Earth and Planetary Science Letters 395 (2014) 241–253

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

www.elsevier.com/locate/epsl

Hydrocarbon flux from natural deepwater Gulf of Mexico vents

Andrew J. Smith [a,b,c,d,*], Peter B. Flemings [a,b,c], Patrick M. Fulton [a]

[a] Institute for Geophysics, The University of Texas at Austin, Austin, TX 78758, USA
[b] Jackson School of Geosciences, The University of Texas at Austin, Austin, TX 78713, USA
[c] Bureau of Economic Geology, The University of Texas at Austin, Austin, TX 78758, USA
[d] CAGE – Centre for Arctic Gas Hydrate, Environment and Climate, UiT The Arctic University of Norway, Tromsø, Norway

ARTICLE INFO

Article history:
Received 2 March 2013
Received in revised form 9 February 2014
Accepted 26 March 2014
Available online 16 April 2014
Editor: C. Sotin

Keywords:
Gulf of Mexico
hydrocarbon flux
gas hydrate
salinity
temperature

ABSTRACT

High salinities and high temperatures at the seafloor record the upward flow of water and hydrocarbons from depth at natural vents in the deepwater Gulf of Mexico. We present a multiphase heat- and solute-transport model, in which water supplied from depth transports heat and salt, and hydrocarbon transports heat. We show that there is a unique water and hydrocarbon flux that simulates the observed salinity and temperature. We estimate the hydrocarbon flux to be 3.2–15 $\times 10^4$ t yr^{-1} and 1.8–8.0 $\times 10^4$ t yr^{-1} from two vents at lease blocks MC852/853 and GB425. These fluxes are 1–4 orders of magnitude greater than previous estimates from individual deepwater vents. If these results are extrapolated to the entire Gulf of Mexico, then we estimate the regional hydrocarbon flux to be at least 100× greater than previous estimates and 14–120% of the hydrocarbon flux from the Macondo oil spill. Large natural seepage may inoculate marine basins such as the Gulf of Mexico from oil spills like the 2010 *Deepwater Horizon* blowout by sustaining populations of hydrocarbon-degrading bacteria.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

Natural vents expel water and hydrocarbons on continental margins around the world. Deepwater vents are the site of poorly understood biological communities (Paull et al., 1984) and gas hydrate (Brooks et al., 1986), an ice-like crystalline compound that contains methane and other light gases in a lattice of water molecules (Sloan, 1998). Elevated salinities and high temperature gradients have been observed in the subsurface near the seafloor of vent edifices (Hornbach et al., 2005; Paull et al., 2005; Ruppel et al., 2005a; Sahling et al., 2009). Vents release considerable quantities of hydrocarbon into the ocean (Suess et al., 1999) and atmosphere (Solomon et al., 2009), which may contribute significantly to oceanic and atmospheric carbon budgets (Judd, 2003; Milkov et al., 2003).

Different approaches are used to quantify the flux of water and hydrocarbons from these vents, and each approach has limitations. Commonly, upward water flow of 1–10 mm yr^{-1} is estimated from the subsurface salinity gradient measured near the seafloor based on one-dimensional advection–diffusion models (Egeberg, 2000; Reitz et al., 2007). However, as previous workers have pointed out (Hornbach et al., 2005), these fluxes are too low to explain the temperature gradients that are present. In addition, these models all assume only water flow despite direct evidence of multiphase flow, such as active gas and oil venting (Heeschen et al., 2005; Leifer and Macdonald, 2003; MacDonald et al., 2000; Torres et al., 2002), sea-surface slicks observed from space (Macdonald et al., 1993), and the retrieval of oil-stained cores and highly gas-charged sediment from vent surfaces (Ruppel et al., 2005a; Winters et al., 2007). Video imaging (Leifer and Macdonald, 2003), sonar data (Hornafius et al., 1999), and turbine tents on the seafloor (Leifer and Boles, 2005) have been used to quantify the emission of hydrocarbons from individual vents. These techniques, however, do not constrain fluxes of both water and hydrocarbons, and they do not measure flow over long timescales. In addition, video-imaging techniques and turbine tents can only quantify flux at localized seep points, and therefore may not be effective for measuring flux from large vents.

