The first geothermal heat flux measurement below the West Antarctic Ice Sheet

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Geothermal heat flux represents an important boundary condition for ice sheet dynamics and mass balance. It influences ice sheet mass balance directly, through its control of basal melting and freezing, and indirectly as a result of the dependence of ice sliding velocity on subglacial water volume and/or pressure. Until now, geothermal flux reaching the base of the Antarctic ice sheet has been inferred indirectly from geophysical and glaciological models. We measured directly the geothermal heat flux below the West Antarctic Ice Sheet (WAIS), under Subglacial Lake Whillans (SLW), as part of the Whillans Ice Stream Subglacial Access Research Drilling (WISSARD) project. The one-dimensional, conductive heat flux is the product of thermal gradient and thermal conductivity. We developed a borehole tool to determine the thermal gradient in lake sediments, after penetrating ~800 m of ice using a hot water drilling system. We used the needle-probe method to measure the thermal conductivity of sediments recovered from the bottom of the lake with a gravity-driven multi-corer. We installed also a fiberoptic Distributed Temperature Sensor (DTS) to measure englacial ice temperatures and estimate conductive heat loss from the ice base. The subglacial thermal gradient was determined during two separate deployments of the geothermal tool, which penetrated ~1.1 m into the sediments at the bottom of SLW, yielding essentially identical vertical temperature gradients: 0.21±0.07 °K/m. Fifteen sediment thermal conductivity measurements yield an average value of 1.36±0.12 W/m-K. Based on these measurements we calculate the geothermal heat flux to be 285±85 W/m^2. This value is somewhat higher than that estimated from the WAIS-Divide ice core site, 230 mW/m^2, ~800 km away, and much higher than regional estimates based on magnetics and a global seismic model, generally ≤100 mW/m^2. It is also about three times higher than the conductive heat flux into the ice estimated from repeat DTS measurements in January 2013 and 2014. Elevated geothermal flux in this area could result from thermal perturbations associated with rifting, crustal thinning, or volcanic activity. Geothermal heat input of this magnitude is likely to cause basal melt rate of a few cm/year. If this value is representative of conditions below this part of the WAIS, it might help explain the occurrence of active subglacial lakes and fast-moving ice streams.

- Marine ice sheet instability (*Free Fallin')*