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Natural oil seepage at Kobuleti Ridge, eastern Black Sea

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ABSTRACT

Analysis of Advanced Synthetic Aperture Radar satellite images in combination with water column and seafloor investigations documented natural oil seepage from Pechori Mound and Colkheti Seep in 1000–1200 m water depth in the eastern Black Sea offshore Georgia. Hydroacoustic imaging of the water column using multibeam echosounder evidenced numerous gas emissions from both structures. Gas bubbles rose as high as 45 m below sea surface. It is proposed that oil coatings around gas bubbles hamper their dissolution allowing them to reach the sea surface where widespread oil slicks are formed. Slow rise velocities (14 ± 1 cm s^{-1}) of bubbles with radii of 2.6 ± 0.3 mm ($n = 101$) derived from video data obtained with the remotely operated vehicle MARUM QUEST4000, corroborate the assumption that bubbles are oil-coated. High resolution seafloor mapping with the autonomous underwater vehicle MARUM SEAL5000 at Colkheti Seep revealed a crater-strewn morphology whose formation is explained by frequent rafting of shallow gas hydrate deposits. Satellite imaging of oil slicks on the sea surface above both sites indicates that oil seepage is rather persistent since 2003. An order-of-magnitude estimation of minimum oil seepage rates suggests discharge rates of ~40 liters per hour from both sites. The data presented are the first comprehensive description of oil seepage in the Black Sea.

1. Introduction

Natural seepage of methane and gas hydrate dissociation have been identified as major sources sustaining the Black Sea's high content of dissolved methane (Kessler et al., 2006; Schmale et al., 2011). Three types of submarine cold seeps may be distinguished in the Black Sea depending on water depth and seafloor morphology. One type is found in shallow waters on the shelf and upper continental slope. Thousands of seeps discharging predominantly biogenic methane have been discovered at the Dnepr and Danube paleodeltas offshore Ukraine and Romania (Michaelis et al., 2002; Naudts et al., 2006; Schmale et al., 2010) as well as at the shelf and upper slope offshore Bulgaria (Dimitrov, 2002), Turkey (Çifçi et al., 2003; Ergün et al., 2002), and Georgia (Egorov et al., 2003). A second type is located within the gas hydrate stability zone (GHSZ) below 725 m below sea level (bsl) (Naudts et al., 2006; Pape et al., 2010). Here, fractions of the ascending gas are sequestered as gas hydrates while the rest is emitted to the hydrosphere (Naudts et al., 2006; Römer et al., 2012a). Observations on these seeps are sparse and have been made only locally as at the Batumi Seep area offshore Georgia (Klaucke et al., 2006; Nikolovska et al., 2008; Pape et al., 2011) or the Kerch Flare offshore Ukraine (Römer et al., 2012a). These seeps are fueled by biogenic methane with admixtures of higher low molecular weight hydrocarbons (LMWH) (Heeschen et al., 2011; Pape et al., 2010; Römer et al., 2012a). A third seep type is characterized by significant relief as mounds or mud volcanoes. Black Sea mud volcanoes discovered to date are exclusively located in the deep sea (Akhmetzhanov et al., 2007; Bohrmann et al., 2003; Feseker et al., 2009; Ivanov et al., 1996; Krastel et al., 2003; Mazzini et al., 2008; Meisner et al., 1996). Gas discharges and gas hydrate precipitates have been reported for many of those sites (Bohrmann et al., 2003; Greinert et al., 2006; Ivanov et al., 1996; Klapp et al., 2010; Sahling et al., 2009).

Especially the eastern Black Sea basin is known for its oil potential (Robinson et al., 1996), yet few is known about oil occurrence in shallow sediments and oil seepage which is common in other hydrocarbon provinces, e.g. the Gulf of Mexico (Brooks et al., 1984; MacDonald et al., 1993). Several mud volcanoes emit mixtures of thermogenic hydrocarbons and biogenic LMWH (Blinova

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et al., 2003; Feseker et al., 2009; Kruglyakova et al., 2004; Stadnitskaia et al., 2008) but no oil seepage has been observed so far. A single site offshore Turkey was previously reported where oil reaches the sea surface (Kruglyakova et al., 2004; Robinson et al., 1996) but no detailed information has been presented.

In this study, we describe oil seepage at Kobuleti Ridge offshore Georgia, as novel seepage type in the Black Sea. The two seep structures Pechori Mound and Colkheti Seep have been discovered, along with other mound-like structures with oil impregnated sediments, during the Training-Trough-Research (TTR) cruise 15 with R/V LOGACHEV (Akhmetzhanov et al., 2007).

Previous studies in the Black Sea indicate that free gas emissions from depth below 100 m do not reach the sea surface due to dissolution (McGinnis et al., 2006; Schmale et al., 2010). Generally, bubbles reaching the sea surface from greater depth have only been reported for sites of combined oil and gas seepage in the Gulf of Mexico (De Beukelaer et al., 2003; MacDonald et al., 2002) and one gas seep in the Sea of Okhotsk (Cranston et al., 1994). It was previously proposed that bubble dissolution is significantly impeded by oil coatings (De Beukelaer et al., 2003; Leifer and MacDonald, 2003). The potential contribution of these emissions to local atmospheric methane concentrations in the Gulf of Mexico is discussed controversial (Hu et al., 2012; Solomon et al., 2009). Oil-coated bubbles that reach the sea surface form widespread oil slicks which are visible on *Synthetic Aperture Radar* (SAR) satellite images (De Beukelaer et al., 2003; Garcia-Pineda, 2009; Leifer and MacDonald, 2003).

