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CHARACTERIZATION OF THE MAIN KARST AQUIFERS OF THE MIDDLE VALSERIANA (NORTHERN ITALY) BASED ON ISOTOPIC AND HYDROGEOCHEMICAL DATA: NOSSANA AND PONTE DEL COSTONE SPRINGS

HYDROGEOCHEMISTRY, GROUNDWATER AGE,
PALEOGROUNDWATER AND ISOTOPES IN HYDROGEOLOGY

X SEPTEMBER 2021

UniAcque SERVIZIO IDRICO INTEGRATO

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UNIVERSITÀ DEGLI STUDI DI MILANO

Study Goals

Chemical-physical characterization

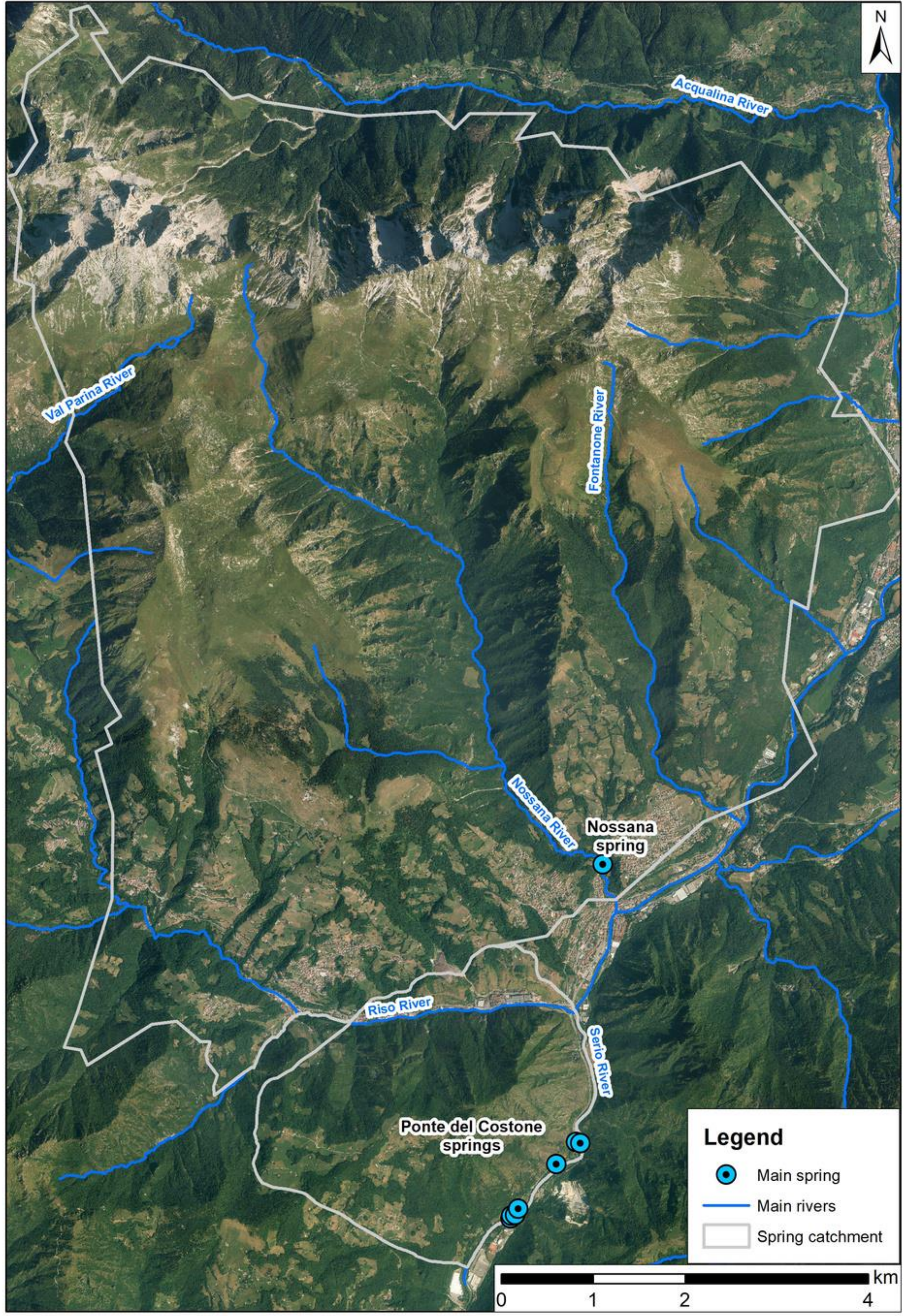
Isotopic characterization

Residence time estimation

Definition of the internal dynamics of the two water systems

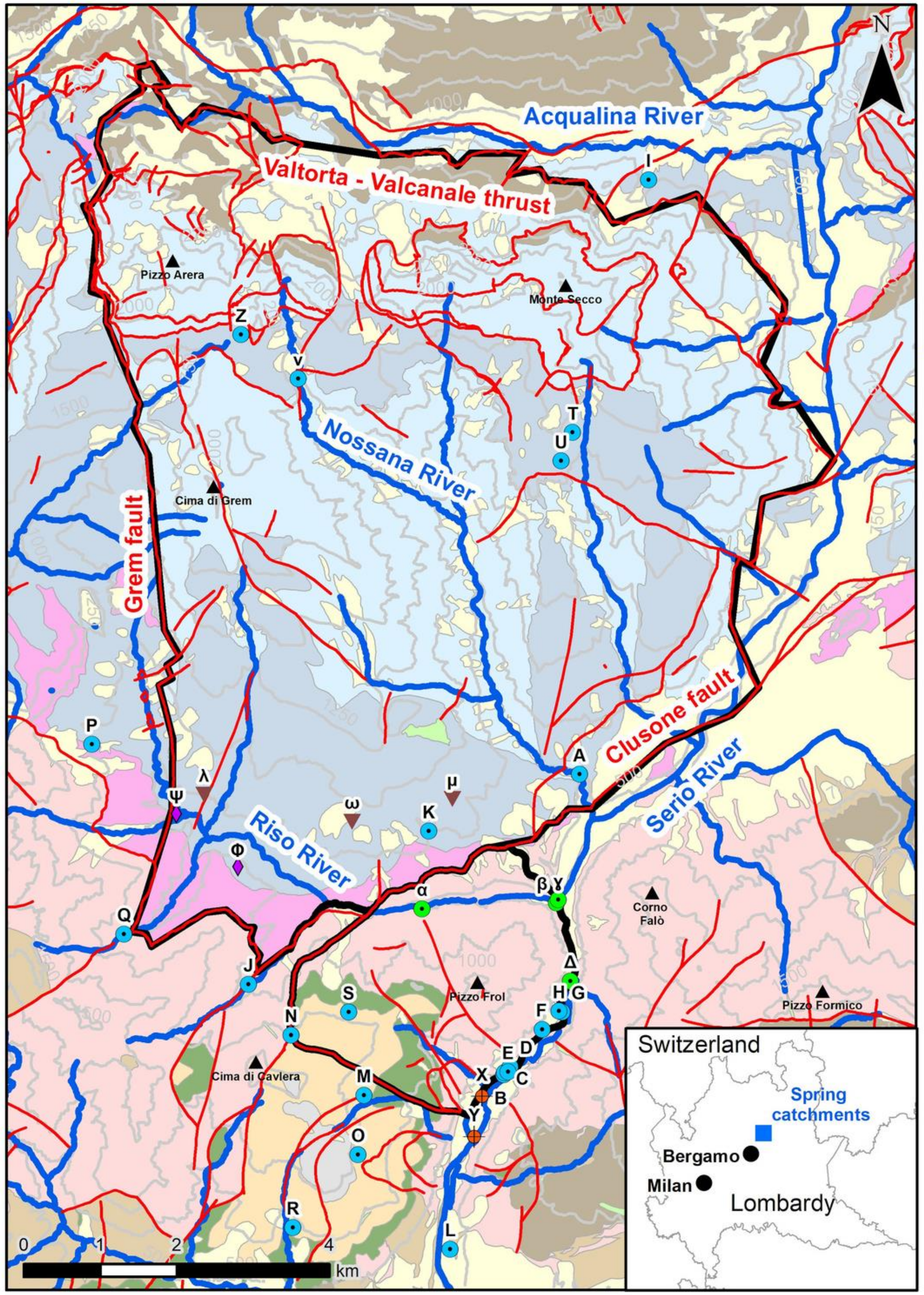
Study Area

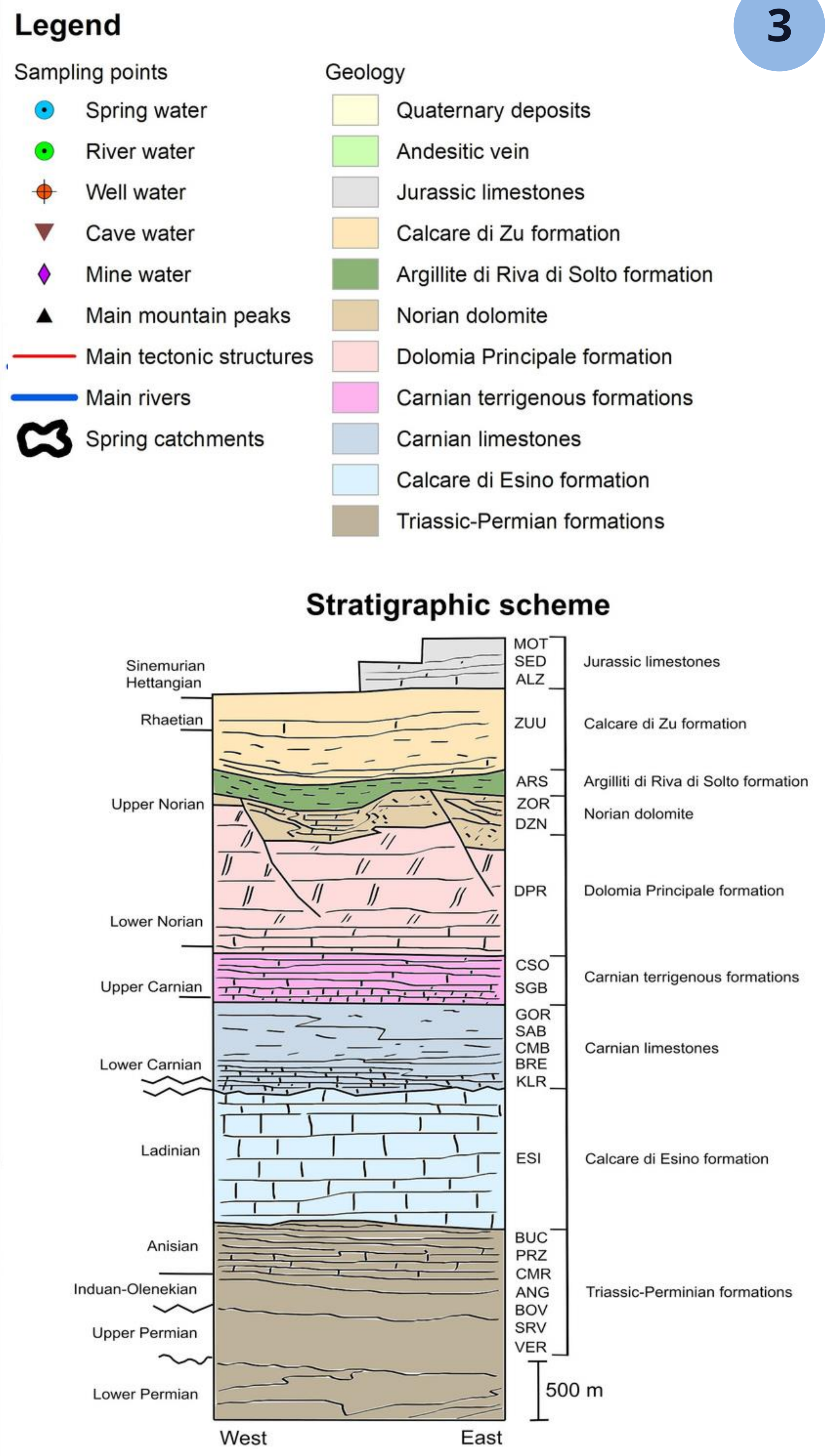
- The springs are located in Northern Italy, in the **Central Pre-Alps** within the Province of Bergamo, Lombardy Region
