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Climate warming, euxinia and carbon isotope perturbations during the Carnian (Triassic) Crisis in South China

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ABSTRACT

The Carnian Humid Episode (CHE), also known as the Carnian Pluvial Event, and associated biotic changes are major enigmas of the Mesozoic record in western Tethys. We show that the CHE also occurred in eastern Tethys (South China), suggestive of a much more widespread and probably global climate perturbation. Oxygen isotope records from conodont apatite indicate a double-pulse warming event. The CHE coincided with an initial warming of 4 °C. This was followed by a transient cooling period and then a prolonged ~7 °C warming in the later Carnian (Tuvalian 2). Carbon isotope perturbations associated with the CHE of western Tethys occurred contemporaneously in South China, and mark the start of a prolonged period of carbon cycle instability that persisted until the late Carnian. The dry-wet transition during the CHE coincides with the negative carbon isotope excursion and the temperature rise, pointing to an intensification of hydrologic cycle activities due to climatic warming. While carbonate platform shutdown in western Tethys is associated with an influx of siliciclastic sediment, the eastern Tethyan carbonate platforms are overlain by deep-water anoxic facies. The transition from oxygenated to euxinic facies was via a condensed, manganiferous carbonate (MnO content up to 15.1 wt%), that records an intense Mn shuttle operating in the basin. Significant siliciclastic influx in South China only occurred after the CHE climatic changes and was probably due to foreland basin development at the onset of the Indosinian Orogeny. The mid-Carnian biotic crisis thus coincided with several phenomena associated with major extinction events: a carbonate production crisis, climate warming, $\delta^{13}C$ oscillations, marine anoxia, biotic turnover and flood basalt eruptions (of the Wrangellia Large Igneous Province).

1. Introduction

Environmental and biotic changes during the Carnian Stage (~237–227 Ma) of the Triassic are amongst the most enigmatic of the geological record (Simms and Ruffell, 1989; Ogg, 2015). Prominent amongst these was the Carnian Humid Episode (CHE, after Ruffell et al., 2015, but also known as Carnian Pluvial Event or Carnian Pluvial Phase), a short-lived phase (<1 Myr, Zhang et al., 2015) of increased rainfall. The CHE has been attributed to an intensification of a mega-monsoonal climate (Parrish, 1993; Kozur and Bachmann, 2010), although climate change driven by voluminous volcanism and greenhouse gas exhalation has also been suggested (Dal Corso et al., 2012). A contemporaneous major increase in siliciclastic influx to marine areas has been implicated in the shutdown of carbonate platforms and the demise of reef ecosystems in western Tethys and the peri-Gondwana margin (e.g., Hornung et al., 2007a). The CHE also coincided with extinctions amongst crinoids and scallops, while nekton such as ammonoids and conodonts also suffered losses (Simms and Ruffell, 1989; Rigo et al., 2007), suggesting a broad-reaching marine crisis. Terrestrial floras record a shift towards hygrophytic forms in the late Julian substage (early Carnian, ~237–233 Ma) before returning to xerophytic associations by the early Tuvalian substage (late Carnian, ~233–227 Ma) (Roghi et al., 2010; Mueller et al., 2016);

