Deep time paleoclimate reconstruction using carbonate clumped isotope thermometry: A status report

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Carbonate clumped isotope thermometry holds great promise for addressing questions in Paleozoic paleoclimate and paleoceanography because of its ability to simultaneously record temperature and fluid δ¹⁸O. Here we review recent developments in the method related to 1) temperature calibration in biogenic carbonates; 2) scenarios where original clumped isotope signals are likely to be preserved or altered; and 3) applications of the method to Paleozoic paleoclimates. Most biogenic carbonates (including foraminifera, corals, otoliths, mammalian bioapatite) conform to a single temperature calibration curve. Mollusks deviate from this calibration, showing a slightly lower temperature sensitivity that is similar to the theoretical temperature sensitivity of the thermometer. The origin of the difference between mollusks and other biogenic carbonates is unclear and stands as an important mystery to solve because it bears on proper selection of paleotemperature equations for fossil biogenic carbonates. A detailed calibration is lacking for brachiopods. The question of preservation is addressed by ongoing experimental and empirical observations. Experiments are aimed at determining Arrhenius parameters for rates of solid-state ¹³C-¹⁸O bond reordering that will allow prediction of temperature-time combinations of elevated heating (for example, as experienced by a fossil during burial) resulting in measurable reordering of C-O bonds (and hence, alteration of the clumped isotope signal). Published and unpublished data provide examples of nominally-pristine Paleozoic brachiopods that preserve both ‘plausible’ (for example, less than ~35°C) and ‘implausible’ (up to ~180°C) clumped isotope temperatures, and the difference in many cases can be related to inferred burial depth. Published applications of the method have addressed glaciation during the Ordovician/Silurian, and coupling between temperature and inferred CO₂ levels during Silurian and Pennsylvanian. A notable emerging conclusion from these studies and our own analyses of Carboniferous brachiopods is that there is little support for models of low seawater δ¹⁸O (< 3‰ SMOW) during the Paleozoic.

Application of palynostratigraphy to petroleum bearing Permo-Carboniferous sediments – a case study from Oman’s Haushi Group

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A review of the palynostratigraphy in over 1000 wells penetrating Oman’s Permo-Carboniferous Haushi Group has enabled high resolution reservoir-scale subdivision of this interval. The Haushi Group comprises the glacially influenced Al Khlata Formation and the overlying marine to fluvial Gharif Formation. These are respectively the second and most prolific petroleum reservoirs in Oman. Oman-wide mapping of the palynologically-constrained unit thicknesses of the Al Khlata Formation and lower member of the Gharif Formation appear to display considerable influence of both basement faulting and halokinesis from the Late Pre-Cambrian Ara Group Salt. This has resulted in a series of depocentres developing at different times when salt dissolution created accommodation space, which was rapidly filled by sediment.

Palynostratigraphy within the Al Khlata has identified at least 7 palynozone-based lithostratigraphic intervals which can be mapped across the region. A number of structural features appear to control the extent of certain intervals including the Rahab Shale Member, which is thought to represent the last major melt-out of the Gondwana glaciation.

The overlying pre-marine and transgressive marine Lower Gharif interval can be resolved into at least 4 palynozones which reflect changing palaeoenvironments. Palynostratigraphy has facilitated the mapping of both the pre-marine and marine units including a ravinement surface, which precedes the development of the high-stand carbonate facies of the Haushi Limestone in Northern and Central Oman.

After the deposition of the Haushi Limestone a regression occurred and associated palynofloras suggest aridity, supported by the predominance of terrestrial red beds, which include fluvial and fluviolacustrine deposits. This is followed by a mostly palynologically barren interval dominated by palaeosols formed in fluvial and flood plain environments. Low yields of palynomorphs from the upper part of this succession suggest the presence of possible disconformities prior to the marine transgression represented by the overlying Khuff Formation.