Lastly, thank you to my parents, Jreg and Lisa Botner, and my boyfriend, Adam, for lending an ear when I needed to practice presentations and continually supporting me throughout my educational endeavors.

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Introduction

Natural gas extraction from unconventional shale reservoirs has intensified in the U.S. and comprised 40% of total natural gas extraction in 2013 (1, 2). Within the next two decades, it is projected to become the largest contributor to the nation's natural gas supply (2). Although shale gas presents potential for a domestic, cleaner-burning fuel source in the midst of regulatory mandates for decreasing use of coal, the processes of horizontal drilling and hydraulic fracturing ("fracking") to acquire shale gas raise both environmental and health concerns.

Environmental issues surrounding the extraction and use of unconventional natural gas include uncertainties of greenhouse gas, particularly CH_4, emission rates from production and transport (3, 4), increased seismic activity during drilling activities (5), and localized reductions in air quality (6). The prevailing public concern of expanding shale gas development is groundwater contamination in areas of active drilling and production via stray gas migration and wastewater leakage (7-11). CH_4 from natural gas in groundwater can present an explosion hazard at certain concentrations, and may indicate the presence of other potentially harmful chemicals used in hydraulic fracturing or associated with natural gas and/or oil (12, 13).

Within the Utica Shale, directional drilling and hydraulic fracturing has led to the creation of over 1,400 horizontal wells in the state of Ohio (14). Many residents in this region rely on unregulated private groundwater wells, most of which are untested due to the high cost for analysis. While no studies have been performed in the Utica Shale of Ohio, previous studies in the Marcellus Shale regions of Pennsylvania have found elevated levels of CH_4 with an isotopic and alkane ratio signature consistent with that of natural gas in drinking water within 1 km of active gas wells (15, 16), although these studies did not collect baseline data before the onset of shale gas activity.

