Constraining the source and magnitude of CO_2 contamination in shale gases: A case study from the Vaca Muerta Formation, Argentina

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The Vaca Muerta shale of the Neuquén Basin, Argentina, is reported to contain one of the largest resources of shale gas in the world. However, exploitation has been complicated by the unexpected contamination of the hydrocarbon gases by 0.4-9.3% of CO_2. The origin, timing of emplacement and maximum amount of CO_2 that could be encountered in the Formation is currently unknown. We report new measurements from shale gases obtained from 10 production wells sited in two distinct fields (~200 km apart). Regional geology and geophysics indicate that the CO_2 originates from below the shale. $\delta^{13}C_{CO2}$ (-0.9 - -7.7 ‰), mantle rich $^{3}He/^{4}He$ (3.43–3.95±0.10 R_A) (where R_A is the atmospheric ratio of 1.39 x 10^{-6}) and $CO_2/^{3}He$ (6.8–20.2 x 10^{7}) suggest binary mixing between magmatic CO_2 and hydrocarbon gases along with CO_2 loss. Using inverse modelling, we constrain the original source of CO_2 to have $^{3}He/^{4}He$=3.95–4.08 R_A and $CO_2/^{3}He$=8.8–16 x 10^{8}. This is consistent with the presence of an aged CO_2 reservoir under the shale. $^{20}Ne^{\dagger}/^{36}Ar$, $^{84}Kr/^{36}Ar$ and $^{132}Xe/^{36}Ar$ values are consistent with early and later stage of open system Rayleigh fractionation, and when combined with $CO_2/^{3}He$, suggest 51-88% of the original CO_2 has been lost under the shale. Hence, maximum potential magmatic CO_2 concentrations range from 17.1% (mean), up to 25.2% (+1σ error), significantly above the highest level observed in our study, posing a significant risk to further exploration of the Vaca Muerta Formation.