- **Nossana** catchment: **80 km^2**
- **Ponte del Costone** catchment: **10 km^2**
- **High differences in altitude**, from 427 m a.s.l. (Ponte del Costone Springs) to 2512 m a.s.l. (Pizzo Arera mountain).



Study Area

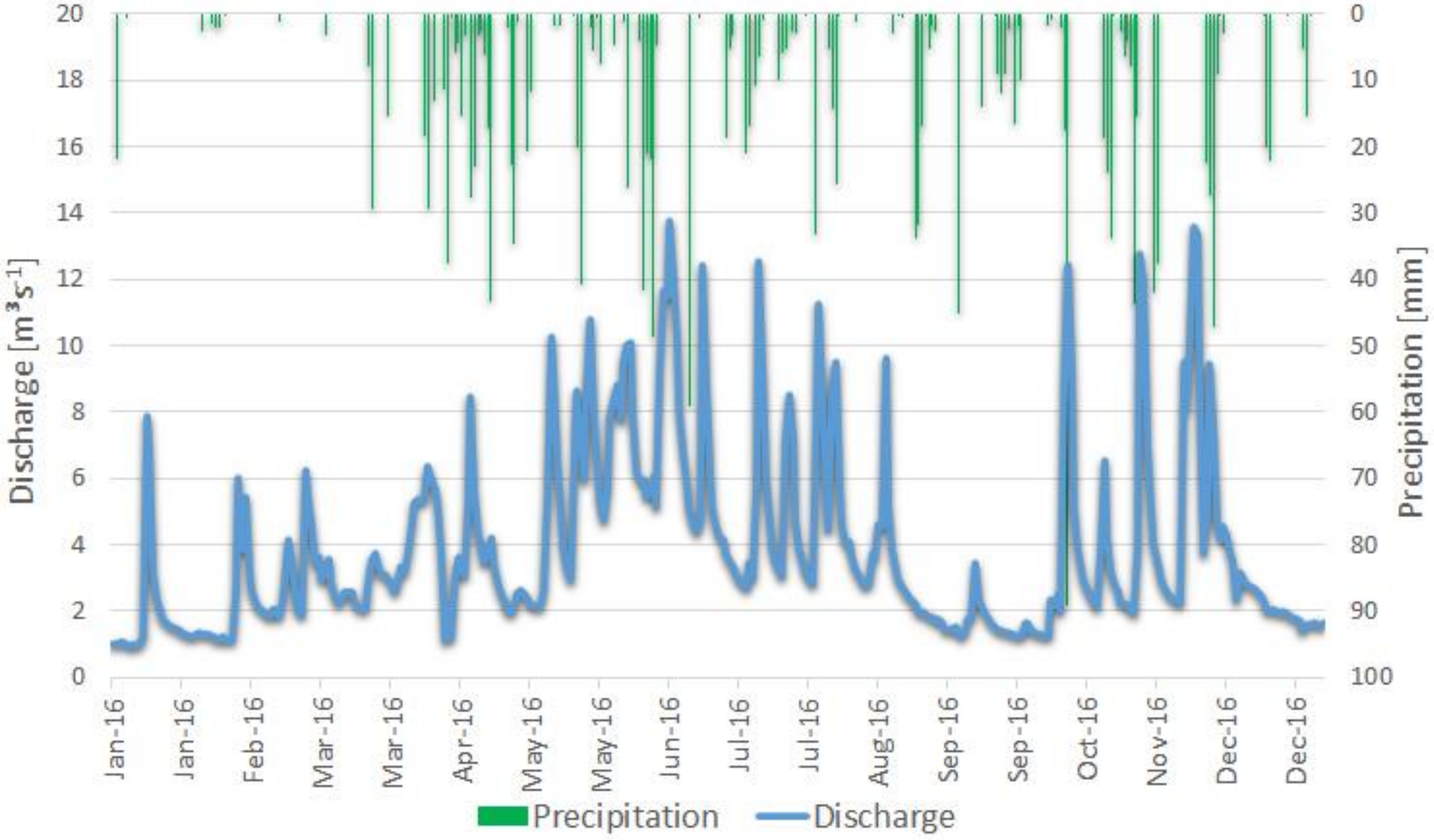
- The whole environment is dominated by **calcareous-dolomitic carbonate series**
- The **Nossana** aquifer is set in the **Calcare di Esino formation** (Ladin - Carnic age)
- The water system of **Ponte del Costone** is formed by 13 springs distributed in about 1 km along the Serio river and it has the **Dolomia Principale Formation** (Noric age) as reservoir rock
- The average **precipitation** is close to **2000 mm/year** with peaks of about 3000 mm/year (Ceriani et al., 2000)