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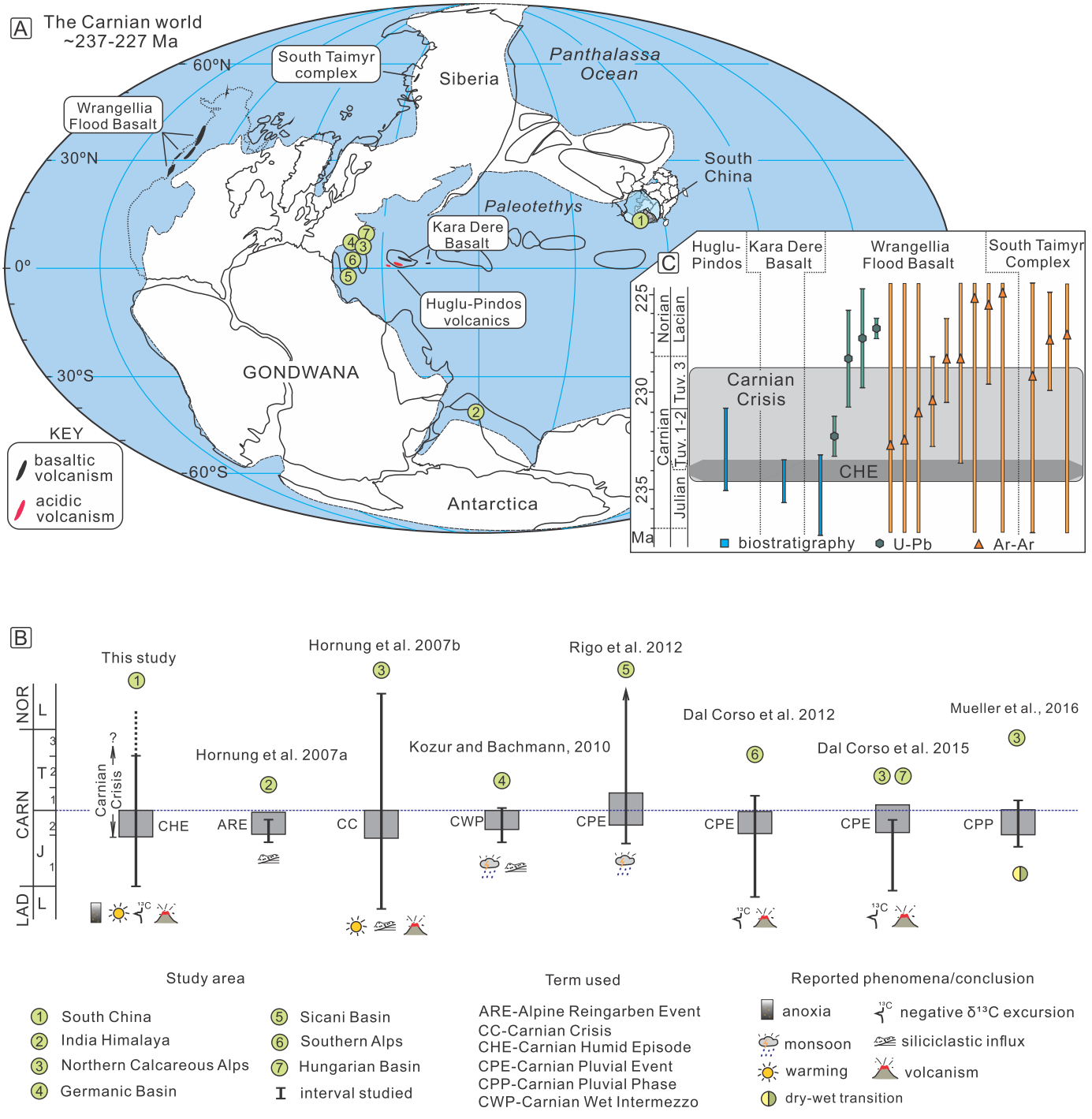

Fig. 1. A) Palaeogeographic reconstruction of the Carnian world (revised after Golonka, 2007); B) summary of previous studies on the Carnian Humid Episode. Gray shading represents the short-lived CHE interval; C) (inset) biostratigraphic and radiometric ages of contemporaneous volcanic activity (Walderhaug et al., 2005; Maury et al., 2008; Greene et al., 2010; Moix et al., 2013).

a change that may have been responsible for elevated extinction rates reported amongst herbivorous tetrapods (Benton, 1986).

Despite the magnitude of the changes, the majority of evidence for the Carnian Crisis has come from western Europe (Fig. 1) and major questions remain as to the global significance and cause(s) of this event. We evaluate the global extent of the CHE and associated environmental changes by investigating palaeotemperature, $\delta^{13}C$, sedimentary facies and redox changes in South China, a region far removed (~13,000 km distant) from the better-studied western Tethyan locations. Our results indicate that the environmental changes in the Carnian were truly global and associated with a carbonate production crisis, double-pulse climate warming, intense oceanic anoxia and large $\delta^{13}C$ oscillations associated with flood basalt eruptions.

2. Geological setting

The studied section at Long Chang (25°26.565′N, 105°28.791′E) outcrops in a road cut ~2 km south of the town of Long Chang (Figs. 2 and 3). In comparison to the well-known section of Enos et al. (1998) in the nearby area (Fig. 2C), our section is more condensed and has been chosen for its excellent outcrop situation