Narrative Progress Report
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Conodont Thermochronology: Expanding the Utility of the (U-Th)/He Method to Marine Carbonates and Shales

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Research problem

(U-Th)/He thermochronometry is a powerful hydrocarbon exploration tool that can provide important constraints on the burial/exhumation histories of source rocks, reservoir rocks, and structural traps and seals. Although the technique can be applied to a wide range of lithologies, marine carbonates and shales present a challenge because they lack the required accessory minerals, limiting opportunities for sampling and for acquiring complete thermal histories. Conodonts have emerged as a novel solution for the application of the method in carbonate-dominated successions; however, additional study is needed. These tooth-like fossils are made of hydroxyapatite with U and Th concentrations similar to magmatic apatite. These microfossils are ubiquitous in Cambrian through Triassic marine successions and are already routinely used for biostratigraphic control and as geothermometers via the conodont color alteration index (CAI). The objective of this study is to test the viability of conodonts as a (U-Th)/He thermochronometer at two different calibration sites. Site 1 focuses on conodonts extracted from outcrops located in footwalls of two major Miocene low-angle normal faults in eastern Nevada and western Utah. Zircon and apatite (U-Th)/He data from the study area, as well as published thermochronology data from the region provide relatively tight constraints on the thermal history of these faults, allowing for direct comparisons with conodont (U-Th)/He results. Site 2 focuses on two core-holes in western Kansas that penetrate relatively continuous sections of Paleozoic carbonates that are well studied in terms of their stratigraphy, paleontology, and geochemistry, but lack needed thermochronometric constraints.

Hypotheses to be tested

This study tests two specific hypotheses. (1) We explore the role of conodont microstructure and CAI on parent isotope distributions and (U-Th)/He dates. Our hypothesis is that hyaline tissue, which varies as a proportion of a whole conodont element, is more prone to parent isotope mobility and results in dispersed and anomalously old (U-Th)/He dates. This tissue type effect may be enhanced with increasing CAI. (2) This study also aims to constrain potential impacts of acid-based rock digestion procedures on geochemical data derived from conodonts. Our hypothesis is that these procedures can affect isotopic concentrations on the margins of the conodont, where parent isotopes may be enriched, and that this effect is enhanced with increasing thermal alteration or CAI.

Research efforts

Our efforts in year 2 have focused on evaluating the underlying causes of open-system behavior on conodont dates. Samples collected from outcrops in the eastern part of the Kansas, that we planned to use for batch experiments exploring the role of laboratory whole-rock digestion procedures on geochemical data derived from conodonts, were dissolved using formic acid-based dissolution procedures. However, conodont yields from our test samples were low and limit the utility of these particular outcrops (Pennsylvanian Toronto Limestone) for our study. R. Ethington, emeritus faculty at the Univ. of Missouri and an expert on conodonts is assisting us with identifying outcrops that will yield high numbers of conodonts needed for statistical rigor. One site has been identified in the Arbuckle Mountains in Oklahoma and another in Missouri. We plan to collect the new samples this month and start whole rock digestion experiments later in the fall semester.

Additional efforts have focused on determining the effects of tissue type heterogeneity in conodonts on isotopic concentrations and to evaluate interior to margin variability and susceptibility to parent loss. To do this, we are using the U-Pb system as a proxy for (U-Th)/He dating (McNay et al., 2017, Jennings et al., 2018). We have dated large (~1 mm in size) sticky tape-mounted and epoxy-mounted and polished conodonts from existing collections (provided by R. Ethington; Univ. of Missouri). The analyzed conodonts come from five well-studied units of known age: Pennsylvanian Houx Limestone (Kansas), Mississippian Cuivre Shale (Missouri), Mississippian Pre-Weldon Shale (Oklahoma), Devonian Holt's Summit Sandstone (Missouri), and Devonian Percha Formation (Arizona). U-Pb spot ages and concentration profiles were obtained from 44 conodont specimens (265 spots) from these units and confirm our earlier efforts (Bidgoli et al., 2018) that suggest high U, Th, and Pb concentrations on the margins of the conodonts. Transects across specimens also suggest improved accuracy of dates moving from conodont margins to interiors. On-going work focuses on obtaining additional data from polished specimens to illustrate U and Pb distributions and better understand influencing factors, including the role of tissue type, microstructural heterogeneities, and color alteration index on conodont U-Pb ages.

Lastly, we continue our efforts on Site 2 in western Kansas. Samples have been described and collected from core in the Rebecca K. Bounds and Cutter KGS #1 coreholes in western Kansas. Mineral separation on the clastic samples is complete. Whole-rock digestion of carbonates and carbonaceous shales will initiate once results are in-hand from batch experiments. Both the clastic apatite and conodont bioapatite will be dated using the (U-Th)/He method in the Spring of 2020.

Professional impact

Funding provided by the Petroleum Research Fund has allowed me to provide various types of support (analytical support, student hourly pay, and graduate stipend and tuition support) for three students (one M.S. student, one undergraduate student, and a postdoctoral fellow). The funding has been critical in providing these students with (1) exposure to geologic field work and sampling, (2) direct experience with state-of-the-art analytical instruments at the University of Kansas - Isotope Geochemistry Laboratory and University of Texas - (U-Th)/He and U-Pb Geo-Thermochronometry Lab, including training on sample preparation, data acquisition and reduction, and interpretation; and (3) opportunities to prepare and present their research results. The ability to fund these students and their research is also critical to my professional advancement in a tenure-track faculty position.

Publications (*student advisee supported by grant)

Bidgoli, T.S., Tyrrell, J.P., Möller, A., Walker, J.D., and Stockli, D.F., 2018, Conodont thermochronology of exhumed footwalls of low-angle normal faults: A pilot study in the Mormon Mountains, Tule Spring Hills, and Beaver Dam Mountains, southeastern Nevada and southwestern Utah: Chemical Geology, v. 495, p. 1-17, doi: 10.1016/j.chemgeo.2018.06.026.

Mcnay, H., *Jennings, D.L., Möller, A., **Bidgoli, T.S.** and Walker, J.D., 2018, Testing the viability of conodonts as a U-Pb geochronometer using Kansas core and outcrop samples: Geological Society of America Abstracts with Programs. v. 50, n. 4 , doi: 10.1130/abs/2018NC-312425.

*Jennings, D., **Bidgoli, T.S.**, Möller, A., and Walker, J.D., 2018, Assessing uranium heterogeneity and U-Pb geochronology viability in conodont elements using Kansas outcrop samples: Geological Society of America Abstracts with Programs, v. 50, n. 6, doi: 10.1130/abs/2018AM-323364.

Bidgoli, T.S. and Wang, W., 2019, Assessing the viability of phosphatic fossils for geo- and thermochronology: AAPG Midcontinent Section Meeting 2019, Wichita, KS.