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New high resolution geochemistry of Lower Jurassic marine sections in western North America: A global positive carbon isotope excursion in the Sinemurian?

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ABSTRACT

Recognising variations in the carbon isotope compositions of marine organic-rich sedimentary rocks can provide insight into changes in ocean chemistry throughout geological time. Further, identification of global excursions in the carbon isotope record has proved to be valuable as a chronostratigraphic correlation tool.

This investigation presents new high-resolution organic carbon isotope data ($\delta^{13}C_{org}$) for marine sediments from 2 regions in North America (Last Creek, British Columbia, Canada and Five Card Draw, Nevada, USA). The carbon isotope profiles demonstrate that there were significant differences between the carbon reservoirs at Five Card Draw and Last Creek, notably in the upper part of the Leslei Zone. The $\delta^{13}C_{org}$ values show a gradual positive CIE (∼ 2‰) at Last Creek in the upper part of the Leslei Zone. This corresponds to a coeval positive CIE of similar duration in Dorset, UK (upper Turneri Zone; Jenkyns and Weedon, 2013), suggesting that this may be a global marine carbon isotope signature, and likely reflects a widespread increase in primary productivity during the Early Sinemurian. In addition, a brief negative CIE is observed in the uppermost Lower Sinemurian at Last Creek. This negative excursion is not recorded in the Dorset section, suggesting localised upwelling of ^{12}C-rich bottom-waters at Last Creek. Further, the signals identified at Last Creek are not present in coeval sections at Five Card Draw, thus highlighting a significant difference between these localities. Osmium (Os) isotope data (initial $^{187}Os/^{188}Os$ values) provide a quantitative determination of the contrasting depositional environments of Five Card Draw and Last Creek (at least partially restricted with high levels of continental inundation and open-ocean, respectively). This demonstrates that basinal restriction may act as a major factor that controls isotopic stratigraphic signatures, thus preventing the identification of global or widespread regional excursions.

1. Introduction

Understanding marine sedimentary rocks and their depositional environments throughout geological time allows us to evaluate past changes in ocean chemistry. The ability to recognise these variations, at both the localised and global scale, enables us to trace temporal alterations in the balance of inputs to the global oceans. To do this, geochemical tracers such as carbon and osmium (Os) isotopes are utilised. Carbon isotope profiling enables us to detect variations in primary productivity (Hesselbo et al., 2000), together with periods of increased bottom-water upwelling, and widespread oxidation of organic matter during eustatic sea level fall (Jenkyns et al., 2002). Osmium isotopes allow tracing of inorganic fluxes into the marine environment, by recording the effects of meteorite impacts, continental weathering, and volcanogenic fluxes (Cohen et al., 1999; Peucker-Ehrenbrink and Ravizza, 2000).

The Jurassic Period witnessed major tectonic events that significantly impacted the global environment; most notably the global tectonic plate reorganisation associated with the break-up of Pangaea. Early Jurassic Pangaean fragmentation into Laurasia and Gondwana established new seaways and marine connections

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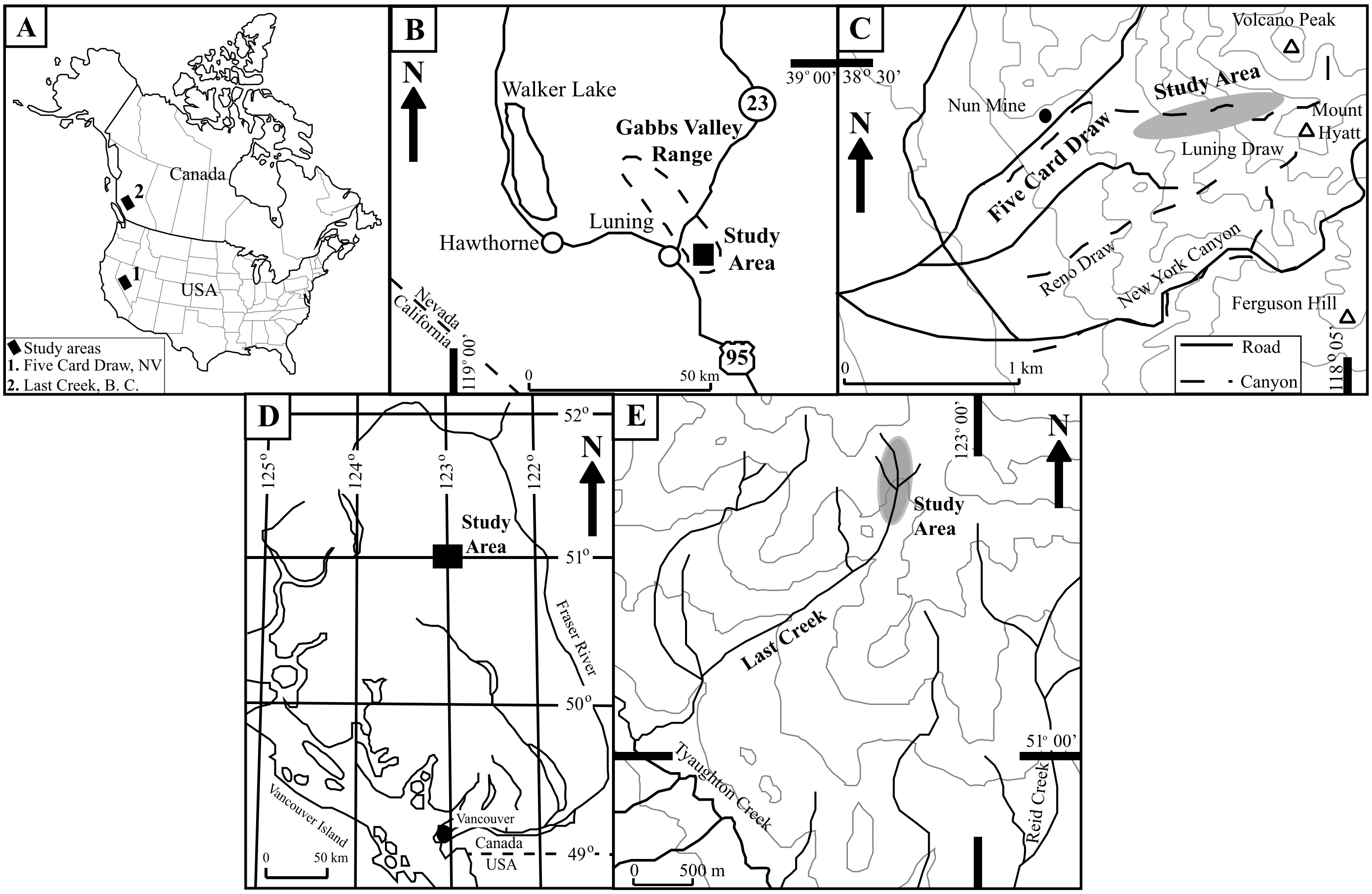

