Fitting a new piece into the Precambrian puzzle: the detrital rutile record and its links to modern plate tectonics

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Plate tectonics is responsible for shaping the Earth's surface, influencing the geological, hydrological and atmospheric cycles. However, there is no consensus on when plate tectonics initiated: was it fully operational during the Archean or did it not develop until the Proterozoic?

Much of what is currently known about the secular evolution of Earth's continental crust and its links to plate tectonics has been recovered from detrital minerals. This is related to the incomplete rock record; the detrital record allows access to information from eroded and unexposed terrains. Most studies have relied on the detrital zircon record, but it is still unclear if the coincidence in age peaks with periods of supercontinent assembly reflects episodic continental growth or bias due to selective preservation of new crust within collisional orogenic belts. Furthermore, because zircon mostly grows in high-temperature conditions, it mostly calibrates magmatic cycles. To understand the evolution of plate tectonics and to assess its influence on continental crust preservation, we developed a new proxy, relevant to a range of metamorphic conditions, including HP-LT.

We investigate the U-Pb distribution ages of detrital rutile, from a range of modern stream sediments and siliciclastic units at sub-amphibolite facies metamorphic grade. Rutile mostly forms in collisional orogens and, by comparison with the zircon record, we can test the existence of a preservation bias. Zircon and rutile age distributions from our sample sets show a significant correlation, both peaks and troughs, that can only be reconciled if the detrital zircon record reflects a preservation bias that occurred during supercontinent assembly.

We further present new U-Pb and trace element data from detrital rutile within two clastic sedimentary units, preserved at sub-greenschist facies conditions in NW Scotland. These are the Torridon (Tonian) and the Ardvreck (Cambrian) groups, whose detrital zircon ages span a significant period between 3 and 1 Ga. By applying Zr-in-rutile thermometry and comparing it to the preserved metamorphic record, we show that both low and high dT/dP conditions can be inferred since at least 2.1 Ga.

Combining the existence of paired metamorphism up to 2.1 Ga with the periodic preservation of the continental crust throughout most of the Earth's history implies that one-sided subduction, a
hallmark of plate tectonics, has operated since at least the late Paleoproterozoic, and that supercontinent assembly during and after this period has been driven by plate tectonic mechanisms.