# Oil & Natural Gas Technology

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# Quarterly Report

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## Heat Flow and Gas Hydrates on the Continental Margin of India: Building on Results from NGHP Expedition 01

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**Heat flow and gas hydrates on the continental margin of India:**

**Building on results of the NGHP Expedition 01**

We previously modeled the very low heat flow measured downhole at Site 18 in the Andaman Basin as resulting from very high sedimentation rate (see the Aug.-Oct. 2010 quarterly report for this project). Although the borehole depth at site 17 extends to 700 meters below sea floor (mbsf), ages were only specified to a depth of 108 mbsf in the Expedition 311 Initial Report [*Collett et al, 2008*]. During this quarter, we redid this analysis using an updated age model extends over the full depth of the borehole (figure 1) [*Flores et al, 2008; Cawthern et al, 2010*].

The initial shipboard based age model only constrained the last 2 My, while the new age model constrains the last 9 My. Initial heat flow modeling efforts were able to reconstruct measured apparent heat flow values by having a very high sedimentation rate of 2000cm/ky followed by 2 My at the observed 10cm/ky sedimentation rate. The high sedimentation rate period produced a very low apparent heat flow, that, when overlain by 2 My of moderate heat flow, matched the measured apparent heat flow. A new sedimentation history based on the updated age constraints was used for updated conductive heat flow models (figure 2). By rerunning the conductive heat flow model using these updated age constraints, we were no longer able to match the apparent heat flow values produced from the model with the apparent heat flow values derived from borehole temperature measurements (figure 3).

The apparent seafloor heat flow derived from the conductive model using the updated age constraints was compared to unsedimented basement of the same age, as well as to the GDH1 model of heat flow as a function of plate age (figure 4) [*Stein and Stein, 1992*]. Our modeled scenario follows the trend of both the unsedimented model and the GDH1 model, until the sedimentation rate increases from 10cm/ky to 2000cm/ky at ~70 My, indicated by a sharp drop in apparent heat flow. This drop is followed by a rise resulting from lowering the sedimentation rate as determined from the updated borehole age model. Allowing the model to run through the entire updated age model results in the seafloor apparent heat flow rising above the borehole derived value. A purely conductive model is incapable of reproducing the low apparent heat flows found at site 17.

