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The unusual sedimentary rock record of the Early Triassic: A case study from the southwestern United States

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Abstract

Sedimentary systems, as well as the earth's biota, changed dramatically following the end-Permian mass extinction. This global sedimentological transformation is reflected in the widespread occurrence of flat-pebble conglomerates, subtidal wrinkle structures, microbialites, and carbonate seafloor fans in various Lower Triassic sections. As a case study, a facies analysis of the Lower Triassic Virgin Limestone Member of the Moenkopi Formation and the Middle and Upper Members of the Union Wash Formation, southwestern United States was conducted and all unusual facies were documented within a palaeoenvironmental framework. The occurrence of the flat-pebble conglomerates and wrinkle structures is significant because these reflect a long-term reduction in vertical bioturbation. In the case of the subtidal microbialites and carbonate seafloor fans, their formation is linked to an increase in alkalinity. The presence of these facies in the uppermost Lower Triassic strata of the southwestern United States indicates that reduced levels of infaunal bioturbation as well as (and perhaps a consequence of) unusual ocean chemistry extended for 5–6 million years after the end-Permian mass extinction, suggesting that depositional environments as well as the biota were significantly affected by the extinction event.

Keywords: Early Triassic; Biotic recovery; Mass extinction; Anachronistic facies

1. Introduction

The end-Permian mass extinction was the largest extinction in the history of life with an eradication of almost 80% of the marine species (Stanley and Yang, 1994). A delayed biotic recovery followed the mass extinction and lasted 5–6 million years (Martin et al., 2001; Mundil et al., 2004). Recent work on the carbon isotopic record has suggested that environmental perturbations occurred many times during the Early Triassic and may have played a role in delaying the recovery (Payne et al., 2004). The lag phase from the recovery, which spanned the Early Triassic, is dominated by depauperate, benthic communities consisting of cosmopolitan members (Hallam and Wignall, 1997) and opportunists (Rodland and

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Bottjer, 2001; Fraiser and Bottjer, 2004). In addition to the low diversity assemblages, an extremely unusual sedimentary rock record also characterizes the Early Triassic. The Early Triassic has been described as a "reef gap" due to the lack of colonial metazoan reefs (Fagerstrom, 1987), a "chert gap" because few siliceous deposits are known from this time (Racki, 1999), and a "coal gap" as a consequence of the lack of significant carbonaceous deposits in Lower Triassic strata (Retallack et al., 1996; Veevers et al., 1996).

Another unusual characteristic of Lower Triassic strata is the abundance of facies such as flat-pebble conglomerates (Wignall and Twitchett, 1999), subtidal wrinkle structures (Pruss et al., 2004), microbial reefs (Schubert and Bottjer, 1992; Baud et al., 1997; Lehrmann, 1999; Pruss and Bottjer, 2004a,b), and carbonate seafloor fans (Woods et al., 1999; Heydari et al., 2003) that have been documented from sections globally. Many of these facies are restricted to Cambrian or earlier times and have thus been referred to as "anachronistic facies" in post-Cambrian deposits (Sepkoski et al., 1991). Facies analysis of the Lower Triassic Virgin Limestone Member of the Moenkopi Formation and the Middle and Upper Members of the Union Wash Formation exposed in eastern California–southern Nevada, USA, has yielded an abundance of these unusual facies, and these have been documented and placed in a stratigraphic framework to determine the palaeoenvironmental implications of these features. In addition to the presence of unusual facies reported from the literature, other facies such as thin-bedded limestone/silty limestone facies, chip facies, and thin-bedded facies are also present. These facies have not yet been described from other sections but are reported here because they also reveal important palaeoenvironmental information. The abundance of flat-pebble conglomerates, wrinkle structures, thin beds and chip facies is likely linked to long-term suppression of infaunal bioturbation whereas the microbialites and carbonate seafloor fans are related to increased alkalinity. The presence of unusual facies during the latest Early Triassic suggests that sedimentary systems may also act as a proxy for ecological change independent of fossil assemblage analyses. This study aims to evaluate the palaeoenvironmental conditions and processes responsible for the widespread formation of unusual facies during the post-extinction interval.

2. Regional and geologic setting

During the Early Triassic, the southwestern margin of North America was a passive margin characterized by a broad shallow epicontinental shelf that extended from southern Idaho as far south as southern Arizona (Marzolf, 1993). The Spathian Moenkopi Formation was deposited on the Colorado Plateau and the Virgin Limestone Member represents a marine incursion during Early Triassic time (Marzolf, 1993). At the localities studied in this research, the Virgin Limestone Member generally unconformably overlies the non-marine Timpoweap Member or the Lower Red Member, and is conformably overlain by the Shnabkaib Member or unconformably overlain by the Middle Red Member. The Virgin Limestone Member crops out as limestone ledges that weather to a

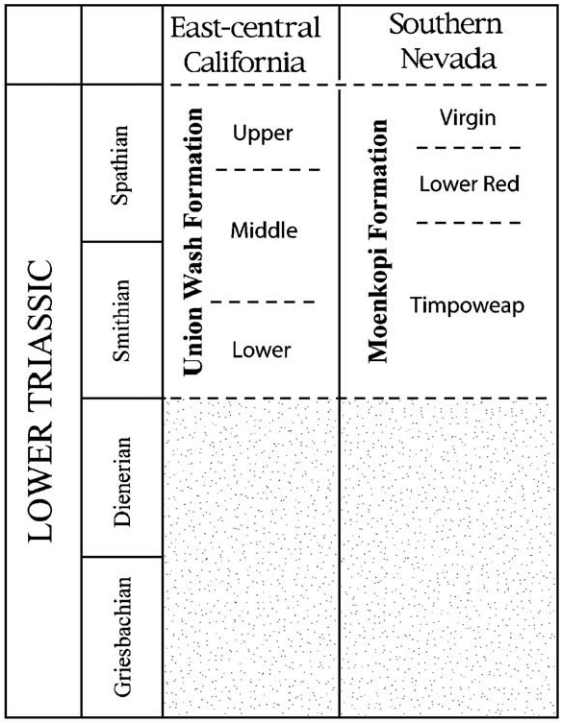

Fig. 1. Diagram showing ages and location of the Moenkopi and Union Wash Formations. Modified from Pruss and Bottjer (2004b).