Figures

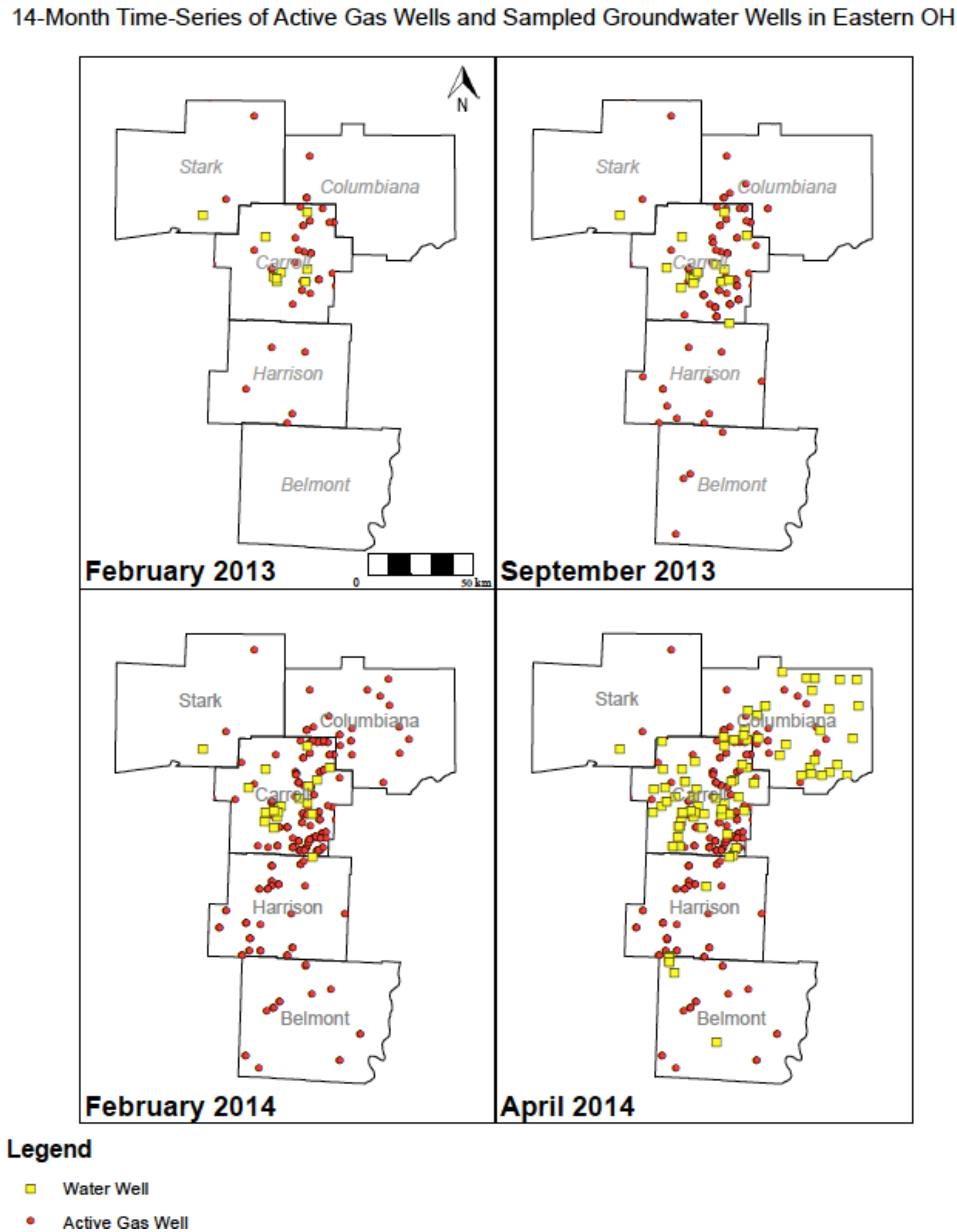

Figure 1. *Map of Ohio counties in the study area over 14 months of the sampling period. Yellow squares are sampled groundwater sites. Red circles are active natural gas wells.*

