University of Utah
Thermal Geophysics
Research Group
Department of Geology and Geophysics
http://thermal.gg.utah.edu

Heat Flow on Hotspot Swells Reflect Fluid Flow Masking Potential Variations in Mantle Heat Flux

Robert N. Harris[1], and Marcia K. McNutt[2]
[1]University of Utah, Salt Lake City, [2]MBARI, Moss Landing, CA

Introduction

The origin of hotspot swells is poorly understood. Heat flow data collected on hotspot swells have been used to argue for and against sublithospheric thermal anomalies. The presence of sublithospheric thermal anomalies has been inferred from interpretations of anomalously high heat flow determinations, whereas the contention that hotspot swells result from normal melting processes within the lithosphere is based on 'normal' heat flow values. These arguments depend in part on the choice of a thermal reference model, but more importantly assume conductive heat transfer through the lithosphere. We provide evidence that heat flow measurements collected on hotspot swells likely reflect shallow fluid flow rather than deep thermal variations within or at the base of the lithosphere.

Take Home Points

1. Substantial variability in closely spaced heat flow observations along profiles over hotspot swells indicates fluid flow.

2. Observed patterns of fluid flow at smaller seamounts indicate that seamounts are hydrologically active.

3. Coupled fluid and heat flow modeling indicate how the presence of topographic relief (the seamounts) stimulates convection.

4. With a flow loop style of fluid flow, significant quantities of heat can be mined biasing regional heat flow values toward low values.

5. Heat flow observations on hotspot swells reflect shallow fluid flow that obscures the deep thermal conditions at the base of the lithosphere.

