

IN THE AFTERMATH OF THE END-PERMIAN MASS EXTINCTION

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SUMMARY

Recovery from the devastating Permian–Triassic (PT) mass extinction ~252 Myr ago is usually assumed to have spanned the entire 5 myr of the Early Triassic (ETR) epoch^[1-7]. The post-crisis interval was characterized by large-scale fluctuations of the global carbon cycle and harsh marine conditions, including a combination of ocean acidification, euxinia, and fluctuating productivity^[8]. During this interval, metazoan-dominated reefs are thought to have been replaced by microbial deposits that are considered the hallmark of the ETR^[4-7].

Here we use field and microscopic investigations to document ETR bioaccumulations and reefs from the western USA comprised of various sponges and serpulids associated with microbialites and other eukaryotic benthic organisms. These metazoan-rich reefs were formed only 1.5 myr after the extinction, in contrast to previous suggestions of a much delayed recovery of complex benthic communities.

We conclude that the predominance of microbial reefs following the mass extinction is restricted to short intervals of the earliest Triassic. We suggest that metazoan reef building continued throughout the ETR wherever permitted by environmental conditions.

CONTEXT

★ Nekto-pelagic taxa (e.g. ammonoids and conodonts) document an *explosive Early Triassic rediversification* after the PT crisis^[8, 9].

★ Metazoan reefs were acknowledged to re-establish during the Middle Triassic^[10-12].

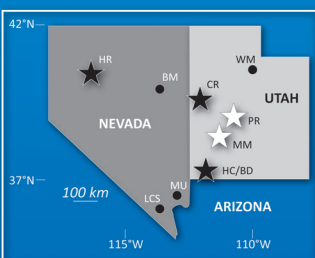
★ Reports of well-dated ETR metazoan reef builders have been exceptional (e.g. sponge concentrations^[13, 14], small bivalve bioherms and a stromatolite-sponge-*Tubiphytes* association^[15, 16] from the Spathian of Utah and Nevada).

★ Despite these rare occurrences, a *global ETR metazoan reef gap seemed remarkable* and was often interpreted as the outcome of harsh environmental conditions and exacerbated biotic competitive pressures^[6, 17].

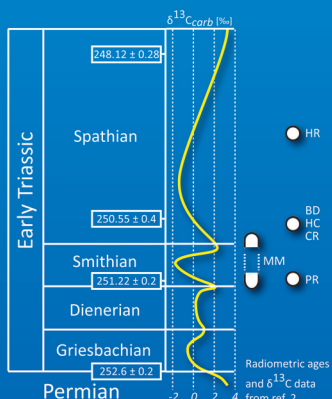
Here we present new evidence for large, *in situ* ETR metazoan bioaccumulations and reefs formed by various sponges and serpulids associated with different microbial carbonates and eukaryotic organisms.

Oldest metazoan bioaccumulations and reefs location: base of the Thaynes Grp. (early Smithian), postdating the PT boundary by only ~1.5 Myr.

