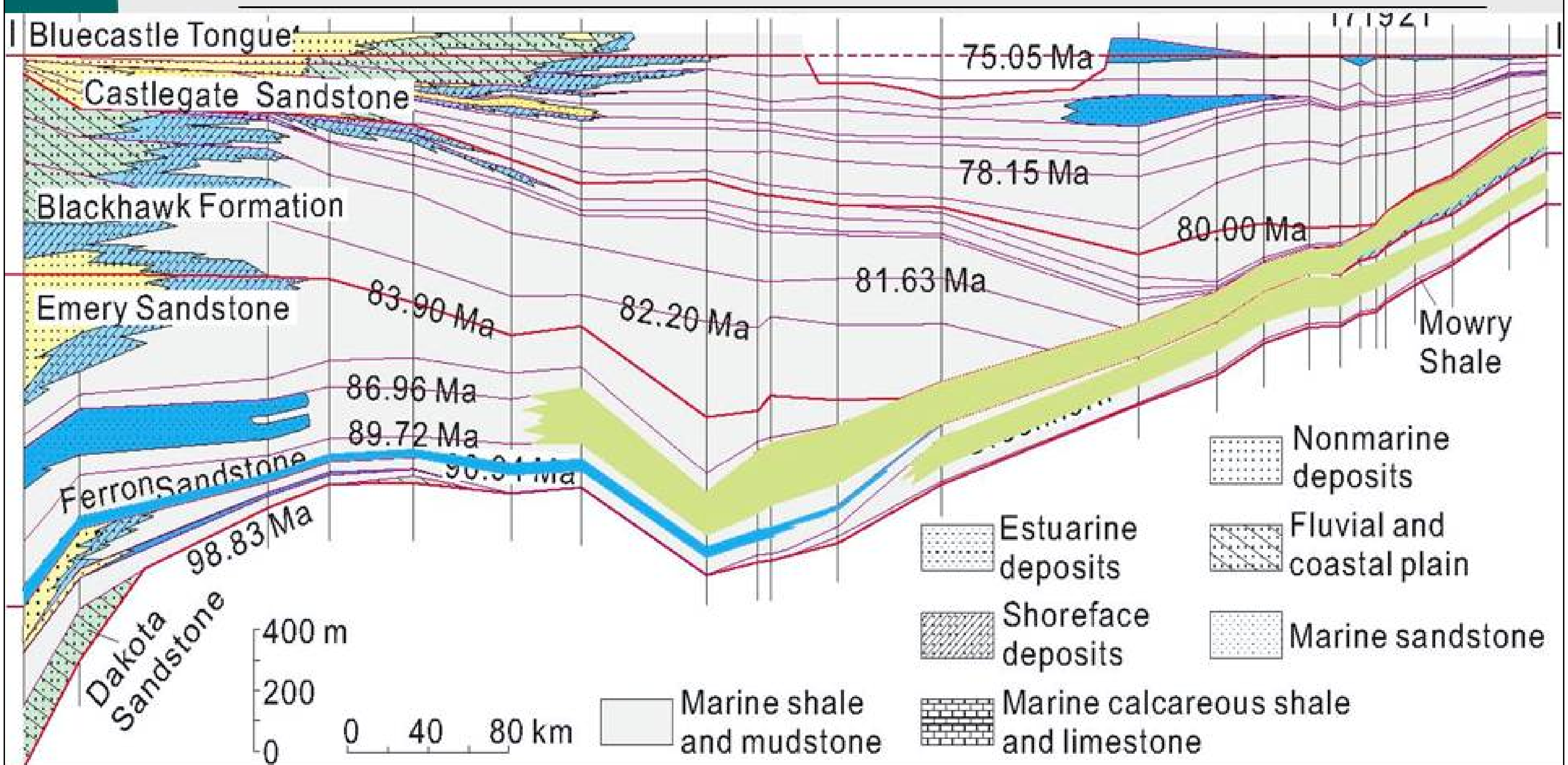


The Cross Sections



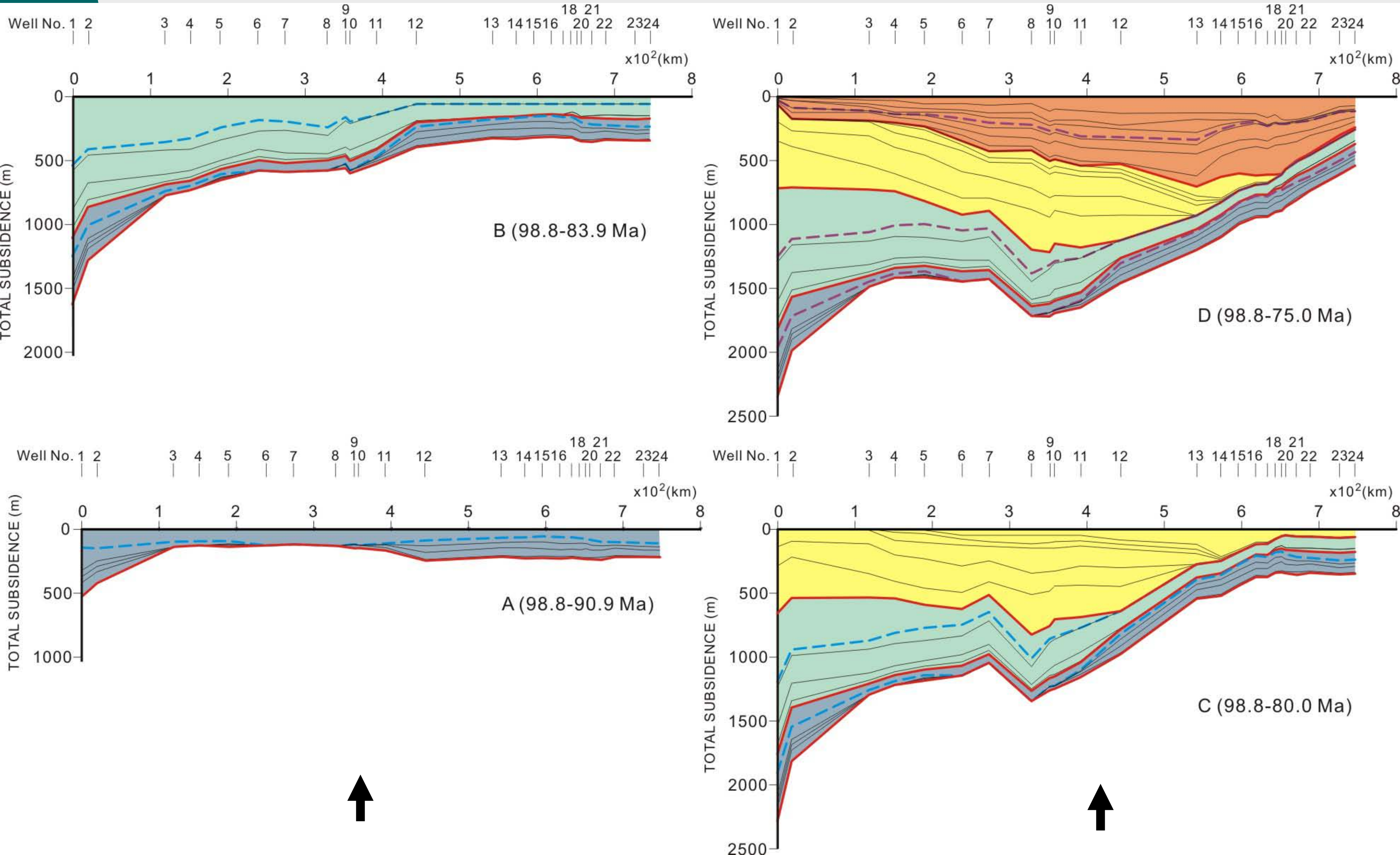
Notes by Presenter: Figure 1. A segment of the Sevier thrust belt and its associated basins in the central Rocky Mountain area of USA, showing locations of I-I and II-II (UT-CO and WY stratigraphic sections), and A-A and B-B (structural sections across eastern Sevier thrust belt in central Utah and northern Utah-westernmost Wyoming). CRT: Canyon Range thrust; PVT: Pavant thrust; CLT: Charleston thrust; WIB: Western Interior Basin.

