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Subsurface migration, environmental impacts, and fate of fugitive gas from energy resource development: a controlled natural gas release experiment in NE British Columbia

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Summary

Petroleum resource development is creating a global legacy of active and inactive onshore energy wells. A portion of these wells exhibit gas migration (GM), releasing fugitive gas (FG) into adjacent geologic formations and overlying soils (Bachu, 2017; BC Oil and Gas Commission, 2013). Once mobilized, FG may traverse the shallow subsurface, emit to the atmosphere and contribute to greenhouse-gas emissions, and impact groundwater. Indeed, the Council of Canadian Academies 2014 report on the “Environmental Impacts of Shale Gas Extraction in Canada” identified FG as the greatest threat to groundwater from shale gas extraction (CCA, 2014). Understanding of GM and FG has increased in recent years but significant knowledge gaps persist such as 1) the incidence and causes of GM, 2) subsurface baseline conditions in regions of development required to delineate GM and FG, and 3) the migration, impacts, and fate of FG. To address the identified knowledge gaps within BC, the Energy and Environment Research Initiative (EERI) at the University of British Columbia has implemented several field-focused research projects, including 1) statistical analyses of regulatory data to elucidate the incidence and causes of GM, 2) characterization of regional hydrogeology and shallow subsurface conditions in the Peace Region of the Montney resource play, and 3) a field investigation of the migration, impacts, and fate of FG in the shallow subsurface through controlled natural gas release. Here, we focus on the third study, for which a controlled natural gas release experiment was carried out in the summer of 2018 in northeastern BC in order to track and understand gas migration in the shallow subsurface. Various monitoring strategies were implemented before, during, and after the release, including groundwater sampling, vadose zone monitoring, atmospheric monitoring, microbiological sampling, and geophysical testing.

Method

The Hudson’s Hope Field Research Station (HHFRS) has been established in the Peace Region of northeastern BC to investigate the migration, impacts, and fate of FG in an area of active oil and gas development (Figures 1 and 2). The HHFRS encompasses approximately 50 square meters of land, and includes a remote off-grid solar power station, a gas injection system, and various infrastructure to house monitoring equipment and supplies. Cone penetration testing (CPT) was conducted prior to the experiment to improve characterization of the stratigraphy and heterogeneity of the subsurface. Nineteen groundwater monitoring wells, 13 of which are multilevel, were drilled throughout the area, as well as 21 soil gas sampling ports. Additional monitoring equipment includes an eddy covariance station to monitor atmospheric emissions, a surface efflux chamber and analyzer system for vadose zone monitoring, a field mass spectrometer for real time gas concentration data, and survey lines for electrical resistivity tomography (ERT) and vertical seismic profile (VSP) measurements.

During the summer of 2018, approximately 100 m^3 of a synthetic Montney gas were injected into an aquifer at 26 m vertical depth over a period of 72 days at a constant rate. All teams (groundwater, vadose zone, microbiology, geophysics, and eddy covariance) collected baseline data before the natural gas release, and continued to monitor throughout the injection period. Post-injection data collection is ongoing.

Observations and Results

Drilling and cone penetration testing (CPT) from the set-up phase of the project depicted a relatively continuous, 12 m thick diamict layer overlying a confined aquifer composed of interbedded sand, silt, and gravel. The aquifer was revealed to be highly heterogeneous with limited lateral continuity of permeable zones. While data collection is ongoing, preliminary results showed that the injected natural gas broke through the confining diamict layer slightly over one month since the beginning of the injection. Groundwater, geophysical, and surface efflux data indicate discrete preferential flow paths of the injected natural gas, which manifest as “hotspots” at the surface where gas is emitted to the atmosphere. The multidisciplinary datasets will continue to be developed to increase the spatiotemporal resolution of the impacts of the injected natural gas and its fate in the environment.