Hawaii

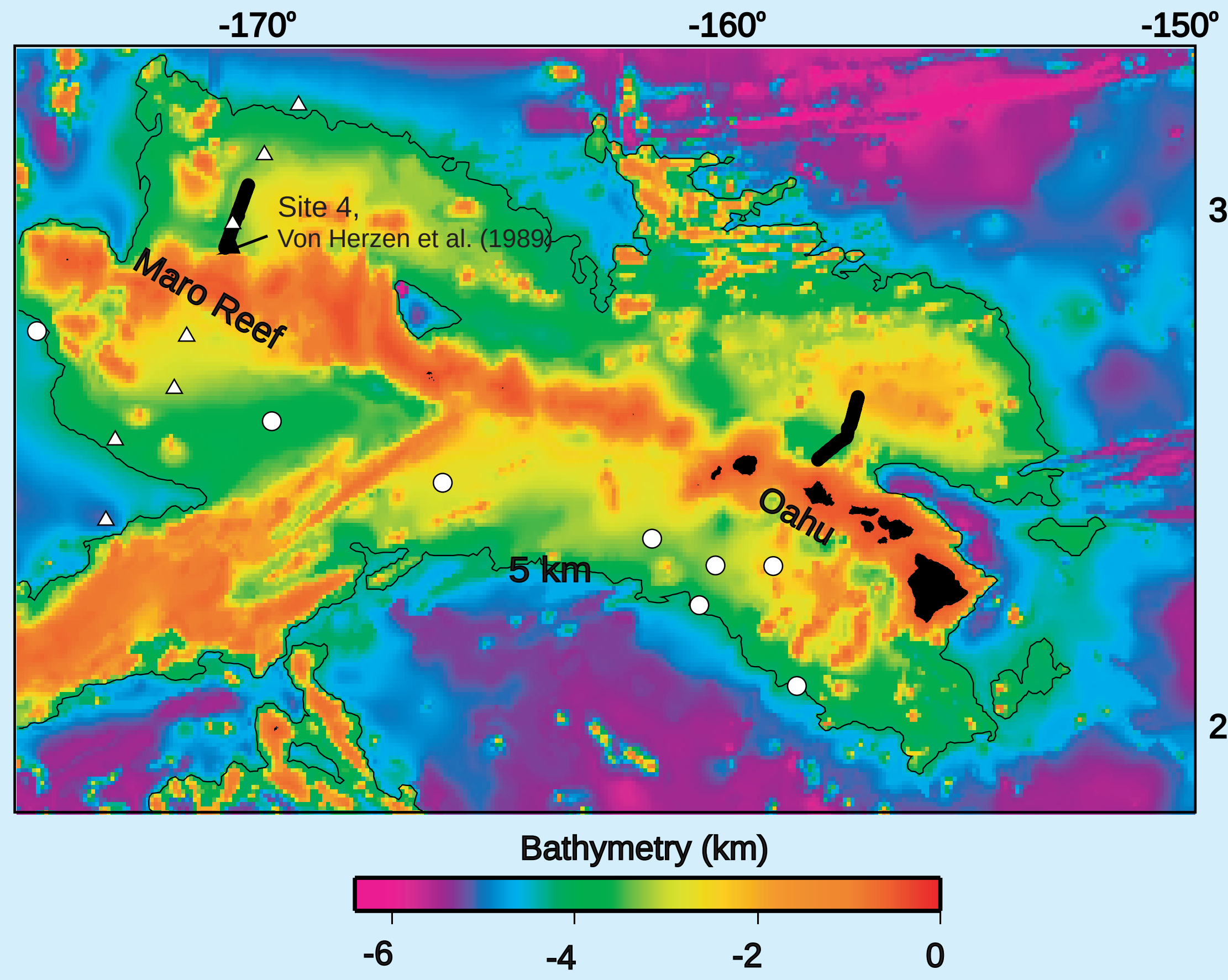


Figure 1. Thermal data from Hawaii. Location of heat flow determinations. White symbols show location of data from South Arch (circles) and Maro Reef (triangles) (Von Herzen et al., 1982, 1989) and thick black lines show data from Harris et al. (2000). The white triangle colocated with the Maro Reef profile is site 4 of Von Herzen et al., (1989). The extent of the Hawaiian swell is approximated with the 5 km bathymetric contour.

Hawaii continued
Coarse Heat Flow Surveys

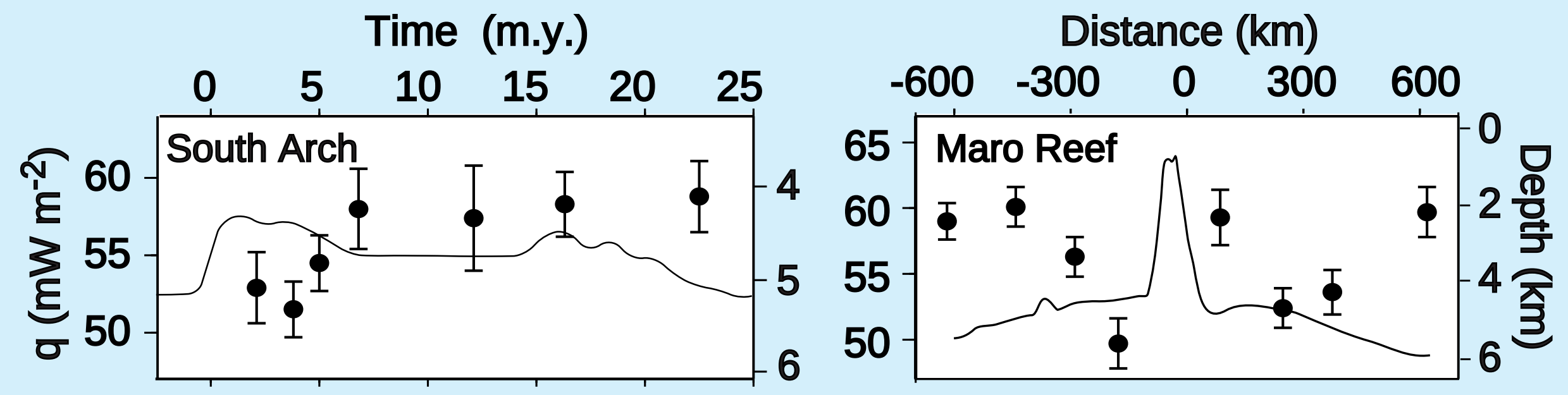


Figure 2. Heat flow values and bathymetry from the South Arch and Maro Reef surveys (Von Herzen et al., 1982, 1989) Time is relative to when the plate passed over the Hawaiian hotsopt. Error bars show 95% confidence limits of heat flow values.