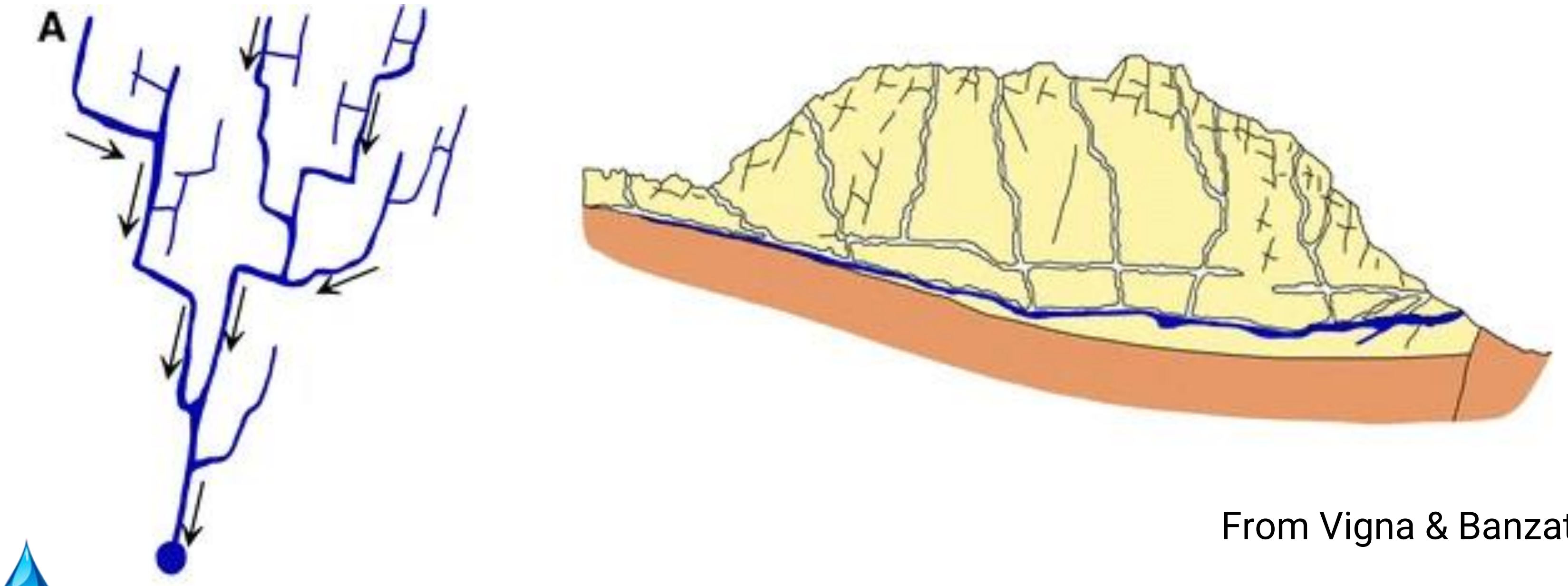




Study Area

Credits: Eco di Bergamo





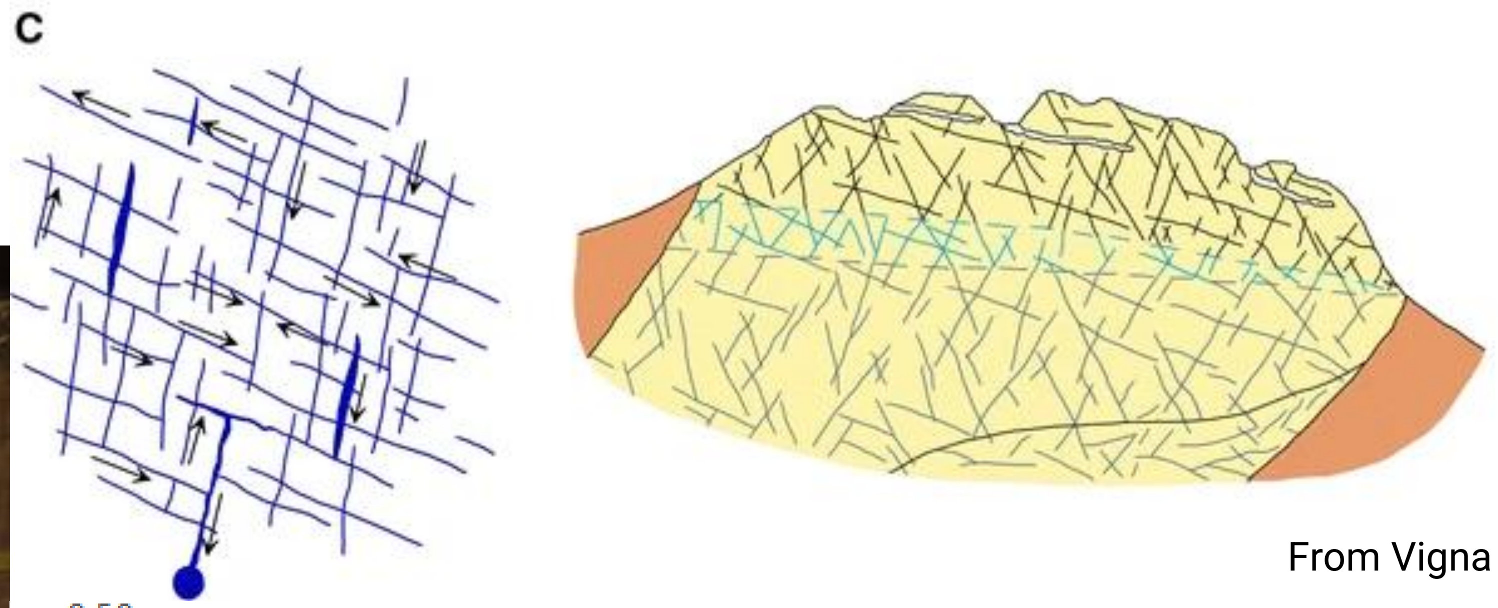
From Vigna & Banzato, 2015

- The **springs** are managed by the public company UniAcque S.p.A. and **feed more than 315,000 people**
- **Nossana** spring **discharge 0.5 - 18 m^3s^{-1}**

