

SEIZE/ SF	Collaborative Research: The Thermal State of 20-25 Ma Lithosphere Subducting at the Costa Rica Margin, Implications for Hydrogeology, Fluxes, and the Seismogenic Zone	
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The 18-24 Ma lithosphere on the Cocos Plate near the Nicoya Peninsula, Costa Rica (Fig. 1) has significantly variable heat flow. Seafloor formed at the East Pacific Rise (EPR) has heat flow ~70% less than expected from conductive lithospheric cooling models but only ~50% of average values for this age. In contrast, seafloor formed at the Cocos-Nazca Spreading Center (CNS) is consistent with conductive lithospheric models but ~50% higher than average values for this age [Fisher *et al.*, 2003]. To explore this issue 360 new heat flow measurements, seismic reflection, and sediment cores were taken during two cruises in the "TicoFlux" study on the R/V Maurice Ewing and R/V Melville. Some of the highlights from this project are listed below.

1. The closely-spaced heat flow measurements (Fig. 1) show that the transition between thermal regimes is remarkably abrupt, only 2-5 km wide. This narrow width suggests a shallow (<600 m) hydrothermal origin, rather than an overall change in the plate's thermal structure (Fig. 2). The transition is more closely associated with basement outcrops on the EPR-generated crust than with the contact of the EPR/CNS crusts, indicating the importance of the outcrops in regional heat extraction [Fisher *et al.*, 2003].
2. Heat flow measurements on seamounts in the cold part of the TicoFlux region show significant recharge and discharge of water. Modeling suggests that lateral flow rates of 3-30 m/yr within the upper 600 m of basement, with basement permeabilities of 10^{-10} to 10^{-8} m², are required to match the cold heat flow on EPR-generated crust [Hutnak *et al.*, submitted, 2003]. This study, and generalizations from it, indicate the important role of seamounts in controlling hydrothermal circulation throughout the oceanic crust [Harris *et al.*, submitted, 2003]
3. The thermal state of the incoming crust controls the updip limit of the seismogenic zone of the Middle America Trench near the Nicoya Peninsula. The updip limit for the low heat flow EPR-generated subducted crust is deeper than for the high heat flow CNS-generated subducted crust [Newman *et al.*, 2002]; as expected if approximately the same temperature is required. Thermal modeling [Harris and Wang, 2002] shows how the thermal structure and temperatures along the main subduction thrust are affected assuming different depths of hydrothermal cooling in the incoming plate. Comparisons with Newman *et al.* [2002] hypocenter locations indicate that the updip limit of seismicity is consistent with temperatures between 100-150°C, but there are large along-strike variations in both the seismicity and thermal regime.
4. It is often suggested that heat flow in the incoming plate at subduction zones is lower than expected for crust of that age, due to increased hydrothermal circulation from flexure and faulting. Testing this suggestion using global heat

flow data shows no significant difference between heat flow near the trench and the global means for the same age crust (Fig. 3). However, on average, heat flow in the overriding plate is ~60% of that in the incoming plate [Stein, 2003].

5. The lower heat flow (~20 mW/m² less compared to the incoming cold Cocos plate) associated with the ODP Leg 170 sites near the Middle American Trench near Nicoya [e.g., Langseth and Silver, 1996] appears to be associated with a locally vigorous hydrothermal circulation, rather than associated with the flexing and faulting of the incoming plate [Hutnak *et al*, submitted, 2003].