High-Resolution Surveys

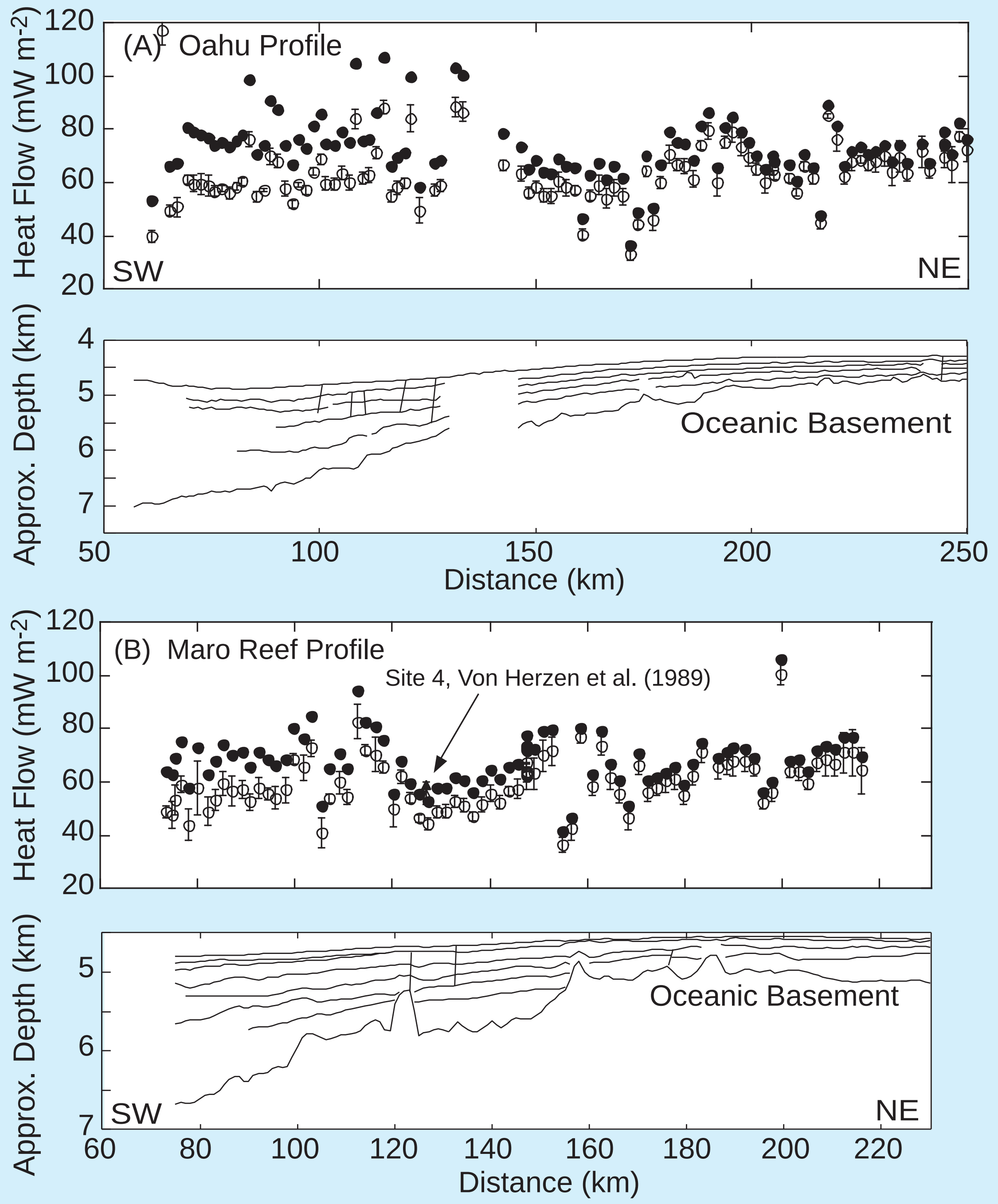


Figure 3. Heat flow profiles collocated with seismic reflection lines for Hawaii. (A) Oahu, (B) Maro Reef. Top panel shows heat flow determinations uncorrected (open circles) and corrected for the effects of sedimentation (solid circles). Lower panel shows line drawing of depth-converted seismic reflection profile (Harris et al., 2000a).

