Contrasting modes of cyclicity, variability and noise in Triassic-Jurassic basin contexts correlate with pCO_2 levels: Eastern North American Rift Basins vs. Colorado Plateau alluvial plain.

Poster

Paul E. Olsen[1], Jessica Hope Whiteside[2], Morgan F Schaller[3], Jonathan Stine[4], Christopher J Lepre[5], David Tibbits[6], Francisco Apen[7], Clara Chang[1], Sean Kinney[6,1]

[1]Lamont-Doherty Earth Observatory of Columbia University; [2]San Diego State University; [3]Rensselaer Polytechnic Institute; [4]University of Minnesota Twin Cities; [5]Bowling Green State University; [6]Rutgers University; [7]Northern Arizona University

Author details

Abstract

Eastern North American Triassic-Early Jurassic rift basins contain predominantly lacustrine and inferred eolian (loess) strata during times of high subsidence, with significant fluvial strata mostly deposited during times of relatively low subsidence rates. In contrast, Triassic-Early Jurassic strata of the Colorado Plateau were deposited on a largely westward-sloping continental alluvial plain system, with mainly fluvial and aeolian (dune and loess) strata, rare lacustrine components, and minor marine incursions. The alluvial plain deposits have accumulation rates an order of magnitude lower than those of the rifts. Both fluvial and lacustrine sequences in both depositional regimes display consistent facies and XRF-chemistry modes that correlate with pCO_2 (pedogenic proxy) levels. High pCO_2 mode correlates with high variability: lacustrine rift sequences show extreme lake level fluctuations and a regular hierarchy of orbital-paced periodicities, while through-going fluvial systems are noisy and erratic. In low pCO_2 mode, facies are more regular: lacustrine rift sequences have muted lake level cyclicity but very regular thickness periodicities, perhaps with major loess components. Low pCO_2 mode rift fluvial systems are monotonous in terms of facies. Contemporaneous and older (hypothesized low pCO_2-mode) Colorado Plateau alluvial plain deposits tend to be very laterally continuous, cyclical sequences, also inferred to be orbitally paced. Thus, in broad strokes, the most dramatically cyclical lacustrine formations of the rifts, such as the Lockatong and lower-to-middle Passaic Fms, correlate in time with the fluvial lower to middle Chinle Fm of the Colorado Plateau (neglecting salt tectonic sub-basins), deposited in high-pCO_2 mode. In contrast, lacustrine intervals with the least visually perceptible cyclicity, such as the upper Passaic Fm, correlate in time with the upper Chinle, the most visually cyclical part of the Colorado Plateau alluvial plain, deposited in low-pCO_2 mode. New dates and cores from the Colorado Plateau are needed to test these process-related hypotheses and their inferred astronomical pacing. We thank the Heising-Simons Foundation for their support and the Navajo Nation for access to oitcrops.

Colorado Plateau & CPCP

Newark-Hartford Basins & APTS

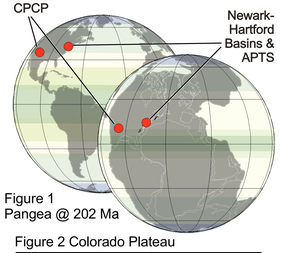


Figure 1
Pangea @ 202 Ma

Figure 2 Colorado Plateau

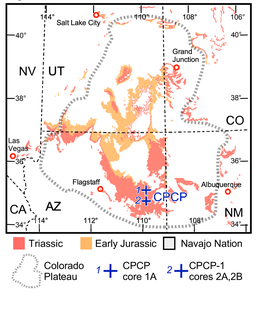
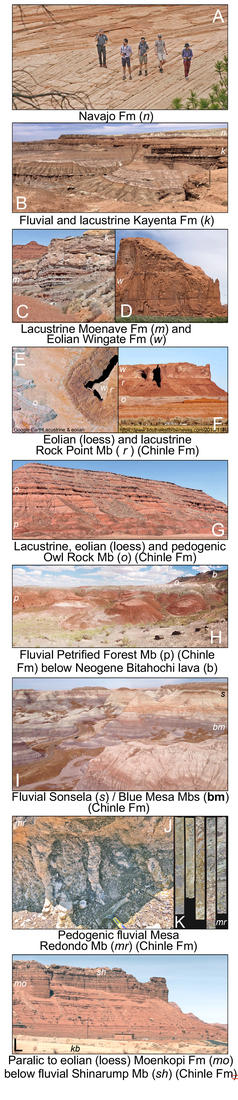


Figure 3: Colorado Plateau Facies Vingettes



The point of this presentation is to outline a relationship between variability in Triassic-Early Jurassic sedimentary facies in contrasting tectonic environments — the Colorado Plateau alluvial plain (Figs. 1-4) and the Eastern US rift basins (Figs. 1, 6-9) — and pCO_2 (Fig. 6).

