Recent sediment dynamics in hadal trenches

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1. Background and motivation

Hadal environments comprise water depths between 6000 m and the deepest depth of ~ 10920 m in the Challenger Deep of the Mariana Trench. These environments are mainly associated with subduction-zone trenches. One of the defining factors of these very deep environments is the high hydrostatic pressure. It has been known for several decades that these environments support life and harbour organisms that are adapted to, and in some cases even require, high hydrostatic pressures (e.g., Bartlett, 2009; Blankenship-Williams and Levin, 2009; Jamieson et al., 2010). To sustain heterotrophic life at such great depths food supply of sufficient quality and quantity is therefore a key requirement. Recent work has shown that surprisingly fresh (nutritious?) material reaches even the greatest depths of the Challenger Deep under oligotrophic surface waters (Glud et al., 2013).

Hadal trenches are amongst the least understood environments on Earth. Consequently, there is great potential for new discoveries which also results in a growing pharmaceutical and biotechnological interest in organisms from these natural high-pressure environments. In this context it is important to understand how sediments and associated bioavailable materials are transported into and within the hadal environments and how this transport affects food supply to the heterotrophic organisms.

There is evidence suggesting that occasional mass-wasting events (turbidity currents?) lead to transport of sediments down the slopes, sometimes reaching the the trench axis. These events might move bioavailable material. But given that they are likely to occur only on time scales of decades or longer they would seem to be not sufficiently frequent to maintain the more continuous food supply required to sustain hadal heterotrophic organisms. In fact, because of their vigorousness, turbidity currents might rather constitute a disturbance to the hadal community. Consequently, it is expected that there are more continuous and subtler processes maintaining food supply on sufficiently short time scales. These processes have not been identified yet but may involve higher-frequency (near-inertial, tidal) fluid dynamics (Turnewitsch et al., 2014).

This project aims to help constrain the time scales of recent sediment transport in hadal trenches. The results will allow us to narrow down the mechanisms through which the more continuous transport of sediments and food particles is taking place.

2. Material and methods

This study took advantage of a short JAMSTEC-led cruise to the Tonga Trench in autumn 2013 (6-21 Oct: cruise YK 13-10 with R/V Yokosuka and Shinkai 6500; chief scientist: Hiroshi Kitazato). The key objective was to investigate for the first time whether there are ^{234}Th deficiencies in the near seafloor water column and excess ^{234}Th in the surface sediments. ^{234}Th is a naturally occurring radioactive nuclide which is highly particle reactive and very short-lived (half life: 24.1 days), which means it can capture sediment dynamics on the aforementioned higher-frequency (near-inertial, tidal) time scales. Sediment and near-seafloor water samples from the deepest site in the Tonga Trench (Horizon Deep: ~10850m) were collected with core liners and Niskin bottles, respectively, both mounted on a free-falling benthic-lander system. Sediment and near-seafloor water samples from the oceanward trench rim (~6250m) were collected with push cores and Niskin bottles, respectively, both mounted on the submersible Shinkai 6500.

Sediments were subsampled for ^{234}Th analyses. Immediately after the cruise, these subsamples were transported in plastic vials to SAMS. Processing of water samples for total (dissolved + particle-associated) ^{234}Th began on board. This involved co-precipitation of dissolved ^{234}Th by MnO_2 formation, followed by pressure filtration of natural particulate matter and MnO_2 onto 1.0µm polycarbonate filters. The filters were folded and also quickly transported to SAMS. At SAMS the beta radioactivity of the filters was measured immediately upon arrival of the filters. Measurements were conducted in a shielded low-level beta counter. Sediments were dried and pressed into pellets. These pellets were also measured in the beta counter. All samples were measured several times to follow the decreasing ^{234}Th radioactivity. These time series allow for the determination of backgrounds and to check for contaminating contributions to the beta signal. These measurements have been completed. However, the counting efficiencies for the sediment pellets still need to be determined. Below we present the preliminary results that already allow some conclusions to be drawn. Because of the conservative behaviour of the direct ^{234}Th parent ^{238}U in oxygenated seawater, the ^{238}U radioactivity in water samples could be calculated from CTD-derived salinity. Due to the non-destructive nature of the ^{234}Th measurements in sediment samples it will also be possible to investigate selected sediment samples for the longer-lived particle tracer ^{210}Pb (half life: 22.3 years). The combination of tracers with different half lives will help to better constrain the time scales of sediment transport.