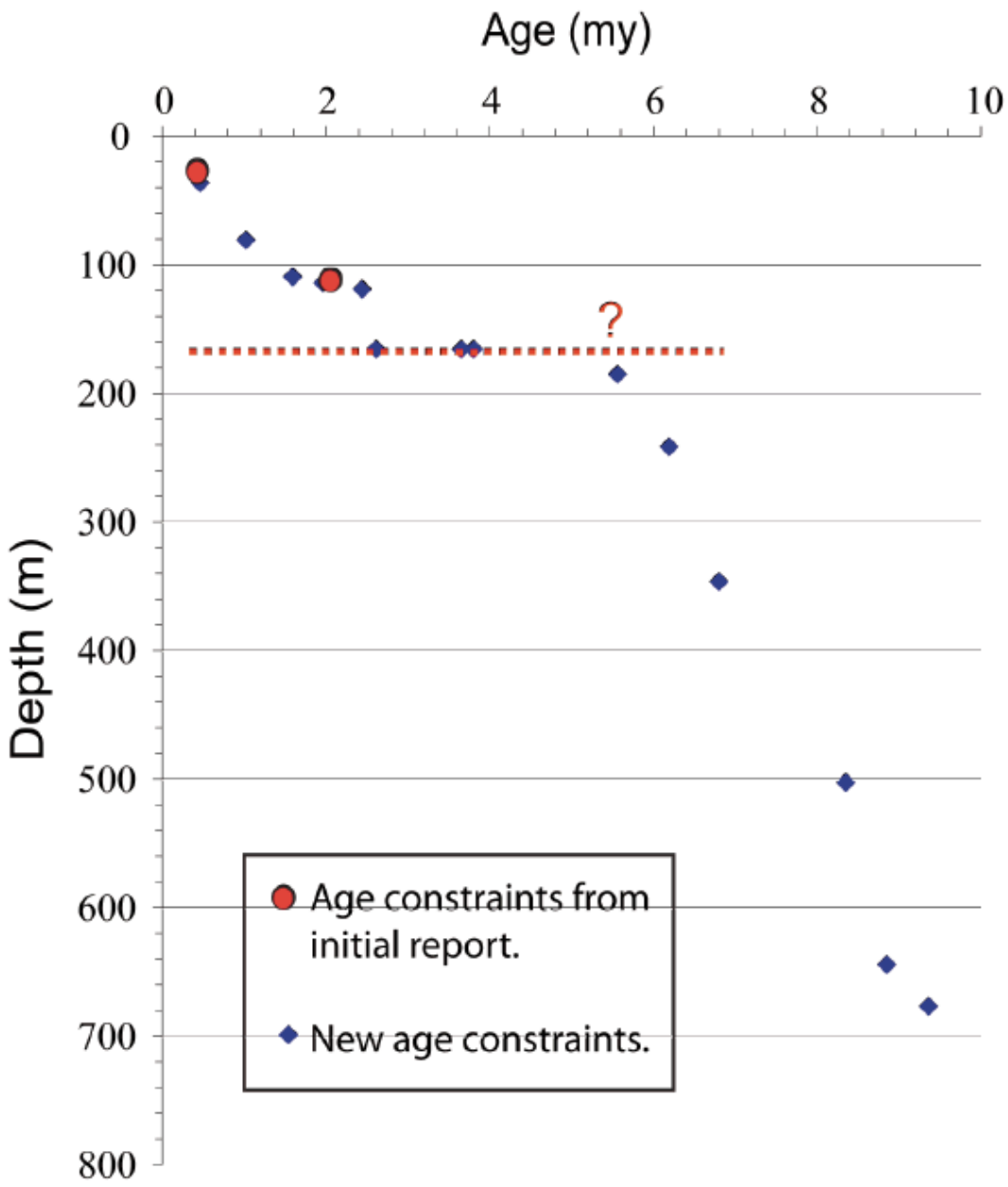


Figure 1. Updated age model showing both initial and updated age constraints [*Flores et al 2008; Cawthern et al 2010*]. There appears to be an unconformity where the region experienced either an erosional or slow sedimentation period from 2.4 to 5.8 Ma.