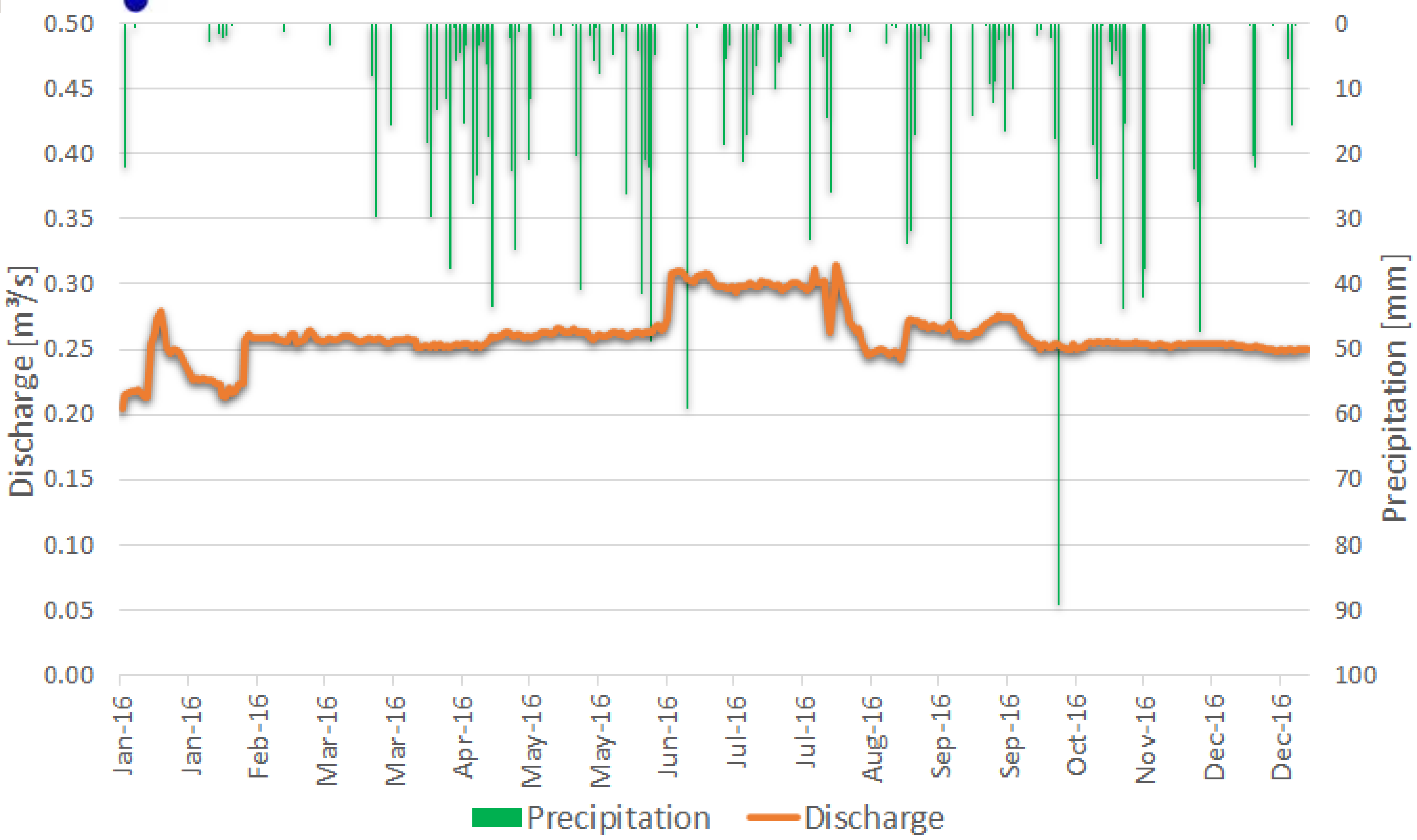
Nossana spring

Study Area

Credits: UniAcque S.p.A.



From Vigna & Banzato, 2015



- The **Ponte del Costone** cumulative **discharge 0.15 - 0.45 m^3s^{-1}**
- System with **dispersive circulation**
- **Three main group** distribuited along Serio river: Galleria del Costone, Merlo, and Bosco (from South to North)

Ponte del Costone springs

Methodology

1 - SAMPLING CAMPAIGN (MAY 2018 - JULY 2019)

34 sampling points were set up. 23 points are related to **natural spring** waters, 4 points to **surface waters**, 2 points to **wells** , 3 points to waters from **karst caves**, and 2 points to the Val del Riso **mine**

2 - HYDROCHEMICAL AND ISOTOPIC ANALYSIS

- **Chemical analyses** were performed at UniAcque S.p.A. laboratories via ion chromatography (IC) and inductively coupled plasma mass spectrometry (ICP-MS)
- **Stable isotopes analyses** (^{18}O, ^{2}H, and ^{13}C) were performed in the laboratory of the Université d'Avignon et des Pays de Vaucluse (France) using an isotope ratio mass spectrometer (IRMS).
- the **$^{3}H/^{3}He$ analysis** was performed in the laboratories of the Institute of Environmental Physics and Oceanography at the University of Bremen (Germany) (Sültenfuß et al., 2009).

Methodology

3 - HYDROCHEMICAL CHARACTERIZATION

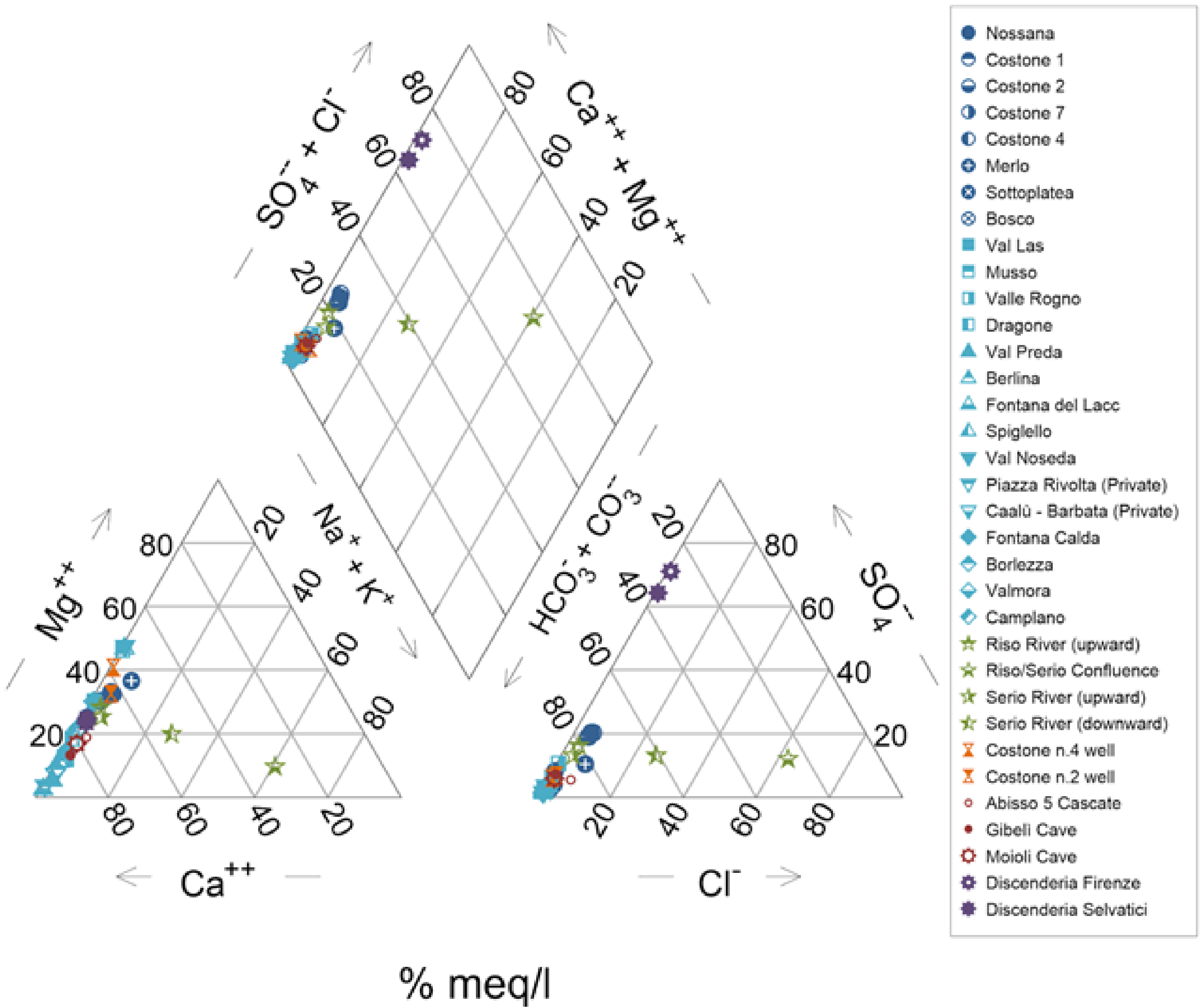
- Through the use of PHREEQC (Parkhurst & Appelo, 2013), **pCO_2** and Saturation Indices were calculated with respect to calcite (**SIc**) and dolomite (**SId**)
- Using Instant Clue software (Nolte et al., 2018), a **Hierarchical Cluster analysis** was performed considering major cations (Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+}), major anions (HCO_3^-, Cl^-, NO_3^-, and SO_4^{2-}), alkalinity ($CaCO_3$), temperature, CO_2 partial pressure, SIc and SId, and electrical conductivity [μS/cm]

