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



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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.

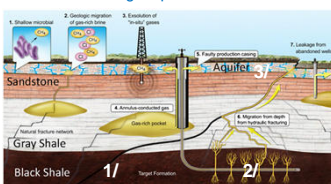
2 The 3 main sources and their associated geochemical signature

The 3 main sources to monitor

1/ The shale play

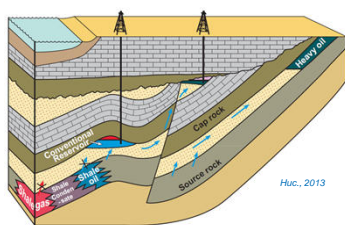
2/ The hydraulic fracturing fluids

3/ The surroundings aquifers

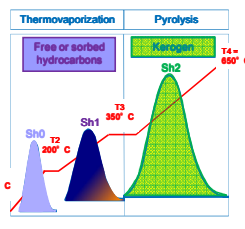


From Darrah et al., 2014

- 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.



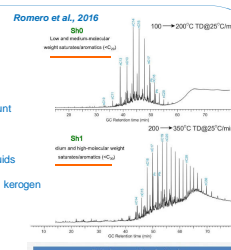
Huc, 2013



Pillot et al. (2014 Patent 1455.009)

Romero et al., OGST, 2015

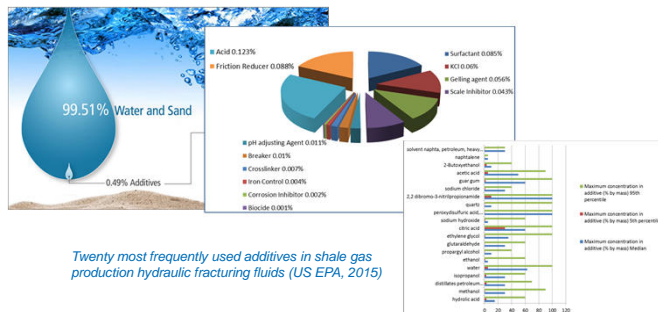
1. Better quantification of the bulk HC amount (minimize loss of light HC)
2. Information on the quality of occurring fluids
3. Better separation between HC fluids and kerogen
4. Better assessment of Tmax value



Typical composition of natural gas from shale basins (g/g)		
Methane	CH ₄	70-90%
Ethane	C ₂ H ₆	0-20%
Propane	C ₃ H ₈	0-20%
Butane	C ₄ H ₁₀	0-20%
Carbon Dioxide	CO ₂	0-8%
Oxygen	O ₂	0-1-2%
Nitrogen	N ₂	0-5%
Hydrogen sulphide	H ₂ S	0-5%
Other gases	Ar, He, Ne	Trace

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



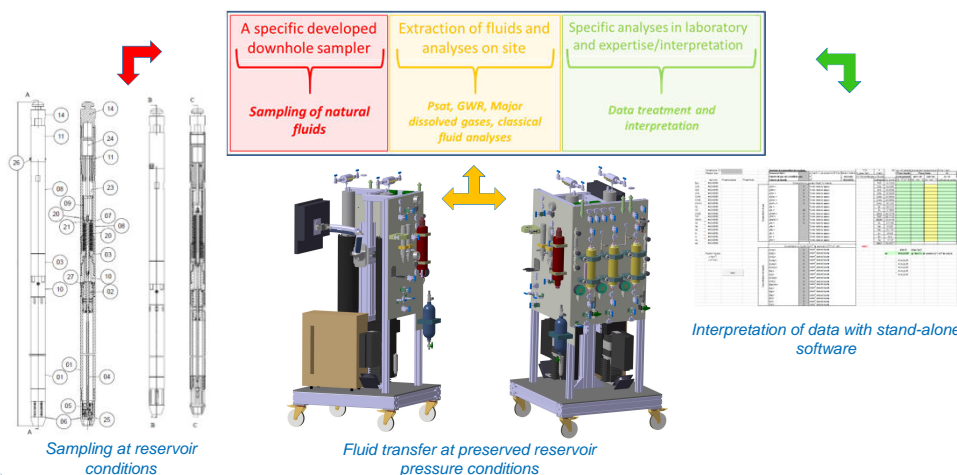
Twenty most frequently used additives in shale gas production hydraulic fracturing fluids (US EPA, 2015)

3/ The surroundings 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
alkalinity	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	29.3 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
SiO ₂	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



Interpretation of data with stand-alone software

The HCs species

Geochemical species	Nature/origin	Location/level (depth)	Interest/priority
Hydrocarbons species	Shale formation	Deep aquifers	Strong
Hydrocarbons species	Sub-surface aquifers	Medium	Medium
Hydrocarbons species	Surface aquifers	Medium	Medium
Hydrocarbons species	Shale formation	Deep aquifers	Strong
Hydrocarbons species	Sub-surface aquifers	Medium	Medium
Hydrocarbons species	Surface aquifers	Medium	Medium
Hydrocarbons species	Shale formation	Deep aquifers	Strong
Hydrocarbons species	Sub-surface aquifers	Medium	Medium
Hydrocarbons species	Surface aquifers	Medium	Medium

The non HCs species

Geochemical species	Nature/origin	Location/level (depth)	Interest/priority
CO ₂	Shale formation	Deep aquifers	Strong
CO ₂	Sub-surface aquifers	Medium	Medium
CO ₂	Surface aquifers	Medium	Medium
CO ₂	Shale formation	Deep aquifers	Strong
CO ₂	Sub-surface aquifers	Medium	Medium
CO ₂	Surface aquifers	Medium	Medium
CO ₂	Shale formation	Deep aquifers	Strong
CO ₂	Sub-surface aquifers	Medium	Medium
CO ₂	Surface aquifers	Medium	Medium

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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