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Early Career Hydrogeologists' Network

HYDROGEOCHEMICAL-MULTIVARIATE ANALYSIS GROUNDWATER IN THE MIDDLE MAGDALENA VALLEY AQUIFER SYSTEM - COLOMBIA: STUDY AT A REGIONAL SCALE

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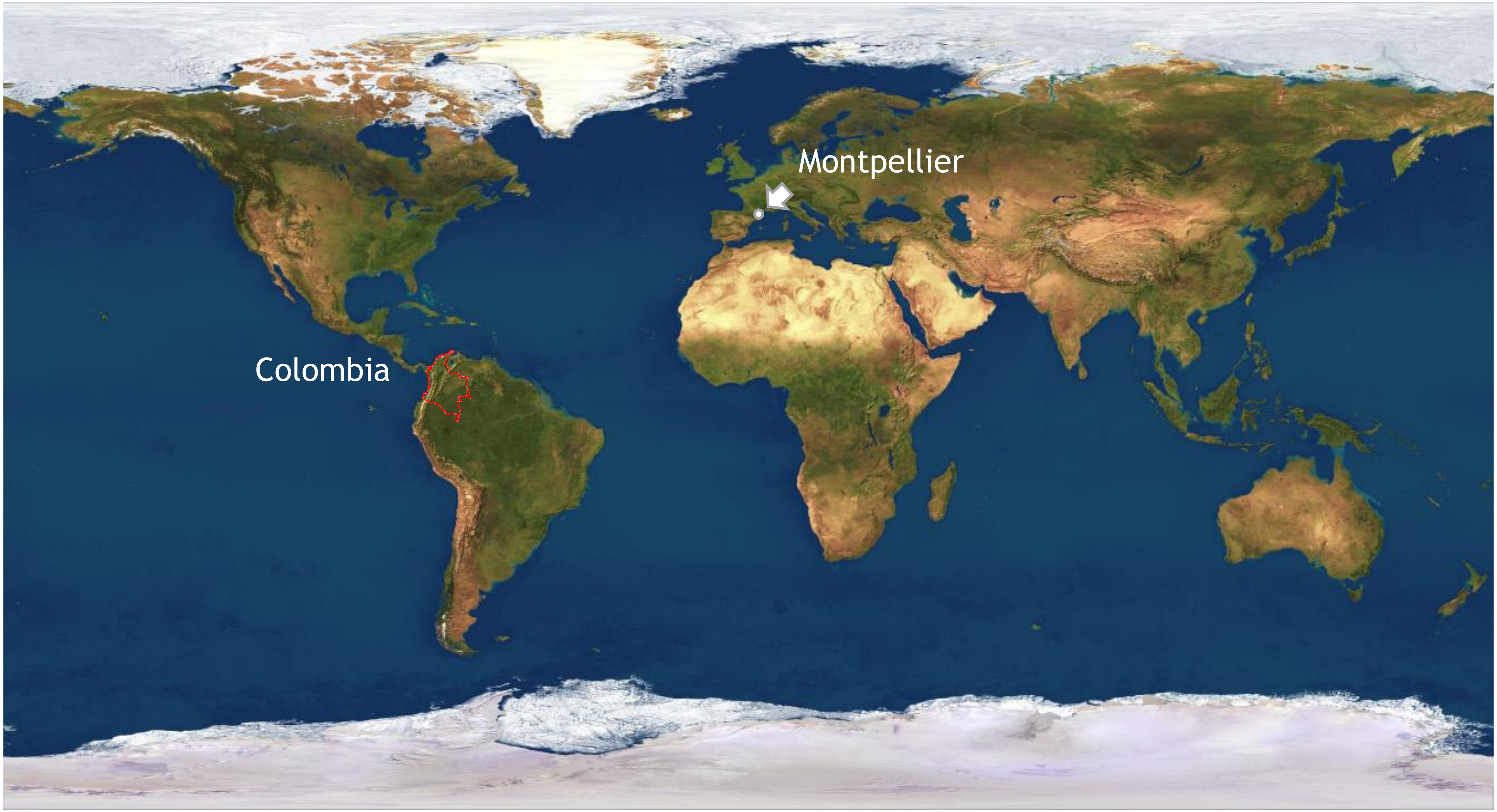
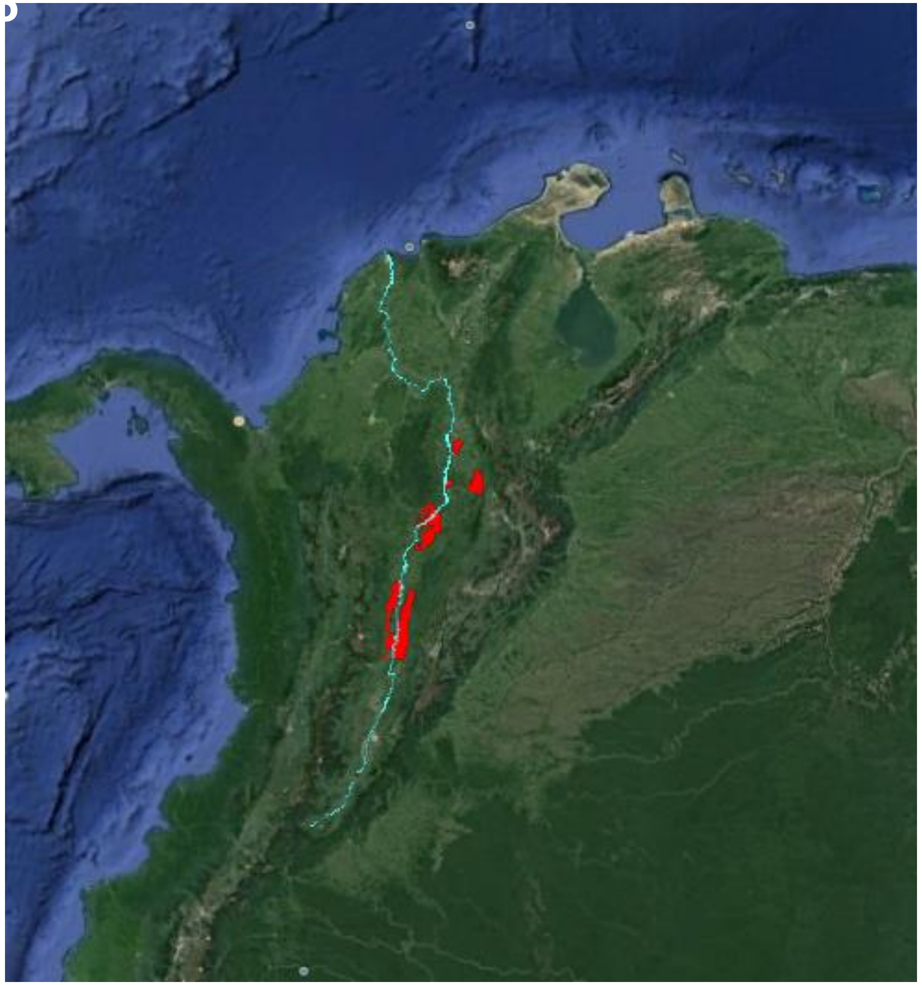
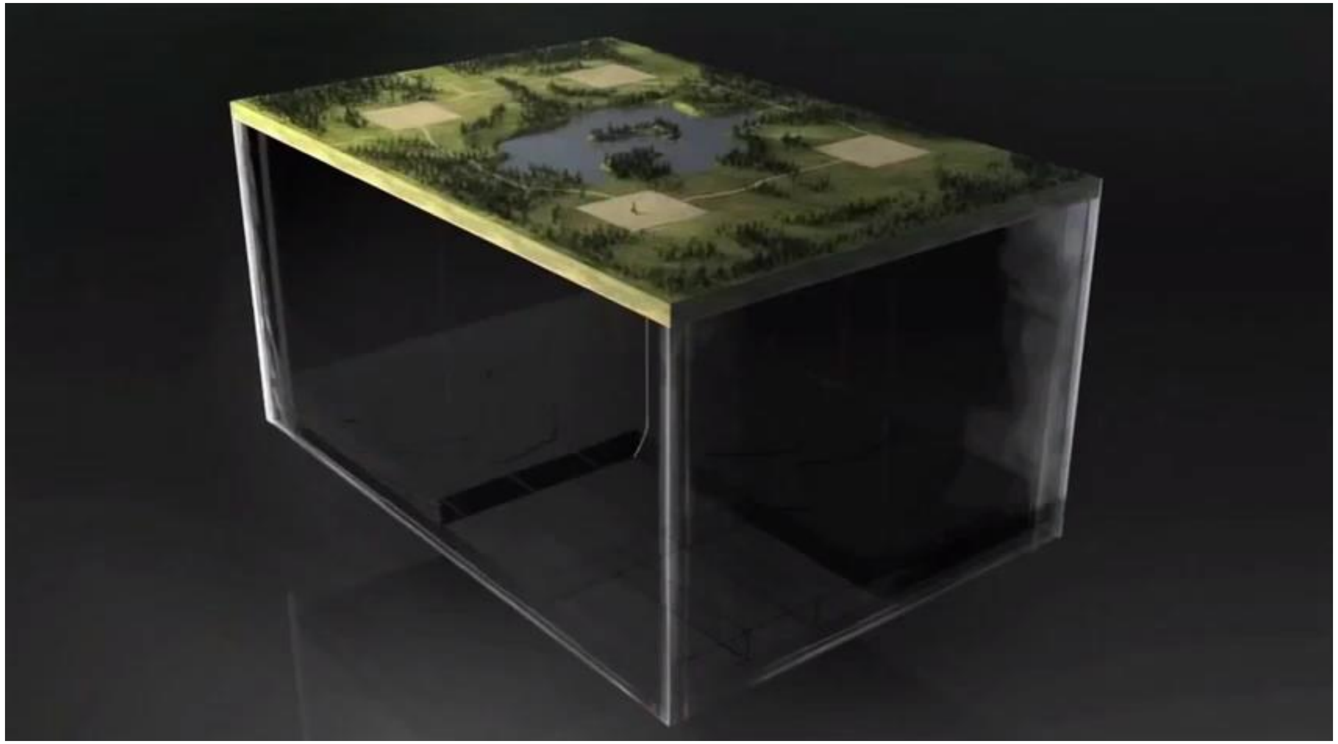

