Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.35529

Geochemical Signatures of Methane Emissions from Non-Producing Oil and Gas Wells in Canada

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The presence of 400,000 non-producing oil and gas wells (OGWs) in Canada poses significant environmental and safety issues. These wells mainly leak methane (CH_4), amongst other pollutants. The geochemistry of released gases remains largely understudied but can help identify high-emitting wells and elucidate leakage pathways. Subsurface methane emissions can originate from three main sources: microbial, thermogenic, or abiotic processes. Among these origins, thermogenic methane has been associated with significantly higher emissions. Furthermore, a modern Canadian OGW typically consists of a system of casings and cement, providing multiple barriers designed to prevent contamination. The surface casing vent (SCV), installed at the wellhead, is designed to vent gas from the annular space between the surface casing and the next casing string. SCV emissions with geochemical signatures identical to those at the wellhead may indicate a failure of well integrity.

In this study, we compiled the geochemical data of 100 OGWs from Canada, with measurements made at the component level (wellhead, SCV and surrounding soil) wherever possible. By analyzing both the $\delta^{13}C$ and $\delta^{2}H$ signatures of the emitted methane and associated hydrocarbon ratios, we attributed an origin (primary microbial, secondary microbial, thermogenic, or abiotic) to our samples. We found that the presence of thermogenic methane at the surface casing vent (SCV) is a good indicator of high-emitting wells, with magnitudes of emissions 100 times higher than microbial emissions (**Figure 1**). Furthermore, our analysis suggests that half of the studied wells emit a mix of thermogenic and microbial methane and that the percentage of wells emitting microbial methane (~23%) is three times higher than previously estimated, with emission rates 1,000 times greater (**Figure 1**). These results suggest that non-producing OGWs could act as pathways facilitating the migration of subsurface microbial methane emissions into the atmosphere. Finally, we highlight the potential of geochemical data to inform effective mitigation and repair strategies.