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Fluid composition of the sediment-influenced Loki's Castle vent field at the ultra-slow spreading Arctic Mid-Ocean Ridge

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Abstract

The hydrothermal vent field Loki's Castle is located in the Mohns-Knipovich bend (73°N) of the ultraslow spreading Arctic Mid-Ocean Ridge (AMOR) close to the Bear Island sediment fan. The hydrothermal field is venting up to 320° C hot black smoker fluids near the summit of an axial volcanic ridge. Even though the active chimneys have grown on a basaltic ridge, geochemical fluid data show a strong sedimentary influence into the hydrothermal circulation at Loki's Castle. Compelling evidence for a sediment input is given by high alkalinity, high concentrations of NH_4^+, H_2, CH_4, C_{2+} hydrocarbons as well as low Mn and Fe contents. The low $\delta^{13}C$ values of CO_2 and CH_4 and the thermogenic isotopic pattern of the C_{2+} hydrocarbons in the high-temperature vent fluids clearly point to thermal degradation of sedimentary organic matter and illustrate diminution of the natural carbon sequestration in sediments by hydrothermal circulation. Thus, carbon-release to the hydrosphere in Arctic regions is especially relevant in areas where the active Arctic Mid-Ocean Ridge system is in contact with the organic matter rich detrital sediment fans.

Keywords: Loki's castle; Arctic mid-ocean ridges; Ultra-slow spreading ridge; Hydrothermal fluids; Sediment-influenced; Gases

1. INTRODUCTION

The slow to ultraslow spreading Arctic Mid-Ocean Ridge (AMOR), as defined by Pedersen et al. (2010b), extends from the northern shelf of Iceland to the Siberian Shelf in the Laptev Sea (Fig. 1). The southern parts of this ridge system are characterized by anomalously thick crust due to the influence of the Iceland and Jan Mayen hot spots (Kodaira et al., 1998; Kandilarov et al., 2012). From the central Mohns Ridge and northward, the AMOR is characterized by thin, or even absent crust, and a diminished magmatic heat budget (Géli et al., 1994; Kandilarov et al., 2010; Dick et al., 2003; Michael et al., 2003). The geological setting is not only characterized by strong variations in crustal thickness, but also by sediments from the Bear Island sediment fan that bury the eastern side of the Knipovich Ridge (Bruvoll et al., 2009). Hydrothermal activity along magma starved ultraslow spreading ridges has proven to be more abundant than previously assumed (German et al., 1998; Edmonds et al., 2003; Baker et al., 2004; Pedersen et al., 2010a; Pedersen et al., 2010b). And where sediments are involved in hydrothermal fluid circulation, mass and heat are not only transferred between circulating fluid and host

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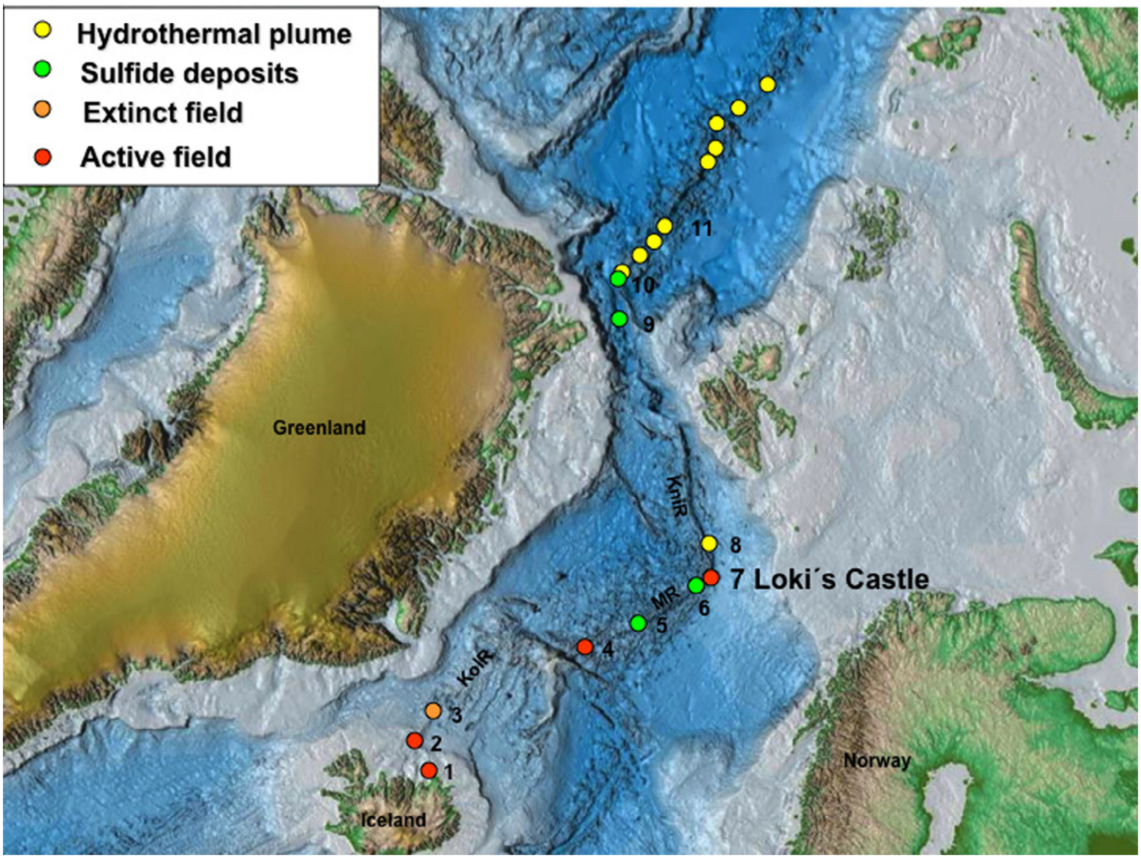