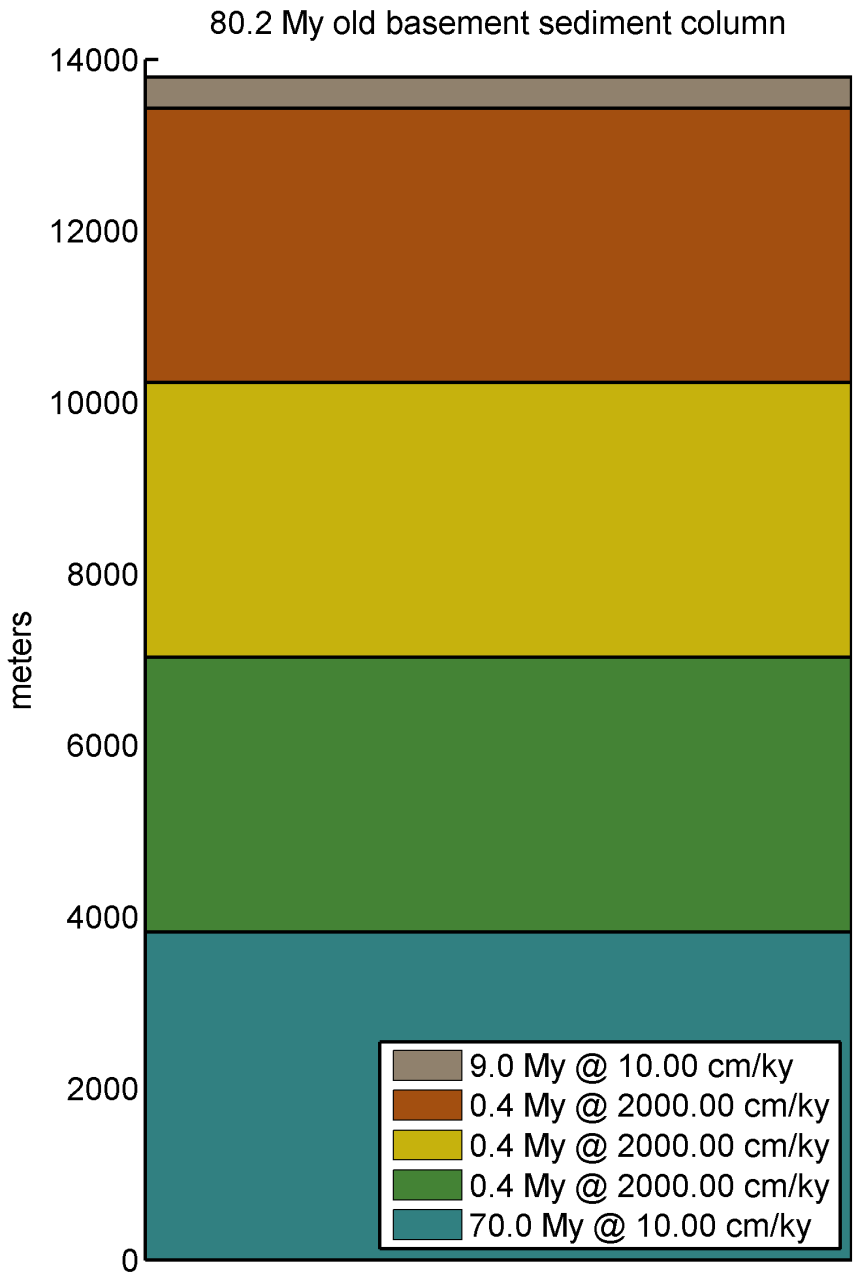


Figure 2. Sedimentation history based on updated age constraints used to model conductive heat flow at NGHP site 17 in the Andaman Basin. Initial ship based age constraints truncated the most recent sedimentation period of 10cm/ky to only 2 My. Subsequent investigations found additional biostratigraphic datums which increased this sedimentation period to 9 My.

