

Heat-flux off coast Chile measured during RV Sonne cruise SO 181-1b

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1 Introduction

The detachment surfaces of subduction zones are the locations where the largest earthquakes in the world occur. Most regions located at convergent margins have experienced such mega-thrust events in historical times (Hyndman and Wang, 1993). Of the 40 largest subduction thrust fault earthquakes that took place in the 20th century five were along the Chilean margin. This includes the largest earthquake ever been reported (magnitude MW = 9.5) that occurred 1960 in the TIPTEQ study area (Kanamori, 1977; Grevemeyer et al., 2003). Current models of great subduction earthquakes state that the size of the ruptured zone, and therefore the magnitude of the event, is controlled by the thermal structure of the plate boundary. E.g. Oleskevich et al. (1999) postulate that the updip limit of stick-slip behavior, where earthquakes can nucleate, coincides with a temperature of 100 to 150°C while the downdip limit is at 350 to 450°C. The key factor of a subduction zones' thermal structure is the thermal state of the incoming plate which itself depends chiefly on the age of the subducted crust. Since the age of the subducted plate changes considerably and often abrupt along the southern Chilean trench, the length of the rupture causing the 1960 earthquake of ~850 km (Plafker and Savage, 1970) is very remarkable.

2 Objectives of the project

The objective of this project is to determine lateral variations in the thermal structure of the subduction zone and its correlation with seismic activity in the area around 37°S to 45.5°S off coast Chile, where the rupture of the 1960 earthquake was located.

Firstly, the thermal state of the incoming Nazca plate, which mainly controls the thermal structure of the subduction zone, has to be analyzed in several corridors along the trench. The plates' age, hydrothermal circulation at the ridge flank, and possibly a reactivation of the circulation caused by flexure of the plate close to the trench are the most important factors determining the thermal state of the subducted plate. Following, the position of the seismogenic zone, thermally defined by its updip and the downdip limits, will be localized and compared to results from seismologic experiments.

3 Methods, Results and Present status

Finite element method (FEM) models will assist us to determine the thermal structure of the incoming plate and the subduction zone. In order to constrain these numerical models heat flux measurements supplying boundary conditions on the incoming plate as well as on the continental slope are essential. Since in the past there were only a few heat flux measurements done in the working area, these boundary conditions will be mainly provided by our deployments of violin bow type heat flux pro-

bes (HF-Probes) during SO 181-1b and heat flux estimates from BSR depths.

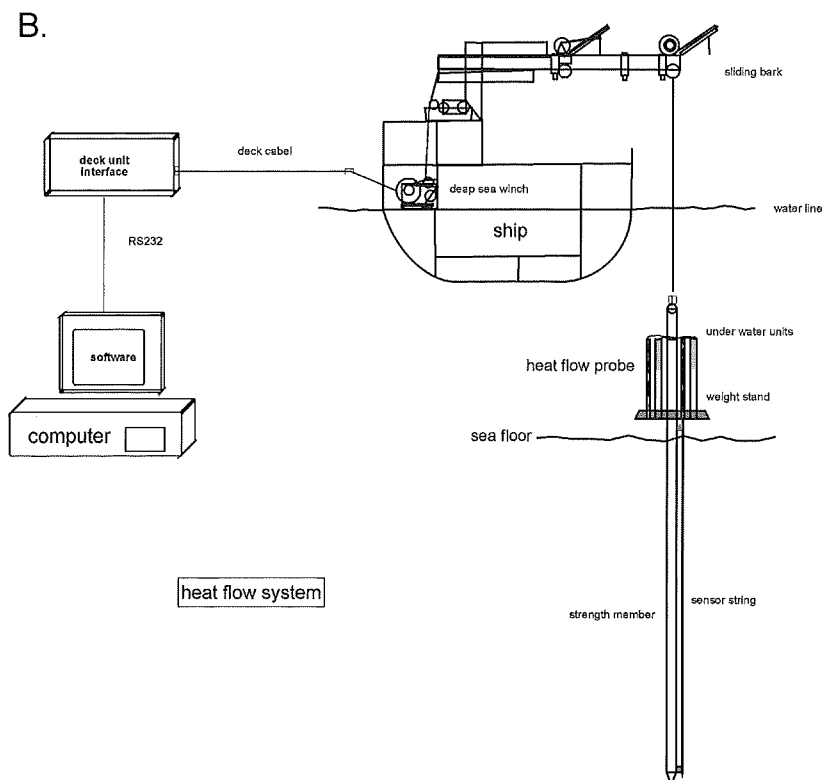
Two different HF-Probes of the violin bow type were deployed during SO 181-1b. The first probe was used for many years and is capable to measure thermal gradients with 11 thermistors that are equally distributed over a sensor-string that is 3 m long. The second probe (figure 1) was developed in the BMBF funded INGGAS project (BMBF grant 03G0564C) in GEOTECHNOLOGIEN in 2001/2002 at the University of Bremen by Dr. H.-H. Gennerich in

the working group of Prof. Dr. H. Villinger. The active length of this probes' sensor string, sampled with 22 thermistors, is extended to a length of 6 m. The increased penetration depth is especially useful for measurements at continental margins, where thermal gradients in the first meters of the sediments are often disturbed by bottom water temperature excursions.

Besides measuring sediment temperatures, both probes are capable of determining thermal conductivities in-situ. Hartmann and



Figure 1: A. Recovery of the new HF-Probe during SO-181-1b. B. Details of HF-Probe operation.



