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Geological cycles and the generation of the Continental Crust

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Alexander du Toit was an early advocate of the theory of continental drift, and the first to realize that the southern continents had at one time formed the supercontinent of Gondwana. The apparently cyclical nature of geological evolution is a feature of the geological record. The advent of radiometric ages has highlighted that the continental crust is characterised by distinctive peaks and troughs in the distribution of ages of igneous crystallization, metamorphism, continental margins and mineralization. These peaks of ages tend to align with the ages of supercontinents, and 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 magmatic activity. In contrast there are other records, such as the Sr isotope ratios of seawater, metamorphic conditions, mantle temperatures, and redox conditions on the Earth, where the records are not sensitive to the numbers of samples of different ages that have been analysed.

Less than 5% of the geological record consists of rocks older than 3 Ga, and there are no known rocks older than 4 Ga. The sedimentary record is biased by preferential sampling of relatively young rocks in their source terrains, and this needs to be accounted for in studies that use sediments to sample the continental crust. Studies based on Nd isotopes in sediments, and 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 growth of continental crust was continuous, but there was a decrease in the rate of crustal growth at ~3 Ga. Before 3 Ga the rates of continental growth were high (~3.0 $km^3.yr^{-1}$), but since 3 Ga the net growth rate was ~0.8 $km^3.yr^{-1}$, perhaps because of higher rates of destruction of crustal materials. It is inferred that subduction-driven plate tectonics and discrete subduction zones have been dominant since ~3 Ga.

Most crustal rocks were derived from pre-existing rocks in the continental crust. Thus it can be difficult to establish the composition of new/juvenile continental crust and hence the conditions and the tectonic setting(s) in which it was generated. However, these can be addressed using time-integrated Rb/Sr ratios for new crustal material. These Rb/Sr ratios indicate that new continental crust was principally mafic over the first 1.5 Ga of Earth's evolution, and that it became more evolved subsequently. It is inferred that significant volumes of pre-3 Ga crust may have been associated with pre-plate tectonic 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 cyclical nature of the geological record on scales that range from mountain building to supercontinents can be reconciled into a 2 stage history of the Earth, from a pre-plate tectonic to a plate tectonic world, that reflects its thermal evolution.