Montpellier
Colombia

View of the Middle Magdalena Valley

Activities in the Middle Magdalena Valley that can modify the conditions of groundwater



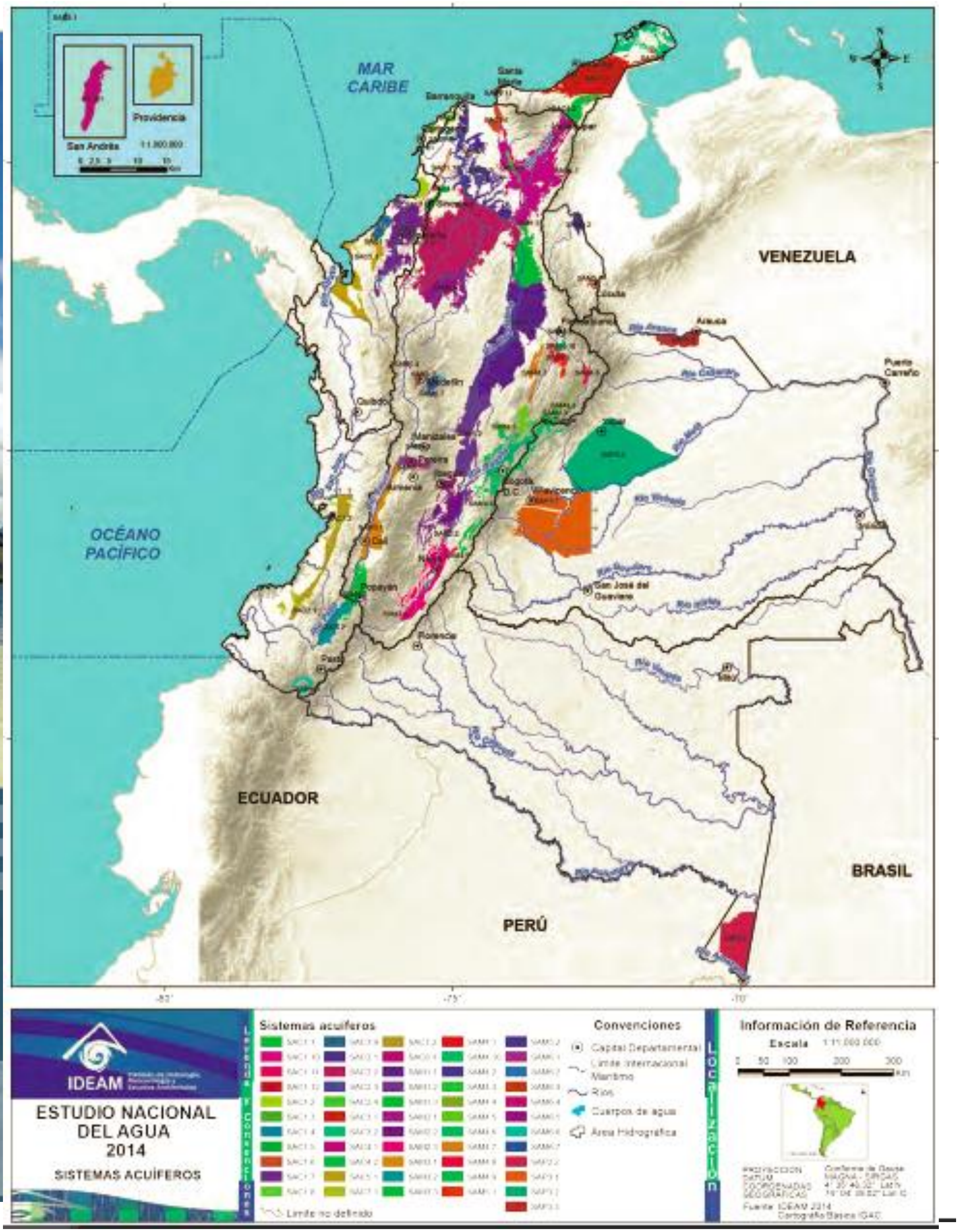
Colombia Middle Magdalena Valley area with the greatest potential hydrocarbon exploitation by hydraulic fracturing.



PRESENTATION OUTLINE

HYDROGEOLOGICAL PROVINCES AND AQUIFER SYSTEMS

16 hydrogeological provinces and 61 aquifer systems content in these provinces.

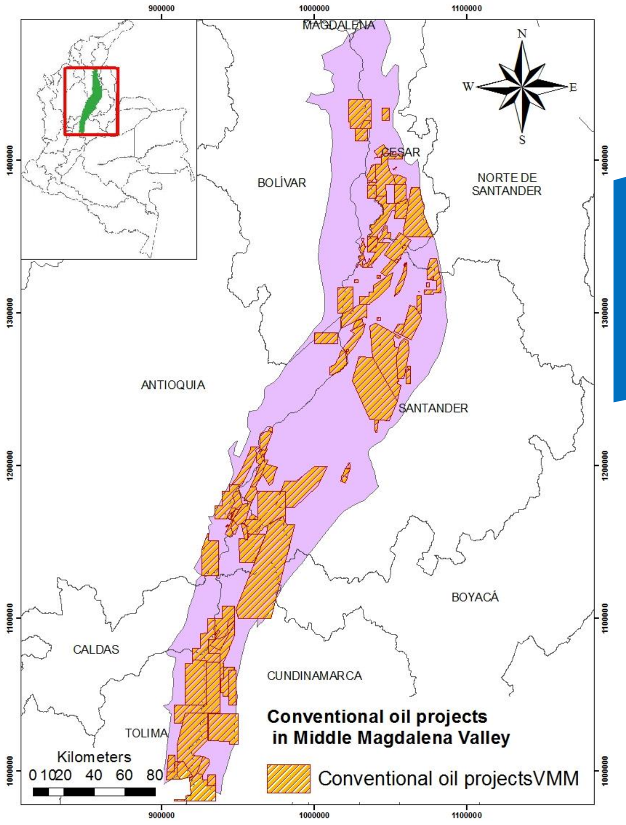


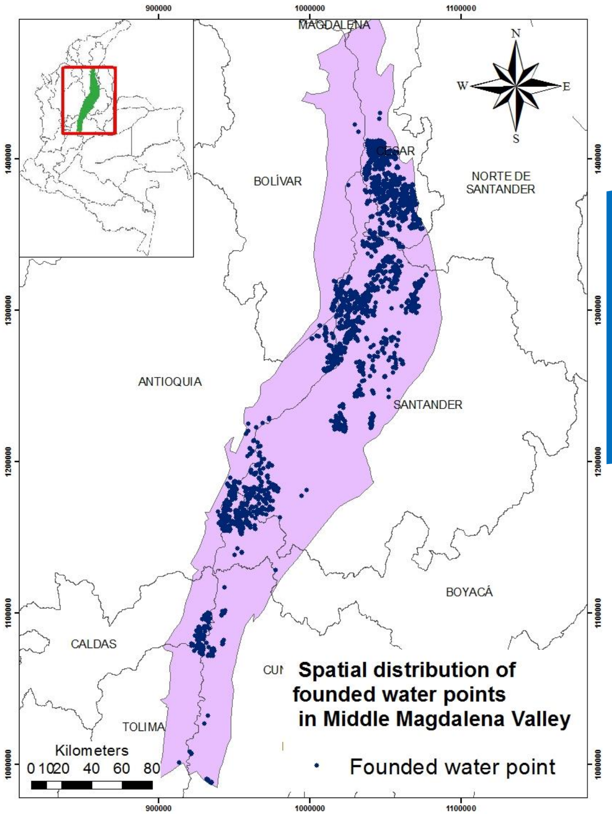
2. SOURCES OF INFORMATION

The information used for this research comes mostly from environmental permit applications, which are required to include characterization data.

information was obtained 95 projects and 4500 points in total were identified.

