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Metamorphic pressure and the changing thickness of orogenic crust through time

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Once formed, continental crust is difficult to destroy, such that we have a detailed material record of its existence on Earth dating back >4 billion years. Despite an abundance of quantitative geochemical and geochronological data, secular change in some first-order properties of the continental crust, including its volume and thickness, remain uncertain. Notwithstanding their utility, estimates of the changing thickness of magmatically-active crust that use the chemical composition of dated crustal magmatic rocks (e.g., Sr/Y, La/Yb) and minerals (e.g., Eu anomaly (Eu/Eu*) in zircon) to track the behavior of pressure-sensitive minerals such as garnet and plagioclase are inevitably complicated by variations in the composition of the source, degree of partial melting, magmatic differentiation and late-stage alteration. Here, we argue that the maximum pressure recorded by equilibrated metamorphic rocks from orogens worldwide, excluding those exhumed from the subduction channel, provides a primary signal of the changing thickness of orogenic crust through time that is unaffected by extensive variables, including chemical composition. We use a thermobaric gradient, T/P, of 500 C.GPa¬–1 to subdivide our metamorphic dataset (n = 935) into two groups, higher T/P (≥500 C.GPa¬–1, n = 599) and lower T/P (<500 C.GPa¬–1, n = 336), which we interpret to reflect metamorphism in the orogen and in the subduction channel, respectively. The higher T/P data provide a quantitative minimum estimate of the maximum thickness attainable by orogenic crust back to the Paleoarchean era. Despite the uncertainties and assumptions involved, the secular variation in the apparent thickness of orogenic crust is consistent with independent geological data, including periods of supercontinent assembly and breakup, and may help constrain a key variable in our quest to better understand the evolution of tectonics on Earth.

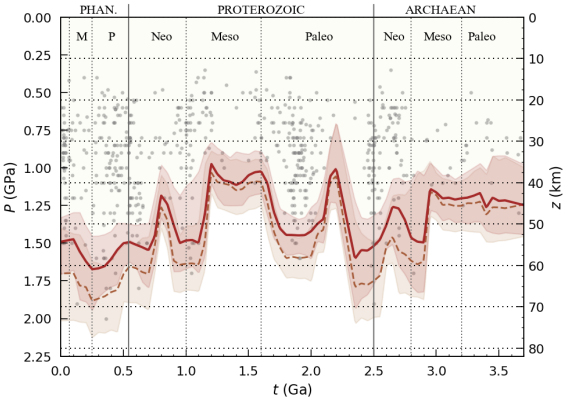


Figure: smoothed pressure–age (P–t) curves for metamorphism with T/P >500 C.GPa¬–1 showing the 95% (solid) and 99% (dashed) percentiles based on the nearest 5% of data. Also shown are the two-sigma uncertainties on each curve, which incorporate an arbitrary uncertainty of ±0.1 GPa on each metamorphic datum. The conversion to crustal depth (z) assumes a bulk crustal density of 2.8 kg.m–3.