Figures and Captions

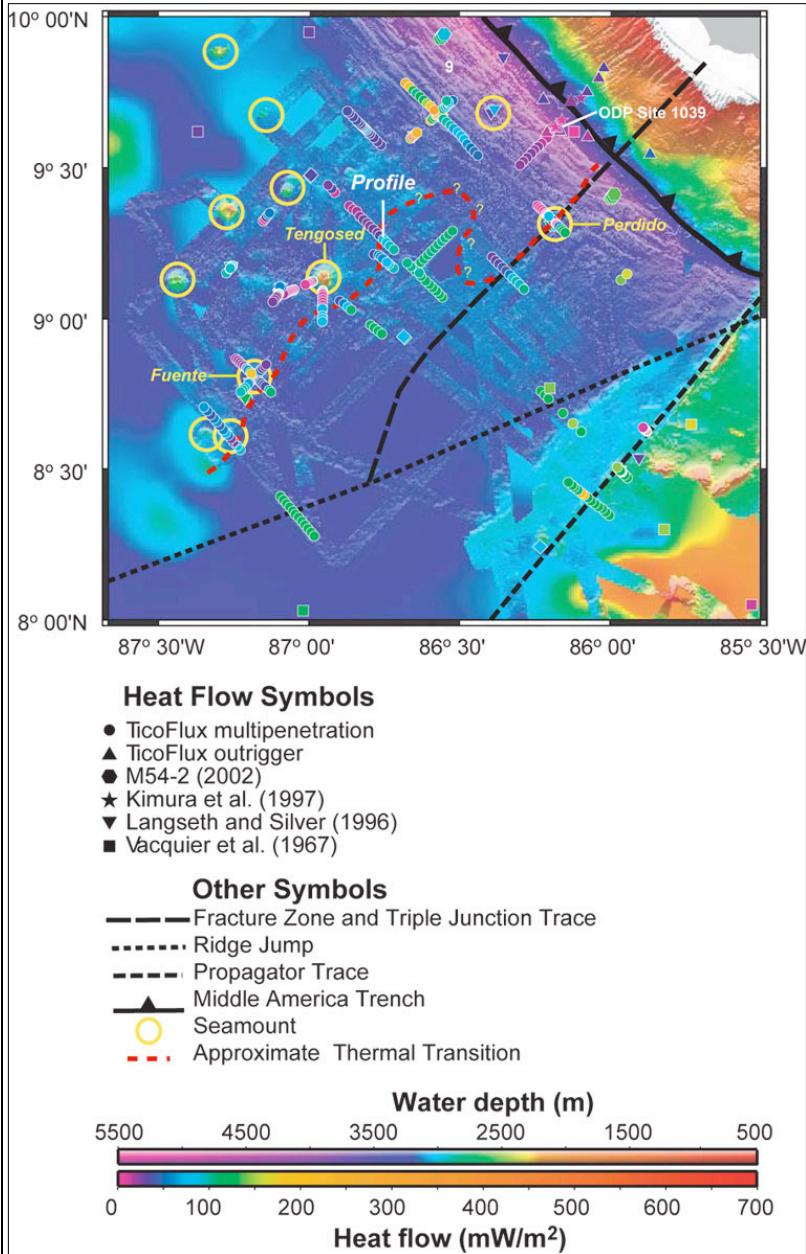


Figure 1: TicoFlux study area with heat flow measurements, bathymetry, and tectonic boundaries. For its crustal age, heat flow on the EPR-generated crust (NW region) is unusually low but that on the CNS-generated crust (SW region) is unusually high. The thermal boundary near the trench is located near the fracture zone trace separating CNS and EPR crust, but occurs closer to the seamounts on EPR crust farther away from the trench [after Hutnak *et al.*, submitted, 2003].