Reunion High-Resolution Surveys

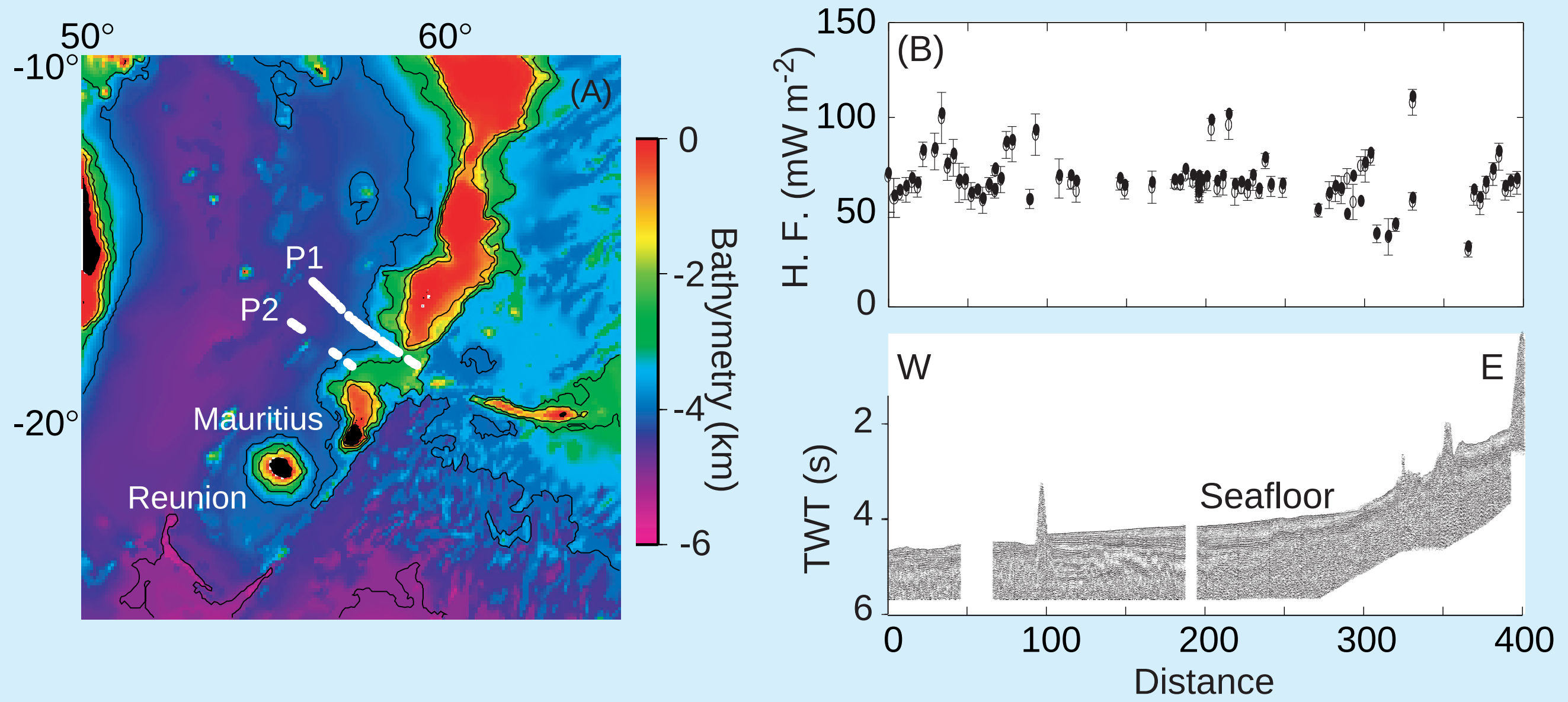


Figure 4. (A) Location of heat flow determinations at Reunion (Bonneville et al., 1997). Heat flow profiles collocated with seismic reflection lines for Reunion. (B) Profile 1. Top panel shows heat flow determinations uncorrected (open circles) and corrected for the effects of sedimentation (solid circles). Lower panels show seismic reflection profile.