GEOGRAPHICAL & CHRONOLOGICAL SETTINGS



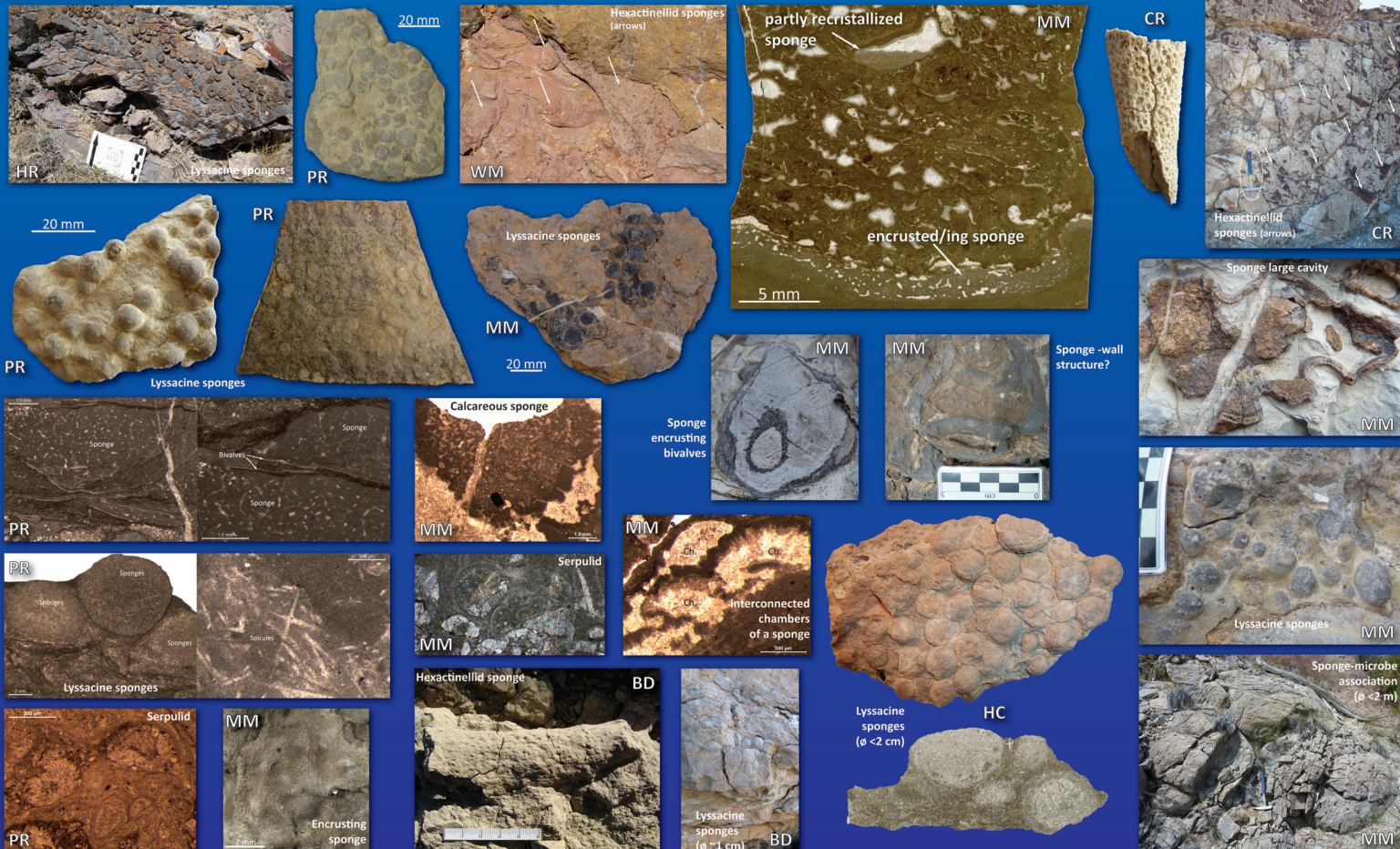
HR: Humboldt R. MM: Mineral M. LCS: Lost Cabin Spring
CR: Confusion R. PR: Pahvant R. MU: Muddy M.
HC: Hurricane Cliffs BM: Butte M. WM: Wasatch M.
BD: Beaver Dam M. White/black stars indicate Smithian and Spathian outcrops, respectively. Black circles indicate previously described Spathian bivalve bioherms (MU^[18]), sponge reef (LCS^[19]), and sponge occurrences (BM & WM^[19]).



SOME COMMON INHABITANTS



SOME CHARACTERISTIC FEATURES



CONCLUSION

These findings profoundly alter the timing of the microbe-dominated benthic communities as well as reef reorganization models after the PT crisis. It is often hypothesized that the large ETR carbon cycle perturbations are linked with deleterious global oceanic conditions leading to a delayed biotic recovery, at least up to the Spathian, when the amplitude and the number of fluctuations decreased. However, the reefs described here occur significantly earlier, indicating that temporary favourable conditions for a broad array of physiologically diverse organisms had already returned, at least regionally. Hence, the ETR metazoan 'reef gap' may be better described as a reef low from which a selective preservation bias and insufficient sampling efforts still need to be factored out.

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