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Data report: heat flow associated with Challenger Mound, IODP Expedition 307[1]

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Chapter contents

Abstract

The aim of Integrated Ocean Drilling Program Expedition 307 was to understand the origin and evolution of the coldwater coral banks in Porcupine Seabight off western Ireland, one of the most intensively studied provinces. Three sites were drilled on and near Challenger Mound in the Porcupine Seabight in May 2005, and core sections penetrating a thick coral reef body were recovered. To examine the thermal effect of possible upward hydrocarbon fluid flow beneath the mound, one of the hypotheses to be tested during Expedition 307, heat flow at and near the mound was calculated using data from Sites U1316, U1317, and U1318. These data were combined with previously published heat flow data in the neighboring region. Heat flow determined by this study is 56 mW/m^2, which is in agreement with the values obtained during previous surveys and may support that there is no hydrocarbon fluid flow at Challenger Mound.

Introduction

The Porcupine Seabight Basin off western Ireland, a north–south trending extensional sedimentary basin filled with post-Devonian sediments, is located on the continental shelf west of Ireland and is ~400 km in length with an average width of ~150 km (Fig. **F1**). Since the late 1970s, a considerable amount of exploration has been carried out by the oil industry (e.g., Shannon et al., 2001) in this area. Integrated Ocean Drilling Program (IODP) Expedition 307 recovered the first complete section through a deepwater coral mound, Challenger Mound in the Porcupine Seabight, and its surrounding sediments in May 2005 (see the **"Expedition 307 summary"** chapter).

Heat flow data provide critical information for understanding the evolution of continental margins. Nine discrete temperature measurements in three holes (U1316A, U1317A, and U1318A) were taken during Expedition 307 drilling (see the **"Expedition 307 summary"** chapter). This paper determines heat flow at Challenger Mound using downhole temperature measurements and thermal conductivities and provides new constraints on the thermal regime.

[1]Tanaka, A., 2009. Data report: heat flow associated with Challenger Mound, IODP Expedition 307. *In* Ferdelman, T.G., Kano, A., Williams, T., Henriet, J.-P., and the Expedition 307 Scientists, *Proc. IODP,* 307: Washington, DC (Integrated Ocean Drilling Program Management International, Inc.).
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In situ temperature measurements and thermal conductivities

In situ temperature measurements obtained during Expedition 307 were made with the Adara advanced piston corer temperature tool (APCT) (Blum, 1997). The APCT fits into the cutting shoe of the advanced piston corer and can therefore be used to measure sediment temperatures during regular piston coring. The tool consists of a platinum resistance-temperature device calibrated over a temperature range of 0°–30°C. After penetration, the sensor records a pulse of frictional heating, which decays while the tool remains in the formation for 10–15 min. Sampling rates of 5 s per measurement were used during Expedition 307. The extrapolation of the frictional heating pulse to equilibrium temperature generally accounts for the nominal accuracy of 0.1°C. However, overall uncertainty may be much larger if the probe does not remain stationary during the measurement period.

Thermal conductivity was measured in intervals where downhole temperature measurements were taken, using whole-round cores and the needle probe method in full-space configuration during Expedition 307. On board the R/V *JOIDES Resolution*, the Teka TK04 measurement system is used, which employs a transient linear source method with a needle probe that is inserted into the soft sediment (Von Herzen and Maxwell, 1959). The TK04 uses an automated routine to find the conductivity by least-squares fitting to the measured temperature-time series, with an accuracy of 5% and a precision of 5%.

Heat flow data

Deployment of the APCT provided insight into the subsurface temperature distribution. Two, three, and four discrete temperature measurements in Holes U1316A, U1317A, and U1318A were taken ranging from 25.5 to 113.7 meters below seafloor (mbsf), and there are no resolvable thermal perturbations (Fig. **F2**). Maximum distance and elevation difference within each paired set among three holes are 14 km and 500 m, respectively. Data from all three holes and well-constrained Hole U1318A show temperature gradients of 39°C/km and 46°C/km with regression standard errors of 0.896 and 0.087, respectively. These estimated values are normal gradients for a passive continental margin and are consistent with the average present-day thermal gradient of ~34°C/km based on three deep (>4 km) wells at Porcupine Basin (Corcoran and Clayton, 2001).

