BURIAL HISTORY OF RESERVOIR STRATA USING TWIN CLUMPED ISOTOPES: Δ_{48} AND Δ_{47}

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PROJECT OBJECTIVES

- Apply clumped isotope methods to diagenetic and 'original' carbonate material from a range of different sedimentary basins in order to ascertain burial history.

PROJECT RATIONALE

Knowledge of the geothermal history of sedimentary basins is vital to understanding the maturation of hydrocarbons. A new approach measures the geothermal history using the clumped isotope method. The deviation, expressed as the Δ_{47} value, is not only known to be dependent on the temperature of formation, but also upon the thermal history (Passey and Henkes, 2012; Shenton et al., 2015). Heating of carbonates during burial breaks existing C-O bonds and there is diffusive migration of C and/or O to new lattice coordinates together with the subsequent reforming of new C-O bonds. This is known as solid-state reordering and tends to drive the Δ_{47} towards a random or stochastic condition. The temperature at which such changes start to take place is known as the blocking temperature and is characteristic of a specific carbonate mineral. Such changes occur without any apparent recrystallization of the sample (i.e. the sample appears unaltered) and without changing the $\delta^{13}C$ and $\delta^{18}O$ value, or other geochemical characteristics. Recently it has been shown that it is also possible to make measurements at mass 48 ($^{12}C^{18}O^{18}O$) and that while the Δ_{48} value behaves in a similar manner to the Δ_{47} value (Fiebig et al., 2019), there are some important differences. One of these is that the rate of solid-state reordering appears to be faster for Δ_{48} when compared to Δ_{47} (Swart et al., 2019).

SCOPE OF WORK

We will make measurements of the Δ_{48} and Δ_{47} in sedimentary basins including the Vaca Muerta Basin (Argentina), Cibao Basin (Dominican Republic), Williston Basin (North America) and Rub'al Khali Basin (Saudi Arabia). A key question at all of these locations will be whether changes in the Δ_{48} and Δ_{47} values of carbonates are a result of recrystallization in fluids with elevated temperatures, or if they reflect solid-state reordering. This question can be answered by examining the Δ_{48} and Δ_{47} of different allochems which exhibit varying degrees of physical evidence of recrystallization. For example, if an originally calcitic fossil, which appears pristine, shows elevated temperatures, this change is likely a result of the blocking temperature having been exceeded during burial. The matrix should also indicate this elevated temperature. If the matrix indicates a different temperature, it is evident that the deposit has experienced a more complex diagenetic and burial history. As

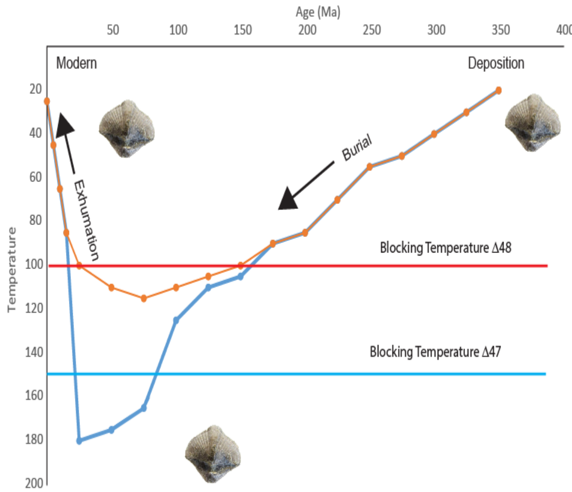

Figure 1: Hypothetical temperature attained during the burial of two basins and the blocking temperatures of Δ_{47} and Δ_{48}.

a result of the observation that Δ_{48} may change more quickly than Δ_{47} when heated and cooled, the Δ_{48} parameter provides additional constraints on the process as well as being able to detect changes below the blocking temperature of Δ_{47}. The difference between the Δ_{48} and Δ_{47} values will be dependent upon the rate of cooling. While rapid cooling will lock in the Δ_{48} and Δ_{47} values at higher temperatures than slow cooling, the rates associated with these processes still need to be determined through laboratory studies. Further information may be obtained in situations where there are mixtures of calcite and dolomite, both of which have differing blocking temperatures (Lloyd et al., 2018; Passey and Henkes, 2012). Two hypothetical cases are presented (Fig. 1). Here two basins have been buried to ~2.5 and 5 km reaching temperatures of ~ 120 and 180°C. If the sample is buried only to 120°C, the Δ_{47} of the calcite will not have been reset. In contrast, the blocking temperature for the Δ_{48} value for calcite will have been exceeded, and therefore a higher temperature will be indicated in material retrieved from the section. In the second case the samples are heated beyond the blocking temperatures. The Δ_{47} values will indicate a higher temperature, while the Δ_{48} will indicate a lower temperature than that conveyed by the Δ_{47}.

SIGNIFICANCE

The twin clumped isotopic proxies can provide new insights into the geothermal and diagenetic evolution of sedimentary basins and will be useful in a range of situations in which traditional methods may not be suitable

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