Combining palaeontological and geochemical data to reconstruct environmental gradients: a case study from the Jurassic Sundance Seaway

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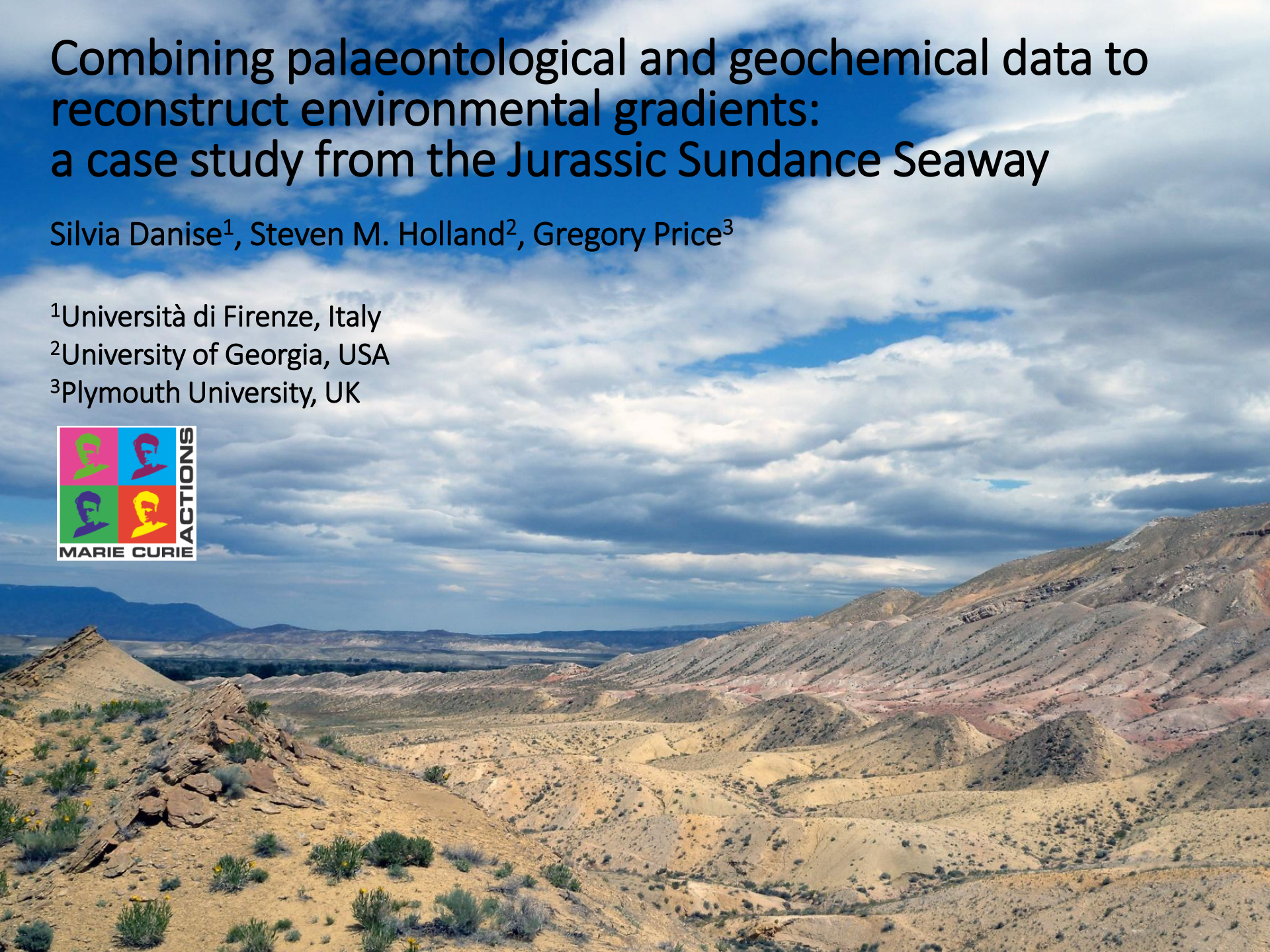
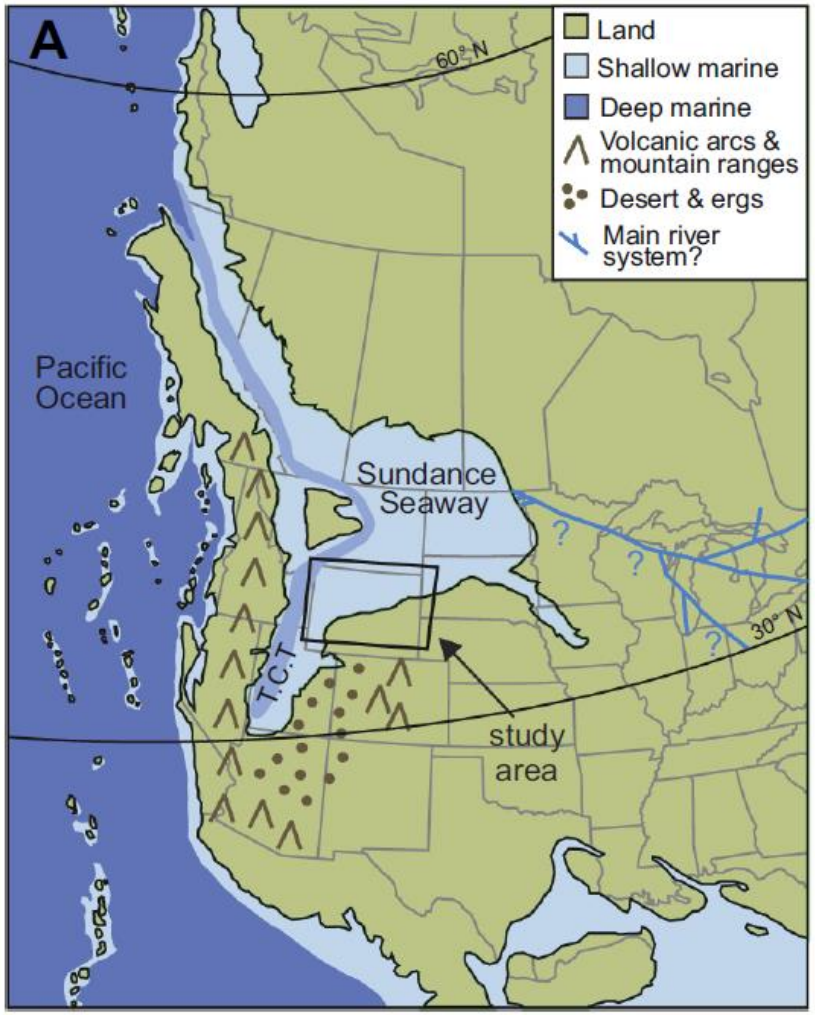