Colorado Plateau (Figs. 3-6)

Eolian dune sand and cyclically interbedded lacustrine carbonates (1) of the **Navajo Fm** (Fig. 3A) advanced time-transgressively to the southwest, interbedding with the partly cyclical fluvio-lacustrine facies of the **Kayenta Fm** (Fig. 3B) during a time of relatively low pCO_2 as the Colorado Plateau drifted into the arid belt (Fig. 7). A facies record of the Jenkyns Event (2,3) should be recorded in the sequence.

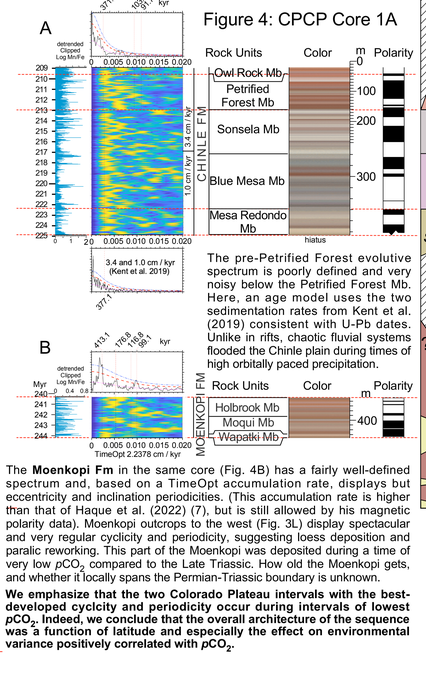
Lacustrine, but not obviously cyclical **Moenave Fm** (Fig. 3C) is laterally and temporally equivalent to eolian strata of the **Wingate Fm** (Fig. 3D) as well as the strongly cyclical, plausibly loess-dominated, **Rock Point Mb** of the Chinle Fm (4) (Fig. 3E, F). At least parts of the Moenave and Wingate were deposited during a time of very high pCO_2 generated by the Central Atlantic Magmatic Province (CAMP), which punctuated an otherwise downward trend in pCO_2 (Fig. 7A), while the Rock Point was deposited during low pCO_2, possibly just prior to the CAMP.

The striking cyclical, plausibly loessitic, partly lacustrine, and pedogenic **Owl Rock Mb** of the Chinle Fm (Fig. 3G) was deposited during a period of dropping pCO_2 and sedimentologically muted climatic variability. Both the Rock Point and Owl Rock Mbs could aggrade by loess deposition even without accommodation space during dry times.

Colorado Plateau Coring Project (CPCP) core 1A (5) (Fig. 4) recovered all of the largely fluvial **Petrified Forest Mb** of the Chinle Fm (Fig. 3H). It shows less facies variability than the underlying rest of the Chinle and was deposited during a distinct drop in pCO_2. There is however a trace of long eccentricity periodicity (Fig. 4A) based on XRF elemental data (6).

In contrast, the largely fluvial **Sonsela, Blue Mesa, and Mesa Redondo** (including Shinarump) Mbs of the Chinle Fm (Fig. 4I, J) are chaotic and were deposited during the most prolonged interval of very high pCO_2 of the Triassic.

Figure 4: CPCP Core 1A



The pre-Petrified Forest evolutive spectrum is poorly defined and very noisy below the Petrified Forest Mb. Here, an age model uses the two sedimentation rates from Kent et al. (2019) consistent with U-Pb dates. Unlike in rifts, chaotic fluvial systems flooded the Chinle plain during times of high orbitally paced precipitation.