UT-CO Section, 99 – 75 Ma

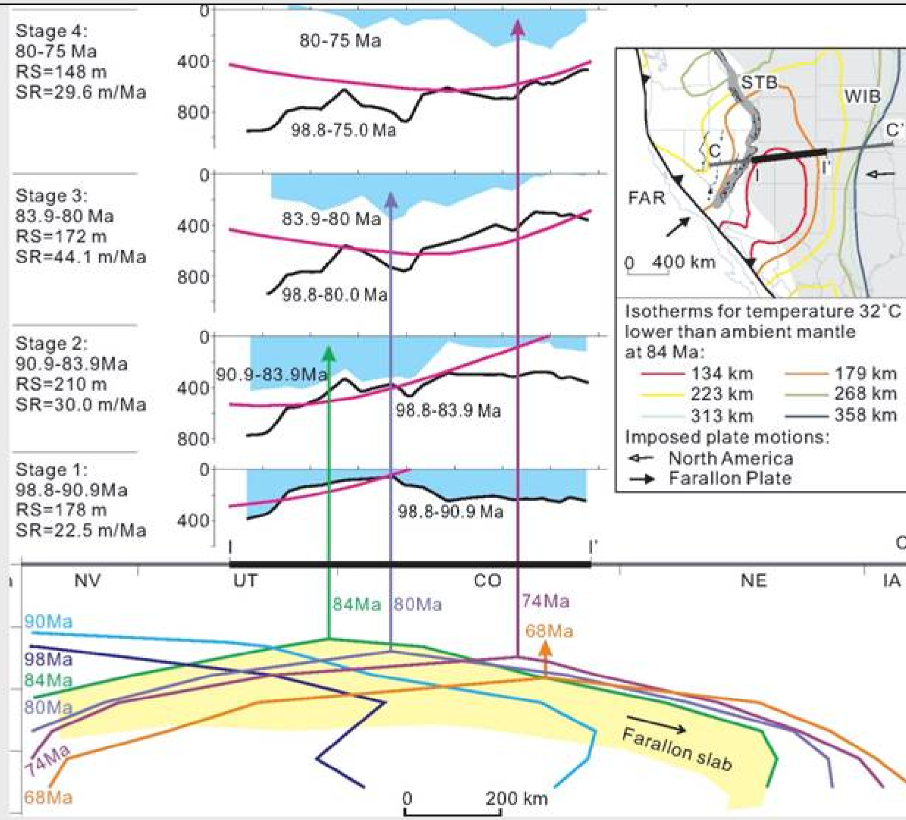


Notes by Presenter: Figure 2. Regional Upper Cretaceous stratigraphy across central Utah and Colorado based on 24 well logs along Section I-I in Figure 1.