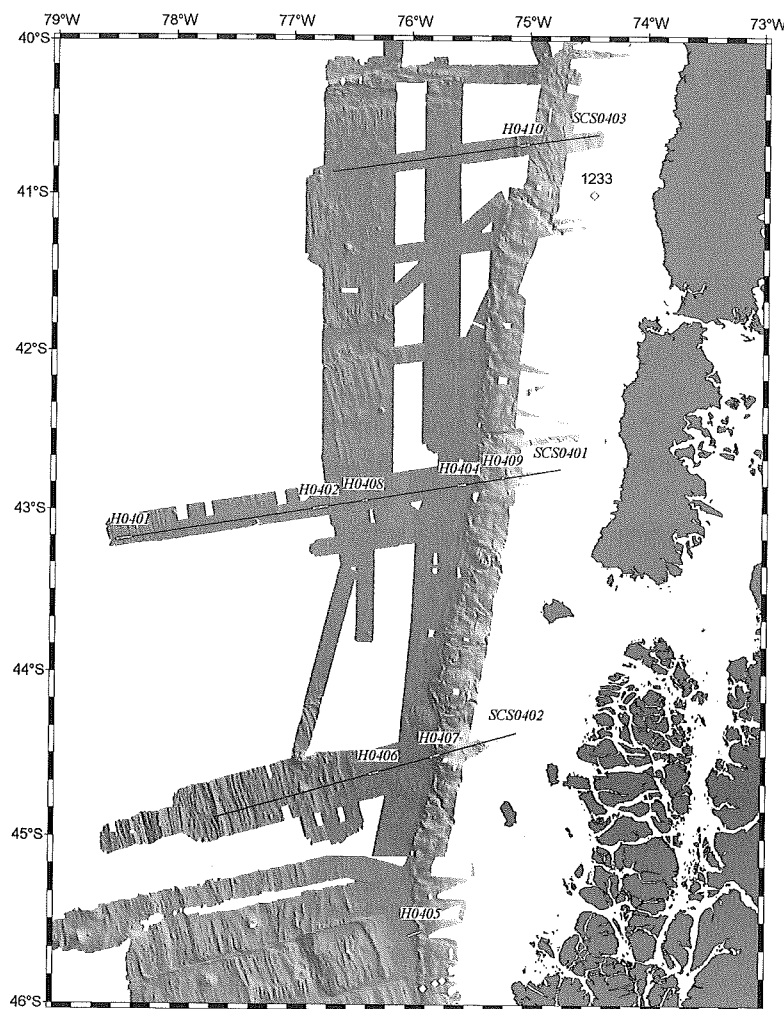


Figure 2: Main study area: with heat flux stations on seismic corridors south of Valdivia, off coast Isla Chiloe and north of the Chile Triple Junction. Squares show locations of ODP Sites drilled during Leg 141 and 202.

Villinger (2002) describe the techniques applied to estimate undisturbed temperature gradients from the measurements that are altered by frictional heating during the probes' penetration. Additionally, they discuss the employed computations of thermal conductivities and heat flux values from HF-Probe data.

Bottom simulating reflectors (BSRs) are abundant in most seismic transects that cross the continental slope of the study area. These BSRs mark the lower boundary of the gas hydrate stability zone, and temperatures at BSR depths can be estimated by utilizing the gas hydrate dissociation temperature-pressure function as published by Dickens and Quinby-Hunt (1994). BSR temperatures and depths calibrated with the sea-floor temperatures and heat flux values measured during SO 181-1b, and thermal conductivity data measured in boreholes of ODP Leg 202, provide the possibility to estimate the heat-flux over wide areas of the

continental slope, as demonstrated by Grevenmeyer and Villinger (2001) and Yamano et al. (1982).

During RV Sonne cruise SO 181-1b 63 successful heat flux measurements at 11 stations (H0401-H0411) were performed. These stations are distributed on seismic transects that image the incoming Nazca plate and continue over the trench on the continental slope (figure 2). All of these transects (SCS0401 -SCS0404) were shot during SO-181-1b, except for the RV-Conrad line 743-corridor #4 where heat flux station H0405 is located. Station H0411 located on the seismics transect SCS0404 offshore Concepcion is not shown, here. It extends a heat flux transect obtained in 2003 aboard the Chilean Navy research vessel Vidal Gormaz (Grevenmeyer, pers. comm.).

In the current stage of the project, the data of all HF-Probe stations has been processed, checked and turned into heat flux estimates.

Picking of BSR depths is in progress and also, first FEM models are under way. These models will, however, be based on a preliminary geometry of the subduction zone until final geometry models, based on the analysis of seismic experiments in the working area, are available.

Heat flux values near the deformation front are highest on the youngest crust (150–200 mW/m²) and very low on the oldest crust (20 mW/m²). However, anomalously low heat flux values around 20 mW/m² in the trench seem to be influenced strongly by sedimentation effects, and extremely low values of 7 mW/m² in the outer rise area offshore Isla Chiloe correlate with apparent sea-water inflow into the oceanic crust. Due to advection of heat into the subduction zone by the downgoing lithosphere, heat flux values decrease landwards of the deformation front to values of 35–70 mW/m².

4 Conclusions

The heat flux data obtained during SO 181-1b fills a huge gap in the global heat flux data set, which contains no information in the TIPTEQ working area north of the Chile Triple Junction and south of Concepcion. Knowledge of heat flux in the working area is an essential constrain for the integrative modeling of subduction processes and their correlation with lateral variations in seismicity.

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