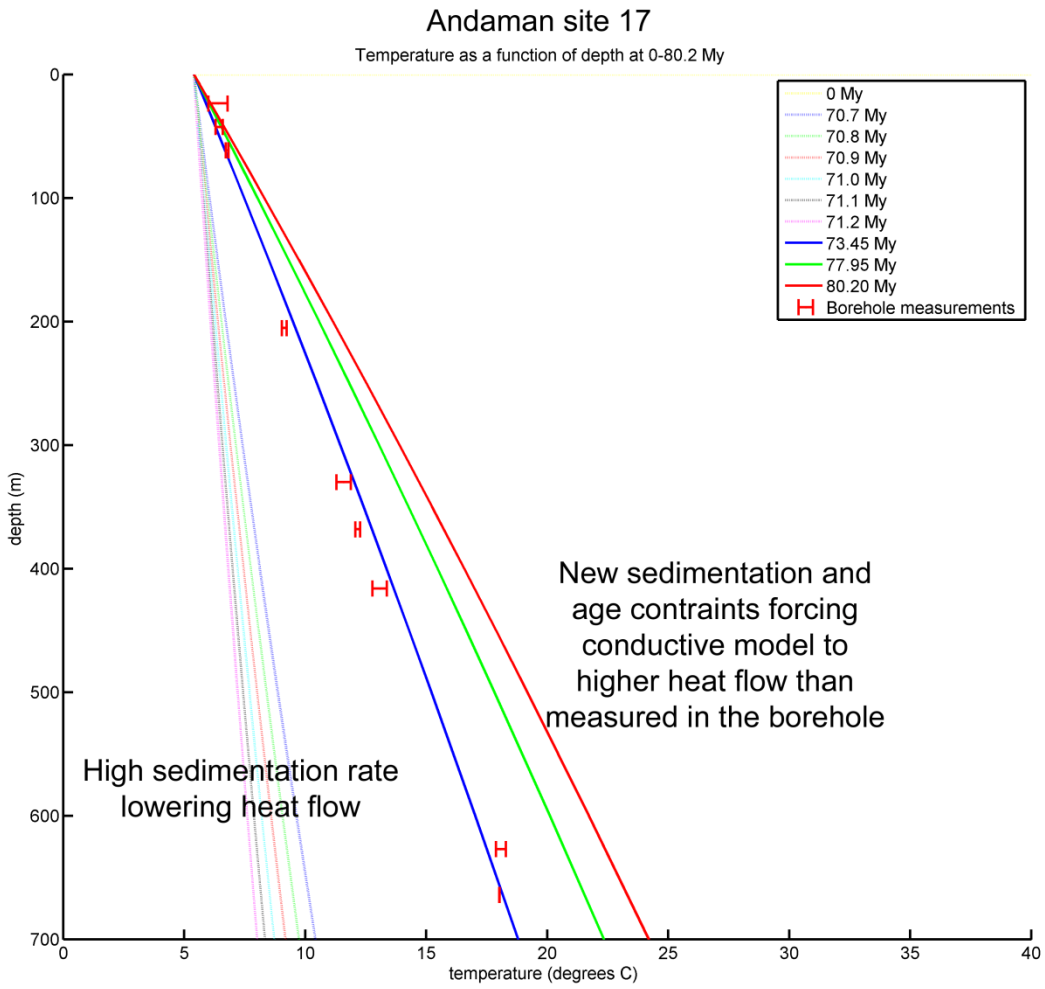


Figure 3. Temperature as a function of depth modeled for the last 10 My using new age constraints. Sedimentation history used in model shown in Figure 2. Times are in basement age. Time zero is initial formation, and 80.2 My corresponds to the present. Dotted lines indicate geothermal gradient at times of very high sedimentation rate (2000cm/ky). Solid lines are three subsequent geothermal gradients taken from the most recent moderate sedimentation rate period (10cm/ky). Error bars show temperature values and associated error measured using borehole temperature tools. The model shows decreasing geothermal gradients throughout the high sedimentation rate period and increasing geothermal gradients during the moderate sedimentation history. Initial age constraints allowed the model to stop at roughly 73.45 Ma, coincident with the solid blue line shown in this model. However the additional 7 My appended by the new age model makes reconstruction of the measured apparent heat flow by a solely conductive model impossible.