ANLA
AUTORIDAD NACIONAL DE LICENCIAS AMBIENTALES

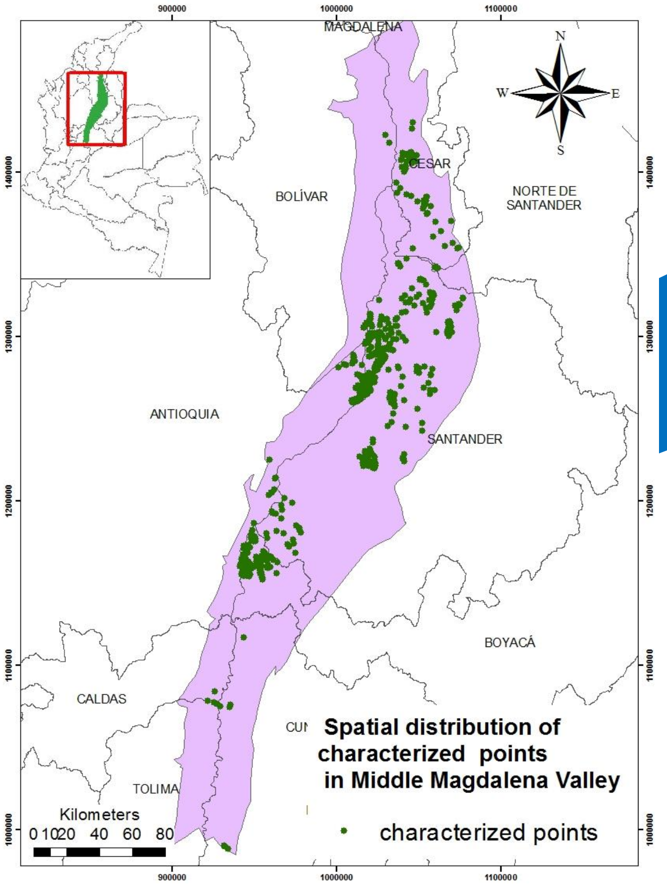




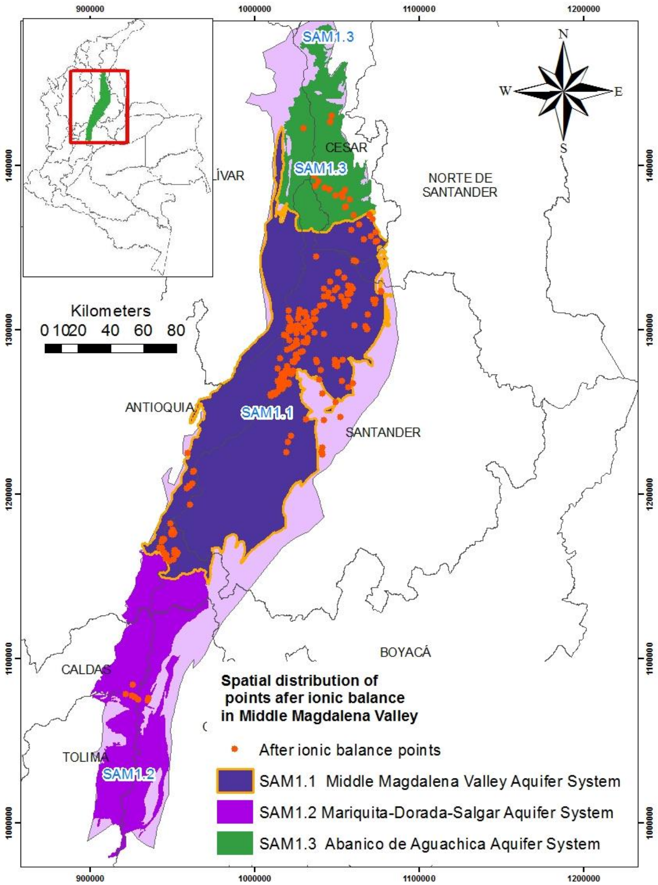
Environmental Impact Assessment Reports

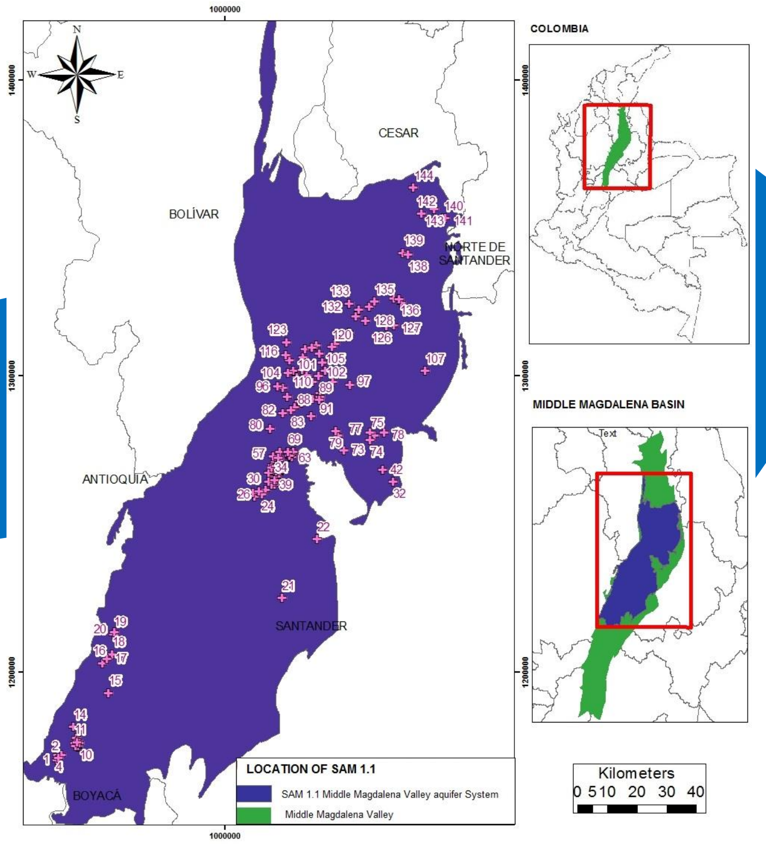
SOURCES OF INFORMATION

Of the 4500 points identified, only 1368 had some type of physicochemical characterization and after review, only 289 good points… Not evenly distributed



Concentrate on the Middle Magdalena Valley, aquifer system (144 samples).





WEB SITE

https://sites.google.com/site/invhidrovmm/visor

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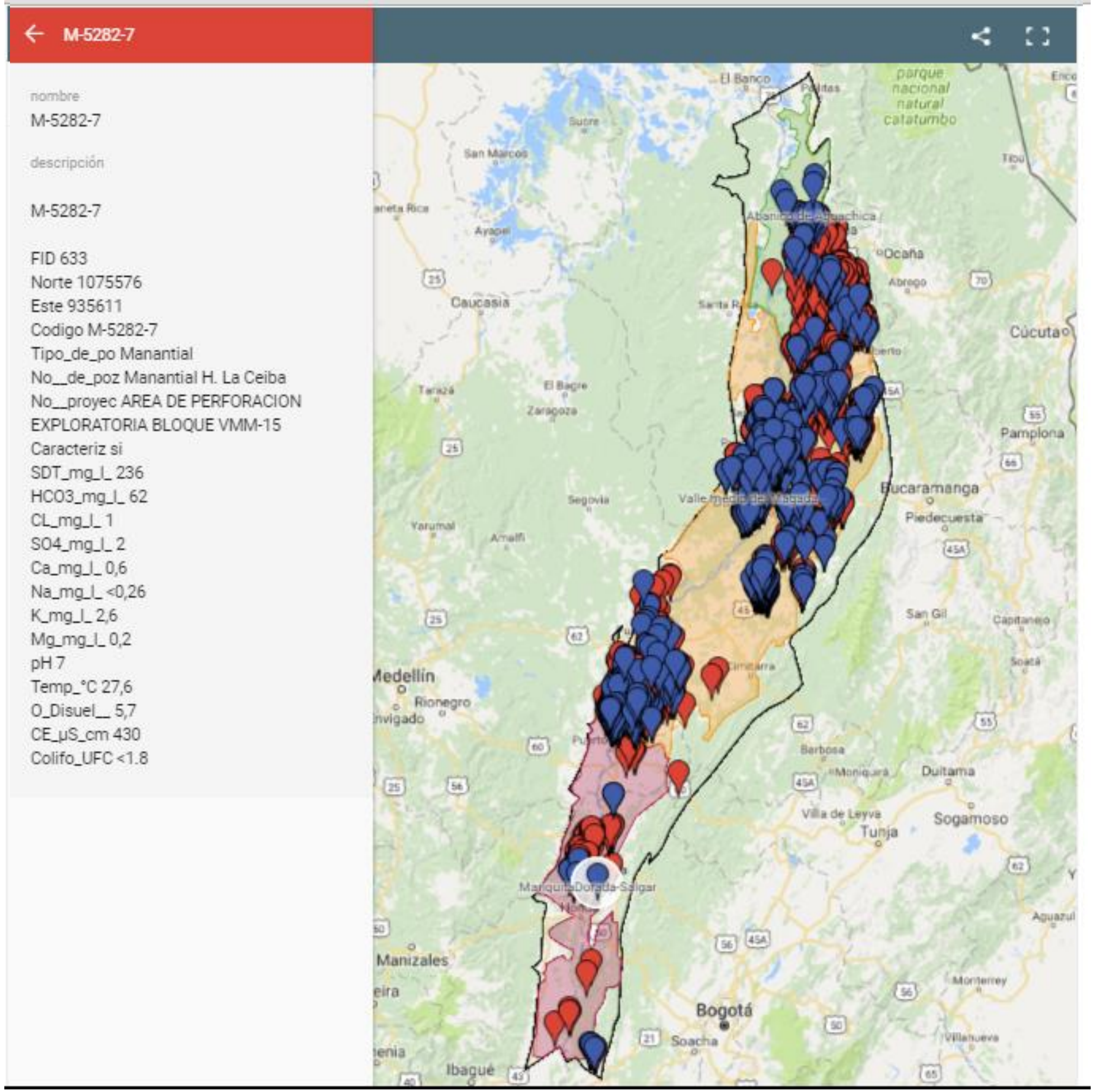
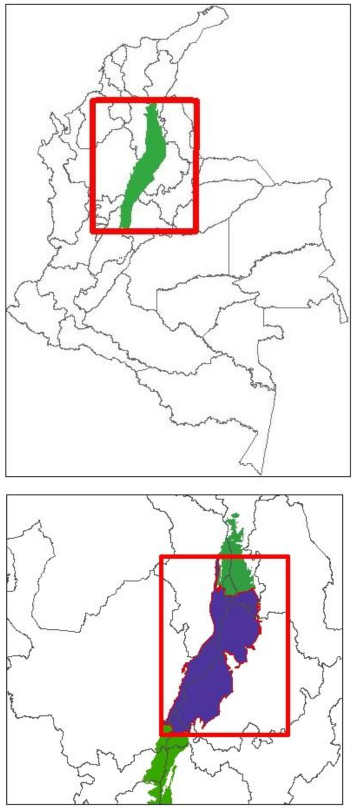
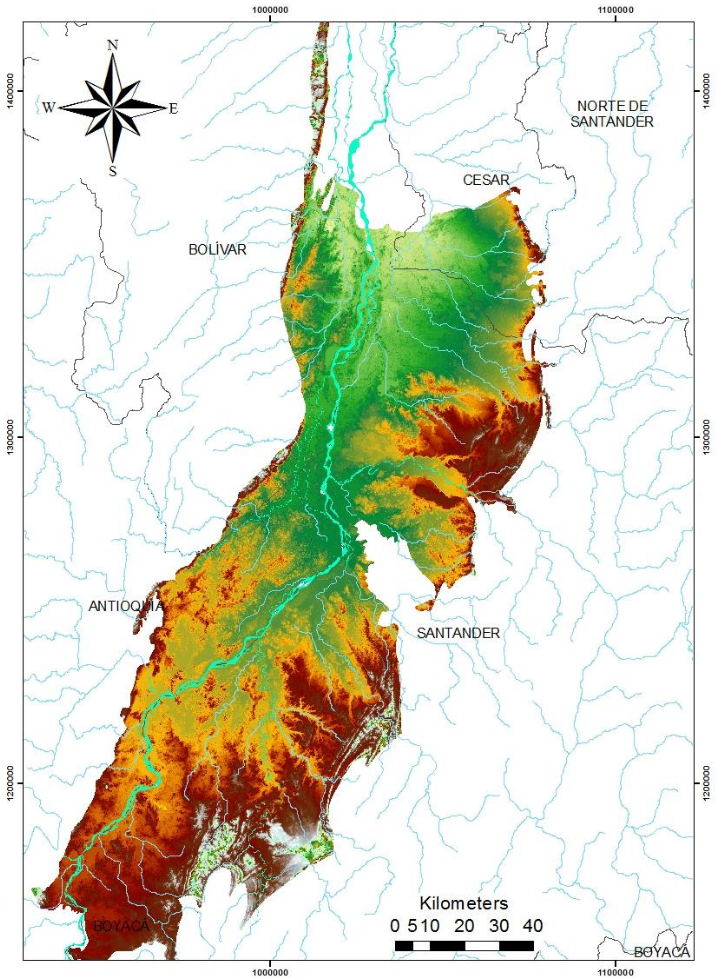