Introduction and aim

- Environmental gradients are among the primary drivers of change in ecological communities through time and space.
- However, what is rare are combined data sets of community composition and the environmental factors that may have caused ecological turnover, largely because many environmental variables are difficult to measure in the stratigraphic record.
- In this study we integrate quantitative abundance estimates of benthic macro-invertebrates with a multivariate dataset of geochemical proxies to potentially estimate the environmental drivers of faunal change through the 13 m.y. history of the Middle–Late Jurassic Sundance Seaway, western United States.



T.C.T. Tween Creek Through: foredeep

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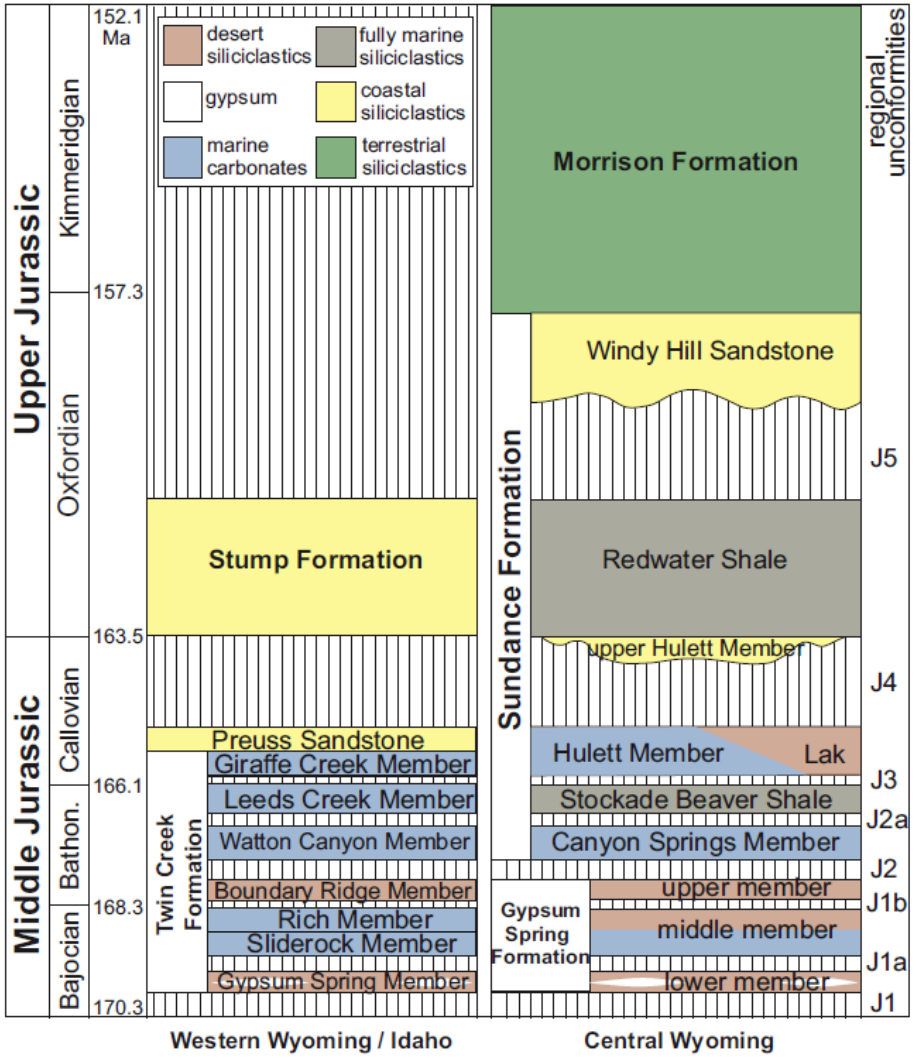
Stratigraphic setting

The studied interval was subdivided into seven third-order depositional sequences (J1 to J5) representing carbonate ramp, wave-dominated, siliciclastic shelf, siliciclastic tidal coast, and mixed evaporite-siliciclastic desert systems.

Of these, five depositional sequences were fossiliferous (J1a, J2, J2a, J4, J5).



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Methods

PALEO-DATASET:

Faunal counts of macro-invertebrates were obtained from marine rocks of the Gypsum Spring, Sundance and Twin Creek formations at 19 localities in Wyoming, Montana and South Dakota.
(35 samples, 62 species)

GEOCHEMICAL DATASET:

From the same localities, calcitic shells of selected species of the family Ostreidae (*Gryphaea planoconvexa*, *Gryphaea nebrascensis*, *Gryphaea* sp., *Liostrea strigilecula*, *Deltoideum* sp.), were analysed for stable isotope ($\delta^{13}C$, $\delta^{18}O$) and elemental geochemistry (Mg/Ca, Sr/Ca, Na/Ca, Ba/Ca)
(35 samples, 6 geochemical proxies)

Deltoideum sp. – sequence J4

Gryphaea sp. – sequence J4

Gryphaea nebrascensis – sequence J2a

Gryphaea planoconvexa – sequence J1a

Liostrea strigilecula – sequence J1a to J4

Species analysed for geochemistry and depositional sequence from where they are found. NOTE: only one species, *Liostrea strigilecula*, is found in every depositional sequence

