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Methane leakage during the evolution of petroleum systems in the Western Canada Sedimentary Basin and the Central Graben area of the North Sea

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Around 500 to 600 Tg (1 Tg = 10^{12} g) of methane enter the atmosphere every year, mainly as product of microbial processes and combustion of fossil fuels and burning biomass. The importance of another source, the geologic emissions of methane, is up to now only loosely constrained. In this study, we addressed the potential methane emissions during the geological evolution of the Western Canada sedimentary basin (WCSB), which holds the largest oil sand accumulations in the world, and the Central Graben area of the North Sea.

In the case of the WCSB, thermogenic gas generation and leakage at the sediment surface were addressed through 3D petroleum systems modeling. In this basin, the accumulated oil experienced intense biodegradation that resulted in large masses of biogenic methane. We quantified this latter mass though a two-step mass balance approach. Firstly, we estimated the rate of petroleum degradation and the magnitude of petroleum loss. After this, we calculated the mass of biogenic methane generated using a model that assumes hexadecane ($C_{16}H_{34}$) as representative of the saturated compounds (Zengler et al., 1999). Our 3D model suggests that 90000-150000 Tg of dry gas (mostly methane) could have leaked during the interval from 80 Ma to 60 Ma. Therefore, uniform leakage rates would have been in the order of 10^{-3}-10^{-2} Tg yr^{-1}. Biogenic methane generation could have taken place at rates of 10^{-4} to 10^{-2} Tg yr^{-1}. However, the effective mass of thermogenic and biogenic methane reaching the atmosphere might have been up to 90% lower than calculated here due to methanotrophic consumption in soils (Etiope and Klusman, 2002).

We addressed the thermogenic gas generation and leakage in the Central Graben through two different methods. The first is based on a previous 3D petroleum system modeling of the region (Neumann, 2006). The second consisted of calculating the mass of generated petroleum based on source rock extension and properties (Schmoker, 1994), and then estimating the gas mass available for leakage based on the concept of petroleum systems and the proportions among its constituents (Hunt, 1995). We propose that a maximum of 10^{-4}-10^{-3} Tg of thermogenic gas (mostly methane) could have leaked annually from the sediment surface. The portion of this gas that reached the atmosphere is unconstrained, and it would depend on the extent of oxidation through the water column.

The maximum rate of thermogenic gas generation in the WCSB is in the order of 10^{-2} Tg yr^{-1} (10^{-8} Tg yr^{-1}Km^{-2}, when normalized to area of kitchen). In the case of the Central Graben, the maximum would be in the order of 10^{-3}Tg yr^{-1} (10^{-8} Tg yr^{-1} Km^{-2}). These results suggest that thermal maturation alone would not be able to promote leakage rates as high as those reported for some single sedimentary basins at present-day, these last reaching up to 3.5 Tg yr^{-1} (Judd, 2004). Mechanisms promoting the release of previously accumulated gas masses in a short time span are thus a basic requisite for petroleum systems to exert an impact on climate.