Using noble gas isotopes to constrain the source of CO_2 in the Vaca Muerta Shale in the Neuquén Basin (Argentina)

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The Neuquén Basin in west-central Argentina contains significant resources of conventional and unconventional hydrocarbons. The Lower Cretaceous Mulichinco Formation is the main reservoir and has been exploited for conventional hydrocarbons since the early 1990s. The source rock, the Upper Jurassic-Lower Cretaceous Vaca Muerta shale has been targeted for shale oil/gas production since 2010. At several locations well gases from both the Mulichinco and Vaca Muerta Formations exhibit high CO_2 concentrations. This study aims to determine the origin of the CO_2 and establish if there is a structural contol on its occurrence, by intergrating measurements of noble gas isotopes from the well gases with regional structural geology.

$\delta^{13}C$ of the CO_2 is between -0.9 and -3.3 ‰, making it difficult to distinguish between a metamorphic or a magmatic origin. $^3He/^4He$ are up to 3.95 R_A and neon isotope ratios clearly indicate that mantle-derived gases have mixed with the *in situ* hydrocarbons. $CO_2/^3He$ ratios are two orders of magnitude lower than the magmatic range and strongly correlate with CO_2 content ($R^2 = 0.99$) indicating significant CO_2 without concomitant He loss. Using our measurements we differentiate between adsorption, dissolution and precipitation of CO_2 as responsible processes for its loss.

The CO_2 is present when the two major fault systems in the basin intersect, with the deeper set propagating into the Upper Jurassic Auquilco Evaporite Fm, beneath the Vaca Muaerta Fm [1]. This indicates that the CO_2 is likely external to the petroleum system, originating from a magmatic source located beneath the Auquilco Fm. We aim to use the noble gas isotopes to differentiate between an asthenosphere-derived melt trapped in the crust during Lower-Middle Jurassic rifting, and subduction-derived melt emplaced in the Early Jurassic-Early Cretaceous. This information can now be used to assist in positioning future drilling acitivities away from likely high CO_2 occurrences.

[1] Howell et al. (2005) *Geol. Soc. London Spec. Pub.* **252**, 1-14.