Detection of micro-seepage of deep-sourced fluids by modelling geochemical and heat flow signals

by Marianne Nuzzo

Over 1000 km of the Gloria transform fracture zone in the NE Atlantic (Figure 1) were recently surveyed during the M-162 expedition onboard the German research vessel Meteor (6th March-10th April 2020), with the aim to identify geochemical and heat-flow (HF) signs of micro-seepage of deep-sourced fluids on the abyssal seafloor.

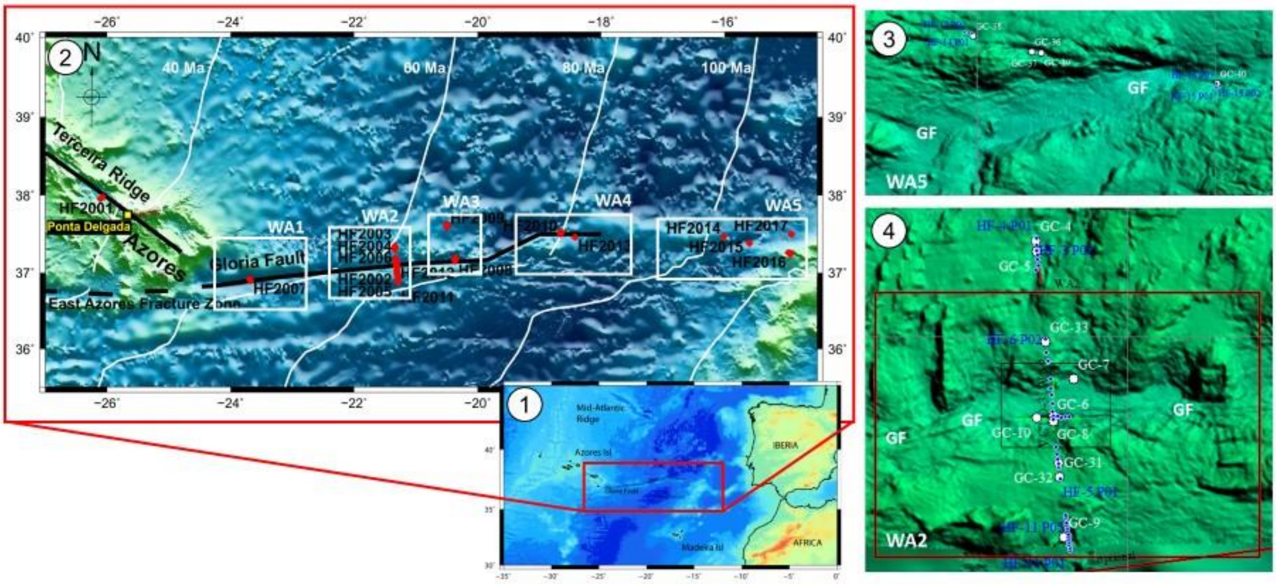

Figure 1: Location of the Gloria Transform Fault and survey areas in the NE Atlantic Ocean (1=NE Atlantic Ocean; 2=Gloria Transform Fault Zone and outline of the five work areas (WAs); 3=WA 3; 4=WA2) (maps modified from Baptista et al., 2017 and Hensen et al., 2019).

While this work is part of a long-term fundamental scientific investigation into the connections between the elemental and HF budgets of the deep lithosphere and the ocean (Hensen *et al*., 2019), the geochemical and geophysical methods used to detect and model seepage in this challenging deep-ocean environment are expected to provide insightful information for environmental monitoring of low-intensity fluid emissions. Moreover, these results might find useful applications in monitoring emissions associated with industrial activities such as Carbon Capture and Storage (CCS) in environments having experienced a complex tectonic history.

Sampling and measurements performed onboard included surface HF measurements (*e.g.* Villinger *et al*., 2010), *in-situ* measurement of methane concentration in the water column (Schmidt *et al*., 2013) and the recovery of 45 gravity cores (GC) for porewater and sediment geochemical analyses. These analyses include pore fluid concentrations of more than 20 solutes, some reflecting inputs from organic matter (methane, ammonium, …) and some from lithogenic sources (lithium, strontium, …). Selected isotopic analyses have now been undertaken and will shed further light into the elements' sources. Sediment samples were also collected for extensive inorganic and organic geochemical analyses.

The first cruise results are thought-provoking. They include the overall indication that upward fluid flow along the fault zone increases from west to east, both based on HF and porewater geochemistry data. With the age of the lithosphere increasing eastward from ~ 40-60 Ma to > 100 Ma as shown on Figure 1 (N. Kaul; *pers. comm*.), this suggests that micro-seepage of deep-sourced fluid could be at least partly favoured by fracturing of the older crust.

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Furthermore, elevated HF anomalies are generally measured along scarps, consistent with the hypothesis of a focussed fluid flow along fault planes (Figure 2).