THE MIDDLE MAGDALENA VALLEY AQUIFER SYSTEM



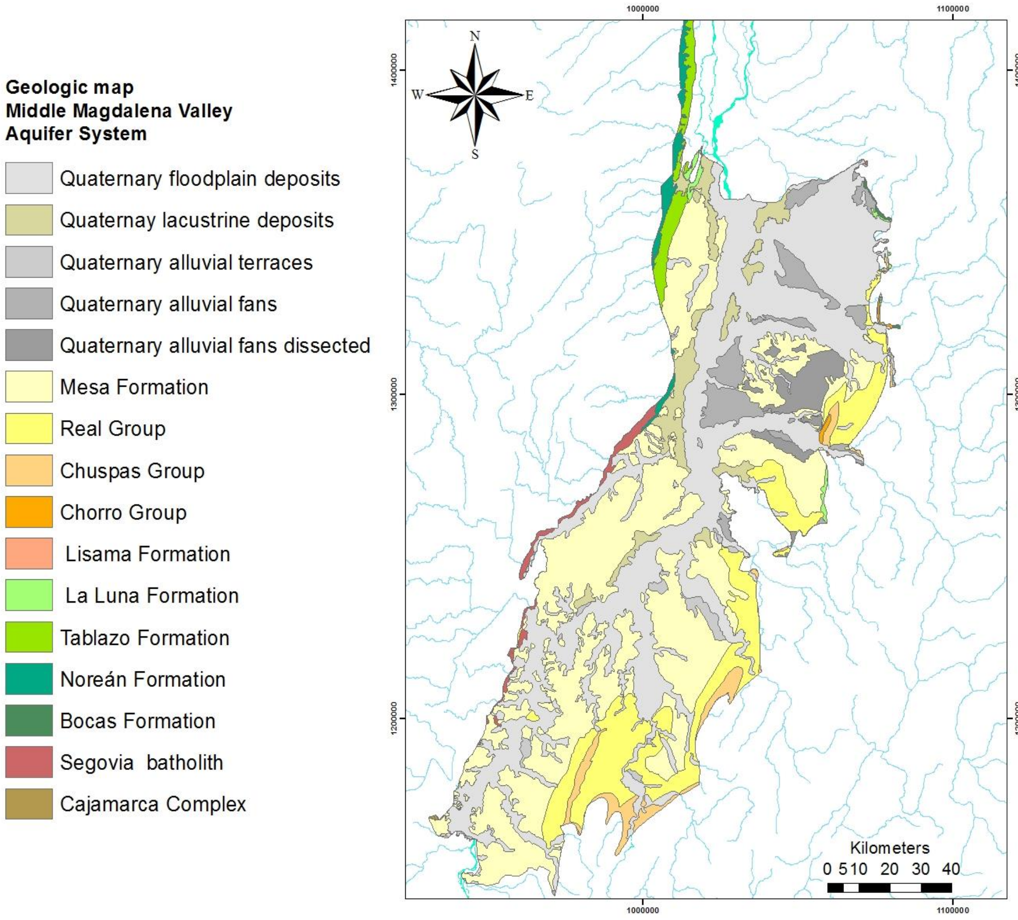
Map location of Middle Magdalena Valley Aquifer System

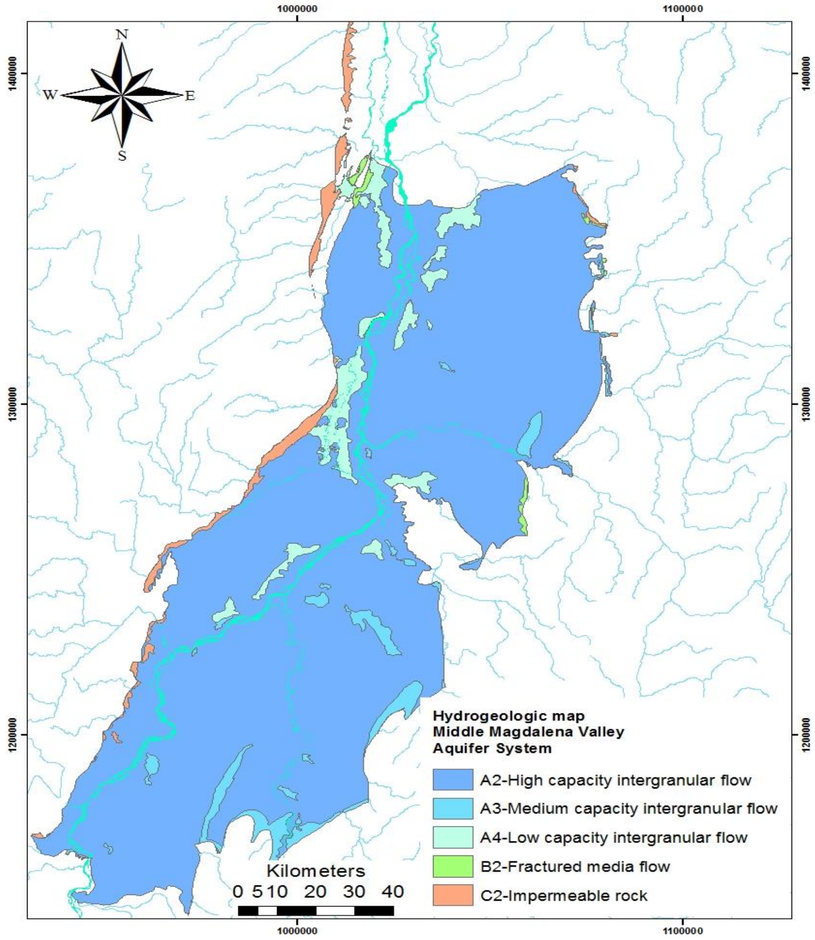


Generalities	
Hydrogeological province	PM1 Middle Magdalena Valley
Area	14 900 km^2
Estimated recharge	0-500 mm/year
Mean Temperature	25.6°C
Mean Rainfall	2871 mm/año
Population	1 012 966

The aquifer system, is located within the hydrogeological province of the Middle Magdalena Valley

GEOLOGY AND HIDROGEOLOGY

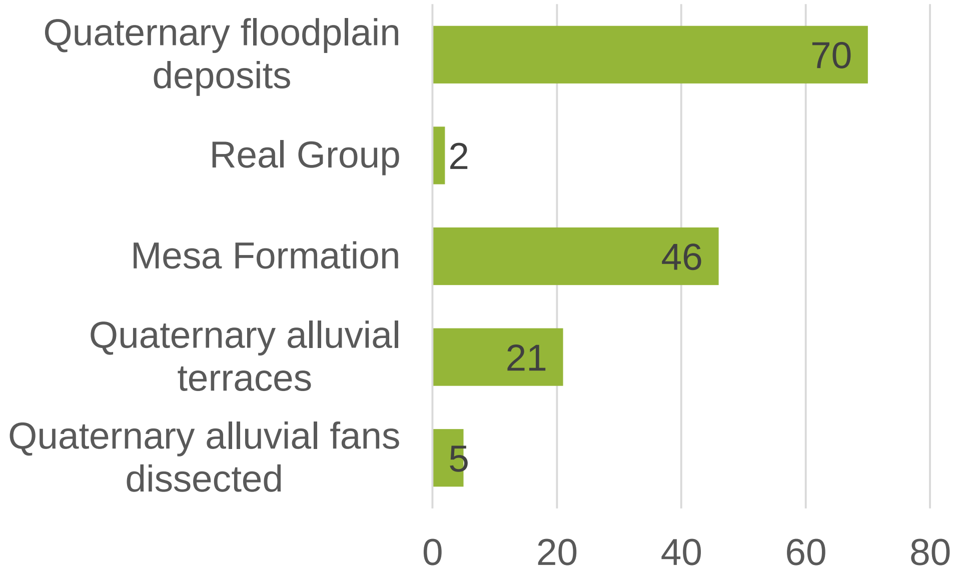




The aquifer system is in an mountainous area that is bounded by several regional marks between the central and eastern ranges of the Andes.