Variability

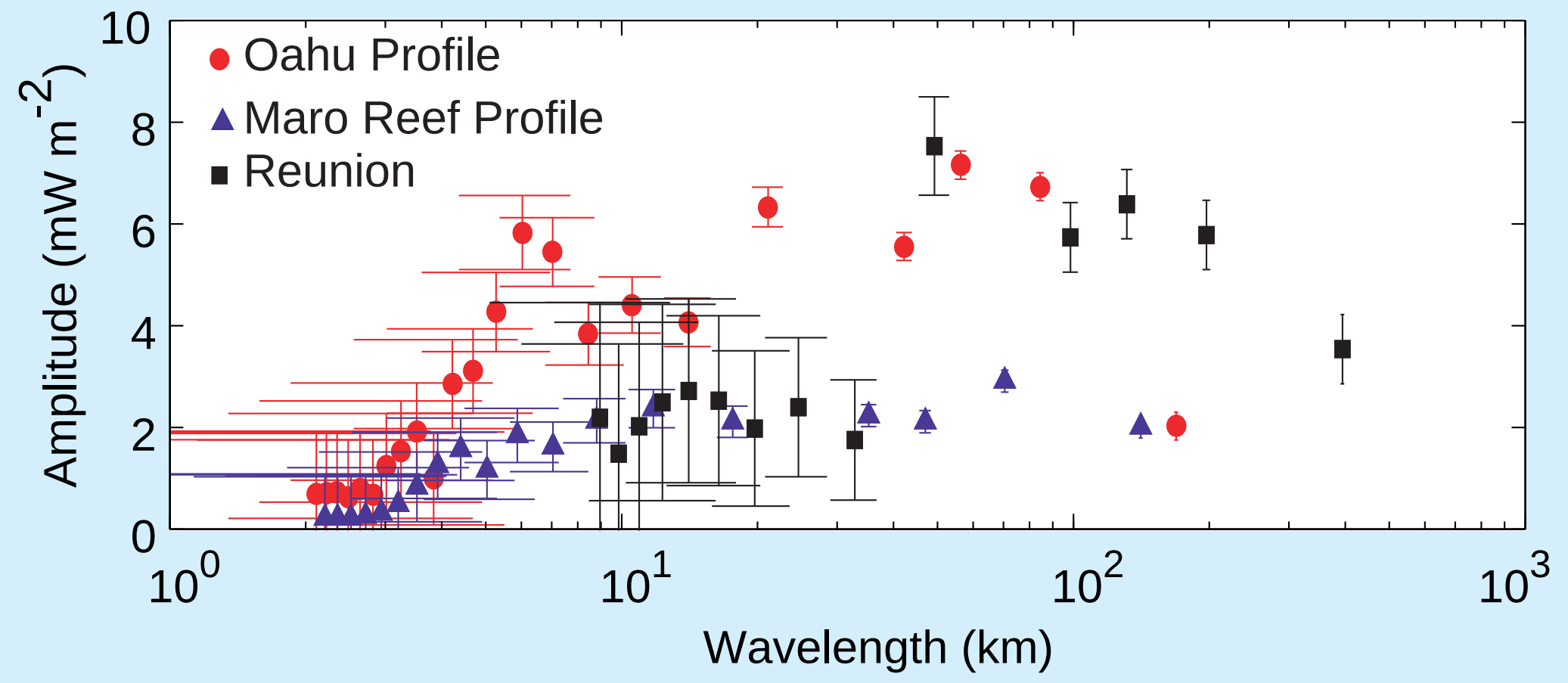
