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Earliest Triassic Ephemeral Refuge at Shangsi, China

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The ocean today is being faced with a series of environmental perturbations that may potentially lead to the 6th mass extinction [1]. Therefore, it is important to look back into Earth's history, to times such as the end-Permian mass extinction (EPME), when comparable environmental conditions provide a baseline for comparison. Understanding how marine refugia were developed and maintained following the 251.95 Ma [3] EPME can help inform resource management of marine ecosystems in the coming centuries. Refugia are isolated environments to which organisms migrate during times of environmental stress, and are therefore essential to the survival of key species during mass extinction events. The study of a large, lowermost Triassic bedding surface within bed 29 at the Shangsi section, South China, suggests that a refugium may not be a single elusive sanctuary, but rather a constantly shifting, short-lived, habitable setting. Numerous earliest Triassic refugia have been described, including wave swept NW Pangean shelves [2], shallow oxic seamounts off the Oman platform margin [7], and microbially dominated, shallow tropical platform environments [4]. The bed 29 surface provides a snapshot of an oligophotic outer-shelf ocean floor during the earliest Triassic (*Hindeodus parvus* Zone) that contains a significant echinoid community. Modern echinoids are densely packed when stable levels of food resources are available under non-stressed conditions; in one study, echinoid density on a small reef near Jamaica was 99.5/m^2 [6]. The echinoids on bed 29 are evenly spaced, averaging 1/m^2 as determined by a quadrat method. This suggests resources were limited, but that the echinoids were temporarily in equilibrium with their stressed environment. Microbial mats provided a food source and firm substrate for the development of an ephemeral community with functional diversity [5] at a reasonably normal level for the time and depositional setting. Geochemical evidence indicates that anoxic conditions occurred sporadically during the latest Permian and the earliest Triassic at this site, but the occurrence of bivalves, trace-fossils and echinoids indicate that bottom water conditions were sufficiently oxygenated to allow for the temporary development of a benthic refuge, potentially due to limited biological productivity in the water column. Total organic carbon (TOC) and phosphorus (P) are low throughout most of the earliest Triassic at Shangsi, suggesting that primary productivity in the water column was quite low, which is supported by the rarity of nektic ammonoids and fish teeth in the unit. Water clarity may have allowed for the growth of bacterial mats at >200 m water depth, stabilizing the seafloor and allowing echinoid grazing. $\delta^{15}N$ values of sedimentary organic matter are consistently around 0‰, the isotopic composition of the atmosphere. This suggests that a large component of the nitrogen available to phytoplankton in the photic zone was derived directly from N-fixing cyanobacteria, likely in response to intense nitrogen limitation. This community was suddenly terminated and succeeded by a *Claraia*-dominated horizon with many encrusting microconchids. The *Claraia* horizon shows evidence for increasing primary productivity in the form of increased P and TOC. Volcanic ash and an associated pulse of terrigenous sediment may have fertilized the water column, allowing phytoplankton in the photic zone to "shade out" benthic primary producers, and smother the echinoids.

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