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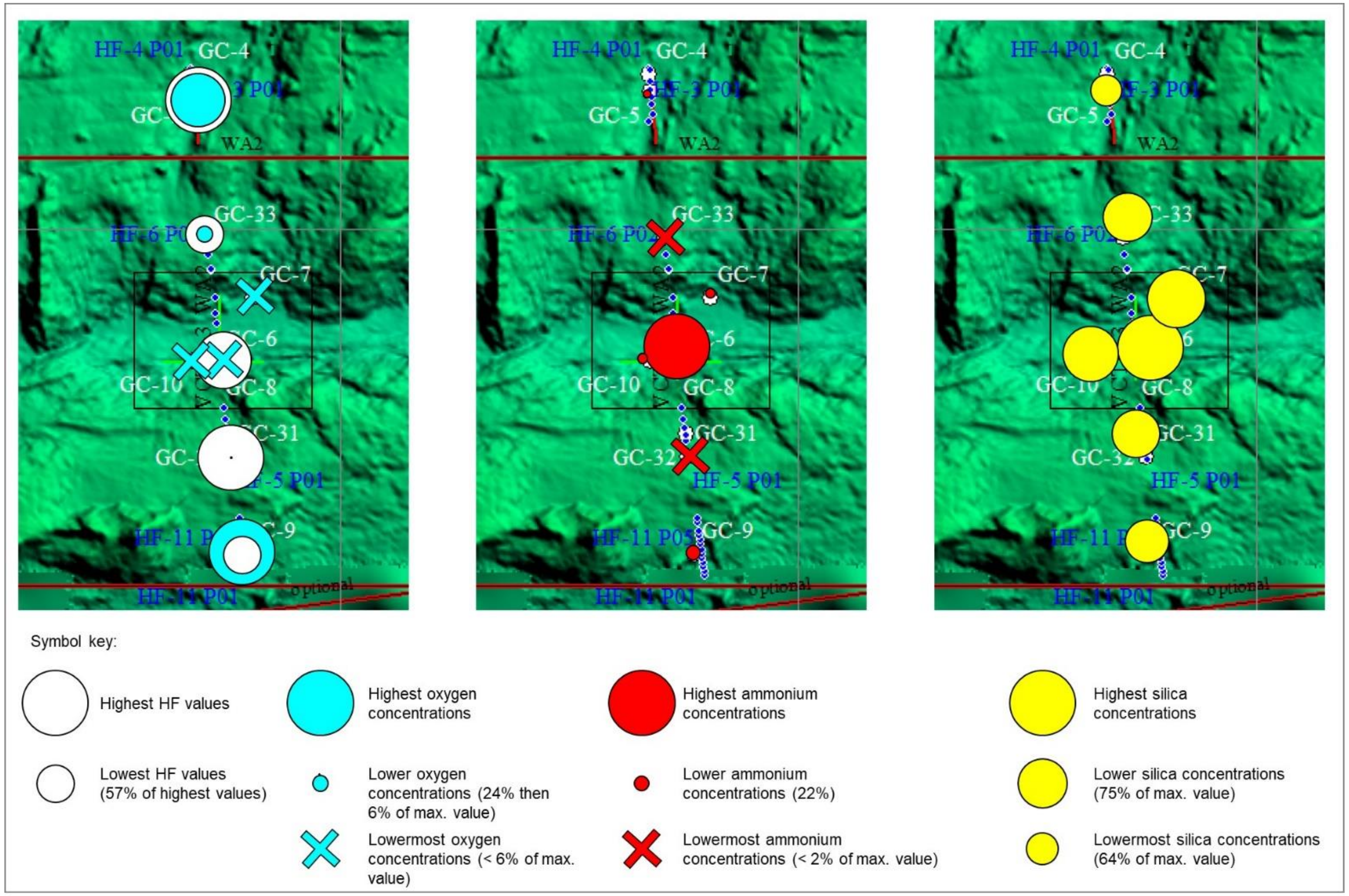

Figure 2: North-South transect across the GF in WA2. ***Left:*** *The relative HF values are indicated by white circles: the highest values measured are shown by the largest circles and the decreasing sizes of the smaller circles reflect the proportional decrease in HF values compared to the highest measurements. Likewise, the sizes of the blue circles represent the relative concentrations of oxygen (O_2) measured in porewaters.*

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Centre: *Relative concentrations of ammonium (NH_4^+) in porewaters are indicated by the sizes of the red circles.* ***Right:*** *Relative concentrations of silica (SiO_4) in porewaters are indicated by the sizes of the yellow circles.*

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Preliminary porewater geochemistry data suggest that an inflow of reducing fluids (*e.g.* methane-enriched) might have taken place in some of these locations in the past as indicated for instance by increased ammonium levels near the fault scarp (Figure 2). Interestingly, however, the methane concentrations in the bottom waters are very low, suggesting that real-time monitoring of emissions might not be the most adequate method to identify low-intensity seepage in these well-mixed deep ocean waters (M. Schmidt, *pers. comm.).*

Essential data being acquired and still missing include geochemical parameters able to reveal contributions from organic and lithogenic sources (*e.g.* methane concentrations in pore fluids and adsorbed on sediments; or geochemical indicators of fluid-mafic rock interactions, respectively) in the porewater. They will be used to produce geochemical models accounting for the porewater profiles observed, *i.e.* unravelling porewater-mineral reactivity effects *versus* advection of deep-sourced fluids (C. Hensen, *pers. comm*.).

Moreover, the first results of the M-162 expedition suggest that upward flow of deep-sourced fluids cannot be ruled out in this type of deep oceanic environment, but that parameters commonly used on continental margins may not be the most adequate to identify micro-seepage in this markedly distinct geological setting.

Please refer to the short M-162 cruise report for more information: https://www.ldf.uni-hamburg.de/meteor/wochenberichte/wochenberichte-meteor/m162-m163/scr-m162.pdf

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