Thermal conductivity was measured on one section of unsplit soft-sediment core, usually at 75 cm, using the TK04 measurement system. The depth profile of thermal conductivity for Sites U1316, U1317, and U1318 is shown in Figure **F3.** No systematic variation among the holes could be resolved. The average thermal conductivity within intervals that coincides with measured temperatures is 1.4 W/(m·K) (Fig. **F4**). Heat flow is estimated at 56 mW/m² using observed thermal gradient and thermal conductivity from three holes.

Thermal conductivity is primarily dependent on variations in sediment bulk density, which is related to other sediment physical properties such as velocity; therefore, these data sets are well correlated (Fig. **F5**). Average gamma ray attenuation (GRA) density at Site U1316 changes at 64 mbsf with an amount of scatter that coincides with a drop in thermal conductivity. Carbonate content increases from 17 wt% in the upper 50 mbsf to 60 wt% over a short interval between ~50 and 55 mbsf and is relatively constant at an average of 28 wt% between ~65 and 119 mbsf (see the **"Site U1316"** chapter). This pattern also corresponds to the depth profile of thermal conductivity. At Site U1317, GRA density increases gradually with depth in the upper ~150 mbsf and drops at ~150 mbsf. This pattern is not well correlated with thermal conductivity and carbonate content. At Site U1318, GRA density slightly increases in the upper 92 mbsf with some peaks and troughs. Two sharp reductions in density were observed at 92 and 132 mbsf, which are well correlated to variations in thermal conductivity. Carbonate concentrations are relatively low and uniform throughout the upper part from 0 to ~86 mbsf and increase at 86 mbsf. This appears to relate to changes in thermal conductivity and GRA density.

Downhole temperature and thermal conductivity measurements from Sites U1316, U1317, and U1318 of Expedition 307 and Hole 981C of Ocean Drilling Program Leg 162 (Shipboard Scientific Party, 1996) were used to derive the heat flow through the continental margin off Ireland. As shown in Figure **F1,** these data have been used to investigate the thermal state of the continental margin, with the global heat flow compilations of Pollack et al. (1993). The estimated heat flow value of 56 mW/m² is quite average among passive continental basins and there may be no thermal perturbations. This may support the results from initial geochemistry and microbiology (see the **"Expedition 307 summary"** chapter), in which a role for hydrocarbon fluid flow at Challenger Mound is not obvious.

Acknowledgments

The author would like to thank the IODP and Transocean crews of the *JOIDES Resolution* for Expedition 307. Data of Adara temperatures and thermal conductivities were provided by Integrated Ocean Drilling Program (IODP) and Ocean Drilling Program (ODP). An anonymous reviewer provided helpful comments to improve the manuscript. Figures were produced with GMT (Wessel and Smith, 1998).

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Figure F1. Heat flow distribution (Pollack et al., 1993) around Expedition 307 sites. Large hexagon is determined in this study and large square is based on data from ODP Leg 162.