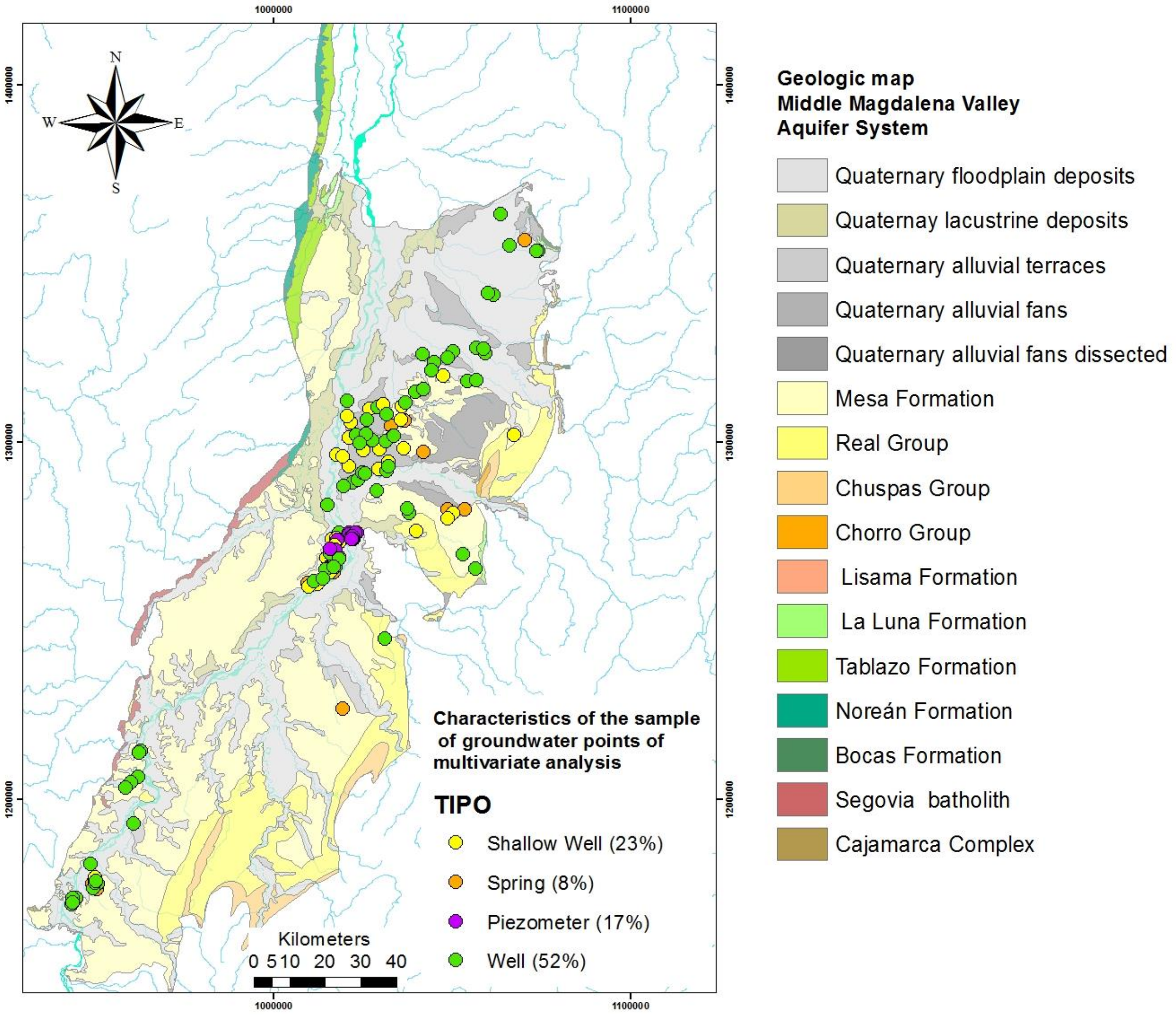
The 95% of the outcropping rocks in the aquifer system have storage capacity of groundwater.

SPATIAL DISTRIBUTION OF SAMPLES



2014	42
2013	58
2012	10
2011	6
2010	7
2009	2
2006	2
2005	16

Shallow Well	33
Spring	12
Piezometer	24
Well	75



STATISTIC ANALYSIS

Parameter	N	Mín.	Máx.	Mean	St. Dev.	Skewness.	Skewness. corrected
pH	144	**4,43**	**8,6**	6,8	0,7	-0,01	-0,01
Electric Conductivity	144	**9,97**	**4158,5**	336,5	552,2	1,618	-0,57
TDS	144	**6,48**	**2703,0**	199,3	354,4	1,483	-0,54
Ca^{++}	144	**0,10**	**291,0**	**17,2**	32,8	1,676	-0,31
Na^{+}	144	**0,31**	**530,0**	**21,1**	54,4	4,883	-0,21
K^{+}	144	**0,02**	**91,1**	3,4	8,1	3,489	-1,03
Mg^{++}	144	**<0,049**	**79,0**	5,3	10,3	1,539	1,54
Fe	144	**<0,073**	**874,0**	13,1	75,1	5,085	-2,82
Cl^{-}	144	**<1,4**	**1217,9**	**23,0**	109,6	4,001	2,13
$SO_4^{=}$	144	**0,05**	**1205,0**	13,0	100,3	4,519	-1,03
HCO_3^{-}	144	**0**	**1347,0**	**81,8**	140,2	1,466	1,466
$N\text{-}NO_3^{-}$.	144	**<0.1**	**89,0**	1,5	7,6	6,063	2,17

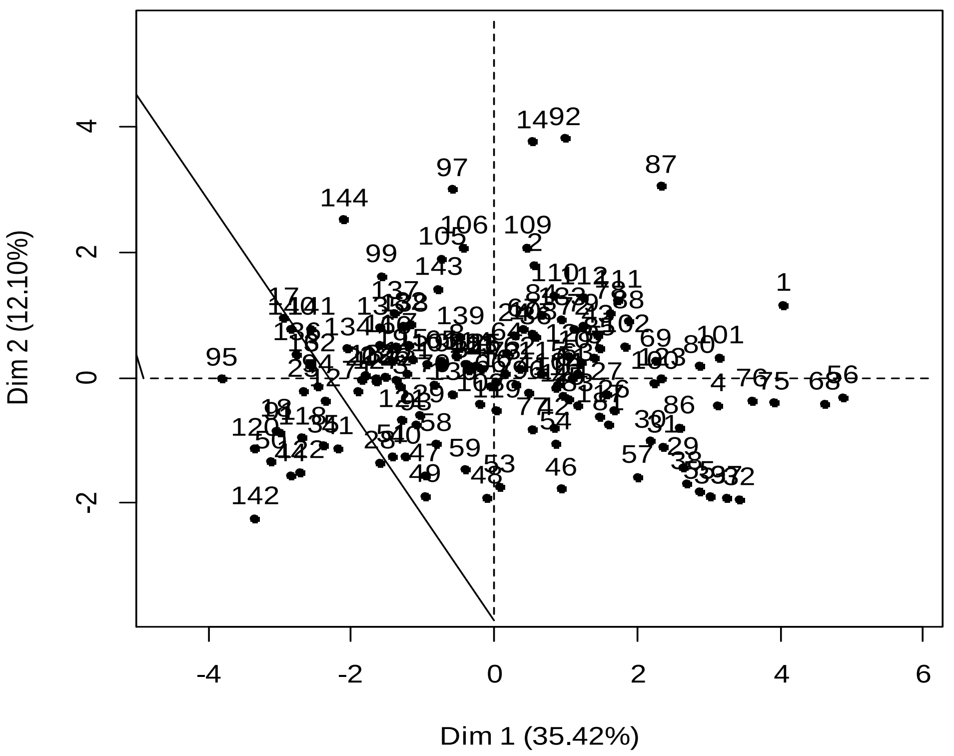
The maximum and minimum values of cations and anions allow to show the degree of spatial heterogeneity of the aquifer system.

PRINCIPAL COMPONENT ANALYSIS-PCA

Factor Analysis			
Variables	**Dim.1**	**Dim.2**	**Dim.3**
pH	0,438	-0,251	-0,464
Ca^{++}	**0,875**	-0,041	-0,143
Na^{+}	**0,758**	0,251	-0,145
K^{+}	**0,694**	0,155	-0,057
Mg^{++}	**0,770**	-0,011	0,135
Fe	0,216	-0,546	0,527
Cl^{-}	0,499	0,078	**0,606**
$SO_4^{=}$	0,162	**0,703**	-0,109
HCO_3^{-}	**0,782**	-0,252	-0,062
$N\text{-}NO_3^{-}$	0,045	0,442	0,512
Eigenvalue	3,54	1,21	1,2
% Expl	35,42	12,09	12
% Cum.	35,42	47,51	59,5

