Use of Mixing Models to Explain Groundwater Quality in Aquifers

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Introduction

- In France groundwater makes up approximately 62% of domestic water supply
- Alluvial aquifers constitute an accessible and easily renewed resource, recharged by surface water
- Around 10 million people depend on this resource and since the beginning of the last century, quality and quantity pressures have been increasing

Focus

- Comps aquifer system used in Nîmes township
- Origin of the water
- mixing processes
- reactive processes


Belgium
Frankfurt
Luxembourg
Paris
France
Switzerland
Milan
Monaco
Andorra


Vers-Pont-du-Gard
Collias
A9
aint-Geniès-de-Malgoirès
Remoulins
La Calmette
Lédenon
N106
Marguerittes
D999
Nîmes
A9
Rhône
Beaucaire
Caissargues
Milhaud
D90
Garons
Bellegarde
A54
s-le-Montueux
D6113
Vauvert
Fourques

Local geology

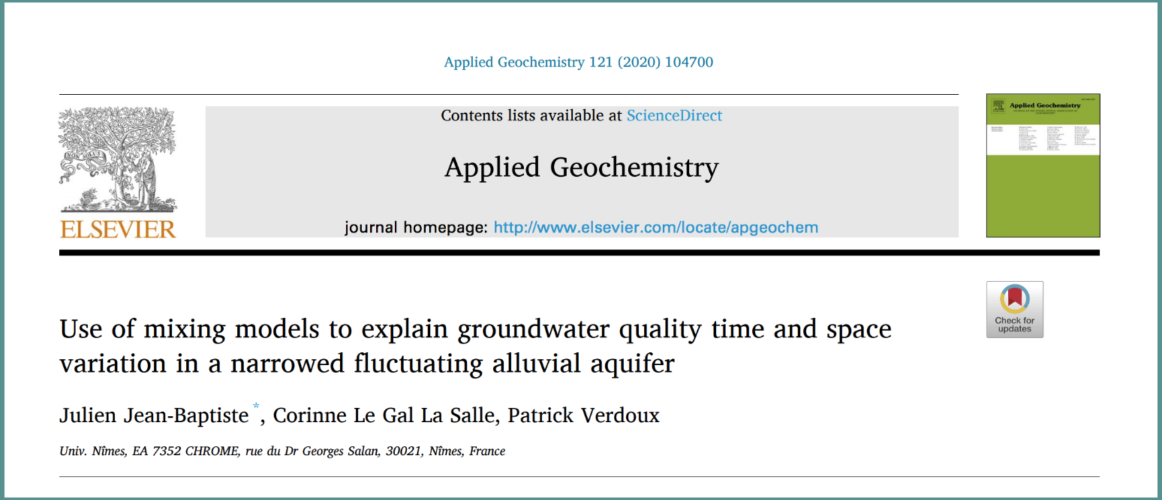
- Comps aquifers is located in between the Rhone and the Gardon Rivers
- Cretaceous limestone massif outcropping and plunging Eastward
- 15 m of Holocene alluvial materials deposited by the Rhone ^ and Gardon valley, the Comps aquifer is covered by 5 m of loam and lies on a 200 m thick impermeable Plaisancien loam formation.

Why I choose aquifers

- I think fresh water can be such an overlooked resource and i think it should be protected better.
- Groundwater makes up 30% of freshwater and about 68% of freshwater is in glaciers and ice caps

Data Source

- Julien Jean-Baptiste, Corinne Le Gal La Salle, Patrick Verdoux, Use of mixing models to explain groundwater quality time and space variation in a narrowed fluctuating alluvial aquifer, Applied Geochemistry, Volume 121, 2020, 104700, ISSN 0883-2927,



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Use of mixing models to explain groundwater quality time and space variation in a narrowed fluctuating alluvial aquifer