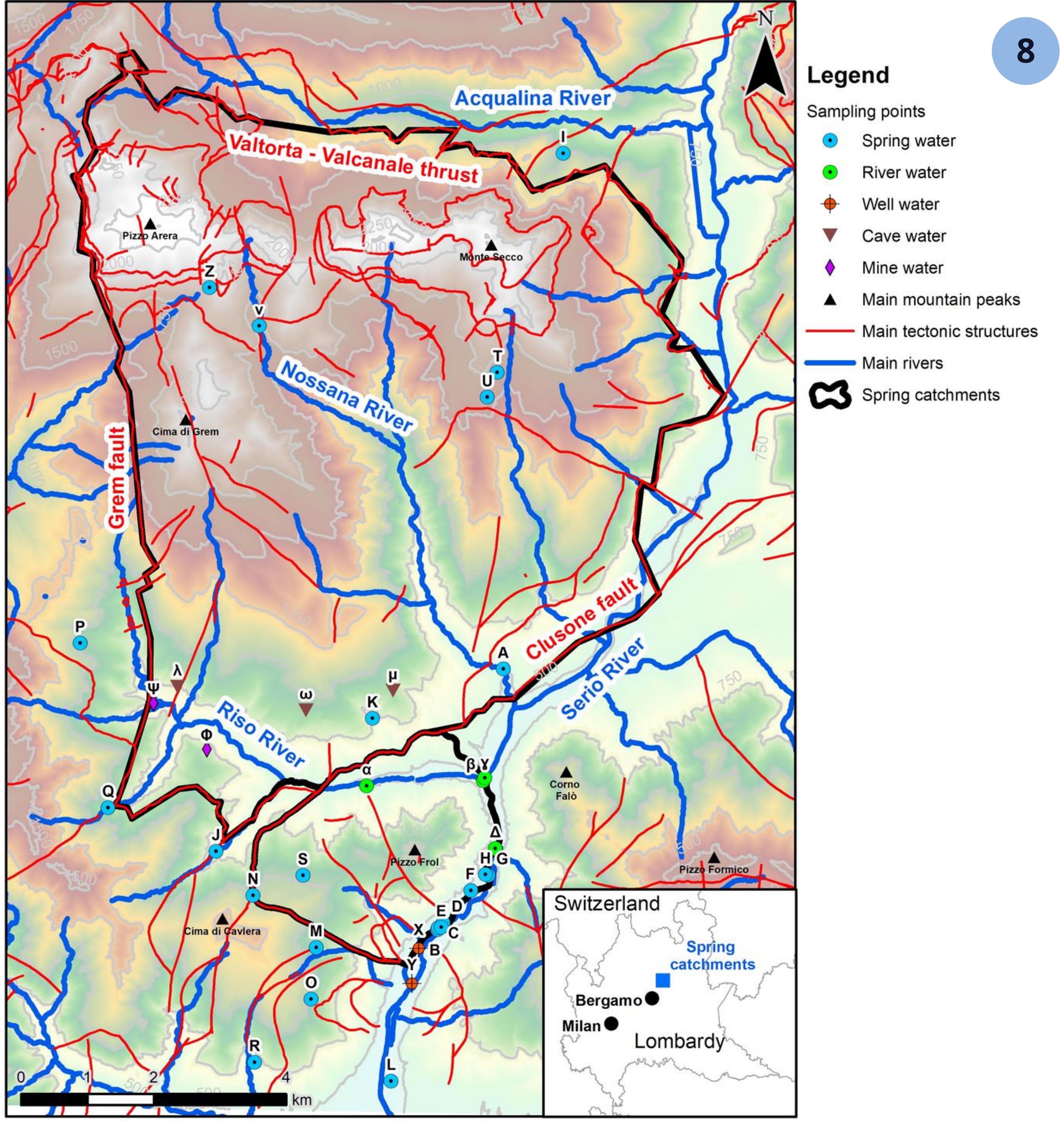
4 - FLOW DYNAMICS FEATURES WITHIN THE WATER SYSTEMS

Through comparison of the results of chemical and isotopic analysis, a **hypothesis** was proposed about **how the flow dynamics** within the two water systems **work**

Sampling phase

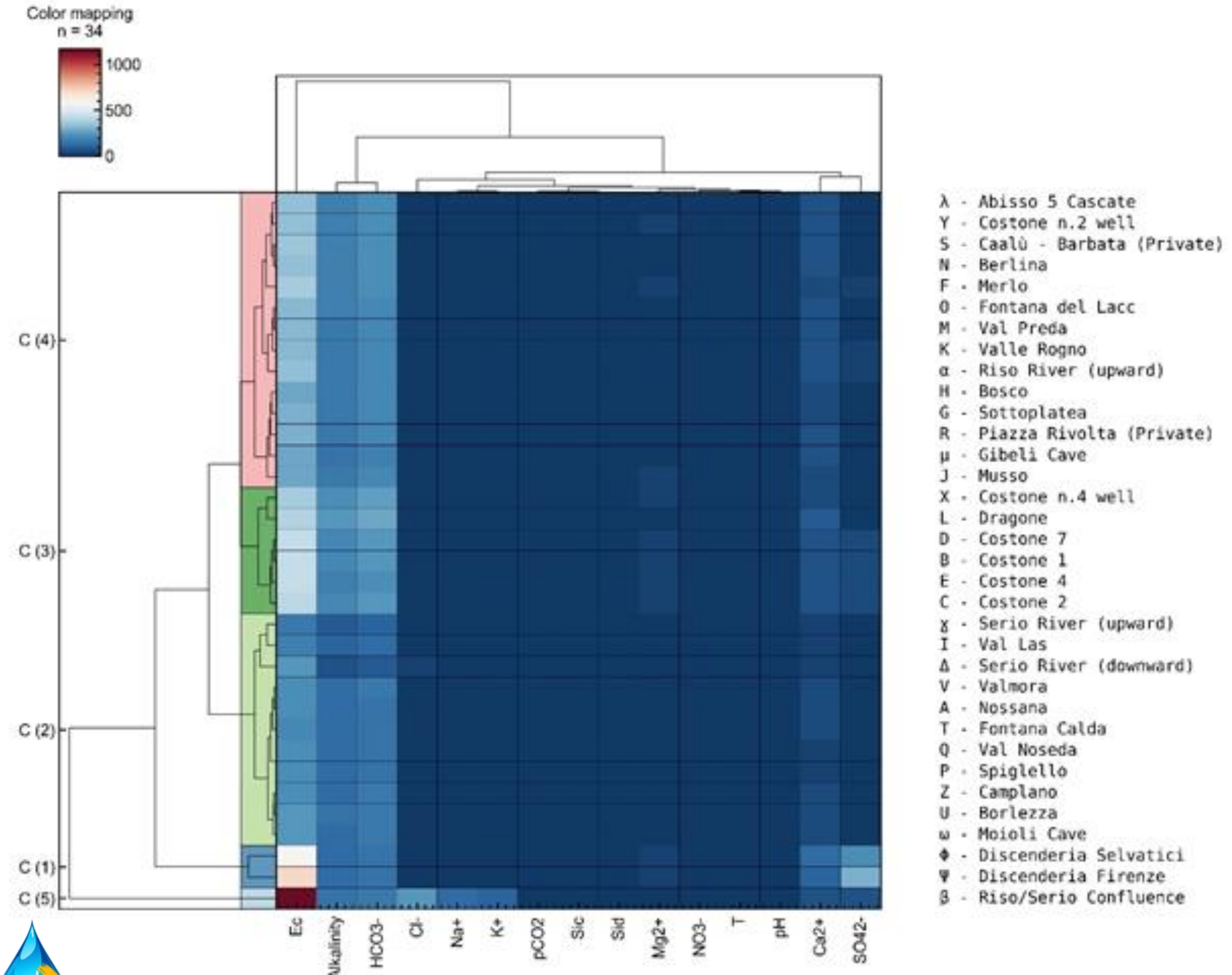
- from **May 2018** to **July 2019**
- focused primarily on the main spring systems: **Nossana** and **Ponte del Costone**
- The waters belong the **magnesium - bicarbonate hydrochemical facies**