Total Subsidence Across UT-CO from 99 to 75 Ma

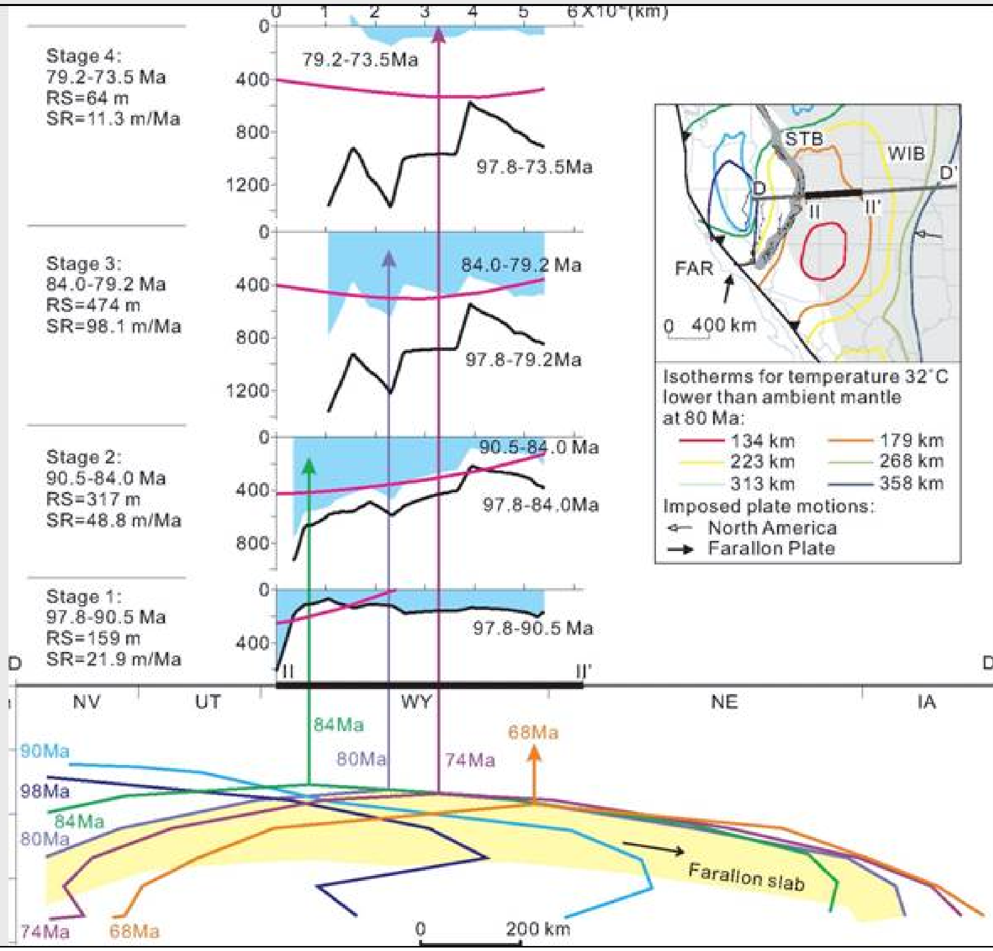


UT-CO Dynamic Subsidence Migration
99 – 75 Ma



Notes by Presenter: Figure 3. A-D show the profiles of cumulative (black curves) and incremental (blue-colored bands) residual subsidence from backstripped Upper Cretaceous strata, with predicted cumulative dynamic subsidence (pink curves) from the inverse convection model of Liu et al. (2008), for different time intervals across central Utah and Colorado (Section I-I in Figure 1, heavy dark line in E; RS: incremental residual subsidence averaged over the whole profile; SR: averaged incremental subsidence rate). E. The inset map showing main tectonic elements: Sevier thrust belt (STB), Western Interior Basin (WIB; shaded), Farallon plate (FAR), and the depth to the upper boundary of the reconstructed Farallon slab at 84 Ma (colored contours), based on isotherms for temperature 32° C lower than ambient mantle (Liu et al., 2008). F shows the calculated upper boundary (colored lines) of the modeled Farallon slab at different times (along Section line C-C of the inset map E) based on the inverse convection model (Liu et al., 2008). Modeled slab at 84 Ma is highlighted in yellow. Vertical arrows indicate locations of the slab crests through time and space across WIB. NV: Nevada; UT: Utah; CO: Colorado; NE: Nebraska; IA: Iowa.

ID – WY Dynamic Subsidence Migration 99 – 75 Ma



Notes by Presenter: Figure 4. A-D show the profiles of cumulative and incremental residual subsidence from backstripped Upper Cretaceous strata, with predicted cumulative dynamic subsidence from the inverse convection model, for different time intervals across southern Wyoming (Section II-II in Figure 1, heavy dark line in E). E. The inset map showing main tectonic elements and the depth to the upper boundary of the reconstructed Farallon slab at 80 Ma. F shows the calculated upper boundary of the modeled Farallon slab at different times (along Section line D-D of the inset map E). Modeled slab at 80 Ma is highlighted in yellow. WY: Wyoming. Labels are equivalent to those in the caption for Figure 3.

Conclusions

Backstripping and decompaction of Late Cretaceous strata from well logs across Utah, Colorado and Wyoming reveals that the long-wavelength subsidence of the Western Interior Basin is characterized by a zone of rapid subsidence flanked by slower-subsiding shoulders.

These zones move eastward over time at a rate equal to the relative migration rate of the Farallon slab, and they are positioned with the zone of maximum subsidence right above shallowest crest of the slab.

Consequently, we conclude that the primary driver for the regional subsidence of the Cretaceous Western Interior basin was the gravitational pull of the sinking slab, also known as dynamic subsidence.

Furthermore, the study has also identified a deficit of negative buoyancy (gravitational pull) by the slab to the south of Wyoming, supporting the hypothesis that this southern part of the thickened slab represents a subducted oceanic plateau.