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Were Archaean continental geothermal gradients much steeper than today?

BURKE AND KIDD[1] have suggested that the scarcity of 'minimum-melting' granites in the Archaean Superior Province of Canada shows that temperatures at the base of the Archaean sialic crust (35 km depth) did not generally exceed 800 °C. From this they deduce a surface geothermal gradient of less than 23 °C km^{-1} compared with 17 °C km^{-1} in such regions today. Although their suggestion for Archaean temperatures at 35 km depth is confirmed by *P–T* determinations on Archaean granulites (summarised in ref. 2) their calculation of the geothermal gradient does not comply with conductive properties and distribution of heat producing elements within the Earth. Their calculation merely divides 800 °C by 35 km, assuming constant thermal conductivity, total absence of heat producing elements in the crust and constant geothermal gradient in the crust[3]. Such an extrapolation bears no relationship to a natural steady state geotherm and cannot be used to infer a surface geothermal gradient. Their 'geothermal gradient' could only be produced by a sub-crustal heat flow of ~2 HFU (compared with modern values of 0.8 HFU) and no crustal heat production. A model geotherm for uniform distribution of heat production in the Archaean crust, fitting temperatures ~800 °C at 35 km depth, gives a near-surface geothermal gradient of ~40 °C km^{-1} (ref. 4). For a more geochemically reasonable, exponential decrease in heat production with depth in the Archaean crust[5], an even larger near-surface geothermal gradient is obtained. The small amount of data available for Archaean *P–T* relationships suggests a surface heat flow at ~3,000 Myr, between two and three times modern values. This lack of data indicates the most urgent need for geothermal studies in Archaean terrains. Continental heat flow as high as that indicated by *P–T* studies has important implications for both lithospheric thickness and the dynamics of lithospheric motion that may not coincide with uniformitarian hypotheses about island arcs, Benioff Zones and so on, during the early history of the Earth[6].

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BURKE AND KIDD REPLY—We did not intend to suggest that our gradients bore any relationship to near-surface geothermal gradients. It may have been clearer to have termed them average geothermal gradients. Our purpose in quoting these gradients was simply to emphasise that the temperature at the base of the crust (and therefore the contribution to conductive heat flow coming from below the crust) cannot have changed greatly since the stabilisation of the Archaean Superior Province greenstone–granodiorite terrains 2,500 Myr ago, and that this can be inferred from the lack of geological evidence for extensive melting of the lower crust in this and similar regions. Near-surface geothermal gradients are irrelevant to our arguments. We disagree completely that 'Archaean *P–T* relationships', presumably inferred from regional metamorphic mineral assemblages and their distribution, yield any information about the near-surface thermal gradients that existed in areas of Archaean continental crust in stable areas remote from orogenic zones. Such assemblages yield information only on the peak thermal gradients during discrete events of metamorphism and orogeny. Very high, near-surface thermal gradients can be inferred from mineral assemblages in many regionally metamorphosed terrains of post-Archaean age; such thermal gradients are also only valid for the time and place of the orogeny, and contain no information about the near-surface heat flow through stable continental crust elsewhere at that time. Such orogenic and metamorphic events have been restricted to zones of plate convergence or arc/continental collision during the latter half of Earth history, and we see no reason to suppose differently for the Archaean.

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