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A comprehensive approach for assessing potential fugitive gas migration associated with petroleum development from low permeability reservoirs: case studies from Western Canada

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With the advent of petroleum development from low permeability reservoirs facilitated by hydraulic fracturing it has become increasingly important to develop tracer tools to scientifically determine potential impacts of anthropogenically induced stray gas migration from depth on shallow aquifers. We have developed a comprehensive approach based on the chemical and isotopic characterization of gases from the production zone, the intermediate zone, and the shallow groundwater zone that has high potential of detecting fugitive gas migration into shallow aquifers independent of the migration pathway. This approach was developed at various sites in Western Canada. Gases from some production zones in the shale and tight gas areas in Alberta and north-eastern British Columbia revealed considerable variations in gas dryness (C1/C2+C3+C4+C5) among plays, but carbon isotope fingerprints of methane, ethane and propane were always characteristic of thermogenic gas (δ13C > -46 ‰. Gases from the intermediate zone were obtained through mud-gas sampling during drilling of the vertical sections of shale gas wells and through the installation of a multi-level monitoring well at a site in south-eastern Alberta to a depth of 106 m. Isotope analyses revealed a transition of carbon isotope values of methane from as low as -82 ‰ in shallow coal-bearing aquifers (less than 50 m below ground surface) to progressively increasing δ13C values of -62 ‰ at 500 m depth and further increasing methane carbon isotope ratios with increasing depth throughout the deeper portions of the intermediate zone. An extensive Alberta-wide groundwater baseline study was also conducted using both landowner and dedicated groundwater monitoring wells with repeated re-sampling of some wells. Methane is ubiquitous and predominantly of biogenic origin in shallow groundwater in Alberta with median and mean δ13C values of methane in free gas samples of -67.3 and -64.4 ‰ (n = 518) while the majority of free gas samples obtained from shallow groundwater have a dryness parameter > 500. Hence, we observed marked and systematic differences among carbon isotope ratios of methane and heavier hydrocarbons and in the gas dryness parameters of gases among the shale gas production, intermediate, and groundwater zones of Western Canada. These results demonstrate that a chemical and isotopic tracer approach should be highly suitable for identifying potential contamination of shallow aquifers with fugitive gases from the intermediate or production zones induced by unconventional energy resource developments, provided that sufficient baseline data exist. This study was conducted within the G-Baseline project co-funded by NSERC in Canada and ANR in France.