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Coupling hydrothermal convection to a cooling oceanic lithosphere: the effect on the "square root-t" law

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Cooling of the oceanic lithosphere is strongly affected by hydrothermal convection. A scaling law for hydrothermal convection with depth– and temperature dependent permeability is derived to define an equivalent thermal conductivity. Hydrothermal convection is consistently coupled to lithospheric cooling by solving the 1D conductive heat equation with the usual thermal conductivity replaced by the newly derived equivalent thermal conductivity. Depending on rock physics properties such as crack aspect ratio and surface porosity our results show that hydrothermal convection penetrates into the upper part of the lithosphere as a function of age and enforces cooling. Significant deviations of the heat flux versus age from the 1/square root t - law may occur due to hydrothermal convection: For young to moderately old lithosphere steeper than the 1/square root t - slopes - up to 1/t-slopes - are found. For the bathymetry versus age curves slopes steeper than 1/square root t - slopes already occur for very young lithosphere. Due to the higher equivalent thermal conductivity in the presence of hydrothermal convection the plate-cooling related flattening of the heat flux and bathymetry curve is shifted to younger (60 – 80 Ma) lithosphere. In regard to heat flow a hydrothermally assisted cooling plate may be characterized by a logarithmically bell-shaped rather than a flattening 1/square root t - law. Hydrothermal convection leads to an increase of the total heat flux and heat loss with respect to the classical purely conductive cooling model. Thus previous estimates of the fraction of hydrothermally removed heat might be too low. Comparison of the total heat flow and its conductive contribution with observations confirm previous suggestions that for young lithosphere heat flow measurements represent only the conductive part, while at older ages the total heat flow is observed. Within their scatter and uncertainties heat flow and bathymetry data are in general agreement with our hydrothermally enforced cooling model suggesting that hydrothermal convection may be important even up to high ages.