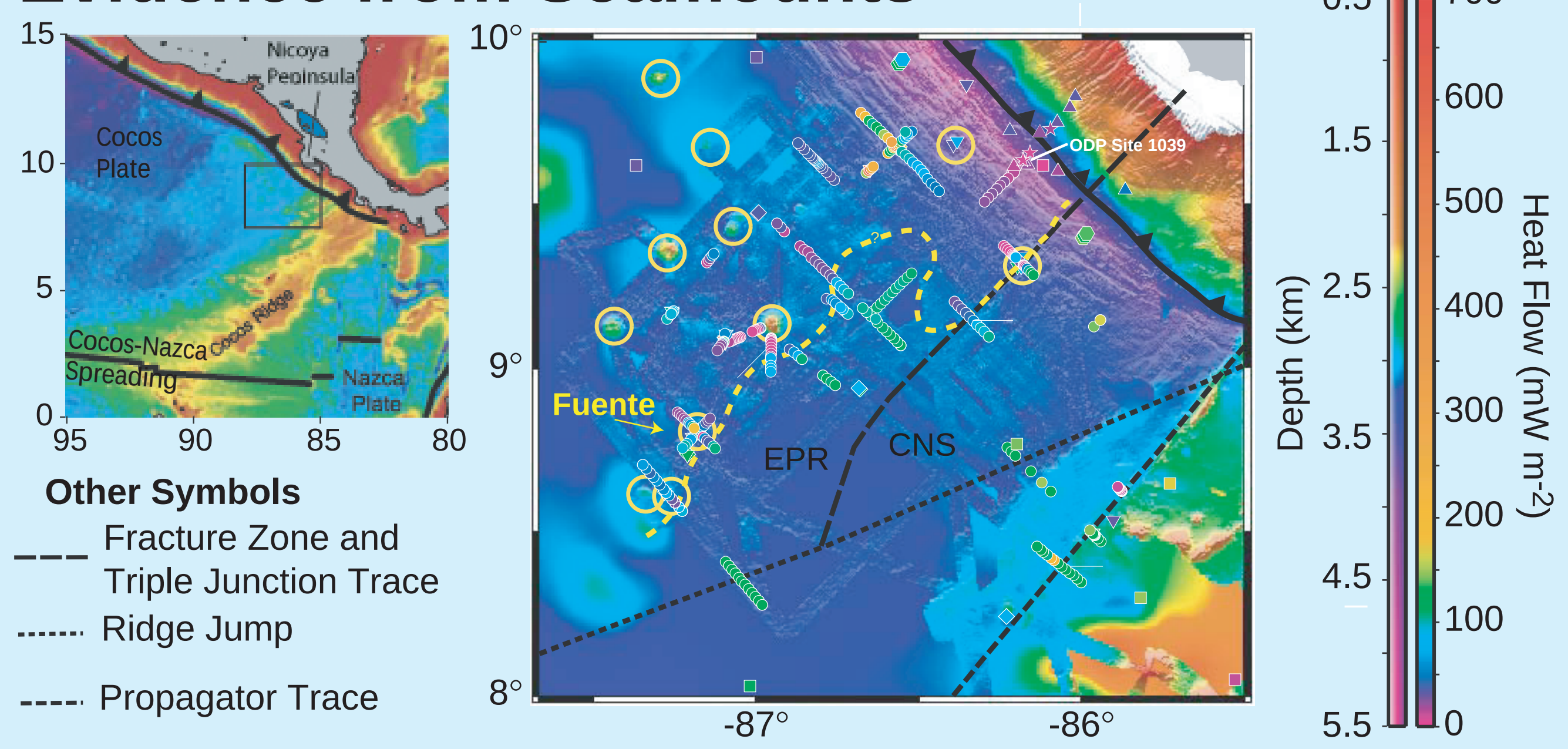


