Heat flow measurements and the thermal state of the Alaska convergent margin

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Subduction zone thermal models are important to understanding subduction dynamics [e.g., *van Keken et al*., 2002], dehydration reactions [e.g., *Moore and Saffer*, 2001], metamorphic reaction progress [e.g., *Peacock*, 2003; *Hacker et al*., 2003], serpentinization in the forearc [*Abers et al*., 2006], and estimates of temperature limits for interplate seismicity [e.g., *Hyndman and Wang*, 1993; *Oleskevich et al*., 1999]. Dehydration reactions have also been implicated in episodic tremor and slip events [*Schwartz and Rokosky*, 2007]. Making progress toward many of the goals in the *GeoPRISMS -- Suduction Cycles and Deformation* science plan requires well-determined thermal models.

In the seismogenic zone, the thermal structure of subduction thrust strongly depends on the thermal state of the incoming oceanic lithosphere, the convergence rate, and plate geometry. In contrast to the convergence rate and slab geometry that are confidently known from plate motion data and seismology, the incoming plate geotherm is less well known. In the absence of heat flow data, models are commonly idealized using conductive cooling models that are parameterized in terms of plate age [*Parsons and Sclater*, 1977; *Stein and Stein*, 1992]. In fact, uncertainties in these generic models lead to significant uncertainties in the position of isotherms along the plate interface. At subduction zones with plentiful heat flow observations, the data commonly require significant departures from predicted geotherms. Uncertainties in the initial geotherm are can be larger if hydrothermal circulation within the incoming crust has been important. Seafloor probe measurements offer an economical method for obtaining transects of heat flow across the margin and along strike. At subduction zones where plentiful heat flow data exist, significant departures from conductive conditions, rapid changes in heat flow along strike (e.g. Costa Rica), and continuing hydrothermal circulation within the downgoing plate (e.g., Muroto, Costa Rica), have been documented.

Of the convergent margins with historic M9.0 megathrust earthquakes only a few have adequate heat flow to constrain thermal models of the shallow subduction zone (Table 1).

Table 1: Characteristics of subduction zones with M9.0+ earthquakes and Nankai margin

Subduction Zone	Largest Magnitude Earthquake	Well-defined Seismogenic Zone?	Slow Earthquakes and Tremor Observed?	Well-Defined Thermal State?
S. Chile	9.5	Yes	No	No
Alaska	**9.2**	**Yes**	**Yes**	**No**
Sumatra	9.1	Yes	No	No
N. Japan	9.0	Yes	No	No
Kamchatka	9.0	Yes	No	No
N. Chile/Peru	9.0	No	No	No
Cascadia	9.0	No	Yes	Yes
Nankai	8.1	Yes	Yes	Yes

The Alaska margin provides a link between the Nankai and Cascadia margins. It has had a magnitude 9.0 or larger earthquake; it has a well-defined seismogenic zone, and it has had observed slow slip and tremor events. Previous thermal models of the Alaska subduction zone [e.g. *Ponko and Peacock*, 1995; *Oleskevich et al*., 1999; *Gutscher and Peacock,* 2003] have been hampered by the lack of heat flow data to initialize models and validate model results. Along the entire >3200 km length of the Alaska-Aleutian subduction zone, there are only 32 heat flux observations on the incoming plate (Figure 1). In contrast, on the Nankai margin, more than 100 surface heat flux observations were used to constrain the thermal state along one trench-perpendicular transect. The existing thermal models for the Alaska subduction zone are not adequately constrained (Figure 2); to date, no thermal models have been published for the Aleutian portion of the subduction zone.

Thermally important targets for GeoPRISMS research includes documenting 1) the thermal state of the Pacific plate prior to subduction. Is hydrothermal circulation ongoing and has it removed significant quantities of heat? 2) Documenting fluid flow along plate bending normal faults. Is fluid flow along plate bending normal faults significant and does its magnitude correlate with along-strike variations in arc volcanism and seismic attenuation anomalies in the upper mantle? 3) Do along strike variations in the thermally predicted distance between the 100° and 350° C isotherm correlate with observed changes in the width of the interplate seismogenic zone? 4) What is the thermal regime in the forearc and where does the trend in heat flow change from decreasing due to the subducting slab to increasing due to mantle wedge flow [e.g., *Wada et al*., 2008; *Wada and Wang*, 2009]. Does this change correlate with patterns of seismic attenunation in the upper mantle.