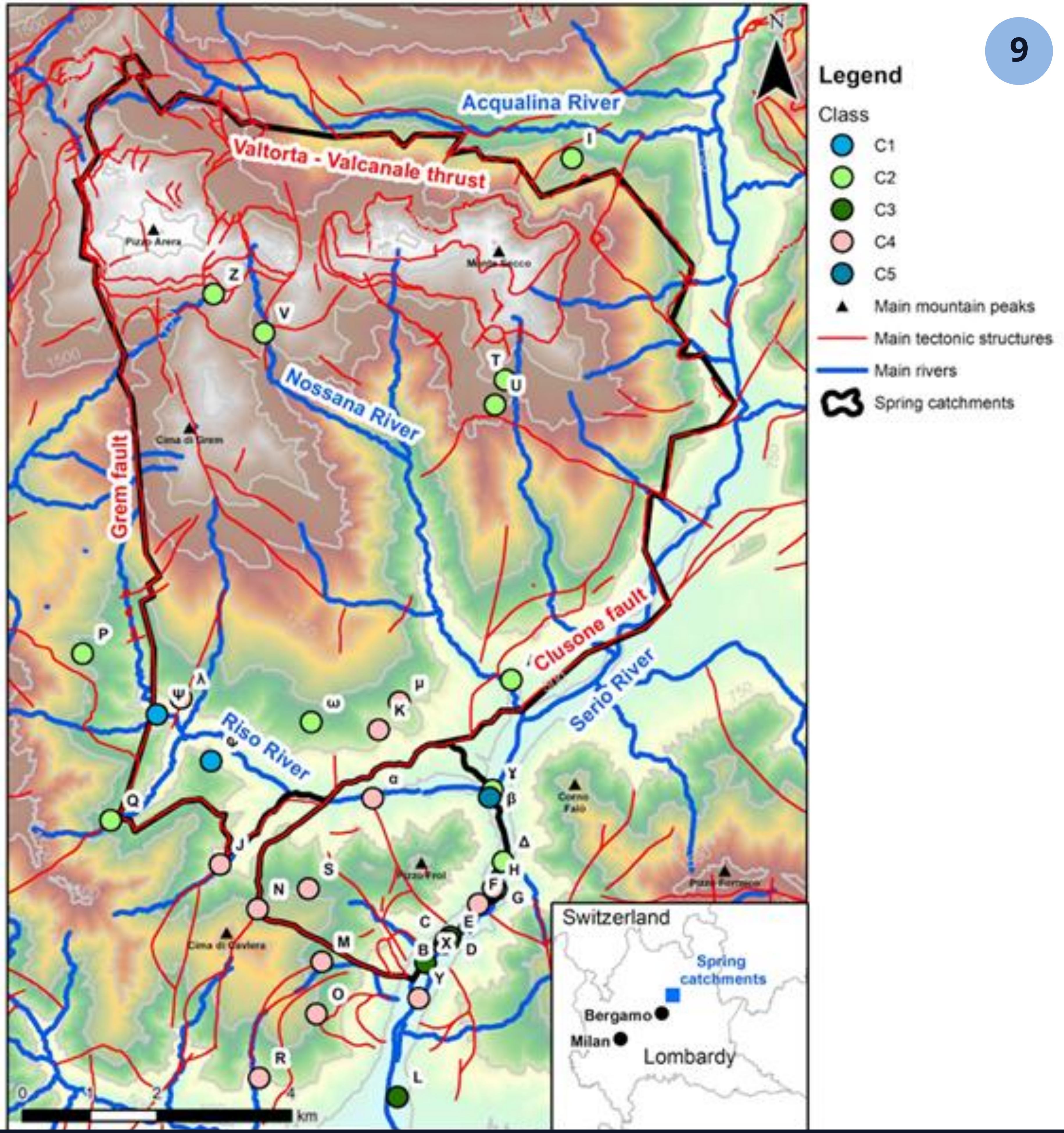




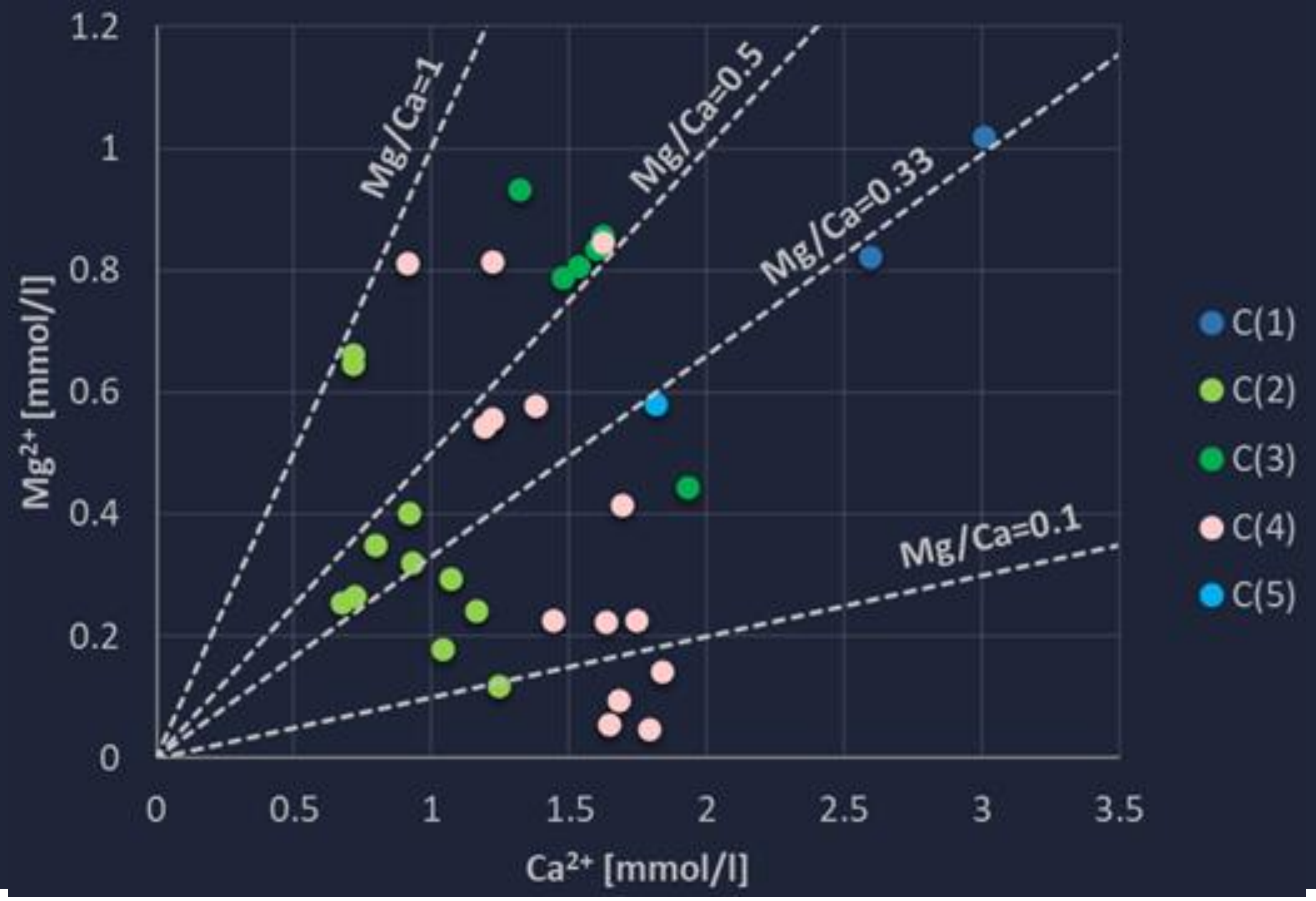
Hierarchical clustering analysis

	T	pH	pCO_2	Alkalinity	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	Cl^-	NO_3^-	SO_4^{2-}
	[°C]		log(atm)	CaCO3 [mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]
C(1)	9.2	8.0	-2.1	120.8	114.2	22.4	3.3	1.0	146.3	3.3	2.5	253.8
C(2)	7.9	8.0	-2.5	116.7	37.0	8.3	1.8	1.1	140.5	3.2	4.1	5.8
C(3)	11.0	7.5	-1.9	207.5	64.4	18.9	3.6	1.0	251.7	7.0	5.0	35.5
C(4)	10.2	7.8	-2.0	171.3	61.2	9.7	2.3	0.8	207.1	3.5	5.5	10.1
C(5)	15.2	8.6	-3.2	142.0	73.9	14.1	116.2	98.2	165.7	249.2	5.7	63.0