We present a new two-phase solute- and heat-transport model that incorporates both the salinity and temperature gradients to predict water and hydrocarbon flux at two deepwater Gulf of Mexico (GoM) vents (Fig. 1). Until now, it has generally been assumed that hydrocarbons do not play a significant role in heat transport because their volumetric heat capacity is low (e.g. methane $\sim 3.2 \times 10^5$ J m^{-3} K^{-1}, oil $\sim 1.2 \times 10^6$ J m^{-3} K^{-1}, while water

Abbreviations: GoM, Gulf of Mexico; BSR, Bottom-simulating reflector; mbsf, Meters below seafloor; SAR, Synthetic aperture radar.

* Corresponding author at: CAGE – Centre for Arctic Gas Hydrate, Environment and Climate, UiT The Arctic University of Norway, Tromsø, Norway. Tel.: +1 214 534 8173.

E-mail address: andrew.j.smith.6022@gmail.com (A.J. Smith).

http://dx.doi.org/10.1016/j.epsl.2014.03.055
0012-821X/© 2014 Elsevier B.V. All rights reserved.

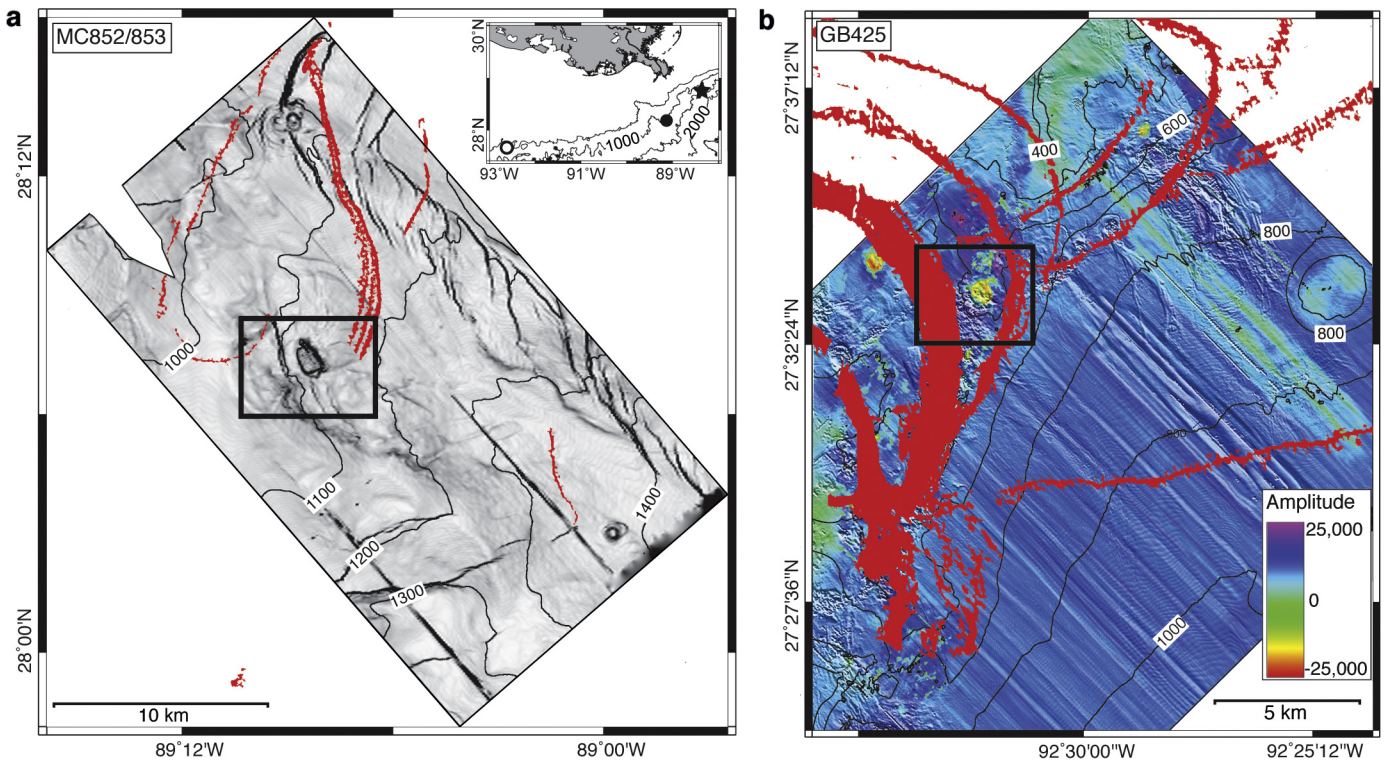

Fig. 1. Seismic maps of the Ursa and Auger Basins in the GoM. Maps are overlain with backscatter anomalies (red) detected from SAR images taken May 2006. Backscatter anomalies are interpreted as oil slicks on the ocean surface. Contours are in meters below sea level (converted from time assuming an acoustic velocity of 1.5 km s^{-1}). (a) Seismic dip map of the Ursa Basin (solid black circle on inset map). Dip maps emphasize steeper gradients with darker colors. The gas vent at MC852/853 (black box, Fig. 2a) is located ~220 km SSE of New Orleans and ~100 km from the *Deepwater Horizon* oil spill (black star). (b) Seafloor seismic amplitude map of the Auger Basin (white circle on inset map). Higher amplitudes (purple) record the presence of authigenic carbonates or hydrates. Lower amplitudes (yellow–red) are interpreted to record locations where there is active gas venting from the seafloor. The gas vent at GB425 (black box, Fig. 3a) is located ~500 km from the *Deepwater Horizon* spill. Seismic data courtesy of Shell (1a) and CGGVeritas (1b).

~4.0×10^6 J m^{-3} K^{-1}) (Liu and Flemings, 2006). In contrast, we develop a mathematical approach to include the thermal contribution of both water and hydrocarbon flow and show that with sufficient flux, the observed subsurface temperature and salinity profiles can be reconciled with the upward flow of multiphase fluids. We then examine the implications of our flux estimates. This method suggests that previous estimates of hydrocarbon flux at any particular vent may be orders of magnitude too low. By extrapolation, this implies a much larger flux into the world's oceans than previously suggested.

2. Key observations at two deepwater GoM vents

2.1. MC852/853 and GB425 vents