In this study, satellite and hydroacoustic investigations in combination with visual seafloor inspections were performed to characterize the two oil seeps Pechori Mound and Colkheti Seep. In the following we describe the seeps and related seepage processes that allow oily bubbles to reach the sea surface from depth >1000 m.

2. Study area and geological settings

The Black Sea is an intercontinental basin (Fig. 1) characterized by a well stratified water mass with an oxygenated uppermost layer and an O_2/H_2S transition around 200 mbsl (Murray et al., 1989). A permanent pycnocline is developed between 100 and 200 mbsl (Murray et al., 1991), impeding ventilation of the deeper water mass. Due to its stable stratification and negligible exchange of water masses through the Bosporus, the Black Sea became the largest surface reservoir of dissolved methane (Kessler et al., 2006; Reeburgh et al., 1991).

The recent Black Sea has a maximum depth of 2206 m (Ross et al., 1974). In the sub-seafloor the Andrusov and Achangelsky Ridges form the Mid-Black Sea-High that separates a western and eastern basin (Fig. 1). These basins developed from a back-arc basin when the Neo-Tethys was closed by subduction under the Eurasian plate (Görür, 1988; Zonenshain and Pichon, 1986) in Late Cretaceous or Early Paleocene (Meredith and Egan, 2002; Nikishin et al., 2003). Latest in Eocene the extensional regime of the evolving basins changed to a compressional one due to the subduction of the African and Arabian plates under the Eurasian plate (Meredith and Egan, 2002; Nikishin et al., 2003).

With respect to hydrocarbon maturation special attention has been drawn to the Oligocene-Miocene Maikopian formation which is known to bear great hydrocarbon potential in the eastern Black

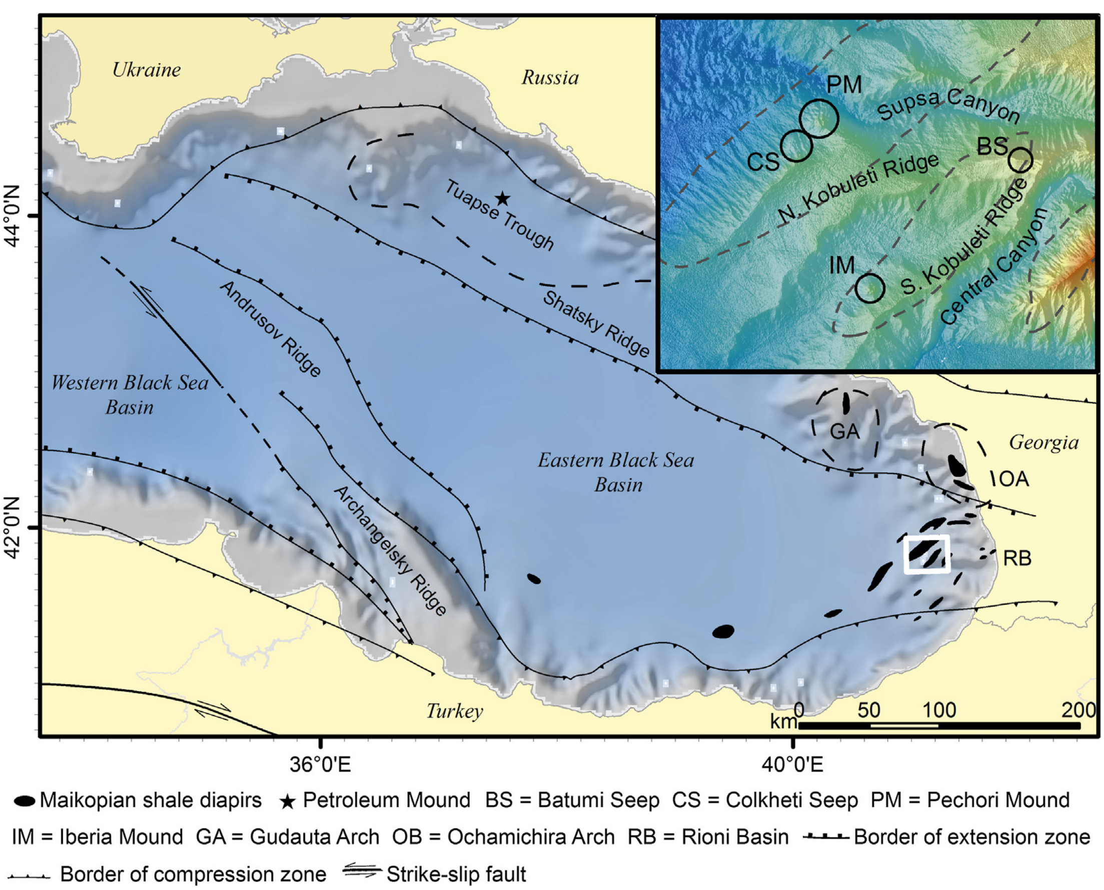

Figure 1. Main geological structures of the eastern Black Sea (after Robinson et al., 1996). Location of the study region in the eastern Black Sea (insert) is indicated by the white box. Locations of Maikopian shale diapirs are adapted from Tugolesov et al. (1985). Dashed lines in the insert indicate locations of Maikopian shale diapirs. Bathymetry: GEBCO 1 min; bathymetry in inset: multibeam echosounder data acquired as part of this study.