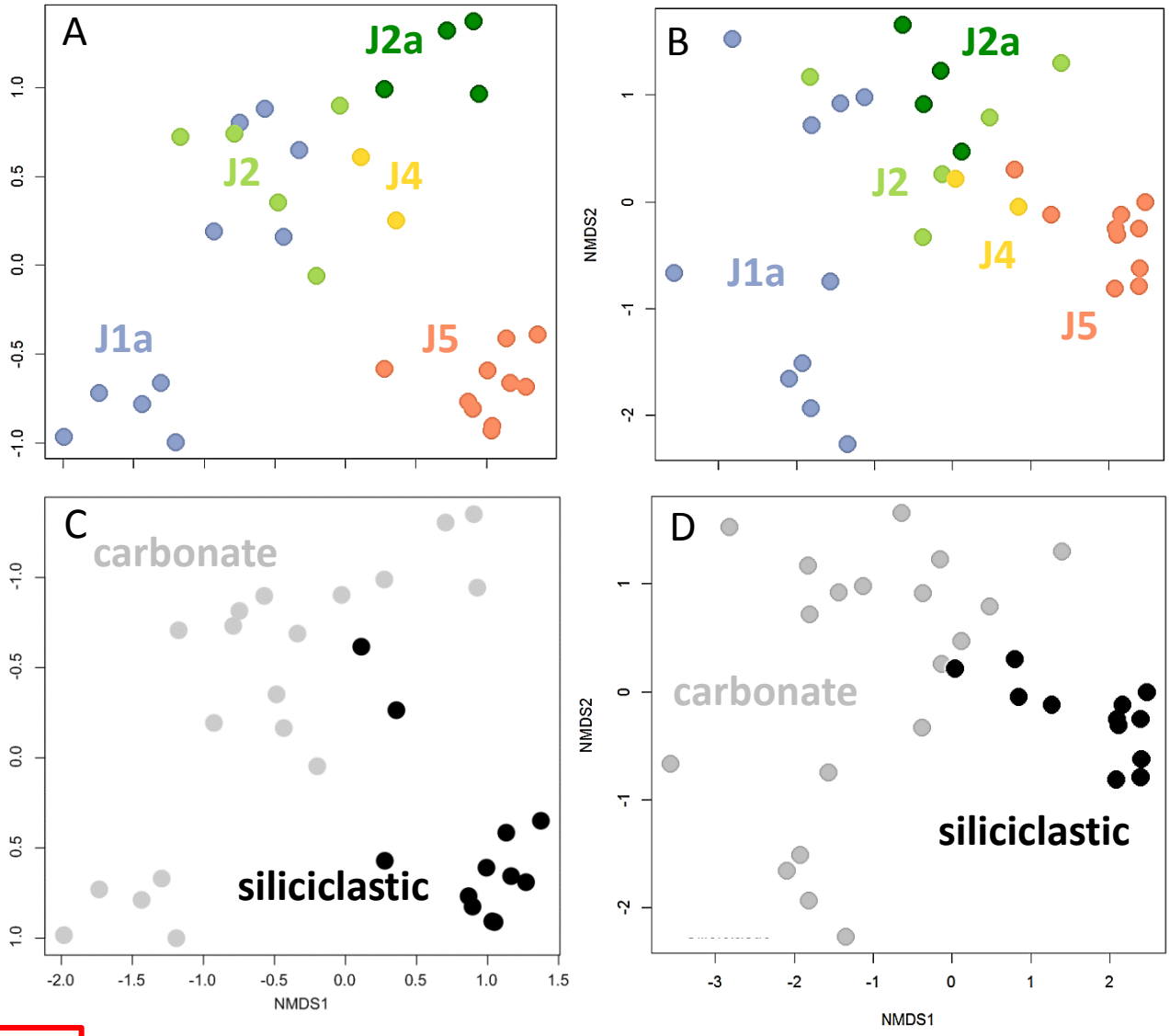
Results

Ordination plots (nMDS) of the two independent datasets are very similar (procrustes correlation: 0.75, p: 0.0001).

Faunal and environmental proxies data form similar clusters, if labelled by depositional sequence (A, B)or main lithology (C, D).

In both (A, B), samples become gradually younger from left to right.