Fig. 1. Maps showing the location of: (A) the study areas in North America; (B) Five Card Draw in Nevada, USA; (C) the Five Card Draw sampling areas; (D) Last Creek in British Columbia, Canada; (E) the Last Creek sampling sites. (B) and (C) modified from Taylor et al. (1983). (D) and (E) modified from Macchioni et al. (2006).

and was accompanied by a steady rise in sea level (Hallam, 1981). This complex and dynamic tectonic period was also associated with significant fluctuations in global ocean chemistry (Cohen et al., 1999; Hesselbo et al., 2000; Cohen and Coe, 2007; Jenkyns, 2010; Jenkyns and Weedon, 2013; Riding et al., 2013; Porter et al., 2013), resulting from a number of factors including increased tectonism.

The identification of global carbon isotope excursions (CIEs) throughout geological time significantly improves our ability to conduct temporal correlations of marine and continental successions. In addition, fluctuations in the marine stable carbon isotope record, on a localised and global scale, enable the recognition of changes in ocean chemistry and the evaluation of variations in the balance of inputs to the global oceans through time. A number of previous workers have recognised oceanic carbon isotope excursions (CIEs) during the Early Jurassic, as both global and smaller-scale events. Widespread attention has been given to the negative CIE during the Early Toarcian oceanic anoxic event (T-OAE at ~182 Ma; Hesselbo et al., 2000; Cohen and Coe, 2007; McArthur et al., 2008; Jenkyns, 2010; Caruthers et al., 2011), that is hypothesised to have resulted from the release of ^{12}C-enriched methane accumulated below the seafloor (Hesselbo et al., 2000; Cohen and Coe, 2007). Other negative CIEs have also been reported across both the Pliensbachian–Toarcian boundary (Hesselbo et al., 2007) and the Sinemurian–Pliensbachian boundary (Korte and Hesselbo, 2011). However, until recently the Sinemurian time interval has remained poorly understood. Work in the UK (Jenkyns and Weedon, 2013 and Riding et al., 2013) has highlighted carbon isotope anomalies in the Sinemurian marine and terrestrial records, but it is not clear from these investigations whether or not these anomalies represent a global signal.

Herein, we present high-resolution carbon isotope data for Sinemurian marine sections from Five Card Draw, Nevada, USA (Taylor et al. 1983; 2001) and Last Creek, British Columbia, Canada (Umhoefer and Tipper, 1998; Smith et al., 1998; Smith and Tipper, 2000; Macchioni et al., 2006) in order to determine whether a global carbon isotope signal can be identified during the Sinemurian. In addition, osmium isotope data is used to quantitatively evaluate differences between the depositional environments of these two North American regions, allowing us to assess how the depositional realm can influence the recording of isotopic anomalies in the stratigraphic record.

2. Geological setting

2.1. Five Card Draw, Nevada, USA

The Sunrise Formation of the Volcano Peak Group cropping out in the Gabbs Valley Range (Fig. 1) is a component of the Pamlico–Luning lithotectonic assemblage of the Walker Lake Terrane (Oldow, 1978; Silberling, 1959; Taylor and Smith, 1992). The formation is part of a platform sequence deposited on basement that had already accreted to western North America by the Jurassic (Fig. 2; Speed, 1979; Taylor and Smith, 1992). The type-section of the Five Card Draw Member of the Sunrise Formation is also the type-section for the Leslei to Harbledownense part of the North American Sinemurian ammonite zonation scheme (Taylor et al., 2001). The section represents a transgressive sequence possibly of eustatic origin (Hallam, 1981), with a depositional environment