'Fossil' geotherms frozen in diamond require very deep (>300 km) early Kalahari cratonic lithosphere

B. C. HOARE*[1], E. L. TOMLINSON[1], B. S. KAMBER[2]

[1] Department of Geology, Trinity College Dublin, Ireland
[2] School of Earth, Environmental and Biological Sciences, Queensland University of Technology, Australia

In the Archaean, global surface heat flow was substantially higher than today because of greater internal radiogenic heat production and primordial heat content within the Earth. Nonetheless, the lithospheric roots of Archaean cratons were apparently surprisingly cool, recording similarly low ambient temperatures to those inferred today, allowing e.g. for the stabilisation of diamond. This finding is seemingly in conflict with a generally 'hotter' Archaean mantle, as is widely postulated, but the paradox could be explained if the sub-cratonic lithospheric mantle was substantially thicker in the Archaean than today.

Here, we report a re-investigation of the thermal structure of the Archaean Kalahari lithosphere using published and unpublished petrological data of diamond inclusions indicated to be of Archaean age. Our thermobarometric calculations agree with earlier findings that the Archaean cratonic mantle root was surprisingly cool. Importantly, the shape of the inclusion-derived P-T array deviates from the modern geotherm recorded by peridotite xenoliths. Specifically, diamond inclusions define a systematically steeper geothermal gradient than is observed in cratonic xenoliths. We find that Archaean diamond inclusion and modern xenolith P-T data cannot be reconciled by a single steady-state geotherm. The P-T conditions recorded in diamond inclusions are incompatible with the current characteristically low present-day heat-production of the overlying crust. Instead, the steeper geotherm implies high heat production in the crust during diamond formation and the distinctive geothermal gradient recorded in the studied diamond inclusions could reflect ancient mantle conditions.

We modelled a suite of 'fossil' geotherms, with increased radiogenic heat production within the crust during the Archaean. Solutions providing very good fits with the diamond inclusion geotherm all require that the Archaean lithosphere must have extended to far greater depths than is preserved today. The required depth ranges from ~ 300 km to ~ 450 km depth, for a modern (~ 1350°C) and a significantly hotter (~ 1600°C) mantle potential temperature, respectively. In either case, it is clear that the Kalahari lithosphere must have experienced significant (at least 100 km) basal erosion subsequent to its formation.