The numbers in red represent the variables identified in each factor

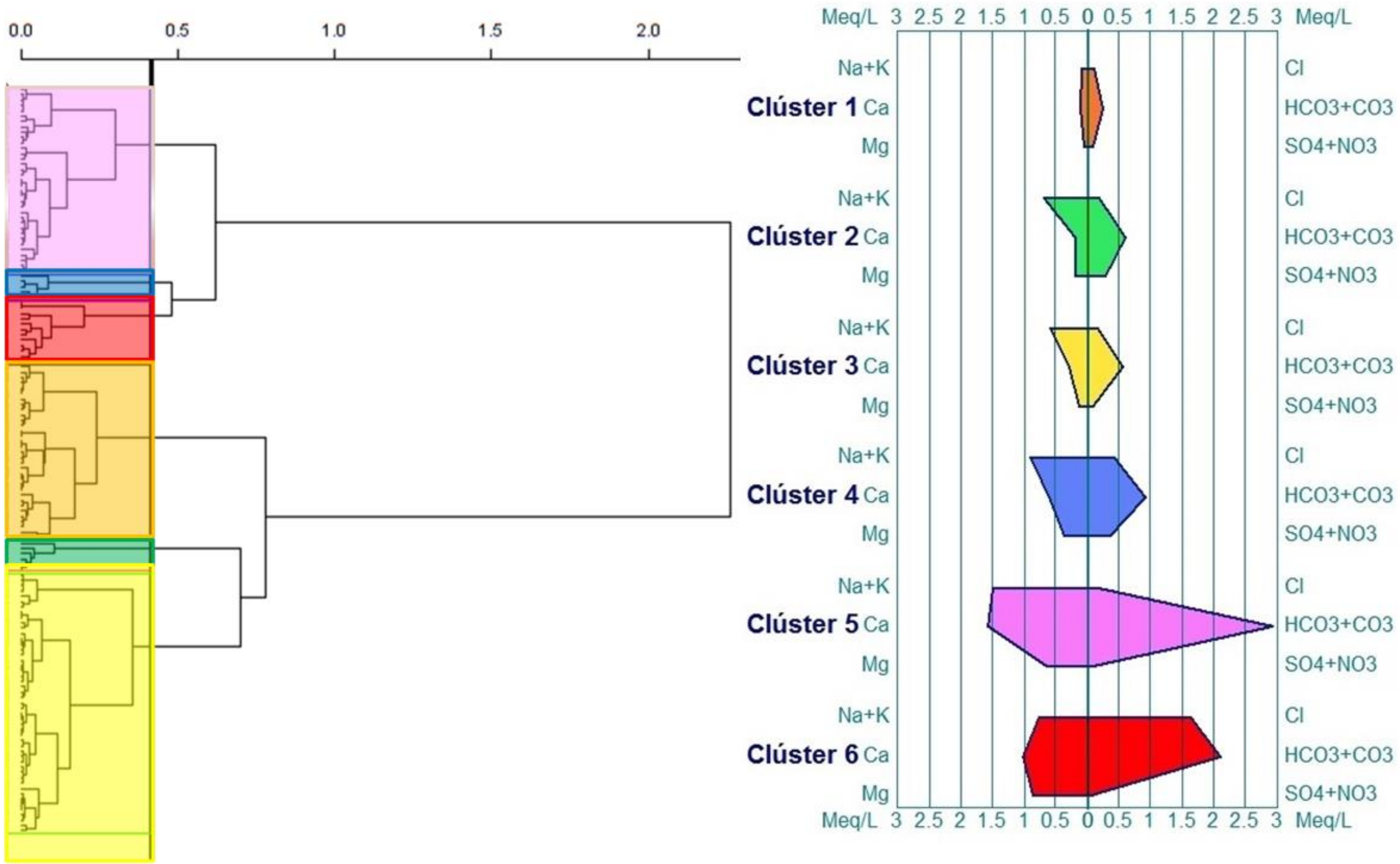
Individuals factor map (PCA)



MAIN PROCESSES

1. Dissolution Silicate
2. Cation Exchange
3. Anthropogenic Pollution

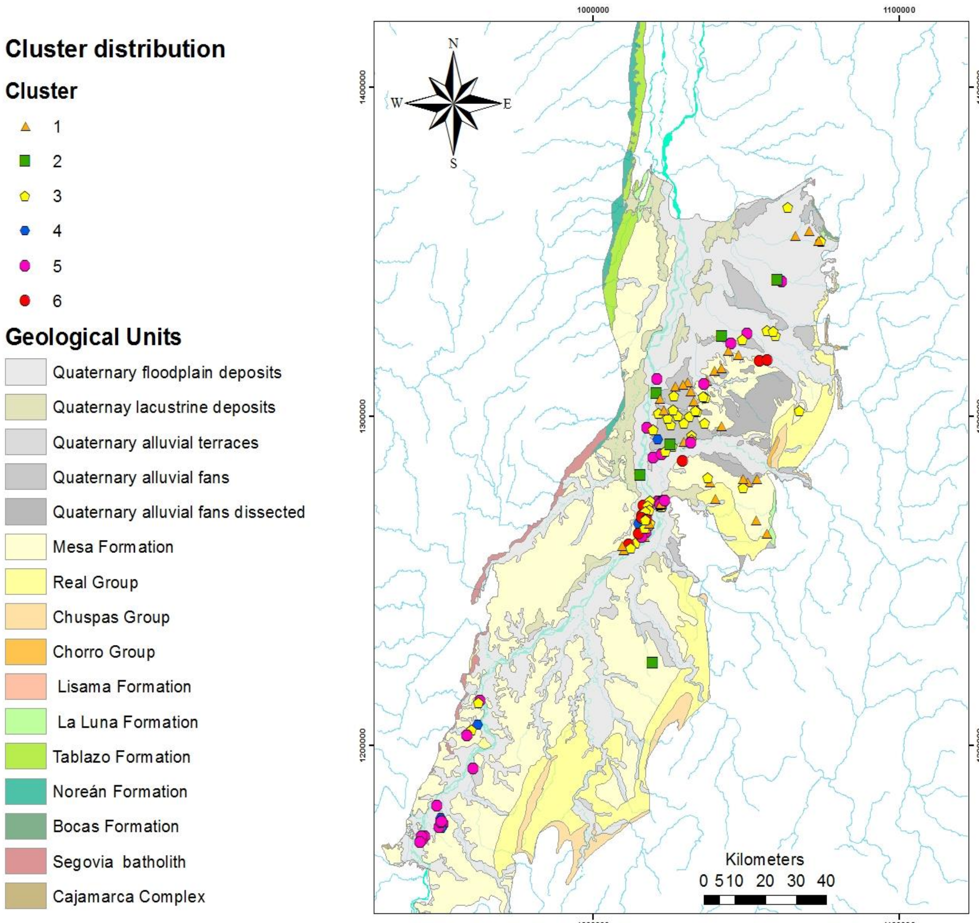
HIERARCHICAL CLUSTER ANALYSIS (HCA)



The differences and similarities between each cluster can be easily identified.

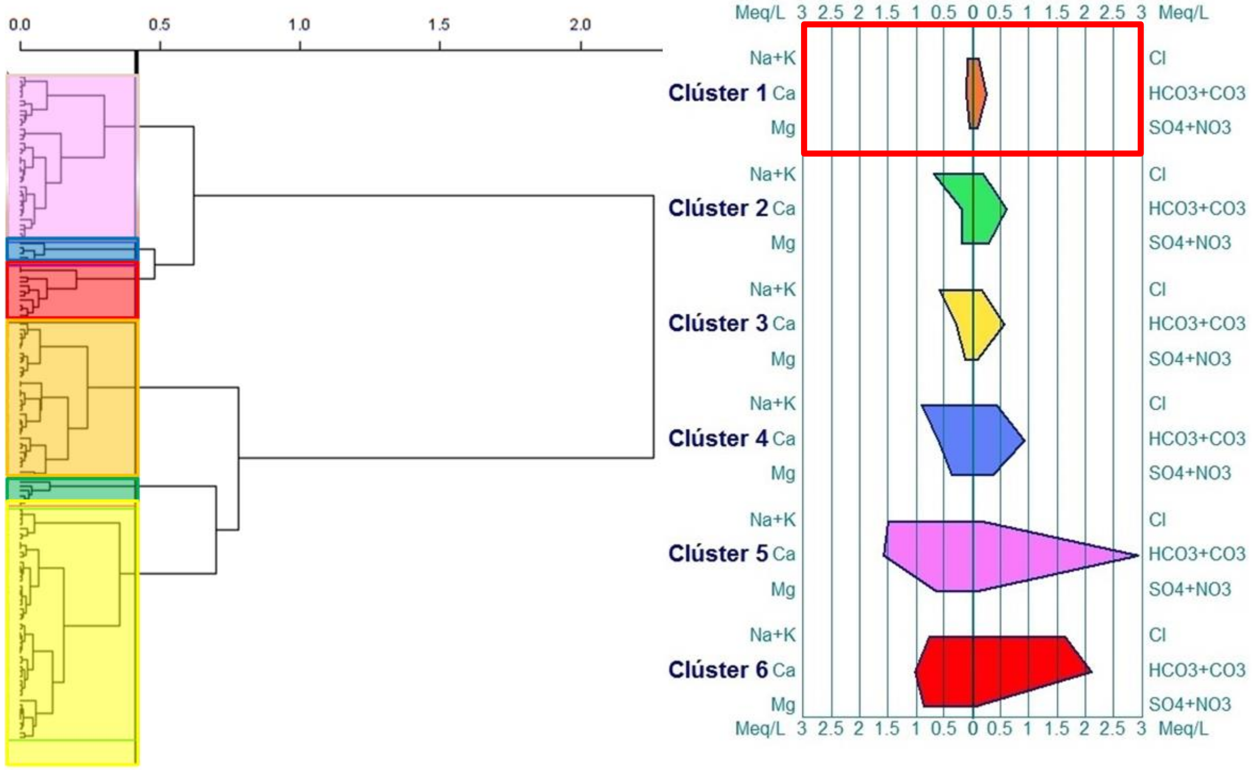
Significantly, the clusters have a less mineralized behavior cluster 1, to the most mineralized cluster 6.

IDENTIFICATION GEOCHEMICAL PROCESSES



For cluster 1 Calcium and Bicarbonate ions are predominant.

