Aquifers survey in the context of source rocks exploitation: from baseline acquisition to long term monitoring.

B. Garcia, V. Rouchon, J-P Deflandre

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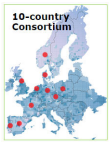

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M4ShaleGas
Measuring, Monitoring, Mitigating, Managing the Environmental Impact of Shale Gas

1 Context and objectives

The exploitation of source rocks implies to **monitor the surroundings aquifers and specially the potable aquifers** present at the sub-surface, as required by USA and Canadian regulations. The acquisition of a **representative aquifer baseline is an absolute necessity prior to the performing of a long term monitoring**.

Indeed, a huge variety of geochemical species is present and we have to demonstrate that we can **distinguish a natural geochemical signature from an anthropogenic geochemical signature** due to the exploitation process. Hydraulic fracturing operations are needed to exploit these resources, that's why 3 main sources have to be considered: **1) the shale formation itself, 2) the fluids used for the hydraulic fracturing operations and 3) the aquifers**.

The main geochemical species to monitor will be presented in this poster with a new geochemical monitoring methodology/technical approach associated with a notion of priority/interest and early warning systems.

2 The 3 main sources and their associated geochemical signature

The 3 main sources to monitor

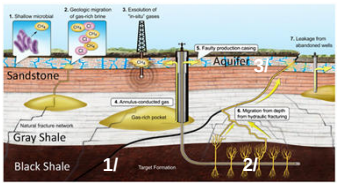
1/ The shale play

2/ The hydraulic fracturing fluids

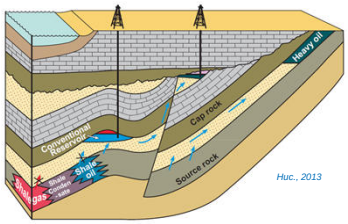
3/ The surroundigs aquifers

- 1/ Shale plays =

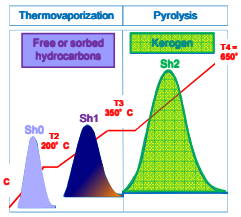
organic matter (O.M.)
+ a heterogeneous mixture of minerals (clay, silt and also carbonate and sandstone)
+ presence of oil and/or gas.



From Darrah et al., 2014



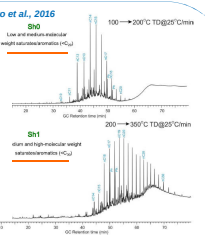
Huc., 2013



Pillot et al. (2014 Patent 14/55.009)
Romero et al., OGST, 2015

1. Better quantification of the bulk HC amount (minimize loss of light HC)
2. Information on the quality of occurring fluids
3. Better separation between HC fluids and kerogen
4. Better assessment of Tmax value

Romero et al., 2016

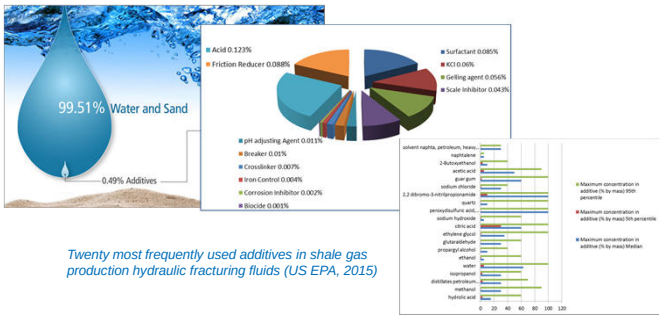


Typical composition of natural gas From naturalgas.org		
Methane	CH_4	70-90%
Ethane	C_2H_6	0-20%
Propane	C_3H_8	0-20%
Butane	C_4H_{10}	0-20%
Carbon Dioxide	CO_2	0-8%
Oxygen	O_2	0 – 0.2%
Nitrogen	N_2	0-5%
Hydrogen sulphide	H_2S	0-5%
Rare gases	AR, He, Ne	Trace

Gases in percent by volume

The Shale Plays:
(i) organic matter and hydrocarbons species (in liquid and gaseous forms) + (ii) non-hydrocarbon species have to be considered

- 2/ The hydraulic fracturing fluids



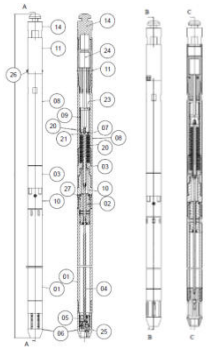
Twenty most frequently used additives in shale gas production hydraulic fracturing fluids (US EPA, 2015)

