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Geology of non-plate tectonic regimes: detrital zircon age records and beyond

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Studying the early evolution of terrestrial bodies in our solar systems is challenging. In part, this is because preserved early records are poorly preserved (e.g., Hadean rocks on Earth) and/or hard to access (e.g., rocks on Mars and Venus). Another commonly underappreciated factor is that the testable predictions for the diverse proposed tectonic regimes for early terrestrial bodies are currently underexplored. A better understanding of the consequences of different tectonic regimes can enhance our ability to constrain the early evolution of terrestrial bodies, including the timing of plate tectonic initiation on Earth. In this contribution, we use the example of detrital zircon geochronology to show how first-order predictions for various tectonic modes can be made based on their basic kinematics via relatively simple tools, and how these predictions can provide 1) abundant additional interpretive probabilities for common datasets, and 2) potentially significant implications for the tectonics of early Earth. Using simple Monte Carlo methods with MATLAB codes, we simulated detrital zircon age predictions for basins predicted by heat-pipe tectonics and cold stagnant-lid tectonics based on their relevant numerical models and/or evolutionary diagrams. We show that the first-order predictions for detrital zircon age patterns can be generated by focusing on simulating key mechanisms (e.g., volcanic resurfacing) that control the detrital zircon age characteristics of these two tectonic regimes. Such simulations can be done by simple codes based on a few parameters reflecting basic kinematics of relevant tectonic regimes. We find that differences between new detrital zircon age predictions and those of plate tectonic settings permit better tectonic discrimination via a globally compiled Archean detrital zircon age dataset. The results indicate a transition from heat-pipe tectonics to plate tectonics within the ca. 3.4-3.2 Ga period. Beyond detrital zircon age patterns, we also summarized other possible categories of first-order predictions for non-plate tectonic models, including metamorphic patterns, structural patterns, and crustal thicknesses. Relevant predictions of these categories are variably explored and can potentially be easily modeled or conceptualized via geological tools.