The biomineral archive of Carboniferous and Permian climates and environments

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Abstract

The Carboniferous and Permian witnessed rapid climate change and very varied environments in a time span of less than 100 my: from a protracted icehouse which produced the glacial events of the late Palaeozoic Ice Age (LPIA) (e.g. Montañez 2022) to the end-Permian hothouse, which lead to the most severe mass extinction of the Big Five (Dal Corso et al. 2022), through an enigmatic and still not well understood greenhouse at mid-Permian times. Tectonics, volcanism and paleogeographic setting were among the main drivers of the change, in a tectonic scenario that forecasts a Pangea B supercontinent configuration in the Carboniferous-Early Permian, its northward latitudinal drift and transformation into the Pangea A configuration by the Late Permian, and the opening of the Neotethys Ocean (Kent & Muttoni 2020).

Several physical and chemical proxies have been used to interpret Carboniferous-Permian climate events and environmental changes, and one of the best archives of proxies is that of biominerals, hierarchically organized biocomposites resulting from controlled biological activity. Among biominerals, those produced by brachiopods provide high-resolution archives in the Carboniferous and Permian. These stenohaline sessile marine invertebrates are very abundant in most upper Palaeozoic sedimentary successions and they dominated benthic palaeocommunities at various depth and in different settings. In particular, brachiopods of the Subphylum Rhynchonelliformea have a low-Mg calcite shell with a characteristic microstructure, which is produced by periodical accretion, with temporary cessation of growth, in near-equilibrium with seawater. Their shell is resistant to diagenesis and can be screened by multiple methods (e.g. Garbelli et al. 2022): it is a faithful recorder of the environmental conditions in which the animal lived throughout its life span, lasting from a few years to several decades. Brachiopod shells can thus be used to reconstruct changes in seawater temperature and pH, seasonality, productivity and complex biotic relationships, even at a short-term scale.

Here, I offer several examples of how chemical (δ13C, δ18O, δ15N, δ11B) and physical (microstructure, morphostructure) proxies preserved in the brachiopod biomineral archive can be used to interpret climate and environments from Carboniferous glacial events to the hothouse at the end of the Permian. Starting from a farfield record of the LPIA in Visean-Serpukhovian brachiopods, I then show that the low-latitude Early Permian ocean waters did not undergo significant cooling during the apex of the late Palaeozoic glaciation, but the low-latitude warm belt and environments became narrower. Analyses of brachiopod shells from the Middle-Late Permian transition provide results that are more enigmatic with evidence of cooling also supported by other proxies (Gong et al. 2022). But the latest Permian

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record of the brachiopod biomineral archive is striking, with undisputed evidence for rapid warming and ocean acidification. If global warming has been proven by multiple evidence, acidification is still debated (Foster et al. 2022). I also offer hints into the potential of detecting seasonality in deep time.

Kent D.V., Muttoni G. 2020. Pangea B and the Late Paleozoic Ice Age. Palaeogeography, Palaeoclimatology, Palaeoecology, 103756.

Dal Corso J., Song H., Callegaro S., Chu D., Sun Y., Hilton J., Grasby S.E., Joachimski M.M., Wignall P.B. 2022. Environmental crises at the Permian–Triassic mass extinction. Nature Reviews Earth & Environment, 3(3), 197-214.

Foster W.J., Hirtz J.A., Farrell C., Reistroffer M., Twitchett R.J. & Martindale R.C. 2022. Bioindicators of severe ocean acidification are absent from the end-Permian mass extinction. Scientific Reports, 12(1), 1202.

Garbelli C., Angiolini L., Posenato R., Harper E.M., Lamare M.D., Shi G.R. & Shen S.Z. 2022. Isotopic time-series (δ13C and δ18O) obtained from the columnar layer of Permian brachiopod shells are a reliable archive of seasonal variations. Palaeogeography, Palaeoclimatology, Palaeoecology, 607, 111264.

Gong Z., Zhang M., Li J., Huang C. 2022. Late Permian˜ 6 My cooling induced by basaltic weathering of the Emeishan large igneous province: Evidence from interbasaltic paleosols. Palaeogeography, Palaeoclimatology, Palaeoecology, 111305.
Montañez I.P. 2022. Current synthesis of the penultimate icehouse and its imprint on the Upper Devonian through Permian stratigraphic record. In Lucas, S. G., Schneider, J. W., Wang, X. and Nikolaeva, S. (eds) 2022. The Carboniferous Timescale. Geological Society, London, Special Publications, 512, 213–245.

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