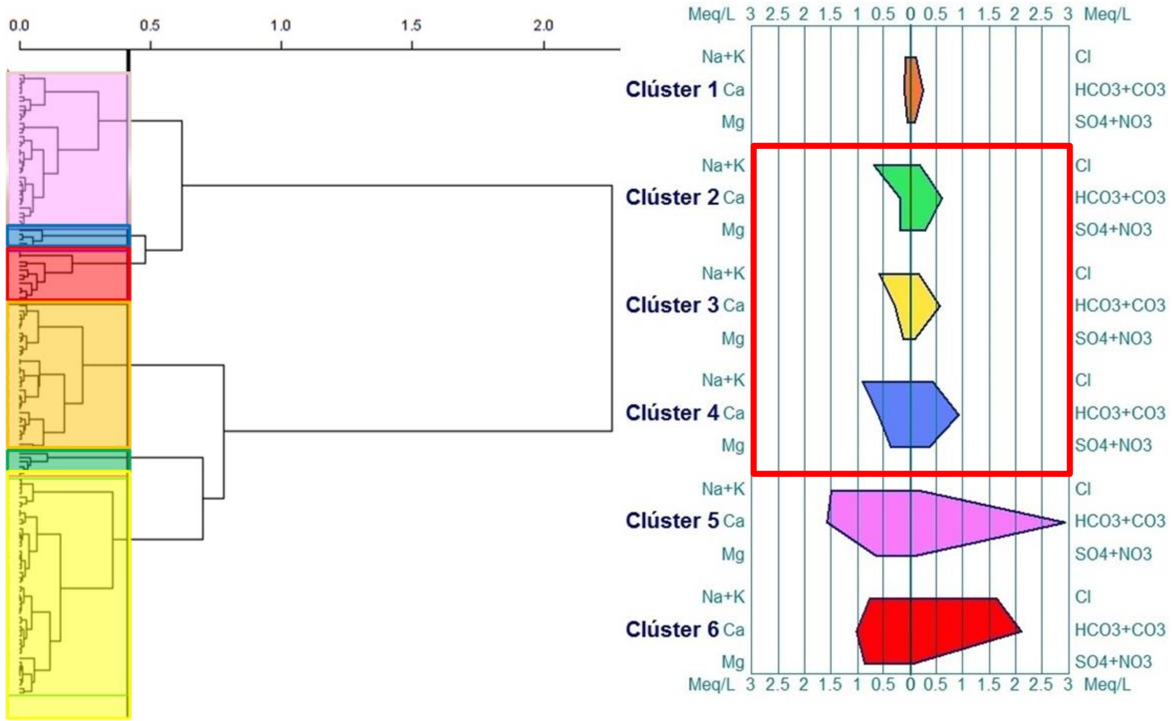
The latter are slightly mineralized and probably have short residence times.



Cluster 1

Stiff diagram average

CLUSTERS 2-3-4



The main hydrogeochemical process of the studied area mentioned is of silicates dissolution due to water rock interaction in the direction of groundwater flow.

The process of Albite and Orthoclase's attack to produce Kaolinite. This process increases the concentration of Potassium and Sodium in the water.

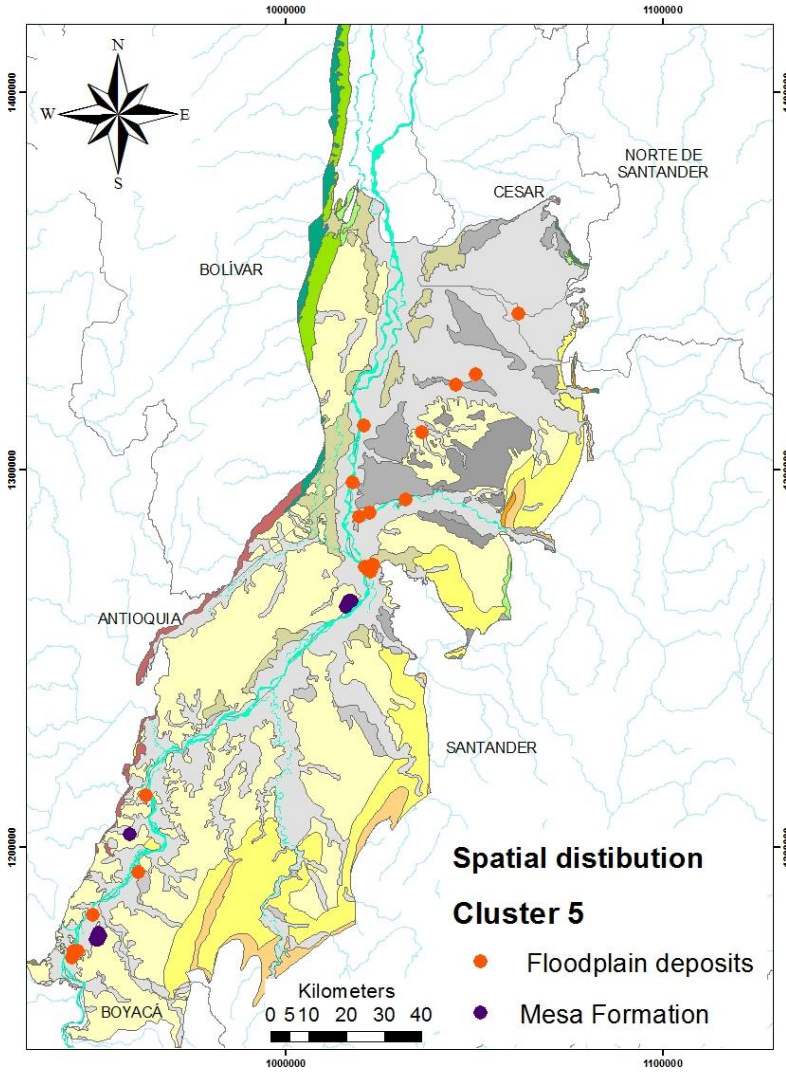
Silicates dissolution

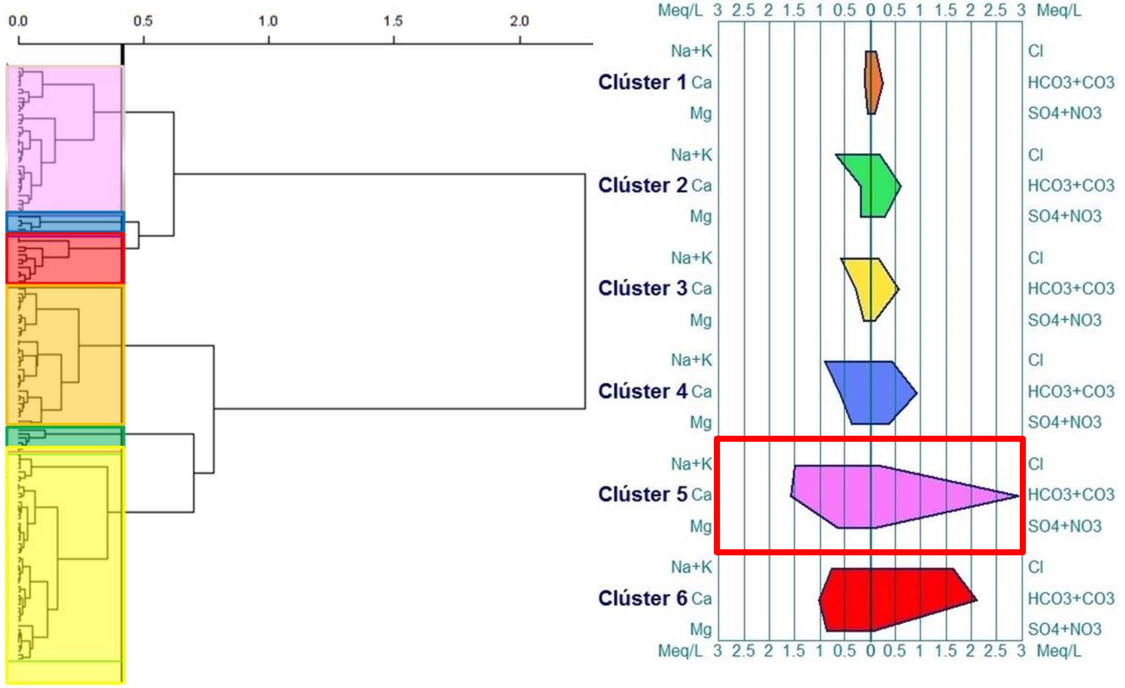
Albite dissolution $$2Si_3O_8AlNa + 9H_2O + 2H^+ + 2HCO_3^- \rightarrow\rightarrow 2Si_2O_5Al_2(OH)_4 + 2Na^+ + 2HCO_3^- + 4SiO_4H_4$$

Orthoclase's dissolution $$2Si_3O_8AlK + 9H_2O + 2H^+ + 2HCO_3^- \rightarrow\rightarrow 2Si_2O_5Al_2(OH)_4 + 2K^+ + 2HCO_3^- + 4SiO_4H_4$$

IDENTIFICATION GEOCHEMICAL PROCESSES

CLUSTER 5





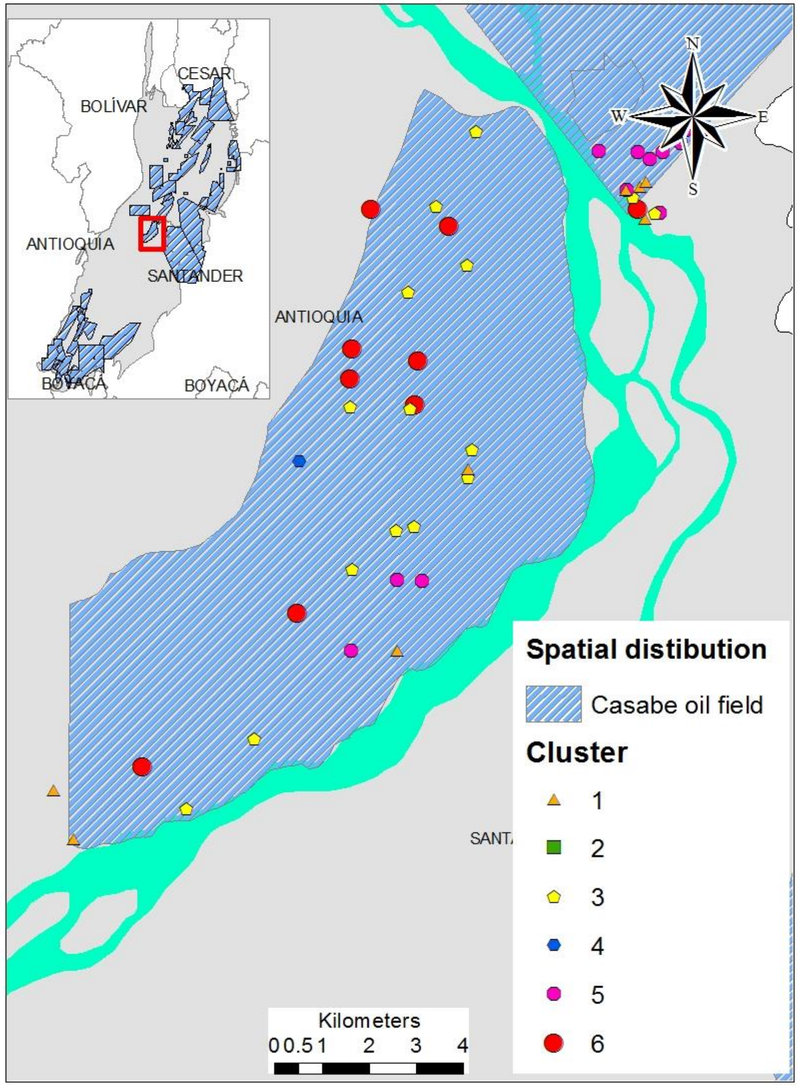
$$\frac{1}{2}Ca^{++} - Clay + Na^{+} \rightarrow \frac{1}{2}Ca^{++} + Na^{+} - Clay$$