Fig. 1. Map after Pedersen et al. (2010b, and references therein) showing the Arctic Mid-Ocean Ridges with the locations of active and extinct vent fields, sulfide deposits and hydrothermal plumes: 1 Grimsey, 2 Kolbeinsey, 3 Squid Forest extinct vent field, 4 Jan Mayen vent fields, 5 Copper Hill sulfide mineralized breccia, 6 Mohn's Treasure sulfide deposit, 7 Loki's Castle, 8 hydrothermal plume, 9 sulfide deposit, 10 sulfide deposits and shimmering water and 11 hydrothermal plumes. KolR = Kolbeinsey Ridge, MR = Mohns Ridge, KniR = Knipovich Ridge.

rock, but also between fluid and sedimentary substrate that leaves its fingerprint on the fluid composition (Von Damm et al., 1985b; Lilley et al., 1993; Butterfield et al., 1994a; Campbell et al., 1994; Proskurowski et al., 2004). To date, the number of known active sediment-associated (including both, sediment-covered and sediment-influenced systems) hydrothermal systems is low compared to bare-rock systems. Nevertheless, the active processes at sediment-associated systems are important to study for several reasons. Heat and mass transfer during hydrothermal circulation through a sedimentary cover to the seafloor are significantly distinct from bare-rock hydrothermal systems (Von Damm, 1990; German and Von Damm, 2003). Furthermore, hydrothermal reactions between fluid and sediments can reduce the efficiency of natural carbon sequestration within the sediments by thermogenic decomposition of carbon species hosted in sediments (Lizarralde et al., 2011). Accordingly, the fluid chemistry of vent systems with thermogenic decomposition of organic matter is dominantly characterized by high concentrations of CH_4 and higher hydrocarbons as well as high NH_4^+ concentrations (e.g. Von Damm et al., 1985b). Subseafloor precipitation of metal sulfides from the venting fluid in sediment-associated systems can lead to massive sulfide deposits within the sediment (e.g. Takai et al., 2012). In addition, sediments can play an important role for microbial activity and diversity associated with the hydrothermal system (Nakagawa et al., 2005; Jaeschke et al., 2012; Dahle et al., 2015). Numerous hydrothermal vent systems associated with sediments are known: Middle Valley on the Juan the Fuca Ridge, Escanaba Trough on the Gorda Ridge, Guaymas Basin in the Gulf of California, several vent fields along the Okinawa Trough (back-arc) in the Western Pacific and the Main Endeavour Segment of the Juan de Fuca Ridge, whereas only Middle Valley, Escanaba Trough and Guaymas Basin are sediment-covered vent systems (Von Damm et al., 1985b; Lilley et al., 1993; Butterfield et al., 1994a; Campbell et al., 1994; Von Damm et al., 2005; Gamo et al., 2006). The Main Endeavour Segment is a ridge segment with no sediment cover, but hosts active vents with hydrothermal fluid compositions that indicate a sedimentary input and is thus classified as sediment-influenced system (Lilley et al., 1993; Proskurowski et al., 2004). The sediment-associated vent fields at the Okinawa Trough, are partly located on volcanic seamounts rising from the thick sediment-covered flat area in the trough (Ishibashi et al., 2015).

During the expedition to the AMOR in the Norwegian-Greenland Sea in summer 2008, Pedersen et al. (2010a) discovered another vent field with sedimentary input.