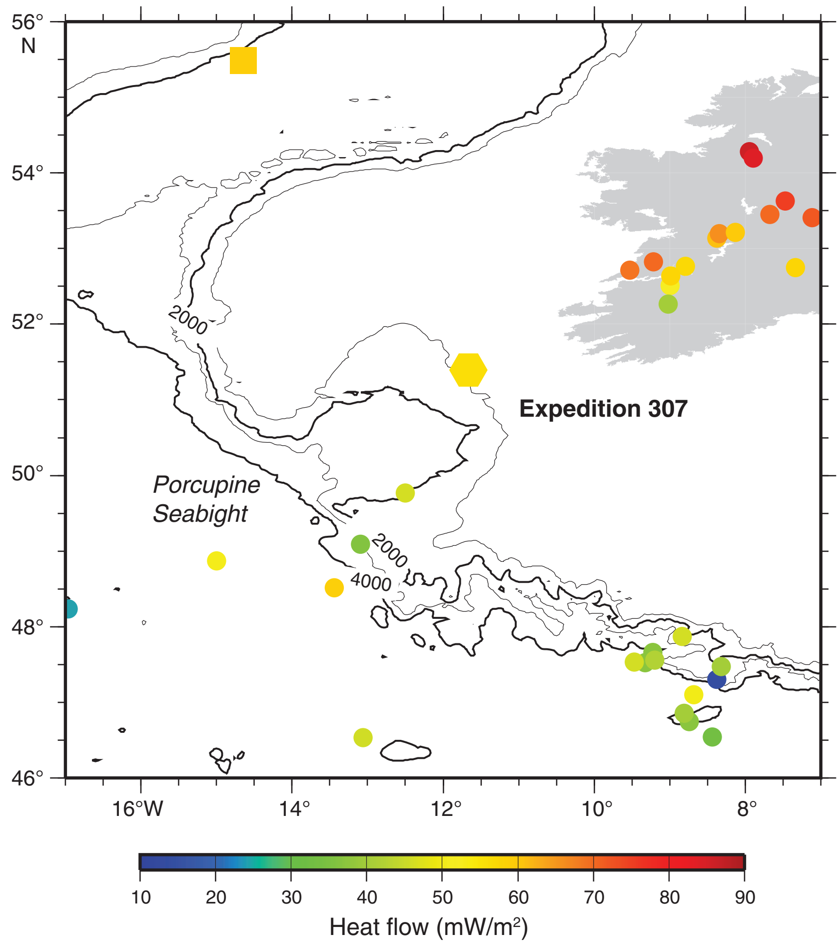

Figure F2. Downhole temperature measurements and calculated thermal gradient; Sites U1316, U1317, and U1318.

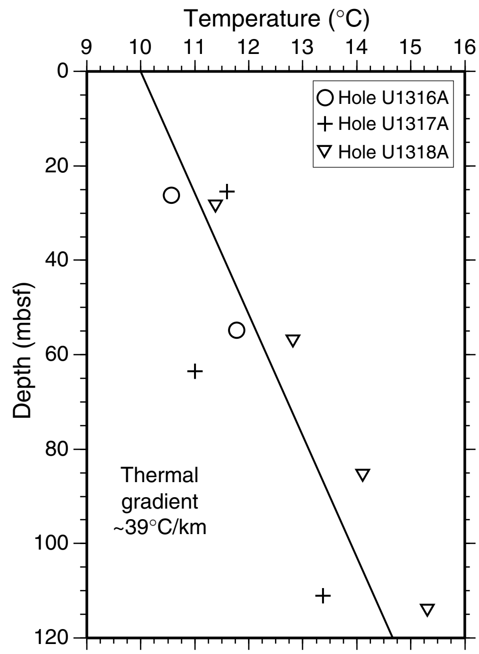

Figure F3. Thermal conductivity distribution with depth; Sites U1316, U1317, and U1318. Gray line = average value in intervals where downhole temperature measurements were taken.

