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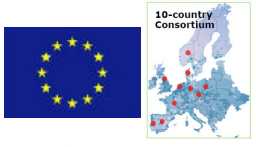
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# Aquifers survey in the context of source rocks exploitation: from baseline acquisition to long term monitoring



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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.

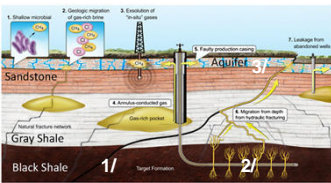
Indeed, a huge variety of geochemical species is present and we have to demonstrate that we can distinguish a natural geochemical signature from an anthropogenic geochemical signature due to the exploitation process. Hydraulic fracturing operations are needed to exploit these resources, that's why 3 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

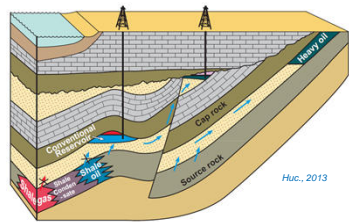
### The 3 main sources to monitor

- 1/ The shale play
- 2/ The hydraulic fracturing fluids
- 3/ The surroundings aquifers

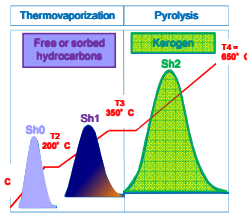


From Darrah et al., 2014

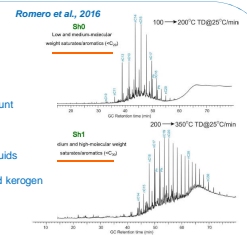
- 1/ Shale plays = organic matter (O.M.) + a heterogeneous mixture of minerals (clay, silt and also carbonate and sandstone) + presence of oil and/or gas.



Huc., 2013



Pillot et al. (2014 Patent 1455.009) Romero et al., OGST, 2015

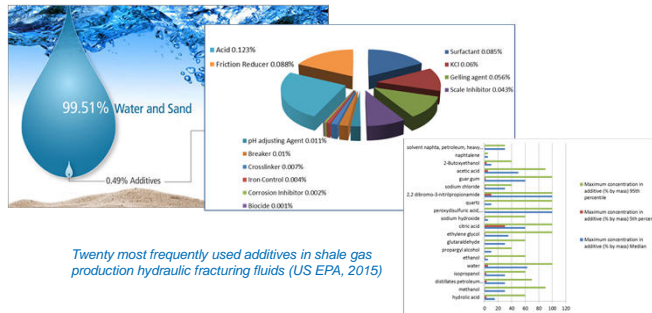


Typical composition of natural gas from shale basins

Component	Chemical Formula	Concentration (%)
Methane	CH <sub>4</sub>	70-90%
Ethane	C <sub>2</sub> H <sub>6</sub>	0-20%
Propane	C <sub>3</sub> H <sub>8</sub>	0-20%
Butane	C <sub>4</sub> H <sub>10</sub>	0-20%
Carbon Dioxide	CO <sub>2</sub>	0-8%
Oxygen	O <sub>2</sub>	0-10%
Nitrogen	N <sub>2</sub>	0-5%
Hydrogen sulphide	H <sub>2</sub> 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

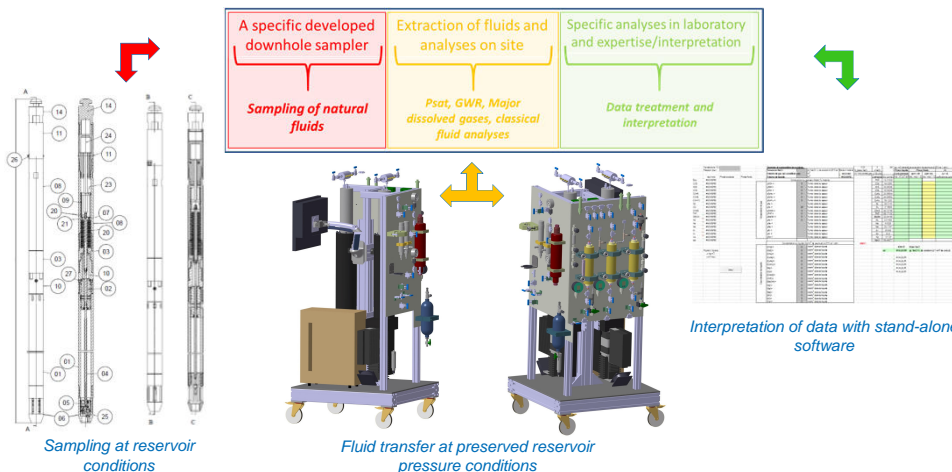
Major Geochemical species	min	average	max
Cl <sup>-</sup>	20 mg/L	156 g/L	218 g/L
Na <sup>+</sup>	21 mg/L	61.7 g/L	85.2 g/L
Ca <sup>2+</sup>	16 mg/L	28.9 mg/L	41.1 g/L
Mg <sup>2+</sup>	23 mg/L	3.2 g/L	8.9 g/L
K <sup>+</sup>	2.5 mg/L	1.8 g/L	6.6 g/L
SO <sub>4</sub> <sup>2-</sup>	26 mg/L	215 mg/L	670 mg/L

Minor Geochemical species	min	average	max
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	238 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 <sub>2</sub>	3.8 mg/L	28.7 mg/L	49 mg/L
Zn	15.2 µg/L	26.5 mg/L	143 mg/L
Mn	2.5 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



### The HCs species

Geochemical species	Stratigraphy	Localization (see monitoring)	Interpretability
Hydrocarbons species: shale formation	Shale formation	Deep aquifers	Strong
Hydrocarbons species: shale formation	Shale formation	Sub-surface aquifers	Strong
Hydrocarbons species: shale formation	Shale formation	Public aquifers	Strong
Hydrocarbons species: shale formation	Shale formation	Deep aquifers	Strong
Hydrocarbons species: shale formation	Shale formation	Sub-surface aquifers	Strong
Hydrocarbons species: shale formation	Shale formation	Public aquifers	Strong

### The non HCs species

Geochemical species	Stratigraphy	Localization (see monitoring)	Interpretability
CO <sub>2</sub>	Shale formation	Deep aquifers	Medium
CO <sub>2</sub>	Shale formation	Sub-surface aquifers	Medium
CO <sub>2</sub>	Shale formation	Public aquifers	Medium
CO <sub>2</sub>	Shale formation	Deep aquifers	Medium
CO <sub>2</sub>	Shale formation	Sub-surface aquifers	Medium
CO <sub>2</sub>	Shale formation	Public aquifers	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)

## References

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