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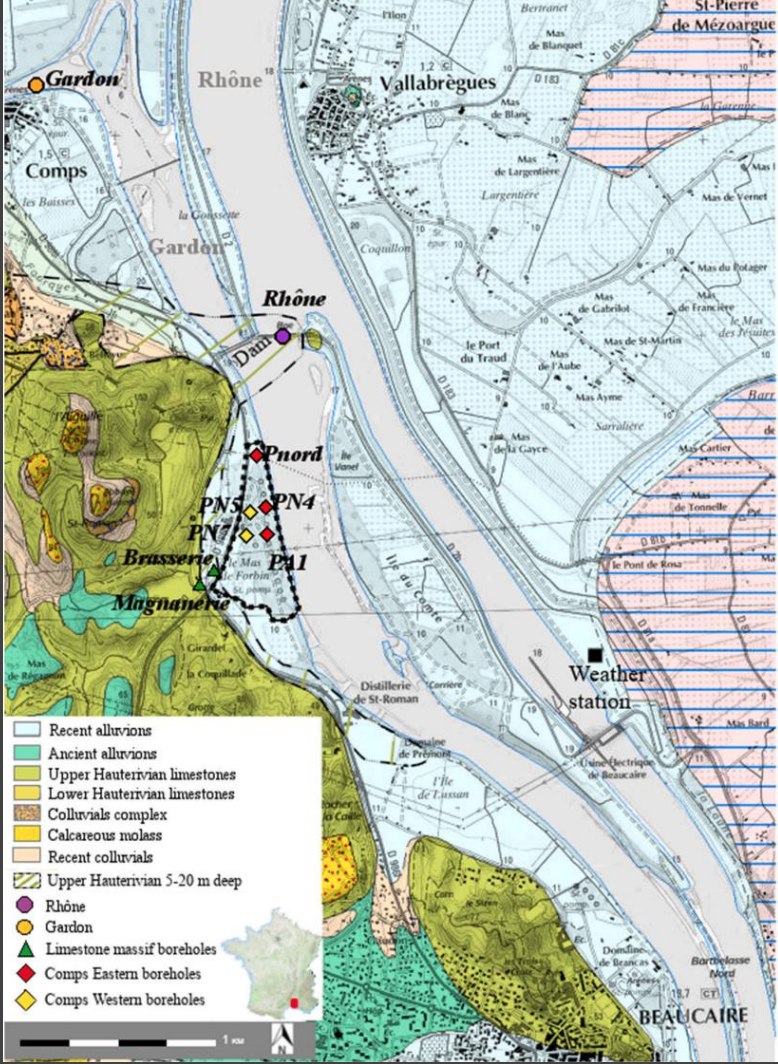
Sample Areas

- Multiply samples taken:
  - Limestone massif boreholes (green triangle)
  - Comps Eastern boreholes (red rhombus)
  - Comps Western boreholes (yellow rhombus)
- Temperature, pH, oxydo-reduction potential, specific conductance at 25 ℃ and dissolved oxygen



Previous work

- Ions : Ca^{2+}, Mg^{2+}, Na^+, K^+, Cl^- , SO_4^{2-} , and NO_3^-
- PHREEQC and GLUE-EMMA were used to do calculations
- Water was collected in 10mL, glass bottles avoiding air bubbles, for $\delta^{18}O$ and δ^2H analyses.
- Everything came back normal and was all well within the stable limits
- Mixing models are accepted when simulated results fall within ±5% for the major ions and 0.5‰ for deuterium.

Piper's Diagram

- Data from fortnightly sampling are given in Table 1 (supplementary data). Major ion analyses, for all considered water bodies in the studied area, exhibit a typical Ca–HCO3 fresh water type (Fig. 3.)
- Limestone massif waters present higher proportion of calcium and nitrate ions while surface waters exhibit higher proportion of magnesium and sodium ions.

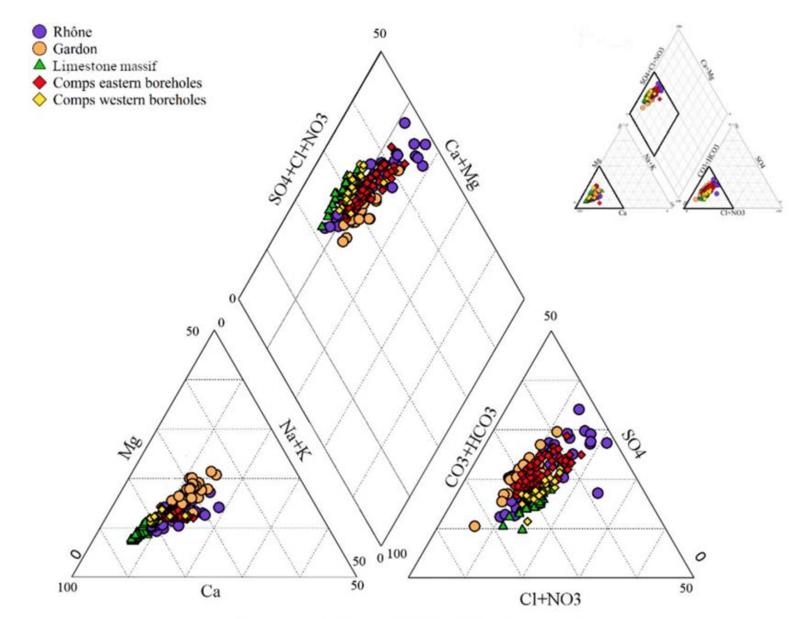


Fig. 3. Piper's diagram of studied waters in the area.

