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Secular changes in sedimentary source compositions and consequences for partial melting in orogenic belts

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Phase equilibrium modelling provides valuable insight into mechanisms happening in the lower crust, such as partial melting, chemical disequilibrium, and phase segregation. In continental collision settings, partial melting of siliciclastic sediments such as shale and greywacke results in the formation of peraluminous magmas and anatectitic networks. When viewed on a global scale, the protolith strata record a compositional secular change from the Archean to Phanerozoic. To explore the consequences of the changes in protolith bulk composition on the nature of crustal reworking mechansims, we used a thermodynamic modelling approach (Perple_X) to forward model the chemical properties of average Archean, Proterozoic, and Phanerozoic shale and greywacke compositions equilibrated along two Barrovian-type geotherms: 1330 °C/GPa and 800 °C/GPa.

Phase equilibria modelling shows that (1) Archean shales can retain nearly twice as much water (4 vol%) than Proterozoic and Phanerozoic shale compositions during prograde metamorphism. (2) High Mg# (e.g. Mg/[FeTotal+Mg]) in the source material increases chlorite stability at higher temperatures. Archean sediments will be subject to greater devolatilzation during the chlorite-biotite phase transition, which will prevent or limit the formation of subsolidus muscovite. (3) As a consequence, fluid-absent biotite dehydration melting is likely to play a greater role in the generation of peraluminous melt during high-grade metamorphism of Archean aged siliciclastic units. Water-absent muscovite dehydration melting becomes predominant through the Proterozoic and Phanerozoic. (4) The resulting anatectic melt evolve towards a lower-viscousity, Ca-rich, and Mg-poor monzogranite from the Archean to the Phanerozoic.

Our findings suggest that secular compositional changes in sedimentary source material within convergent settings, may perceptibly influence the chemical properties of the lower crust and the nature of crustal reworking mechanisms through time. Importantly, the capacity for Archean siliclastic rock to retain a greater amount of water at high temperature will limit the production of anatectic melt during the reworking of ancient terrains.