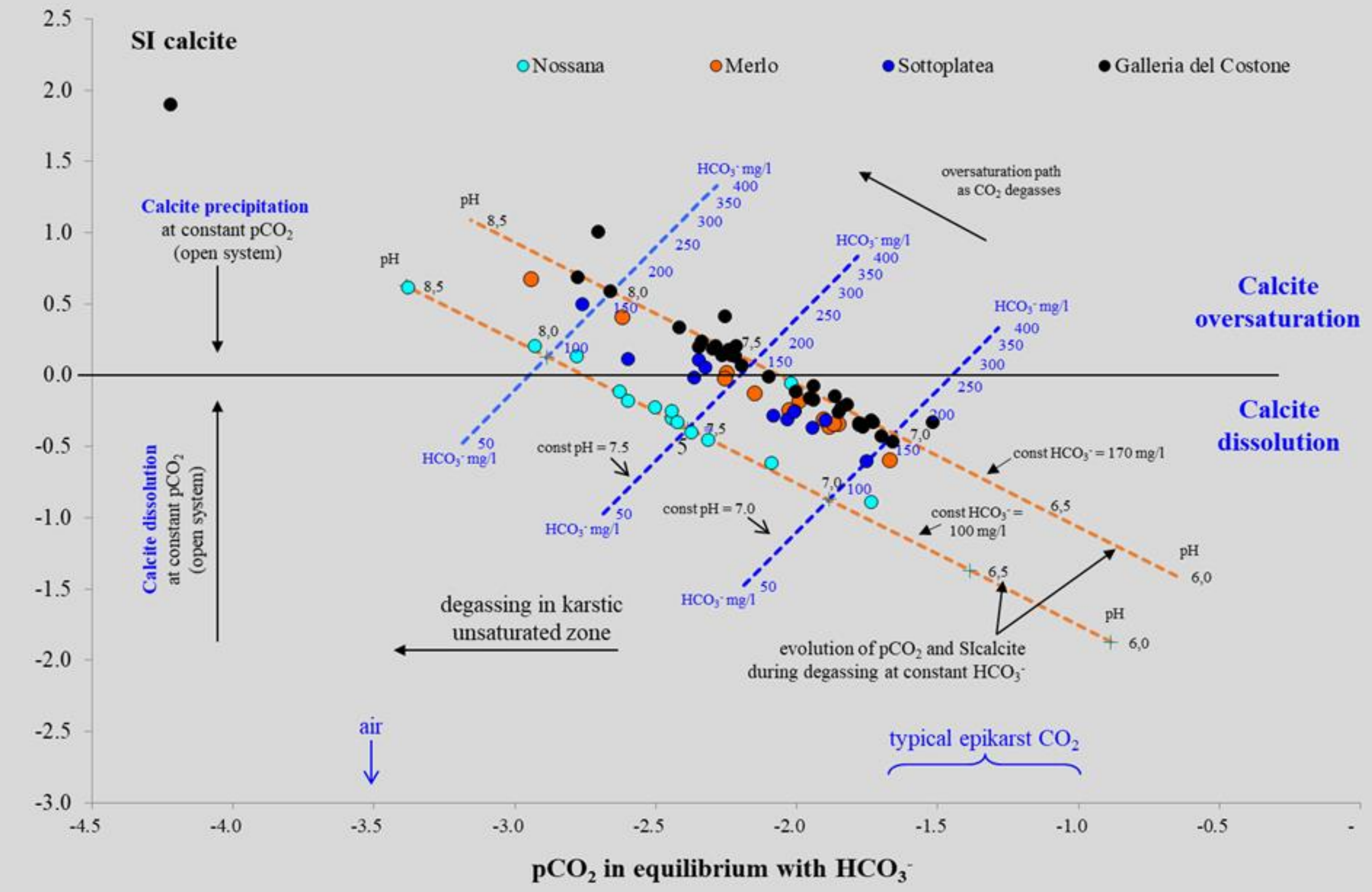


Hydrochemical features



Mg^{2+}/Ca^{2+} graph

- **58%** of the values lie below the **Mg/Ca = 0.5 line**
- **Dissolution dominated by calcite**
- Mean value = 0.38, ranging from 0.03 to 0.93



- The relationship between the partial pressure of CO_2 and the calcite saturation index.
- The pH variation keeping constant the bicarbonate ion content (orange lines)
- The bicarbonate ion variation keeping constant the pH value (blue lines)

→ **Nossana and Ponte del Costone** are characterized by **two different families** of water in terms of **bicarbonate contents**