Previous Work

- The end results of this study were that the water quality was normal and was tested for 60 days and there were no harmful agents in the water
- What they did find however is that the groundwater levels were dropping much more than expected in the summer
- They predict in 2060 that the river level will drop 30-70%

Mixing Models

Phase	SI	log IAP	log KT	
Anhydrite	-1.47	-5.83	-4.36	CaSO4
Aragonite	-0.79	-9.13	-8.34	CaCO3
Calcite	-0.65	-9.13	-8.48	CaCO3
CH4(g)	-32.07	-76.00	-43.93	CH4
CO2(g)	-1.85	-20.00	-18.15	CO2
Dolomite	-0.92	-18.01	-17.09	CaMg(CO3)2
Gypsum	-1.25	-5.83	-4.58	CaSO4:2H2O
H2(g)	-14.00	-14.00	0.00	H2
H2O(g)	-1.51	-0.00	1.51	H2O
H2S(g)	-31.11	-72.70	-41.59	H2S
Halite	-6.29	-4.70	1.58	NaCl
N2(g)	-0.03	-3.29	-3.26	N2
NH3(g)	-18.12	-22.64	-4.52	NH3
O2(g)	-55.12	28.00	83.12	O2
Sulfur	-22.99	-58.70	-35.71	S

Phase	SI	log IAP	log KT	
Anhydrite	-1.48	-5.84	-4.36	CaSO4
Aragonite	-1.07	-9.41	-8.34	CaCO3
Calcite	-0.93	-9.41	-8.48	CaCO3
CH4(g)	-32.20	-76.14	-43.93	CH4
CO2(g)	-1.99	-20.14	-18.15	CO2
Dolomite	-1.42	-18.51	-17.09	CaMg(CO3)2
Gypsum	-1.26	-5.84	-4.58	CaSO4:2H2O
H2(g)	-14.00	-14.00	0.00	H2
H2O(g)	-1.51	-0.00	1.51	H2O
H2S(g)	-30.98	-72.57	-41.59	H2S
Halite	-6.14	-4.55	1.58	NaCl
N2(g)	0.73	-2.53	-3.26	N2
NH3(g)	-17.74	-22.26	-4.52	NH3
O2(g)	-55.12	28.00	83.12	O2
Sulfur	-22.86	-58.57	-35.71	S

Phase	SI	log IAP	log KT	
Anhydrite	-1.47	-5.83	-4.36	CaSO4
Aragonite	-0.79	-9.13	-8.34	CaCO3
Calcite	-0.65	-9.13	-8.48	CaCO3
CH4(g)	-32.07	-76.00	-43.93	CH4
CO2(g)	-1.85	-20.00	-18.15	CO2
Dolomite	-0.92	-18.01	-17.09	CaMg(CO3)2
Gypsum	-1.25	-5.83	-4.58	CaSO4:2H2O
H2(g)	-14.00	-14.00	0.00	H2
H2O(g)	-1.51	-0.00	1.51	H2O
H2S(g)	-31.11	-72.70	-41.59	H2S
Halite	-6.29	-4.70	1.58	NaCl
N2(g)	-0.03	-3.29	-3.26	N2
NH3(g)	-18.12	-22.64	-4.52	NH3
O2(g)	-55.12	28.00	83.12	O2
Sulfur	-22.99	-58.70	-35.71	S

Mixing Models

Phase	SI	log IAP	log KT	
Anhydrite	-1.44	-5.80	-4.36	CaSO4
Aragonite	-0.53	-8.87	-8.34	CaCO3
Calcite	-0.39	-8.87	-8.48	CaCO3
CH4(g)	-31.77	-75.70	-43.93	CH4
CO2(g)	-1.56	-19.71	-18.15	CO2
Dolomite	-0.24	-17.33	-17.09	CaMg(CO3)2
Gypsum	-1.22	-5.80	-4.58	CaSO4:2H2O
H2(g)	-14.00	-14.00	0.00	H2
H2O(g)	-1.51	-0.00	1.51	H2O
H2S(g)	-31.05	-72.64	-41.59	H2S
Halite	-6.06	-4.47	1.58	NaCl
N2(g)	0.57	-2.69	-3.26	N2
NH3(g)	-17.82	-22.34	-4.52	NH3
O2(g)	-55.12	28.00	83.12	O2
Sulfur	-22.93	-58.64	-35.71	S