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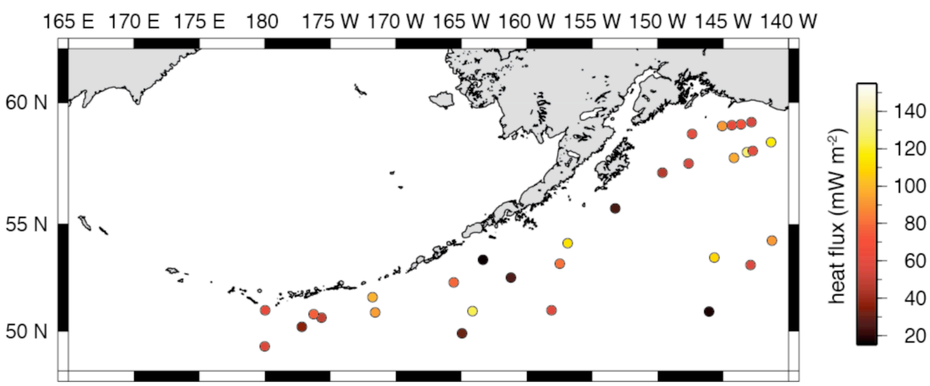

Figure 1. Existing heat flow observations along the Aleutian convergent margin.

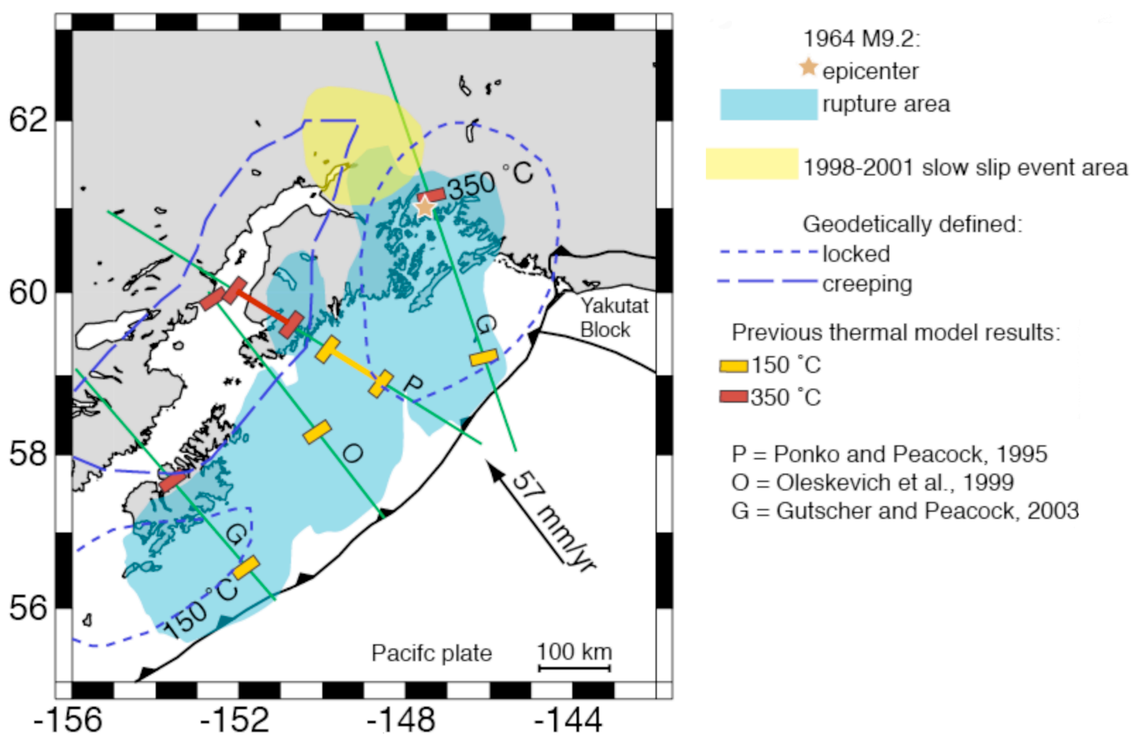

Figure 2: Location and summary of results for previous thermal models for the Alaska margin. The thermal models are 2-D cross-sections along the transects shown (P = *Ponko and Peacock*, 1995; O = *Oleskevich et al*., 1999; G = *Gutscher and Peacock*, 2003). Yellow ticks on the transects show the modeled position of 150 ˚C on the plate boundary fault; red ticks show the modeled position of 350 ˚C on the plate boundary fault. Ranges of locations on line P reflect uncertainty in degree of frictional and radiogenic heating. Blue shading shows 1964 M9.2 earthquake rupture area – assumed to be the full extent of the megathrust seismogenic zone.