Figure 5. Spectral analysis of closely spaced heat flow profiles on hotspot swells. Note spectral peaks on order of 10 km. Along the Oahu profile there is a strong peak at 7 km, along the Maro Reef profile there is a subtle peak at approximately 10 km, and along Reunion profile 1 there is a peak at approximately 50 km.

Evidence from Seamounts



Other Symbols
- Fracture Zone and Triple Junction Trace
- Ridge Jump
- Propagator Trace
- Middle America Trench
- Seamount
- Thermal Transition

Figure 6. Offshore Nicoya Peninsula showing influence of seamounts on seafloor heat flow. Location map of the TicoFlux study area. Region south of the thermal transition shows the expected heat flow (100 mW m^{-2}) for 20 Ma seafloor. Region north of the thermal transition shows a heat flow deficit of about 70% relative to conductive cooling.

Seamounts continued

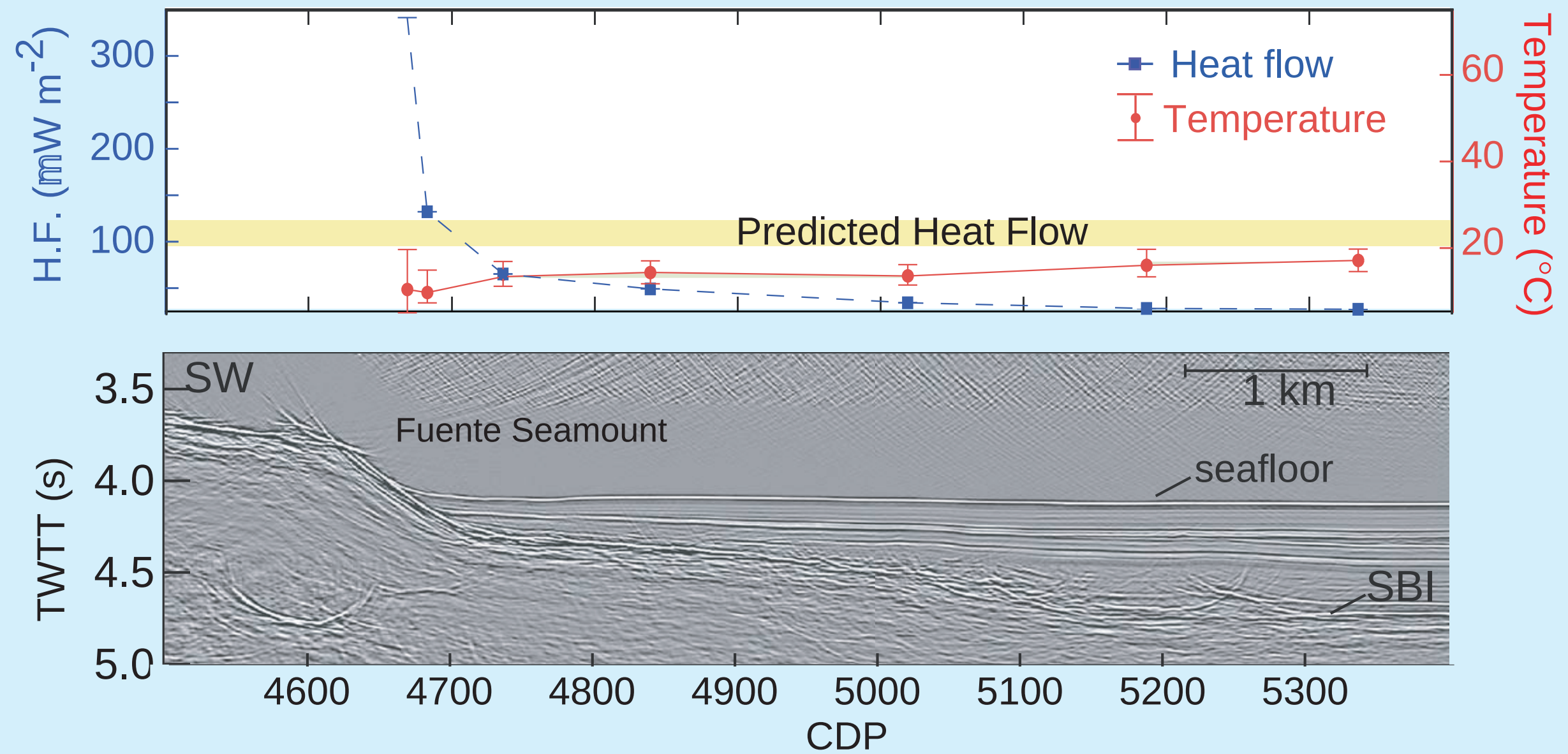


Figure 7. Heat flow determinations and temperature of sediment/basement interface. Yellow bar shows predicted background heat flow. Seismic reflection profile. The sediment thickness ~ 400 m. Figure modified from Hutnak et al., [2004].