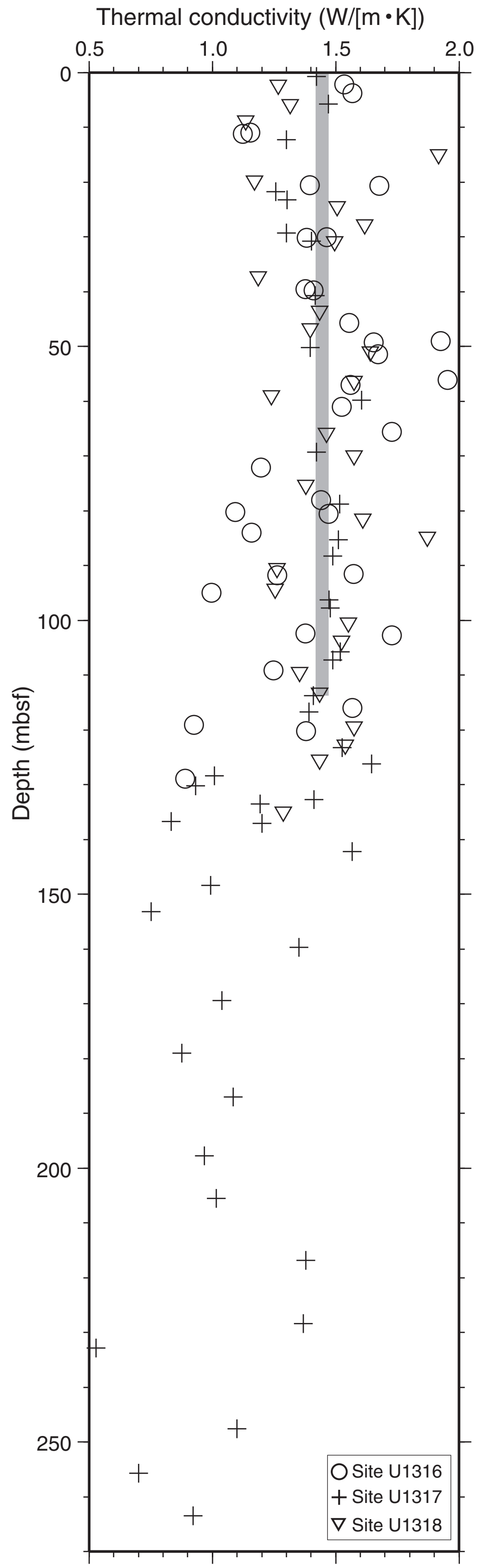

Figure F4. Histogram of thermal conductivity measured on whole-round cores; Sites U1316, U1317, and U1318. Solid line = values in intervals where downhole temperature measurements were taken.

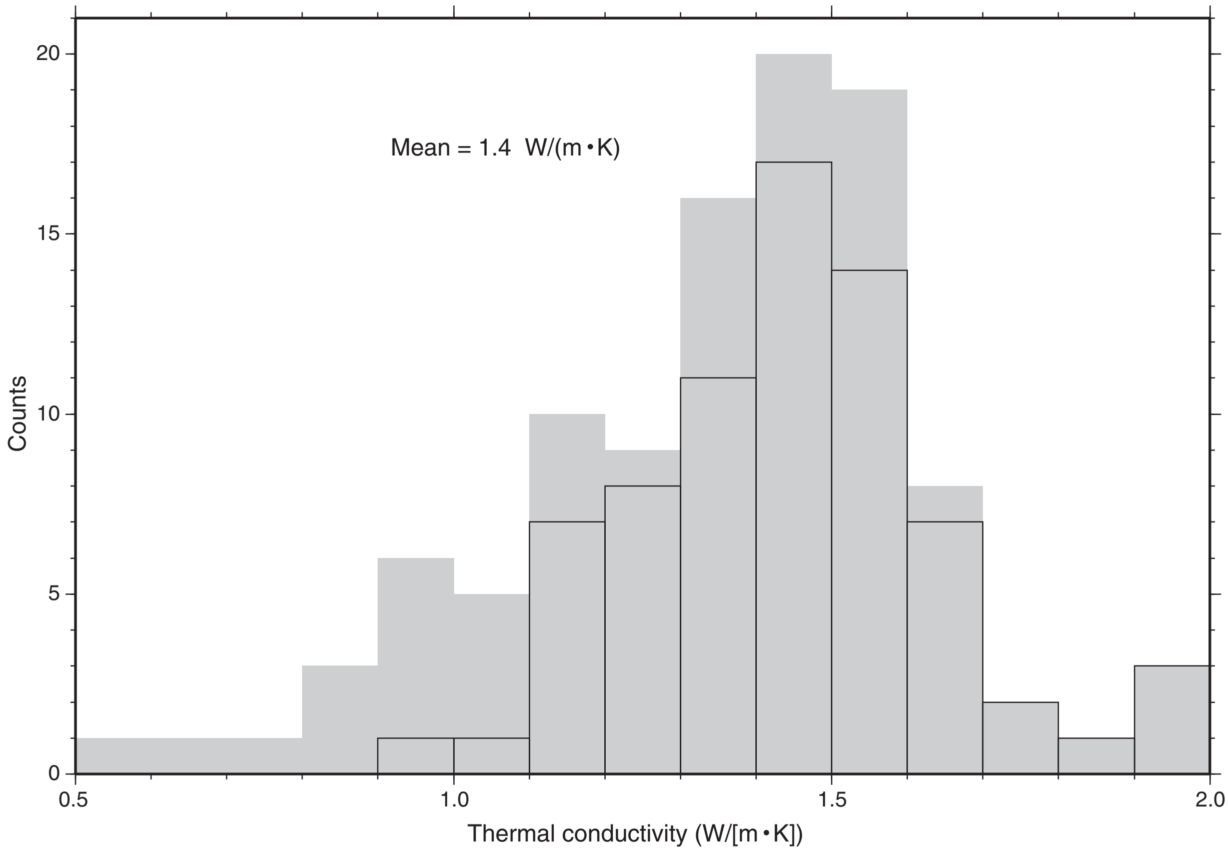

Figure F5. Thermal conductivity measurements (gray circles) at Sites U1316, U1317, and U1318 compared with gamma ray attenuation (GRA) bulk density (crosses).