The **Moenkopi Fm** in the same core (Fig. 4B) has a fairly well-defined spectrum and, based on a TimeOpt accumulation rate, displays but eccentricity and inclination periodicities. (This accumulation rate is higher than that of Haque et al. (2022) (7), but is still allowed by his magnetic polarity data). Moenkopi outcrops to the west (Fig. 3L) display spectacular and very regular cyclicity and periodicity, suggesting loess deposition and paralic reworking. This part of the Moenkopi was deposited during a time of very low pCO_2 compared to the Late Triassic. How old the Moenkopi gets, and whether it locally spans the Permian-Triassic boundary is unknown.

We emphasize that the two Colorado Plateau intervals with the best-developed cyclicity and periodicity occur during intervals of lowest pCO_2. Indeed, we conclude that the overall architecture of the sequence was a function of latitude and especially the effect on environmental variance positively correlated with pCO_2.

Figure 5 Section & Age.

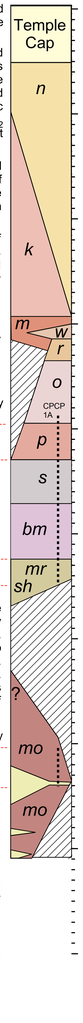
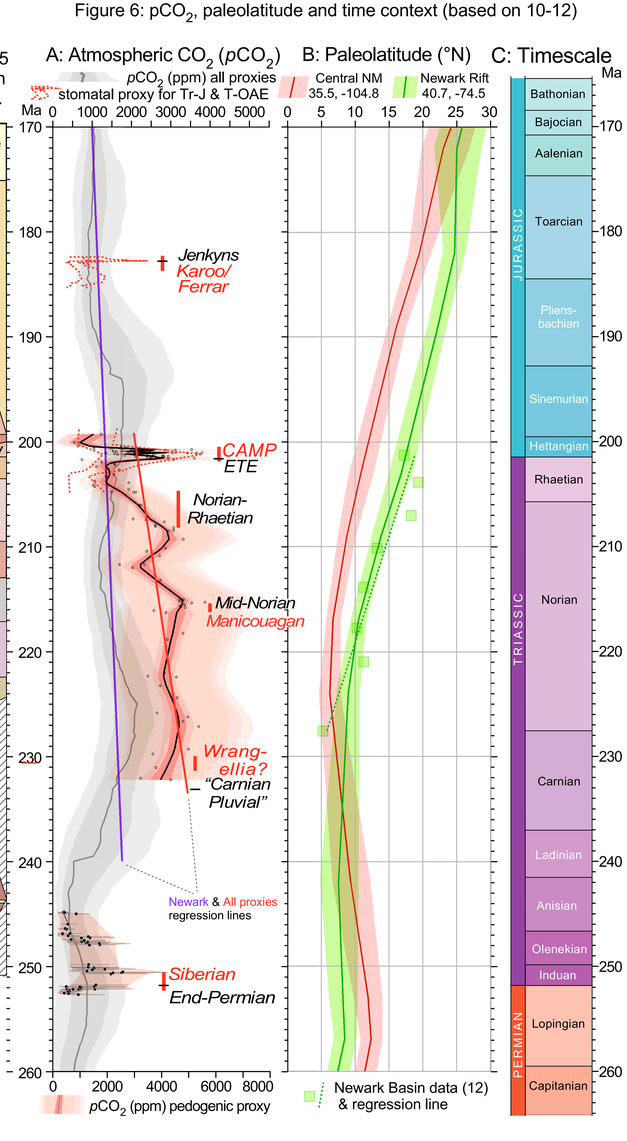


Figure 6: pCO_2, paleolatitude and time context (based on 10-12)

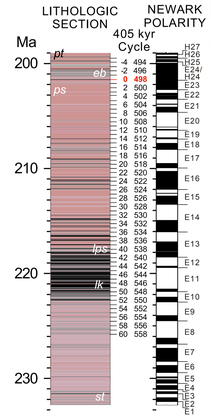


Newark-Hartford Rifts (Figs. 7-9)

The rather monotonous upper Portland Fm (Fig. 7, 8A) is fluvial and was deposited during a time of lower pCO_2 continuing the overall downward trend seen in the Late Triassic (Fig. 6A).

In contrast, the strata such at the **East Berlin Fm,** deposited during the high pCO_2 of the CAMP (Fig 8B, C; 9A) is dramatically cyclical and periodic with an age model based on U-Pb dates the CAMP-flows-themselves (13). Spectra are very well-defined and the accumulation rate can be extremely high (10-25 m/20ky) (14). This reflects high accommodation space in the rift.