- 3/ The surroundigs aquifers

General data	min	average	max
Density	1.1	1.18	1.23
pH	4	5.7	7.9
Total carbon	1.58 mmol/L	2.86 mmol/L	5.31 mmol/L
alcalinity	1.22 meq/L	3.12 meq/L	5.43 meq/L
Major Geochemical species			
Cl^-	20 mg/L	156.6 g/L	218 g/L
Na^+	21 mg/L	61.7 g/L	85.2 g/L
Ca^{2+}	16 mg/L	29.2 g/L	43.1 g/L
Mg^{2+}	23 mg/L	3.2 g/L	8.9 g/L
K^+	2.5 mg/L	1.8 g/L	6.6 g/L
SO_4^{2-}	26 mg/L	215 mg/L	670 mg/L
Minor Geochemical species			
Br	847 µg/L	4.4 g/L	6.6 g/L
Sr	91 µg/L	1.6 g/L	2.7 g/L
B	20 µg/L	125 mg/L	338 mg/L
Li	55.5 µg/L	122.7 mg/L	396 mg/L
Fe	23 µg/L	63.3 mg/L	400 mg/L
SiO2	3.8 mg/L	28.7 mg/L	49 mg/L
Zn	15.2 µg/L	26.5 mg/L	143 mg/L
Mn	3.5 µg/L	16.2 mg/L	87 mg/L
Ba	111 µg/L	16 mg/L	51 mg/L
Pb	1 mg/L	14.7 mg/L	40 mg/L
Rb	7 µg/L	7 mg/L	32.5 mg/L

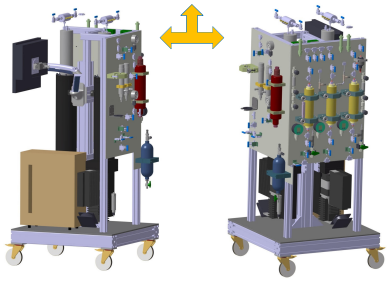
Parameters listed in recommendations by state environmental protection agencies (*Boyer et al., 2011*)

3 A new geochemical monitoring methodology associated with specific techniques

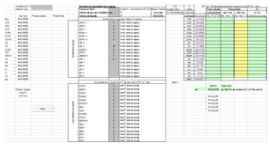


Sampling at reservoir conditions

A specific developed downhole sampler	Extraction of fluids and analyses on site	Specific analyses in laboratory and expertise/interpretation
Sampling of natural fluids	*Psat, GWR, Major dissolved gases, classical fluid analyses*	*Data treatment and interpretation*



Fluid transfer at preserved reservoir pressure conditions



Interpretation of data with stand-alone software

The HCs species

Geochemical species	Nature/origin	Localization (for monitoring)	Interest/priority
low-to-medium molecular weight aliphatic and aromatic hydrocarbons (~C20)	Hydrocarbon species: Shale formation	Deep aquifers	Strong
		Sub-surface aquifers	Strong
		Potable aquifers	Strong
Medium and high molecular weight hydrocarbons (C10–C30 aromatics and saturates)	Hydrocarbon species: Shale formation	Deep aquifers	Strong
		Sub-surface aquifers	Strong
		Potable aquifers	Strong
C1 to C5	Hydrocarbon species: Shale formation	Deep aquifers	Strong
		Sub-surface aquifers	Strong
		Potable aquifers	Strong
$\delta^{13}C_{C1}$ to $\delta^{13}C_{C5}$	Isotopes of carbon for Hydrocarbon species: Shale formation	Deep aquifers	Strong
		Sub-surface aquifers	Strong
		Potable aquifers	Strong

The non HCs species

Geochemical species	Nature/origin	Localization (for monitoring)	Interest/priority
CO_2	Non-hydrocarbon species	Deep aquifers	Medium
		Sub-surface aquifers	Medium
		Potable aquifers	Medium
$\delta^{13}C_{CO2}$	Isotopes of carbon for non-Hydrocarbon species	Deep aquifers	Medium
		Sub-surface aquifers	Medium
		Potable aquifers	Weak
N_2	Non-hydrocarbon species	Deep aquifers	Medium
		Sub-surface aquifers	Medium
		Potable aquifers	Medium
Noble gases (He, Ne, Ar, Kr, Xe)	Non-hydrocarbon species	Deep aquifers	Medium
		Sub-surface aquifers	Strong
		Potable aquifers	Strong

Geochemical species	Nature/origin	Localization (for monitoring)	Interest/priority
Cations (Ca^{2+}, Mg^{2+}, K^+, Sr^{2+})	Non-hydrocarbon species	Deep aquifers	Medium
		Sub-surface aquifers	Strong
		Potable aquifers	Strong
Anions (SO_4^{2-}, NO_3^-, Cl^-)	Non-hydrocarbon species	Deep aquifers	Medium
		Sub-surface aquifers	Strong
		Potable aquifers	Strong
Minor / Trace elements (As, Cr, Hg, Ag, Se, Ba, B, Li, Rb, Sr, Ra, Fe, Mn, Zn, Pb)	Non-hydrocarbon species	Deep aquifers	Weak
		Sub-surface aquifers	Medium
		Potable aquifers	Strong
Organic compounds used in brine fluid (example in table 3 of this report)	Hydrocarbon and non-hydrocarbon species	Deep aquifers	Strong
		Sub-surface aquifers	Strong
		Potable aquifers	Strong
Some specific additives	Hydrocarbon's and non-hydrocarbon species	Deep aquifers	Medium
		Sub-surface aquifers	Medium
		Potable aquifers	Strong

Priority and Early Warning Systems strategy in term of geochemical species

4 Conclusions and perspectives

- A large baseline is necessary to evaluate the aquifers evolution and a possible leakage during the shale formation exploitation
- Specific methodologies and technologies are necessary to propose early warning systems

Perspectives:

- A demonstration on site: proposition in the SECUre project (H2020)

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