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Geological cycles and a two-stage history of the Continental Crust (Robert Wilhelm Bunsen Medal Lecture)

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The continental crust is the archive of Earth history, and the apparently cyclical nature of geological evolution is a feature of the geological record. The advent of radiometric ages has highlighted that the spatial and temporal distribution of the Earth's record of rock units and events is heterogeneous with distinctive peaks and troughs in the distribution of ages of igneous crystallization, metamorphism, continental margins and mineralization. It is argued that the temporal distribution largely reflects the different preservation potential of rocks generated in different tectonic settings, rather than fundamental pulses of activity, and the peaks of ages are linked to the timing of supercontinent assembly. In contrast there are other signals, such as the Sr isotope ratios of seawater, mantle temperatures, and redox conditions on the Earth, where the records are regarded as primary because they are not sensitive to the numbers of samples of different ages that have been analysed.

Models based on the U-Pb, Hf and O isotope ratios of detrital zircons suggest that at least ∼60-70% of the present volume of the continental crust had been generated by 3 Ga. The sedimentary record is biased by preferential sampling of relatively young material in their source terrains. The implication is that there were greater volumes of continental crust in the Archaean than might be inferred from the compositions of detrital zircons and sediments. The growth of continental crust was a continuous rather than an episodic process, but the rates of continental growth were significantly higher before 3 Ga than subsequently. The time-integrated Rb/Sr ratios, and the average SiO_2 contents, indicate that new continental crust was largely mafic over the first 1.5 Ga of Earth's evolution, and that significant volumes of pre-3 Ga crust may have been associated with intraplate magmatism. Since ∼3 Ga there has been an increase in Rb/Sr, SiO_2, and the inferred thickness of new crust, consistent with an increase of continental input into the oceans and the onset of plate tectonics. The 60-70% of the present volume of the continental crust estimated to have been present at 3 Ga, contrasts markedly with the <10% of crust of that age apparently still preserved and it requires ongoing destruction (recycling) of early formed crust and subcontinental mantle lithosphere back into the mantle through processes such as subduction and delamination.