Figure 7: Newark Hartford APTS (15)

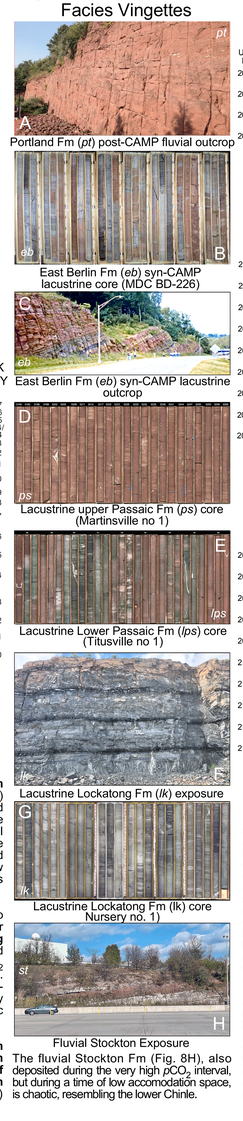


Conversely, upper **Passaic Fm** lacustrine strata (*ps* of Figs. 7, 8D) has extremely visually muted cyclicty, which nonetheless has the best resolved XRF elemental spectra of any part of the sequence (Fig 9B). The interval was deposited during the same time interval of low pCO_2 as the Owl Rock and is plausibly loess-dominated as well.

Very high amplitude cyclicity is also apparent in the middle and lower (lps) **Passaic Fm** and **Lockatong Fm** (Figs. 9E, G; 9C) deposited during the same very high pCO_2 interval as the lower Chinle. Although the spectra have well-defined frequency properties, they are noisier than the upper Passaic (Fig. 9B).

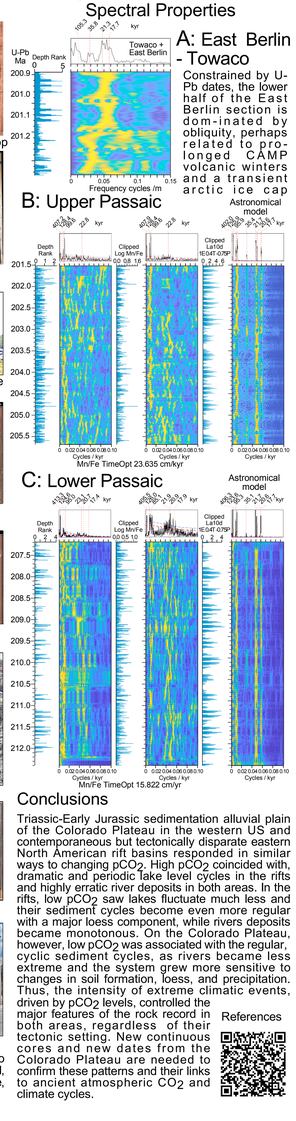
High pCO_2 resulted in high amplitude cycles because high precipitation filled a lake, instead of producing major rivers in line with recent climate modeling results. (16)

Figure 8: Newark - Hartford Facies Vingettes



The fluvial Stockton Fm (Fig. 8H), also deposited during the very high pCO_2 interval, but during a time of low accomodation space, is chaotic, resembling the lower Chinle.

Figure 9: Newark-Hartford Spectral Properties



Conclusions

Triassic-Early Jurassic sedimentation alluvial plain of the Colorado Plateau in the western US and contemporaneous but tectonically disparate eastern North American rift basins responded in similar ways to changing pCO_2. High pCO_2 coincided with, dramatic and periodic lake level cycles in the rifts and highly erratic river deposits in both areas. In the rifts, low pCO_2 saw lakes fluctuate much less and their sediment cycles become even more regular with a major loess component, while rivers deposits became monotonous. On the Colorado Plateau, however, low pCO_2 was associated with the regular, cyclic sediment cycles, as rivers became less extreme and the system grew more sensitive to changes in soil formation, loess, and precipitation. Thus, the intensity of extreme climatic events, driven by pCO_2 levels, controlled the major features of the rock record in both areas, regardless of their tectonic setting. New continuous cores and new dates from the Colorado Plateau are needed to confirm these patterns and their links to ancient atmospheric CO_2 and climate cycles.

References