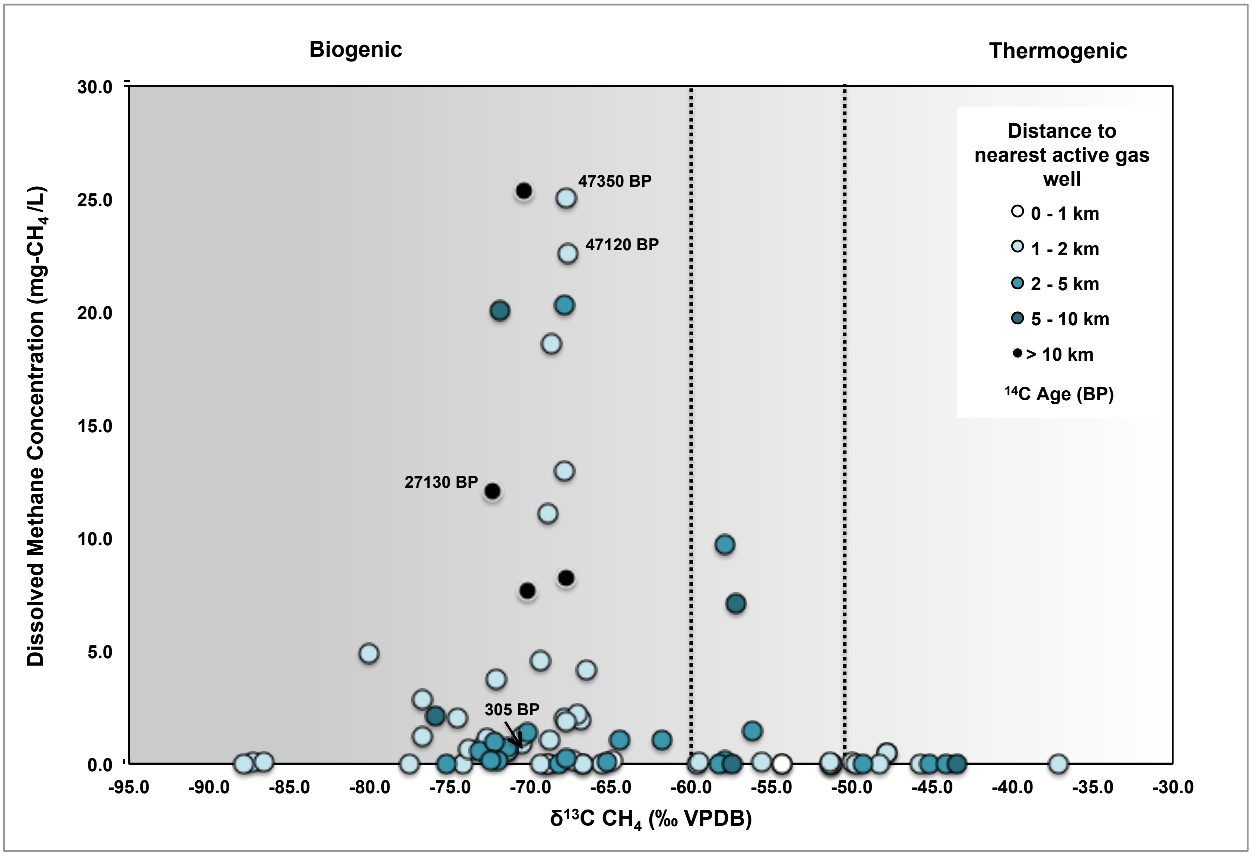

Figure 2. *CH_4 concentration compared to the carbon stable isotope composition of groundwater samples. Symbol shade represents distance to the nearest active gas well in km, with lighter shades denoting a closer proximity to active wells. Four data points are labeled with ^{14}C-CH_4 age (BP). Biogenic and thermogenic carbon isotopic signature ranges are separated by dotted lines.* (Osborn et al., 2011, Jackson et al. 2013).