PALEO-DATASET **GEOCHEMICAL DATASET**



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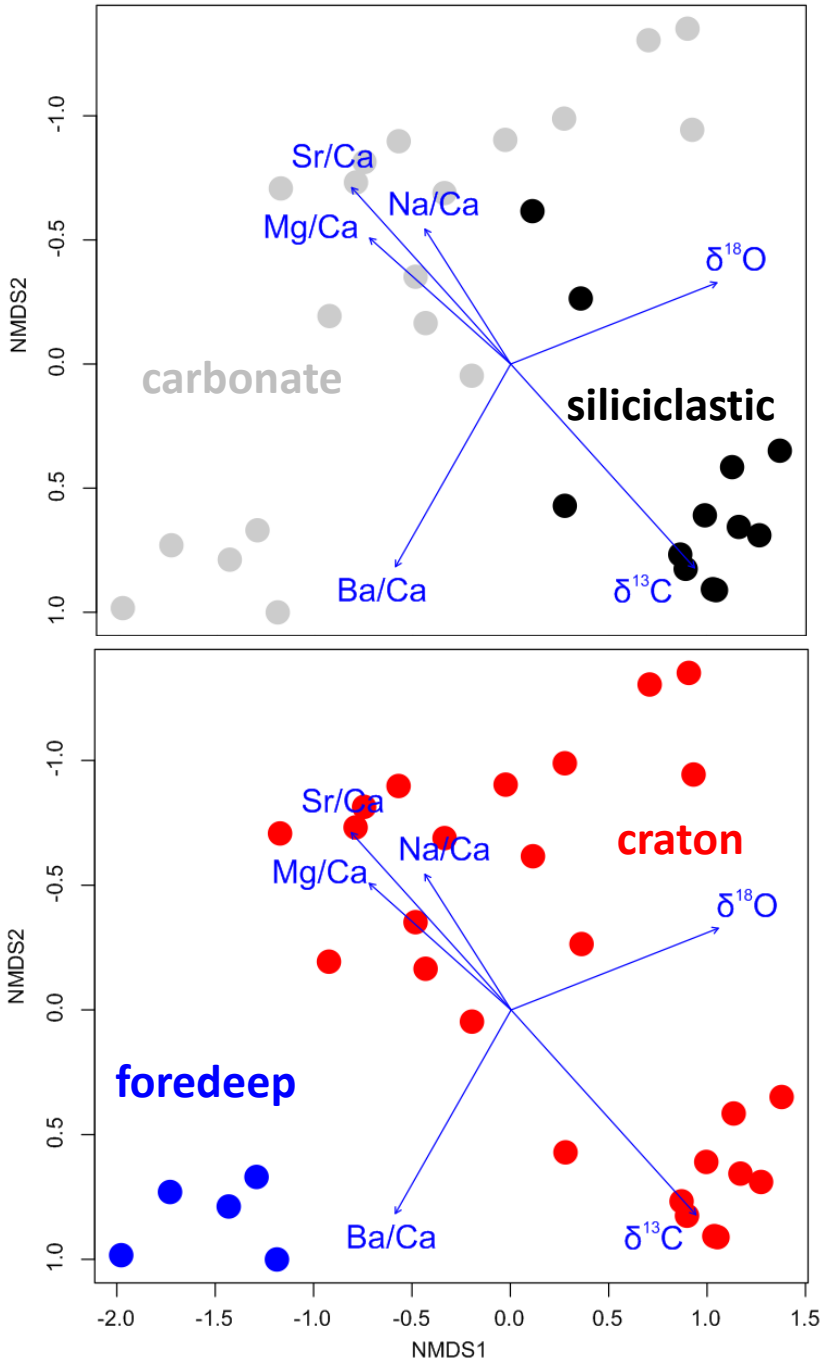
Discussion

Vector fitting of geochemical data on the palaeontological ordination shows that the main faunal turnover event, corresponding to the shift from carbonate to siliciclastic deposition at the Middle–Late Jurassic transition, correlates with an increase in productivity (increase of $\delta^{13}C$) and a decrease in temperature (decrease of Mg/Ca ratio) through time.

Position of fauna in the seaway (craton vs. foredeep) correlates instead with variations of $\delta^{18}O$ and Ba/Ca ratio, suggesting a strong salinity gradient in the seawy, with decreasing salinity moving from the craton towards the foredeep.



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Conclusions

- The combination of quantitative palaeoecological censuses of macro-invertebrates and geochemical proxies allowed to directly measure environmental gradients, and to interpret their role in shaping faunal change through time.
- A wider application of this method has the potential of enhancing our understanding of the role of environmental and climate change in shaping ecological and evolutionary trends.

