Relationships between strain rate in continental plate boundary zones and probability of gas leakage

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Résumé

Strain is one factor influencing the permeability of the brittle crust and sedimentary basins. Natural gas emissions were previously studied as hydrocarbon indices for oil and gas exploration, more recently because they provide a minor contribution to green-house gas budgets, and also because understanding the various factors underlying their distribution can help evaluate risks of leakage associated with geological carbon storage. We here consider natural gas emission sites as indicators of focused flow pathways connecting a gas reservoir in a sedimentary basin or upper crust to the surface, and correlate various global CH4 and CO2 geological emission data sets with the global strain rate map (GSRM) of Kreemer et al. (2014). Only the on-land part of the data sets is used because the oceanic part is not constrained well enough. In a first approach, we count the number of fluid emission sites reported in a global inventory of natural gas seepages in each 0.25○ x 0.2○ cell of the GSRM grid and find that the density of sites in plate boundary zones increases with strain rate, but only moderately, as the relationship obtained may be fit with a power exponent of 0.5. Second, estimates on a 1○x1○ grid of methane fluxes from geothermal manifestations and from onshore seeps (Etiope et al., 2019) are compared with GSRM strain rates. Relationships are also found, with weaker exponents. We then examine theoretical relationships between strain rate and probability of percolation. First, percolation theory relates the probability of leakage to the moments of the distribution of hydraulically conductive fractures (Mourzenko et al., 2005). Second, relationships between these moments and strain rate may be proposed based on Kostrov summation method assuming fault zones that slipped recently are permeable but seal after a given time. These models predict a stronger dependency between leakage probability and strain rate. We discuss why this may be the case.

Mots-Clés: strain, fluid, permeability, percolation, CO2, natural gas, plate boundaries, GSRM

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