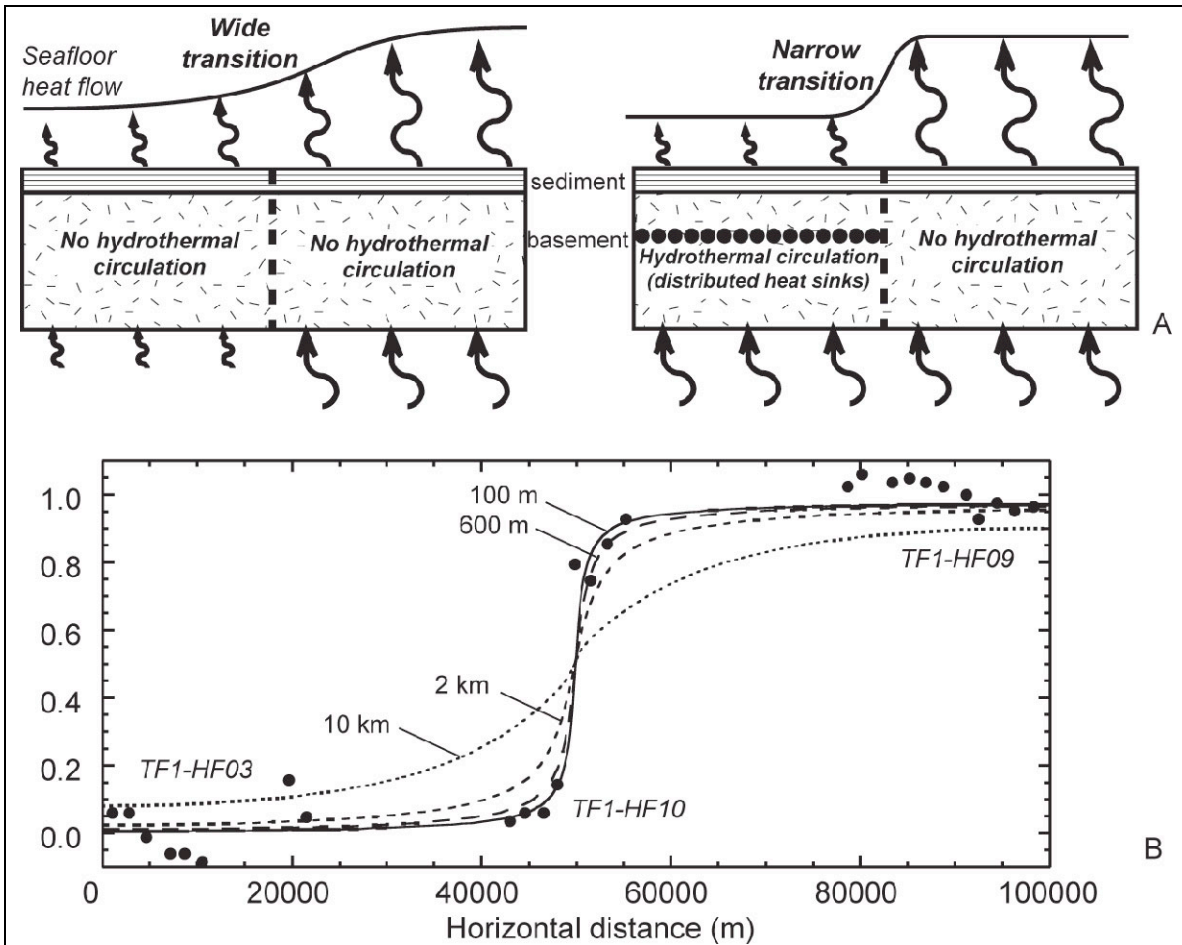


Figure 2: Conceptualization, heat flow data, and thermal models for thermal transition in the TicoFlux area. (Top) Cartoons show the expected variation in heat flow depending on a deep (left) or shallow mechanism (right). (Bottom) Heat flow measurements show an abrupt increase, consistent with models of shallow (<600 m) hydrothermal circulation. Location of this profile is shown on Fig. 1.