We study two vents in the northern GoM at lease blocks MC852/853 and GB425 (Fig. 1). Synthetic-aperture-radar (SAR) images display persistent oil on the sea surface above both vents (Fig. 1) (Garcia-Pineda et al., 2012). At MC852/853, three-dimensional seismic data reveal that the vent is elevated ~75 m above the seafloor and is roughly circular with a ~1.2 km diameter (Fig. 2a, b). At GB425, the vent has a similar diameter and is elevated 40 m relative to the surrounding seafloor (Fig. 3a, b). A seismically transparent zone is present underneath both vents that extends to depths >1000 m below seafloor (mbsf) (Figs. 2b and 3b); such a zone is commonly interpreted to record the presence of gas (Yin et al., 2003).

At MC852/853, there is a strong, negative-polarity seismic reflection that rises rapidly at the vent's boundaries and is horizontal within a few meters of the seafloor beneath the vent edifice (Fig. 2b). We interpret this reflection to be the bottom-simulating reflector (BSR), which records a negative impedance contrast between hydrate and water above and gas and water below (Shipley et al., 1979). Carbonate chimneys, active oil seepage, and chemosynthetic communities are present (MacDonald et al., 2003). Vent sediments are gas-charged (MacDonald et al., 2003; Winters et al., 2007), and gas bubbles are released upon slight disturbance of the mound (MacDonald et al., 2003).

At GB425, there is a negative-polarity seismic reflection at the seafloor, but no clear BSR (Fig. 3b). This negative-polarity event records a significant decrease in acoustic impedance at the water-seafloor interface and most likely records the presence of free gas at or near the seafloor (Reilly and Flemings, 2010). Thermogenic gas hydrates have been recovered from the mound; however, the temperature, salinity, and gas composition (>99% CH_4) at the seafloor suggest that only gas and water, not hydrate, are stable at the vent surface (Ruppel et al., 2005a). Oil seepage, free-gas expulsion, and a methane-dependent biological community are also present (MacDonald et al., 2000).

The vent fluids are sourced by thick sandstones that span more than 500 km^2 (Reilly and Flemings, 2010). These sandstone bodies onlap salt; at their structural crest, the pore pressure exceeds the least-principal stress, resulting in fracture of the overlying material and the expulsion of fluids vertically (Reilly and Flemings, 2010). Both vents are imaged as a transparent zone extending upwards from a sandstone crest (Figs. 2b and 3b). At GB425, we have shown through analysis of 3D seismic data and direct pressure measurements that the source of the venting fluids is ~3200 mbsf (Reilly and Flemings, 2010). Analysis of the available data at MC852/853 suggests that fluids are leaked from ~1500 mbsf (Fig. 2b).

Download English Version:

https://daneshyari.com/en/article/6429296

Download Persian Version:

https://daneshyari.com/article/6429296

Daneshyari.com