3. Preliminary results and conclusions

Preliminary results suggest that there were active sediment dynamics both at the oceanward trench rim and in the Horizon Deep. This can be deduced from the first ever ^{234}Th data from such great depths and the occurrence of ^{234}Th deficiencies (relative to the non-particle-reactive parent radionuclide ^{238}U) in the near seafloor waters and excess ^{234}Th in the underlying surface sediments (Fig. 1). However, the water-column deficiency was considerably higher at the trench rim. This is most likely due to sediment resuspension in the currents of the deep western boundary current that flows northward along the Kermadec and Tonga Arc. However, water-column deficiencies and sediment excesses in the Horizon Deep strongly suggests that even at the greatest depths of the Tonga Trench there are processes that actively resuspend surface sediments. Given the short half life of ^{234}Th, these processes must take place on short time scales of only days to weeks. Possible candidates are bioturbation and bioresuspension as well as fluid dynamics that are more vigorous than typically anticipated for hadal trenches. Photos of the seafloor provide evidence for bioturbation. And the Tonga region is characterised by generation and propagation of moderate to intense internal tides. Future research will have to clarify which phenomenon is more important in producing the observed ^{234}Th signals. The results of these future activities will have important implications for our mechanistic understanding of the factors that control food supply to heterotrophic communities of hadal trenches.

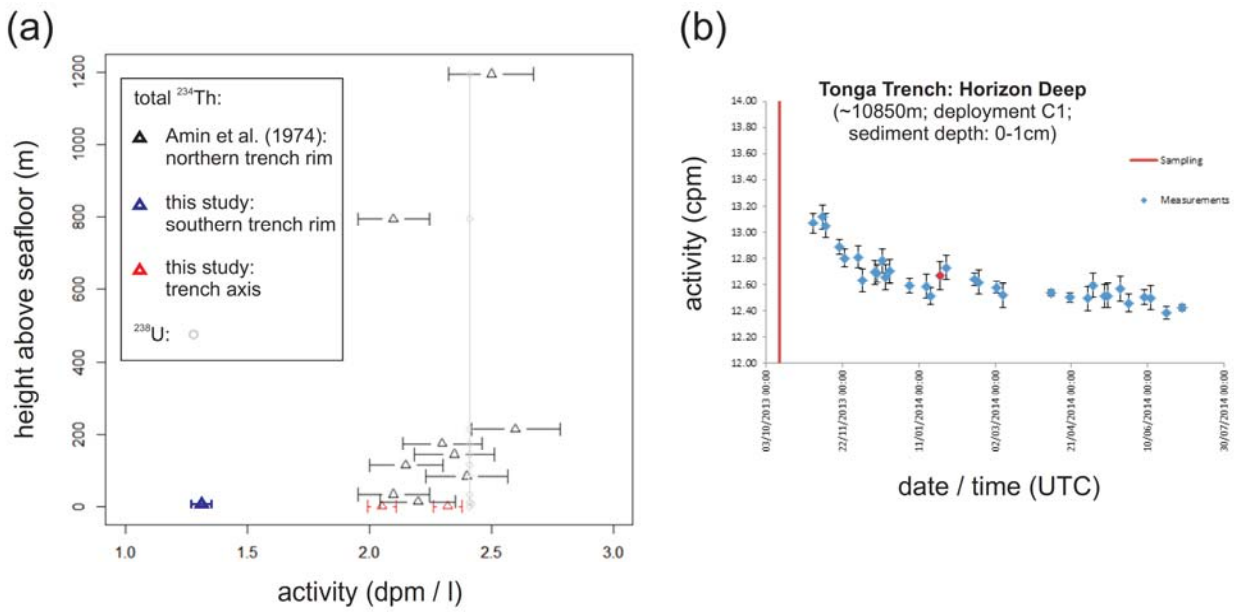

Figure 1. (a) New near-seafloor ^{234}Th data from the oceanward rim (blue) and trench axis (red: Horizon Deep) of the Tonga Trench. ^{234}Th data from the more northern oceanward trench rim are plotted for comparison (black: Amin et al., 1974). (b) Decay of beta (^{234}Th) radioactivity since sample collection. This example is for a surface sediment from the Horizon Deep.

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