Modeling Archean sub-continental mantle dynamics and heat flow using diamond stability constraints

Craig O'Neill[1], **Louis Moresi**[2]

[1] *The University of Sydney School of Geosciences, Division of Geology and Geophysics, Edgeworth David Building F05, NSW, Australia, 2006*
[2] *CSIRO Exploration & Mining, PO Box 437 Nedlands WA 6009*

Models for the thermal history of the Earth have, historically, frequently ignored a conflict in geological observations concerning the Archean thermal regime. The Archean continental thermal regime was, in most places, relatively mild in comparison to the higher upper mantle temperatures inferred for the Archean. Recent numerical experiments (eg. Lenardic 1998) involving simple convecting systems have provided a physical basis for the postulation that this inconsistency can be resolved if the oceans carried a greater proportion of the global heat flux in the Archean.

A particle-in-cell finite element code (Moresi et al, 2001) was employed to extend realistic convection models of the modern Earth (Lenardic et al., 2000) to Archean conditions. The models incorporate a strongly temperature viscosity, yield criterion for the lithosphere which allows a plate- like mode of convection to develop, and chemically distinct continental crust. A mode of convection with mobile oceanic regions and continents with relatively thick thermal roots is stable up to the high Rayleigh numbers (a measure of convective vigour) applicable to the Archean. Given this observation, the increase in the partitioning of heat flux implied for simple Archean convection models, similarly occurs for systems capable of generating plate-like motion. This result is robust under a wide range of parameter variations. The continental crust modulates the thermal conditions of the mantle, extending the depth of the thermal boundary layer beneath the continent, thus providing a mechanism for stabilising the sub-continental thermal field. This effect can explain the primary features of the Archaean thermal record.

Constraints provided by Archaean diamonds not only requires that the conditions necessary for diamond stability existed in the Archaean continental lithosphere, but also that those conditions have remained relatively unperturbed for 3Gyr (eg. Boyd et al., 1985). We have examined the length of time the sub-continental mantle lithosphere spends in the diamond stability field for a number of convection models which satisfy the Archean heat flow partitioning contraints in the mean. While such systems can account for the provisional existence of Archaean diamonds, they do not directly explain their longevity even in the centre of a craton. We therefore postulate that the thermal stability required for the preservation of Archaean diamonds can only be provided if the cratonic roots are also chemically stabilised against convective recycling.

References

BOYD, F. R., GURNEY, J. J., RICHARDSON, S. H., 1985, Evidence for a 150-200km thick Archaean lithosphere from diamond inclusion thermobarometry, Nature, 315, 387-389.

LENARDIC, A., 1998, On the partitioning of mantle heat loss below oceans and continents over time and its relation to the Archaean paradox, Geophysical Journal International, 134, 706-720.

LENARDIC, A. ; MORESI, L. ; MHLHAUS, H., 2000, The role of the mobile belts for the longevity of deep cratonic lithosphere: The crumple zone model, Geophys. Res. Lett. Vol. 27 , No. 8 , p. 1235

MORESI, L, MUHLHAUS, H.-B. AND DUFOUR , F., 2001 Particle in cell solution for creeping viscous flows with internal interfaces. Proceedings of the 5th International Workshop on Bifurcation and Localisation (IWBL'99), Perth, Muhlhaus,H-B, Dyskin, A and Pasternak, E (eds), Balkema