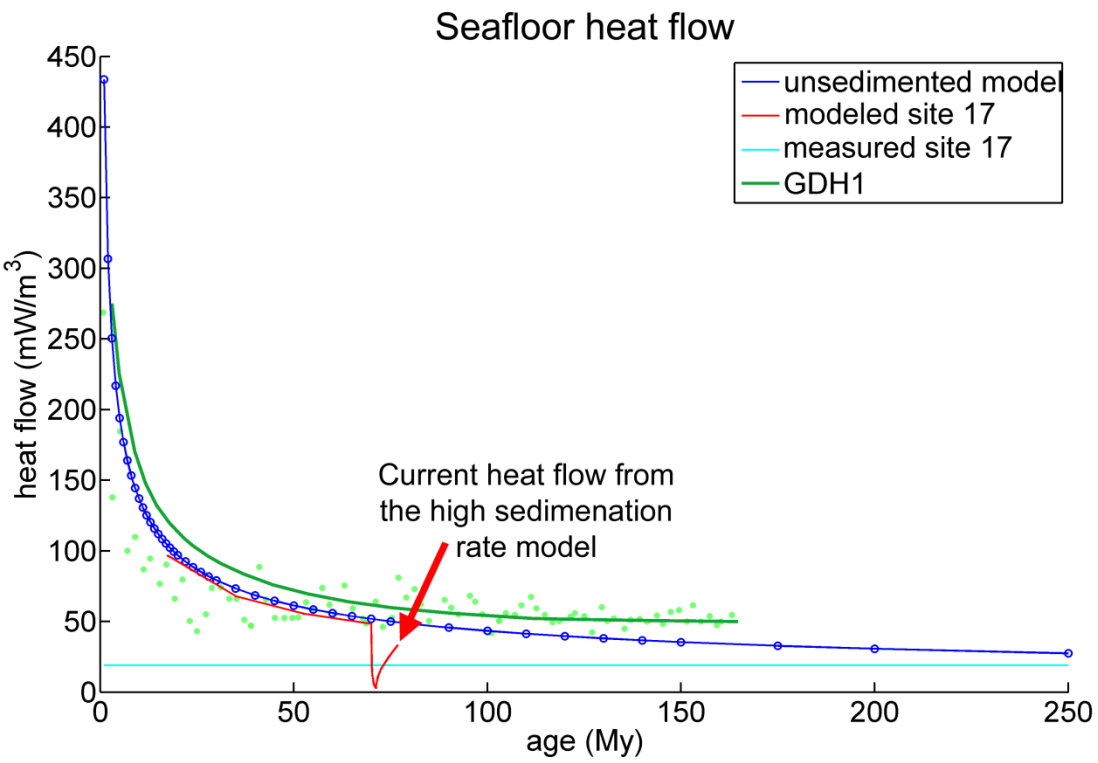


Figure 4. Comparison of modeled seafloor apparent heat flow as a function of plate age. The blue line is an unsedimented conductive model, the green line is the GDH1 model, green dots are measured values for plates around the world of various ages. The horizontal cyan line shows the current measured apparent heat flow at site 17. The red line is the apparent seafloor heat flow as a function of plate age modeled using updated age constraints. The sharp drop in apparent heat flow is from an increase in sedimentation rate, and the following rise in apparent heat flow is a result of relaxing the sedimentation rate to values dictated by the updated biostratigraphic datums. This updated model is unable to reconstruct the current apparent heat flow conditions at site 17.

References:

Cawthern, T., Johnson, J.E., Bryce, J., Blichert-Toft, J., 2010. A ~10 Ma Petrochemical Record from the Andaman Accretionary Wedge: Implications for Arc Evolution. Abstract V14A-04 presented at 2010 Fall Meeting, AGU, San Francisco, Calif., 13-17 Dec.

Collett TS, Riedel M, Cochran J, Boswell R, Presley J, Kumar P, Sathe A, Lall M, Sibal V, and the NGHP Expedition 01 Scientists (2008), National Gas Hydrate Program Expedition 01 initial report, Dir. Gen. of Hydrocarbons, Minist. of Pet. and Nat. Gas, New Delhi.

Flores, J.-A., Mejía-Molina, A.E., Álvarez, C., Sierro, F.J., Giosan, L., and Johnson, J.E., 2008. Calcareous Nannofossil Biostratigraphy from Sediment Cores Recovered in the Arabian Sea, Bay of Bengal, and Andaman Sea during NGHP Expedition 01. International Conference on Gas Hydrates, Noida India, Feb. 6-8, 2008.

Stein, C.A. & Stein, S., 1992. A model for the global variation in oceanic depth and heat flow with lithospheric age. *Nature*, 359(6391), 123-129.

***Table 1***. *Project costing profile for Budget Period 10. Budget period 10 represents work conducted during a no-cost extension of the project. Unexpended funds were available to cover work during this time period because other funds were used to support related efforts during earlier budget periods. Consequently we spent less than planned during several earlier budget periods. A portion of the PI salary, which had accidentally been systematically undercharged since the beginning of the grant, was covered to allow for time spent advising GRA Kannberg over the course of the project. Kannberg is currently trying to wrap up loose ends while working on a different gas hydrate-related project as a visiting student at Scripps Institution of Oceanography. Remaining funds will be used to cover publication charges.*

| | January (planned) | January (actual) | February (planned) | February (actual) | March (planned) | March (actual) |
|---|---|---|---|---|---|---|
| PI salary & fringe benefits | 0 | 2520..54 | 0 | 0 | 0 | 0 |
| GRA salary & fringe benefits | 0 | 0 | 0 | 0 | 0 | 0 |
| Computer subscription | 0 | 0 | 0 | 0 | 0 | 0 |
| Travel and supplies | 0 | 1055.29 | 0 | 0 | 0 | 0 |
| Tuition | 0 | 0 | 0 | 0 | 0 | 0 |
| Indirect Costs | 0 | 1652.04 | 0 | 0 | 0 | 0 |
| Total | 0 | 5227.87 | 0 | 0 | 0 | 0 |

**PUBLICATIONS, CONFERENCE PRESENTATIONS AND OTHER PRODUCTS:**

No publications, conference presentations or other products related to this project were produced during this quarter. Revisions are underway on a publication submitted to Marine Geophysical Research in June 2010 (budget period 7).

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