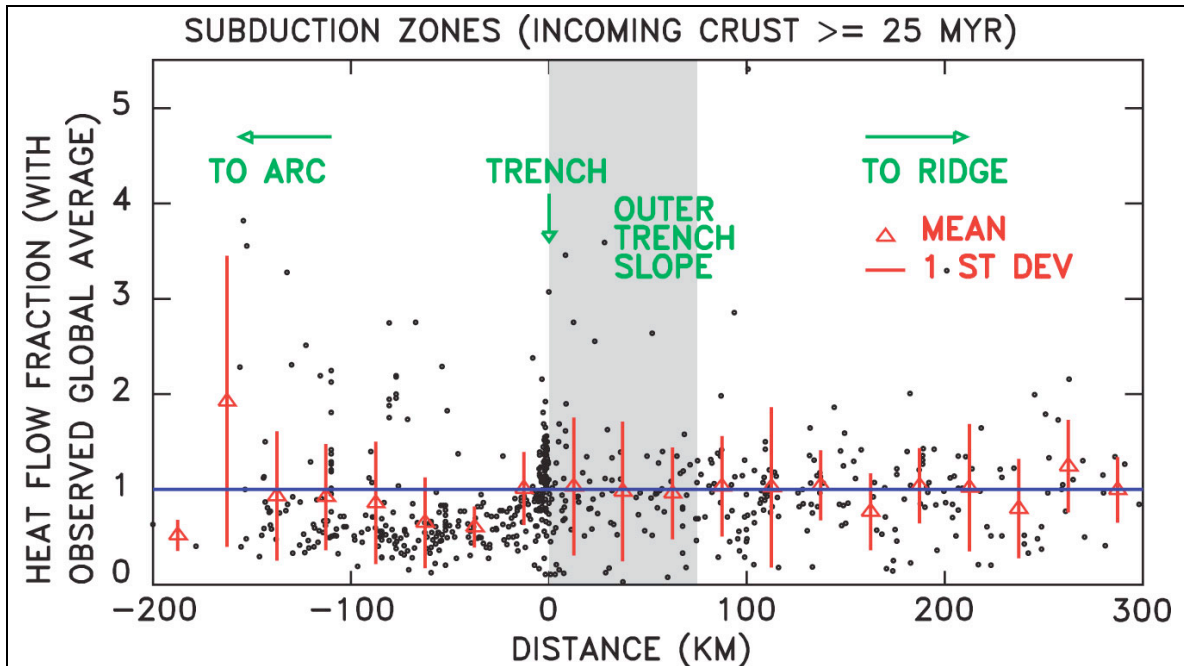


Figure 3: Heat flow fraction (measured with respect to observed global average for that age) with distance from the trench axis. Within the faulted outer trench slope, heat flow is not different than global averages (Stein, 2003).

Publications and Presentations

Fisher, A. T., C. A. Stein, R. N. Harris, K. Wang, E. A. Silver, M. Pfender, M. Hutnak, A. Cherkaoui, R. Bodzin, and H. Villinger, Abrupt thermal transition reveals hydrothermal boundary and role of seamounts within the Cocos Plate, *Geophys. Res. Lett.*, 30, doi:10.1029/2002GL016766, 2003.

Harris R. N., A. T. Fisher, and D. S. Chapman, 2004, Fluid flow through seamounts and implications for global mass fluxes, *Geology*, 32, 725-728, doi: 10.1130/G20387.1.

Harris, R. N., and K. Wang, Thermal models of the Middle America Trench at the Nicoya Peninsula, Costa Rica, *Geophys. Res. Lett.*, 29 doi:10.1029/2002GL015406, 2002.

Hutnak, M., A. T. Fisher, C. A. Stein, R. Harris, K. Wang, E. Silver, G. Spinelli, M. Pfender, H. Villinger, P. C. Pisani, H. Deshon, B. MacKnight, The thermal state of 18-24 Ma upper lithosphere subducting below the Nicoya Peninsula, northern Costa Rica margin, SEIZE margin volume, submitted, 2003.

Stein, C. A., Heat flow and flexure at subduction zones, *Geophys. Res. Lett.*, No. 23, 2197 doi 10.1029/2003GL018478, 05 December 2003.

At least 8 AGU abstracts and 1 for the NSF-MARGINS Theoretical Institute.

Also so far there has been one completed MS thesis (Friedmann), and 3 completed undergraduate senior thesis (MacKnight, Bodzin, Cleary) based on this research project.