Additional information on, respectively, palaeoecological and geochemical data, can be found in the following publications:

- S. Danise & S.M. Holland. 2017. *Palaeontology* 60, 213–232.
- S. Danise et al. 2020. *Gondwana Research* 82, 97-107.

[Palaeontology, 2017, pp. 1–20]

FAUNAL RESPONSE TO SEA-LEVEL AND CLIMATE CHANGE IN A SHORT-LIVED SEAWAY: JURASSIC OF THE WESTERN INTERIOR, USA

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Abstract: Understanding how regional ecosystems respond to sea-level and environmental perturbations is a main challenge in palaeoecology. Here we use quantitative abundance estimates, integrated within a sequence stratigraphic and environmental framework, to reconstruct benthic community changes through the 13 myr history of the Jurassic Sundance Seaway in the western United States. Sundance Seaway communities are notable for their low richness and high dominance relative to most areas globally in the Jurassic, and this probably reflects steep temperature and salinity gradients along the 2000 km length of the Seaway that hindered colonization of species from the open ocean. Ordination of samples shows a main turnover event at the Middle–Upper Jurassic transition, which coincided with a shift from carbonate to siliciclastic depositional systems in the Seaway, probably initiated by northward drift from subtropical latitudes to more humid temperate latitudes, and possibly global cooling. Turnover was not uniform across the onshore–offshore gradient, but was higher in offshore environments. The higher resilience of onshore communities to third-order sea-level fluctuations and to the change from a carbonate to a siliciclastic system was driven by a few abundant eurytopic species that persisted from the opening to the closing of the Seaway. Lower stability in offshore facies was instead controlled by the presence of more volatile stenotopic species. Such increased onshore stability in community composition contrasts with the well-documented onshore increase in taxonomic turnover rates, and this study underscores how ecological analyses of relative abundance may contrast with taxonomically based analyses. We also demonstrate the importance of a stratigraphic palaeobiological approach to reconstructing the links between environmental and faunal gradients, and how their evolution through time produces local stratigraphic changes in community composition.

Key words: Jurassic, climate change, sea level, cooling event, benthos, stratigraphic palaeobiology.

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Isotopic evidence for partial geochemical decoupling between a Jurassic epicontinental sea and the open ocean

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ABSTRACT

We report stable isotope ratios ($\delta^{13}C$, $\delta^{18}O$), minor and trace elements (Mn, Fe, Sr, Mg) together with Ca concentrations from bivalve shells and belemnites from the Middle-Upper Jurassic Sundance Seaway (western United States), we compare them with coeval open-ocean Tethyan data, and reconstruct the palaeo-circulation of seaway waters. The Sundance Seaway was a 2000 km long epicontinental sea with a single entrance at mid latitudes (55–60°N), which would have fostered substantial evolution of seawater chemistry relative to its open-ocean source. Samples are distributed across the 13-million-year marine history of the seaway, and across a 540 km east-west transect spanning Wyoming. Delta^{13}C values are in the same range as Tethyan data, and this suggests that they might record global changes in the carbon cycle, with one exception in the Oxfordian. Delta^{18}O values from the seaway are in contrast highly depleted compared with Tethyan data (−2 to −6‰), and they indicate unrealistically high palaeotemperatures (20–40 °C), assuming an isotopic composition of seawater of −1‰, as generally used for the Jurassic. Given more realistic temperature estimates from Mg/Ca ratios of bivalve shells (10–25 °C), we explain such negative $\delta^{18}O$ values by the southward inflow of normal-salinity, isotopically depleted (−3, −4‰), Arctic water into the seaway. Such water would become progressively more saline and denser as it flowed towards the southernmost portion of the seaway. In the Late Jurassic, characterised by wetter climate conditions, less dense Sundance waters may have instead exhibited a northward flow, reducing the southward surface flow from the Arctic. The observed partial geochemical decoupling of Sundance Seaway water masses from the open ocean strongly recommends caution in interpreting the geochemical record of ancient shallow seas, where local, regional and global drivers of change all need to be considered.