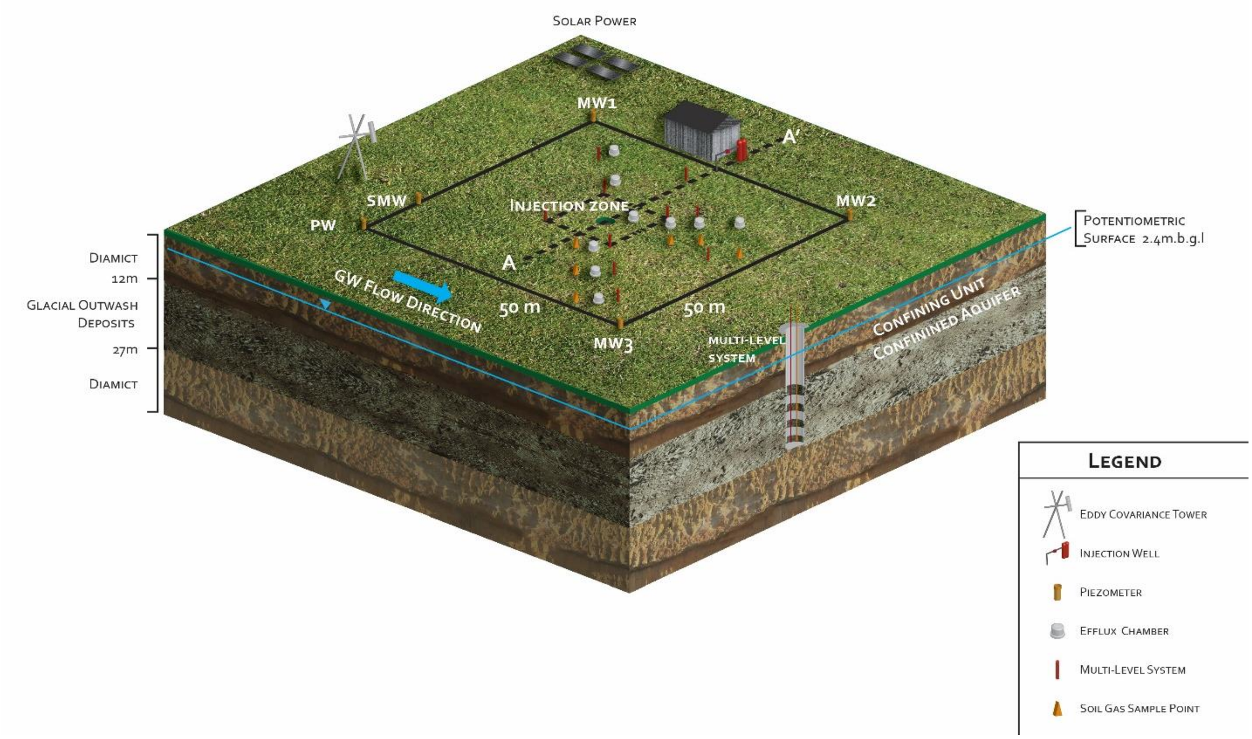

Figure 1. Conceptual model of HHFRS and the controlled natural gas release experiment infrastructure, as well as the subsurface geology of the site (Cahill et al., 2019).

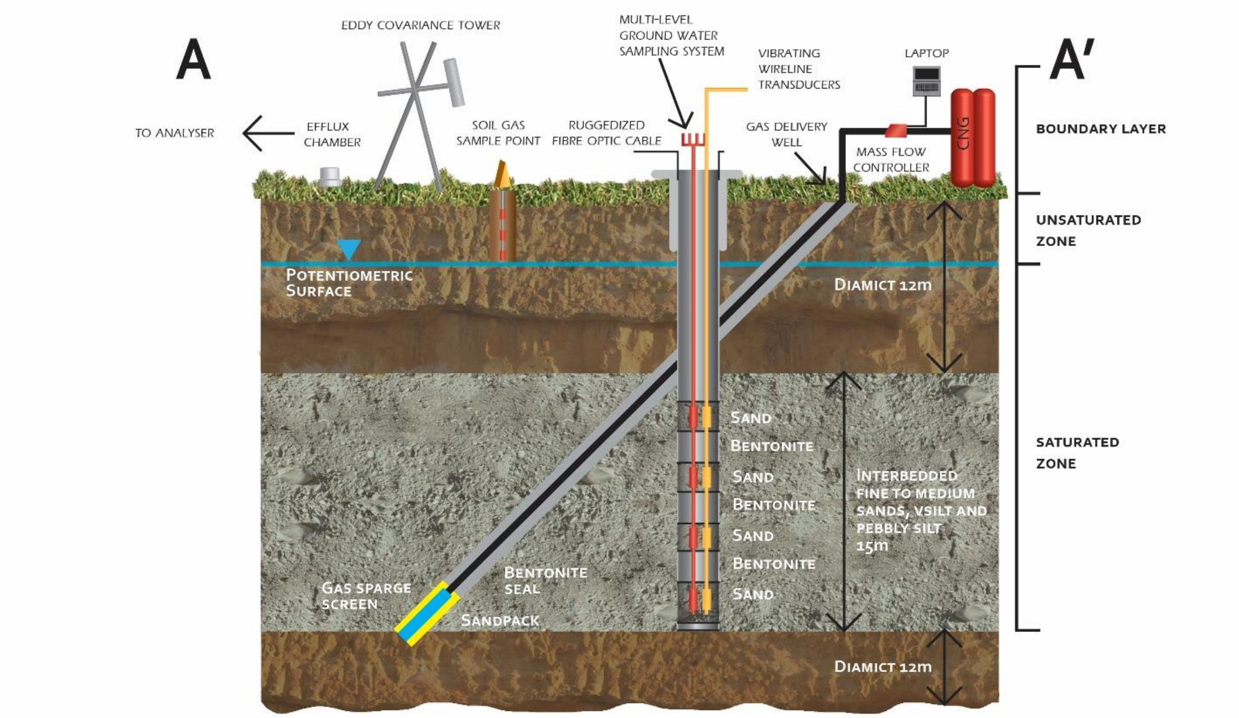

Figure 2. Cross-section A-A’ (see Figure 1), showing the natural gas release system and the monitoring infrastructure in the saturated, unsaturated, and atmospheric layers (Cahill et al., 2019).

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