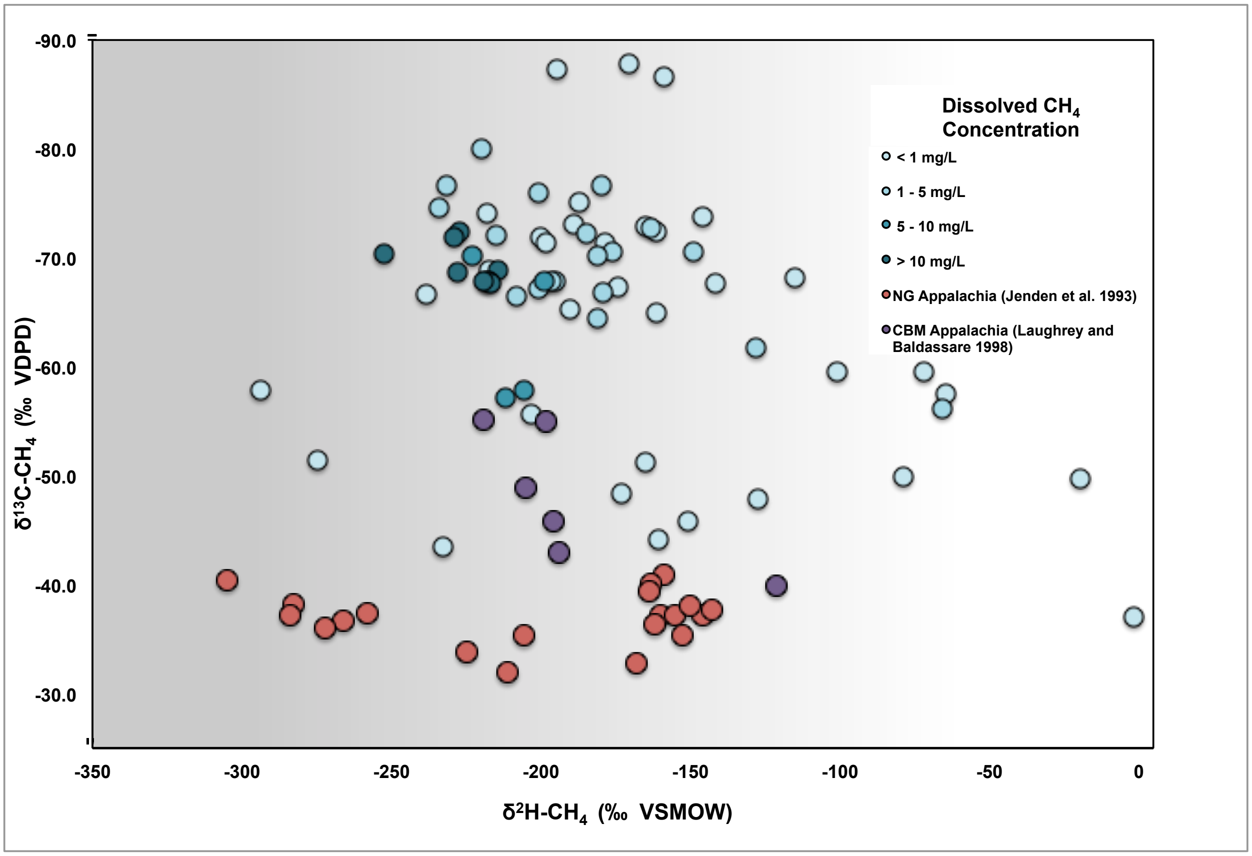

Figure 3. *Carbon and hydrogen stable isotopic composition of CH_4 in groundwater (shown as symbols with a turquoise color scale). Symbol shade represents the relative dissolved CH_4 concentration, with higher concentrations represented by darker shades. Purple symbols represent the stable isotopic composition of coalbed methane in Appalachia from Laughrey and Baldassare* (1998), *while red data points characterize the stable isotopic composition of Appalachian natural gas samples* (Jenden et al., 1993).

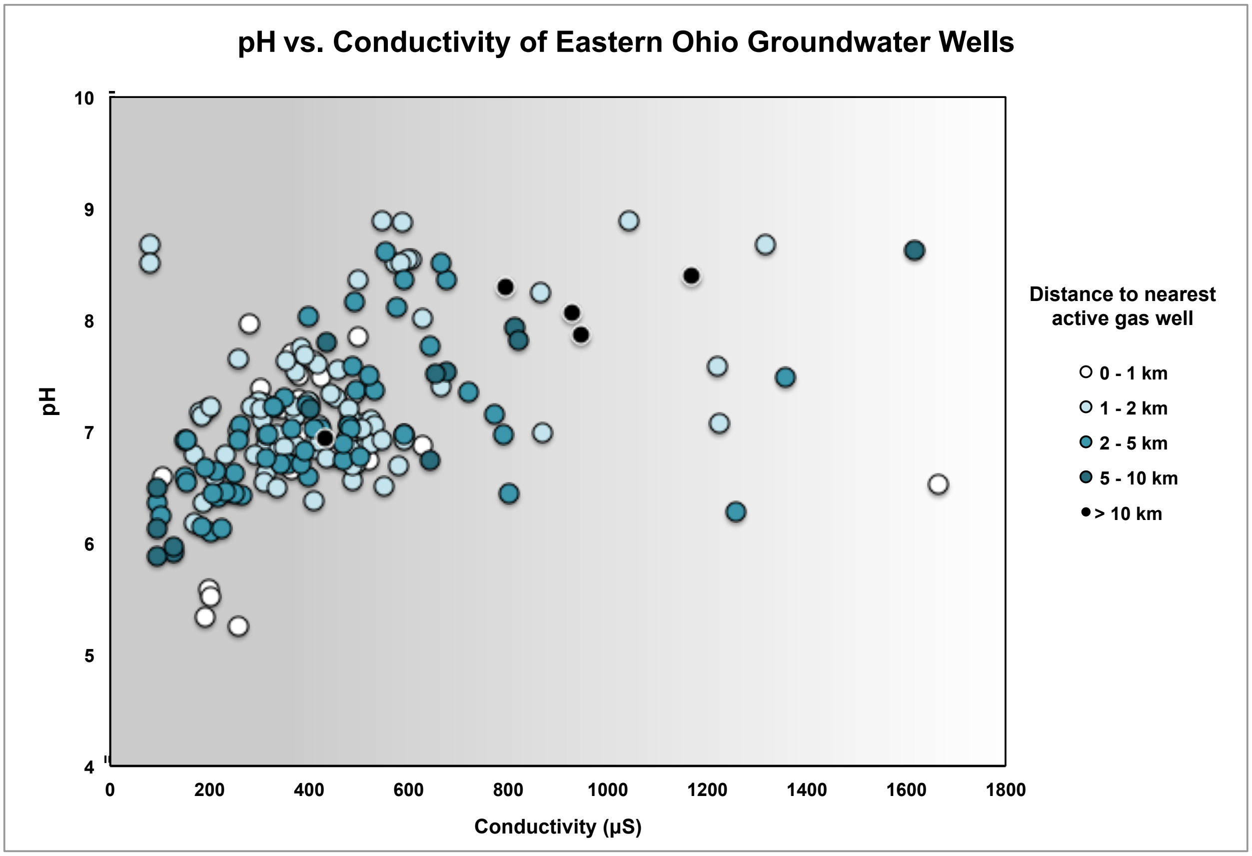

Figure 4. *pH and conductivity (in microsiemens) of groundwater sites. Symbol shade represents distance to the nearest active gas well in kilometers, with lighter shades denoting a closer proximity to active wells.*