Phase	SI	log IAP	log KT	
Anhydrite	-1.47	-5.83	-4.36	CaSO4
Aragonite	-0.79	-9.13	-8.34	CaCO3
Calcite	-0.65	-9.13	-8.48	CaCO3
CH4(g)	-32.07	-76.00	-43.93	CH4
CO2(g)	-1.85	-20.00	-18.15	CO2
Dolomite	-0.92	-18.01	-17.09	CaMg(CO3)2
Gypsum	-1.25	-5.83	-4.58	CaSO4:2H2O
H2(g)	-14.00	-14.00	0.00	H2
H2O(g)	-1.51	-0.00	1.51	H2O
H2S(g)	-31.11	-72.70	-41.59	H2S
Halite	-6.29	-4.70	1.58	NaCl
N2(g)	-0.03	-3.29	-3.26	N2
NH3(g)	-18.12	-22.64	-4.52	NH3
O2(g)	-55.12	28.00	83.12	O2
Sulfur	-22.99	-58.70	-35.71	S

Phase	SI	log IAP	log KT	
Anhydrite	-1.45	-5.81	-4.36	CaSO4
Aragonite	-0.64	-8.97	-8.34	CaCO3
Calcite	-0.49	-8.97	-8.48	CaCO3
CH4(g)	-31.82	-75.75	-43.93	CH4
CO2(g)	-1.68	-19.83	-18.15	CO2
Dolomite	-0.52	-17.61	-17.09	CaMg(CO3)2
Gypsum	-1.23	-5.81	-4.58	CaSO4:2H2O
H2(g)	-13.98	-13.98	0.00	H2
H2O(g)	-1.51	-0.00	1.51	H2O
H2S(g)	-31.00	-72.59	-41.59	H2S
Halite	-6.16	-4.57	1.58	NaCl
N2(g)	0.37	-2.89	-3.26	N2
NH3(g)	-17.89	-22.42	-4.52	NH3
O2(g)	-55.16	27.96	83.12	O2
Sulfur	-22.90	-58.61	-35.71	S

Mixing Models

Phase	SI	log IAP	log KT	
Anhydrite	-1.39	-5.75	-4.36	CaSO4
Aragonite	-0.96	-9.30	-8.34	CaCO3
Calcite	-0.82	-9.30	-8.48	CaCO3
CH4(g)	-32.21	-76.14	-43.93	CH4
CO2(g)	-1.99	-20.14	-18.15	CO2
Dolomite	-1.27	-18.36	-17.09	CaMg(CO3)2
Gypsum	-1.17	-5.75	-4.58	CaSO4:2H2O
H2(g)	-14.00	-14.00	0.00	H2
H2O(g)	-1.51	-0.00	1.51	H2O
H2S(g)	-31.00	-72.59	-41.59	H2S
Halite	-6.11	-4.53	1.58	NaCl
N2(g)	0.78	-2.48	-3.26	N2
NH3(g)	-17.72	-22.24	-4.52	NH3
O2(g)	-55.12	28.00	83.12	O2
Sulfur	-22.88	-58.59	-35.71	S

Phase	SI	log IAP	log KT	
Anhydrite	-1.10	-5.46	-4.36	CaSO4
Aragonite	-0.31	-8.65	-8.34	CaCO3
Calcite	-0.17	-8.65	-8.48	CaCO3
CH4(g)	-31.86	-75.79	-43.93	CH4
CO2(g)	-1.64	-19.79	-18.15	CO2
Dolomite	-0.18	-17.27	-17.09	CaMg(CO3)2
Gypsum	-0.88	-5.47	-4.58	CaSO4:2H2O
H2(g)	-14.00	-14.00	0.00	H2
H2O(g)	-1.51	-0.00	1.51	H2O
H2S(g)	-31.02	-72.60	-41.59	H2S
Halite	-6.11	-4.53	1.58	NaCl
N2(g)	0.55	-2.71	-3.26	N2
NH3(g)	-17.83	-22.36	-4.52	NH3
O2(g)	-55.12	28.00	83.12	O2
Sulfur	-22.89	-58.60	-35.71	S

Phase	SI	log IAP	log KT	
Anhydrite	-1.22	-5.58	-4.36	CaSO4
Aragonite	-0.57	-8.91	-8.34	CaCO3
Calcite	-0.43	-8.91	-8.48	CaCO3
CH4(g)	-32.00	-75.93	-43.93	CH4
CO2(g)	-1.78	-19.93	-18.15	CO2
Dolomite	-0.62	-17.71	-17.09	CaMg(CO3)2
Gypsum	-1.00	-5.58	-4.58	CaSO4:2H2O
H2(g)	-14.00	-14.00	0.00	H2
H2O(g)	-1.51	-0.00	1.51	H2O
H2S(g)	-31.02	-72.61	-41.59	H2S
Halite	-6.11	-4.53	1.58	NaCl
N2(g)	0.68	-2.58	-3.26	N2
NH3(g)	-17.77	-22.29	-4.52	NH3
O2(g)	-55.12	28.00	83.12	O2
Sulfur	-22.90	-58.60	-35.71	S

Questions?