Improving Thermal Models Using a New Approach to Constrain Paleo Geothermal Gradients and Paleo Water/Rock Ratios with the Geochemical Record of Recrystallized Carbonates

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Abstract

Accurate thermal models are essential to predict the maturity of source rocks away from control wells, and to provide a predictive context to diagenetic transformations impacting reservoir units. In settings dominated by carbonates, constraining thermal histories can be complicated by the lack of traditional geothermal proxies such as apatite fission track, vitrinite reflectance, or conodont index. Here, we show the combined results of two PhD studies that illustrate the potential of clumped isotopes paleothermometry to constrain the thermal histories of carbonate buildups. We also demonstrate that when paired with LA ICPMS U-Pb dating, this technique yields much less ambiguous time-temperature paths for the studied wells, thus resulting in more tightly constrained thermal models at the scale of the basin. The case studies selected for our work were the Marion Plateau (ODP Leg 194 - Coral Sea) and Resolution Guyot (ODP Leg 143 - Western Pacific Ocean). At both locations, we investigated the diagenetic history of the unit through petrography, cathodoluminescence, FTIR/XRD and clumped isotope of different cement phases. Results clearly indicate that most carbonates, including micrite and early dolomites, recrystallize even at shallow burial depths, and that the recrystallization process is faithfully recorded in both the clumped isotope and the U-Pb data. Interestingly, it would appear that this recrystallization is often (though not always) occurring at very low water/rock ratio as demonstrated by the correlation between the

calculated oxygen isotope composition of the diagenetic water and clumped isotope temperatures. The implication is that significant reservoir-scale water flow may not be a prerequisite for substantial modification of petrophysical properties via recrystallization of carbonates, at least not when fine-grained carbonates are present. In addition, our data shows that this recrystallization process has the potential to record paleo geothermal gradients: on the Marion Plateau, the recrystallized dolomites follow the modern geothermal gradient. At Resolution Guyot, the data yields a modern geothermal gradient but also a second, warmer geothermal gradient for the cements dating back to the Lower Cretaceous. The U-Pb ages at Resolution Guyot can thus be combined with the thermal values obtained from clumped isotopes in order to derive a history of temperature through time and burial depth at this particular location. Our overall conclusion is that the new workflow we developed combining clumped isotopes and U-Pb dating appears robust, and can be used in thermal models studies either on its own or in conjunction with other thermal indicators. The next step in establishing this technique is to apply it to more challenging case studies with complex thermal histories and see how it performs.

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