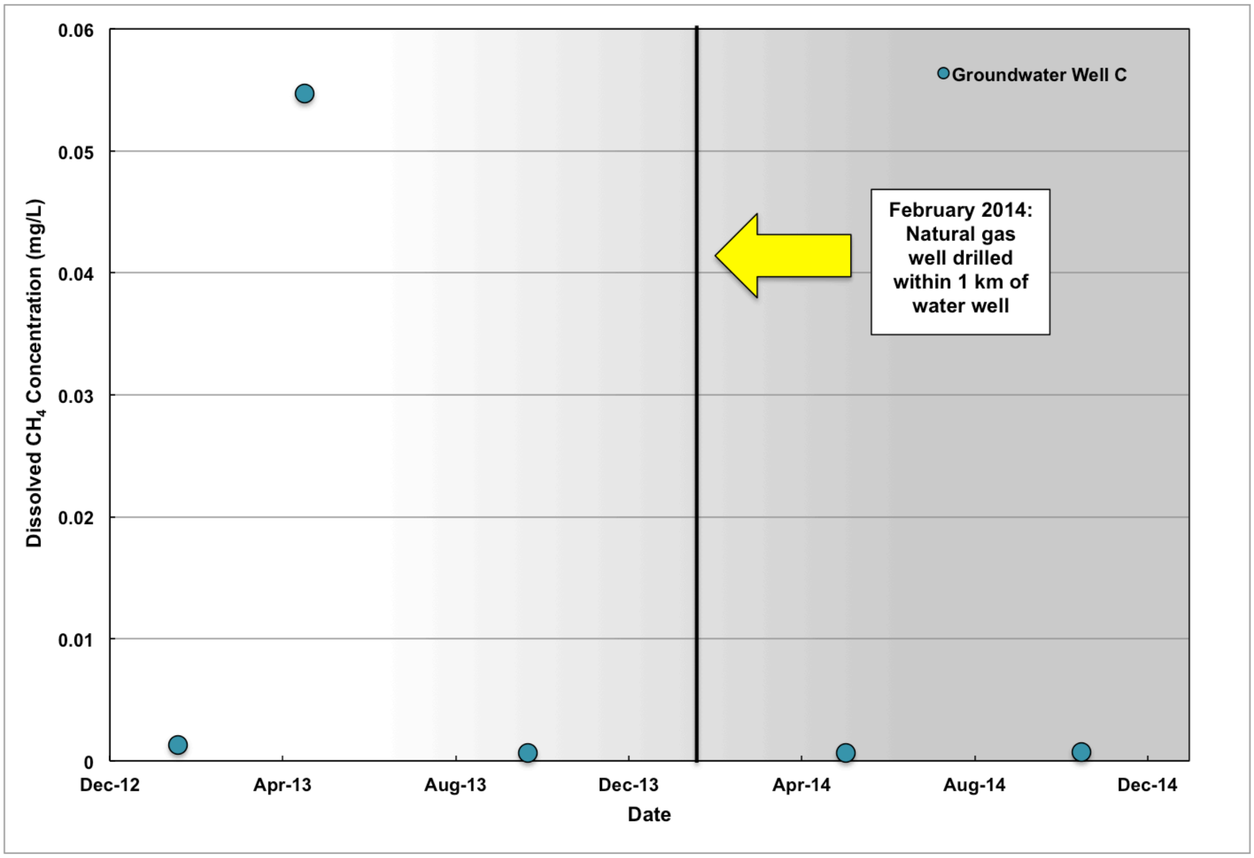

Figure 5. *The dissolved CH_4 concentration of groundwater well "C" in Carroll County, Ohio over two years of monitoring. In January 2013, a natural gas well was drilled within 1 kilometer of the water well, but no significant changes in groundwater CH_4 concentration were observed. Variability in CH_4 concentrations prior to nearby gas drilling is likely due to exposure of groundwater to air.*

Figure 6.