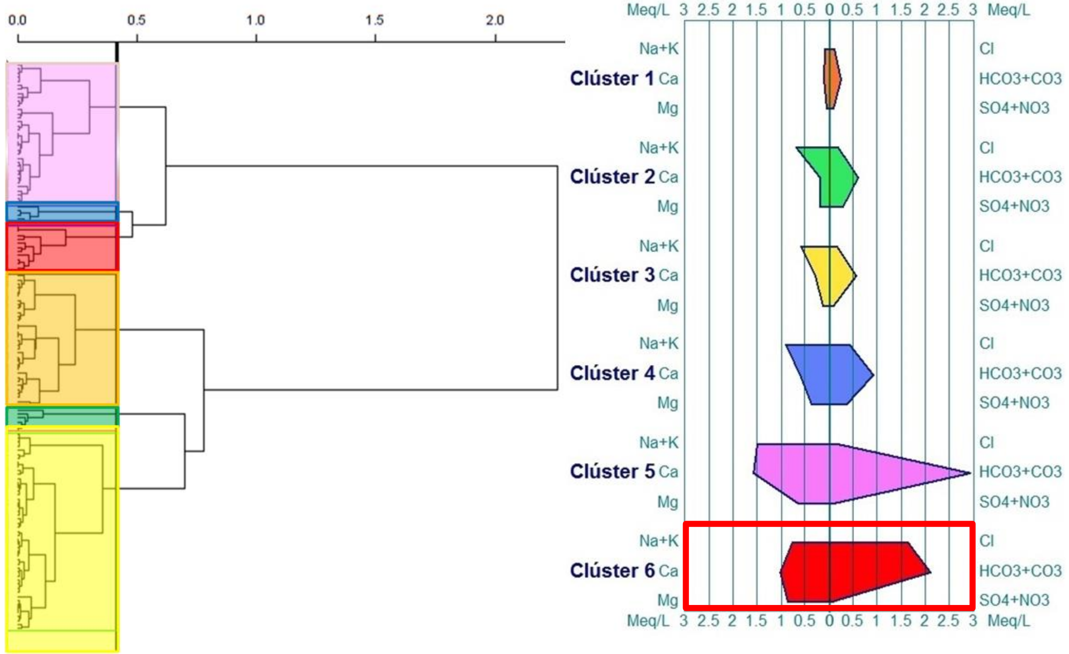
25 of 35 samples comprising this cluster are on the quaternary floodplain deposits, which is composed for fine-grained deposits with clay matrix.

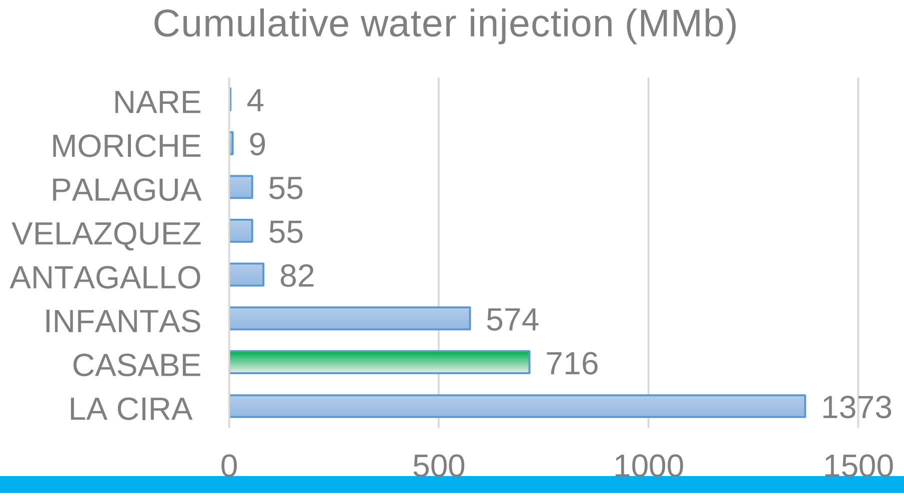
It causes the cation exchange, the Sodium is replaced by Calcium in the water (the second identified Hydrogeochemical) process.

IDENTIFICATION GEOCHEMICAL PROCESSES

CLUSTER 6

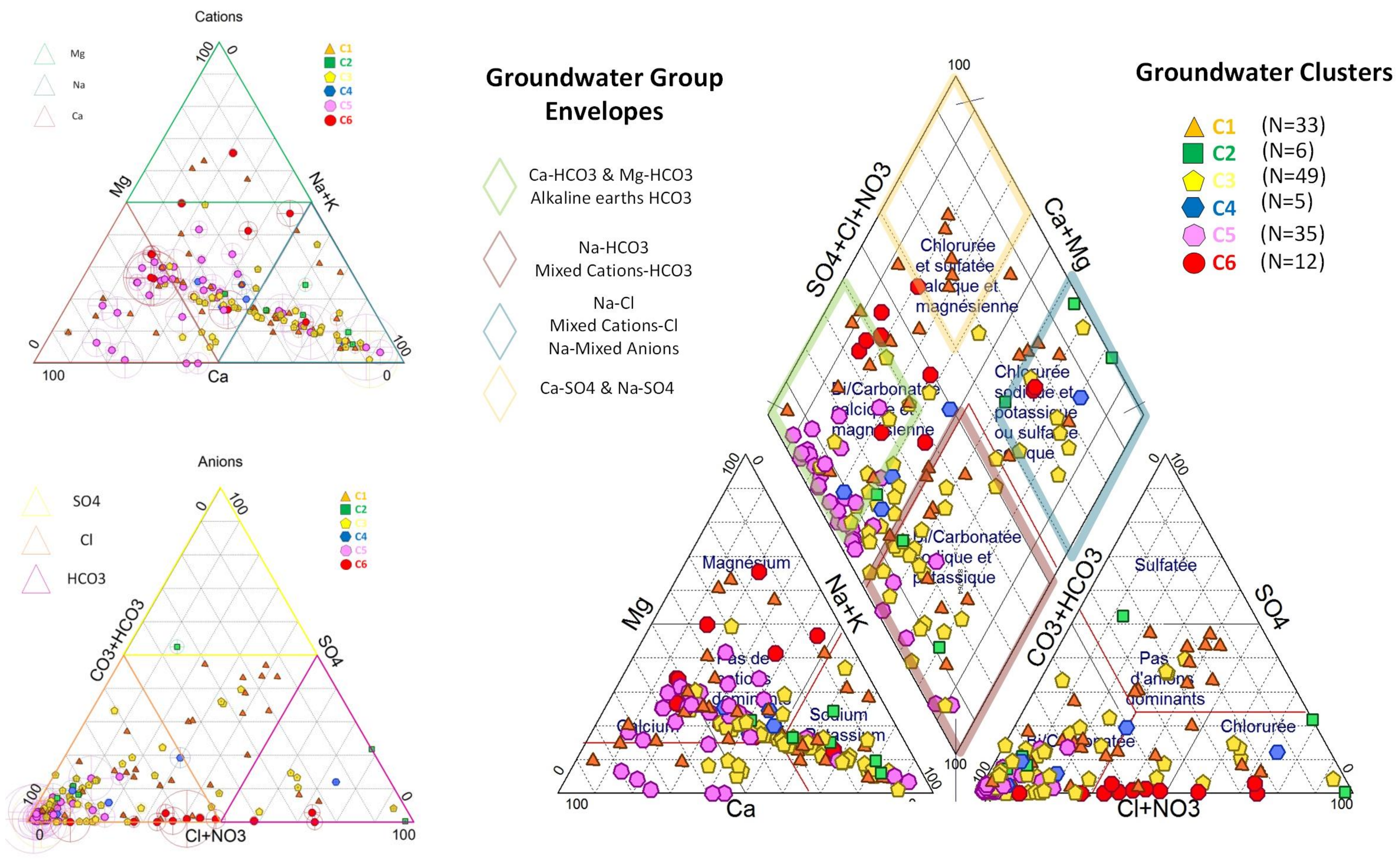






It is believed that the source of contamination by Chloride, is for lack of integrity of the injector wells, or production water spills on surface.

WATER TYPES



3 types of waters were determined

1. A Calcium-Magnesium-Bicarbonate mixing
2. Bicarbonate Sodium
3. Sodium Chloride.

Piper Diagram

CONCLUSIONS AND REMARKS

- The analysis of the groundwater aquifer system Middle Magdalena Valley based on 144 samples showed that the groundwater type Calcium-Magnesium-Bicarbonate is the dominant water throughout the studied area.
- These observations were supported by a statistical analysis, including a factors analysis and Hierarchical Cluster Analysis (HCA), which allowed the identification of parameters that contribute to variation between samples, and grouping them according to their behavior, it was found that the first factor is related to the dissolution of silicates and possible cation exchange, the second and third factor associated to contamination processes of anthropogenic origin.
- 6 clusters were identified each different geochemical patterns revealed the heterogeneity of the aquifer.

Thank you!