Flow Models

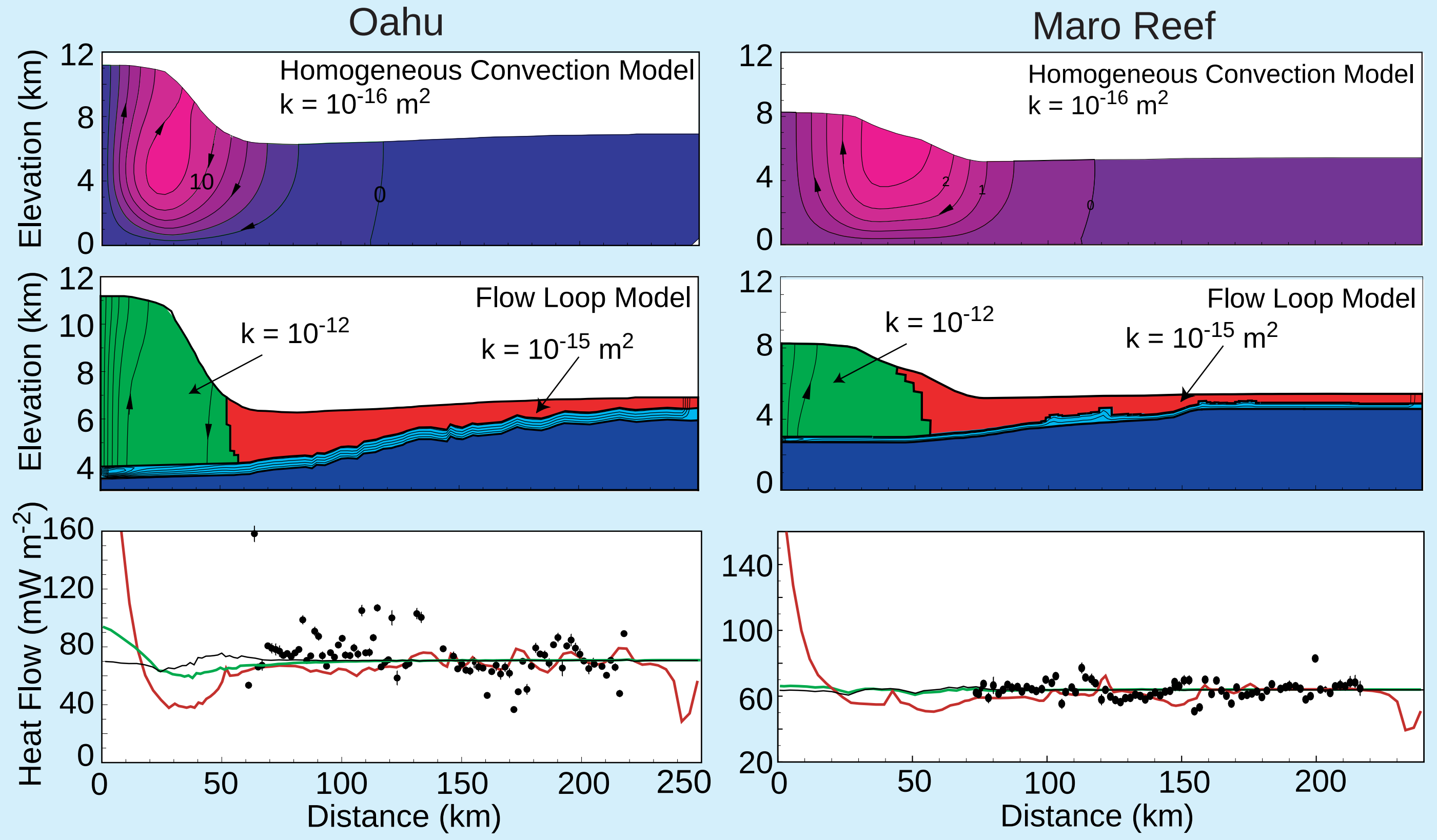


Figure 8. Heat flow determinations (dots) and modelsfor Oahu and Maro Reef. Contours show stream function. Permeability is given in each panel. Conductive (black), homogeneous convection (green), and flow loop (red) models [Harris et al., 2000b].

References

Bonneville, A., R. P. Von Herzen, and F. Lucazeau, 1997, Heat flow over Reunion hotspot track: Additional evidence for thermal rejuvenation of oceanic lithosphere, J. Geophys. Res., 102, 22,731-22,747.

Harris, R.N., R. P. Von Herzen, M. K. McNutt, G. Garven, and K. Jordahl, 2000a, Submarine hydrogeology of the Hawaiian archipelagic apron: 1. Heat flow patterns north of Oahu and Maro Reef: J. Geophys. Res., 105, 21,353–21,369.

Harris, R.N., G. Garven, J. Georgen, M. K. McNutt, L. Christiansen, and R. P. Von Herzen, 2000a, Submarine hydrogeology of the Hawaiian archipelagic apron: 2. Numerical simulations of coupled heat transport and fluid flow J. Geophys. Res., 105, 21,371–21,385.

Hutnak, M., A. T. Fisher, C. A. Stein, R. Harris,K. Wang, E. Silver, et al., in press, The thermal state of the 18-24 Ma upper lithosphere subducting below the Nicoya Peninsula, nothern Costa Rica, in MARGINS Theoretical Institute: SIEZE Volume, eds., T. Dixon, C. Moore, E. Silver, S. Stein, K. Furlong, and K. Brown, Columbia Univ. Press.

Von Herzen, R.P., R. S. Detrick, S. T. Crough, D. Epp, and W. Fehn, 1982, Thermal origin of the Hawaiian Swell: Heat flow evidence and thermal models, J. Geophys. Res., v. 87, p. 6711-6723.

Von Herzen, R.P., M. J. Cordery, R. S. Detrick, and C. Fang 1989, Heat flow and the thermal origin of hotspot swells: The Hawaiian Swell revisited, J. Geophys. Res., 94, 13,783-13,799.