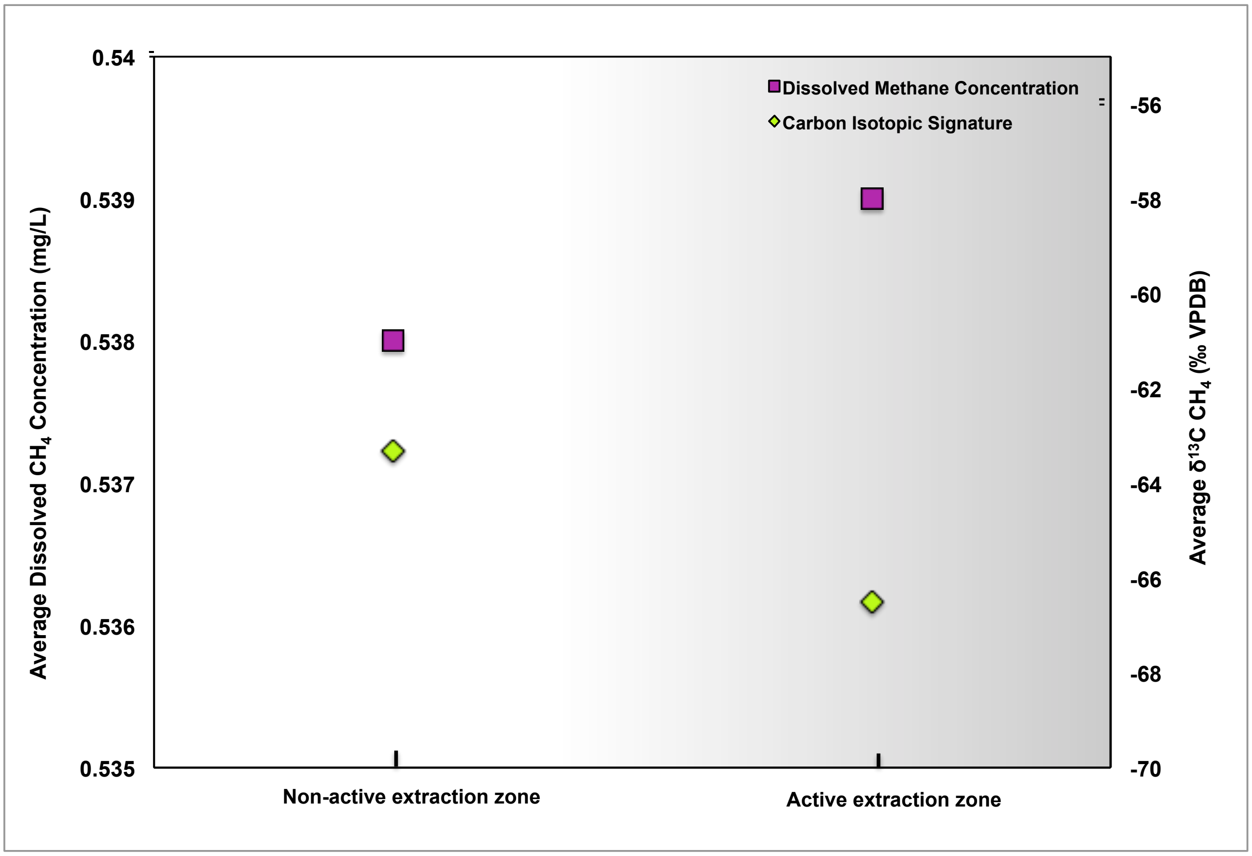

Figure 6. *The average dissolved CH_4 concentration and average $\delta^{13}C\text{-}CH_4$ value of groundwater monitoring sites in active and non-active extraction zones of the study area. A water well within an active extraction zone is defined as being within 1 kilometer of an active natural gas well. Three groundwater samples containing dissolved CH_4 values consistently greater than 10 mg/L were not included in the average dissolved CH_4 calculation.*

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