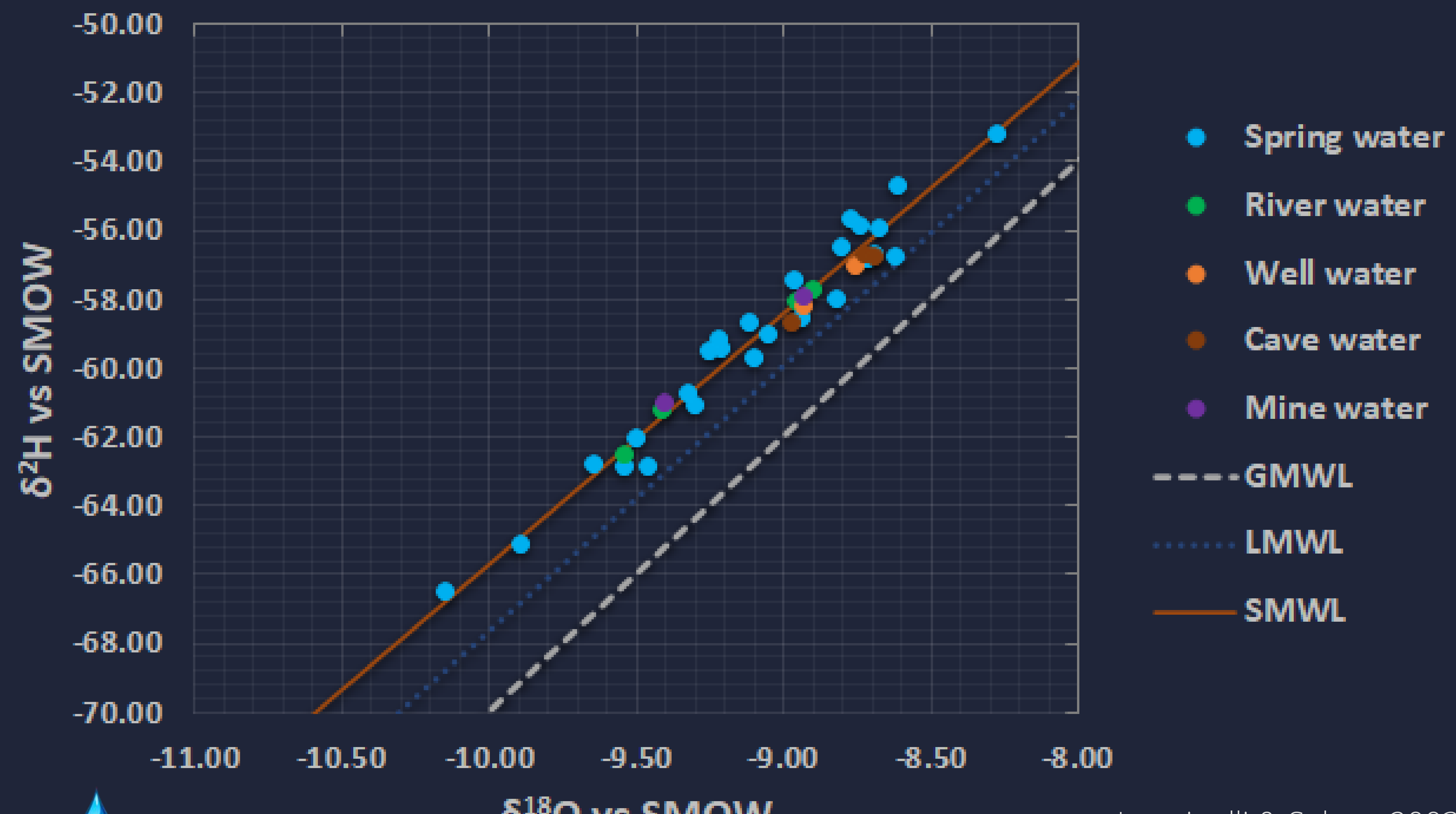
Isotopic features

		δ18O vs SMOW	δ2Hvs SMOW	δ13C vs PDB
Type of water	n°	Range	Range	Range
Spring	23	-10.15 to -8.27	-66.54 to -53.22	-13.56 to -4.49
River	4	-9.54 to -8.90	-62.54 to -57.74	-8.59 to -5.14
Well	2	-8.93 to -8.75	-58.22 to -57.07	-7.36 to -0.34
Cave	3	-8.97 to -8.69	-58.67 to -56.70	-8.91 to -4.40
Mine	2	-9.40 to -8.93	-61.02 to -57.97	-2.11 to -0.79

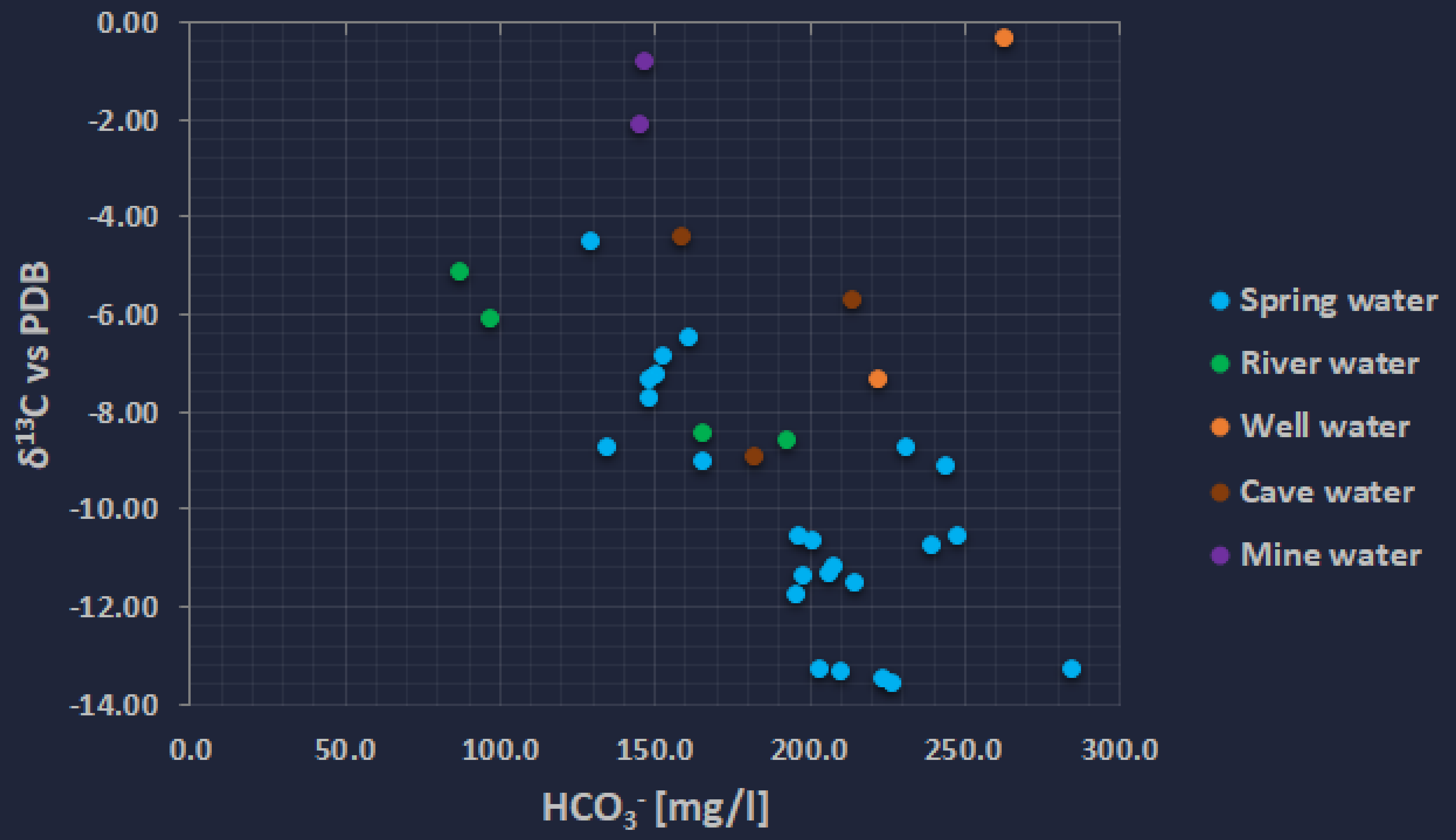
- Study area Meteoric Water Line:

$$\delta\,^{2}H = 7.71\delta^{18}O + 9.40$$

- **Deuterium enrichment** given by re-evaporation due to effect of secondary valleys (Riso Valley)
- **^{13}C** suggests an **isotopic composition** of spring waters attributable to **different contributions**

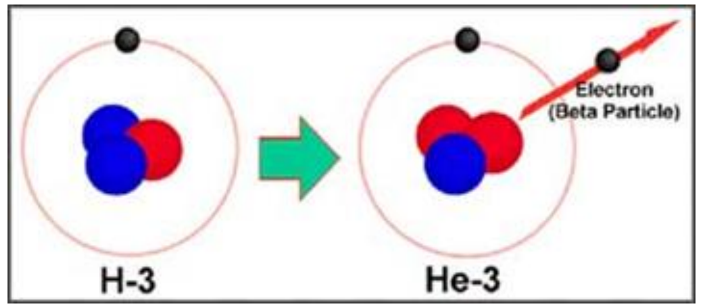


Longinelli & Selmo, 2003



Residence time estimation

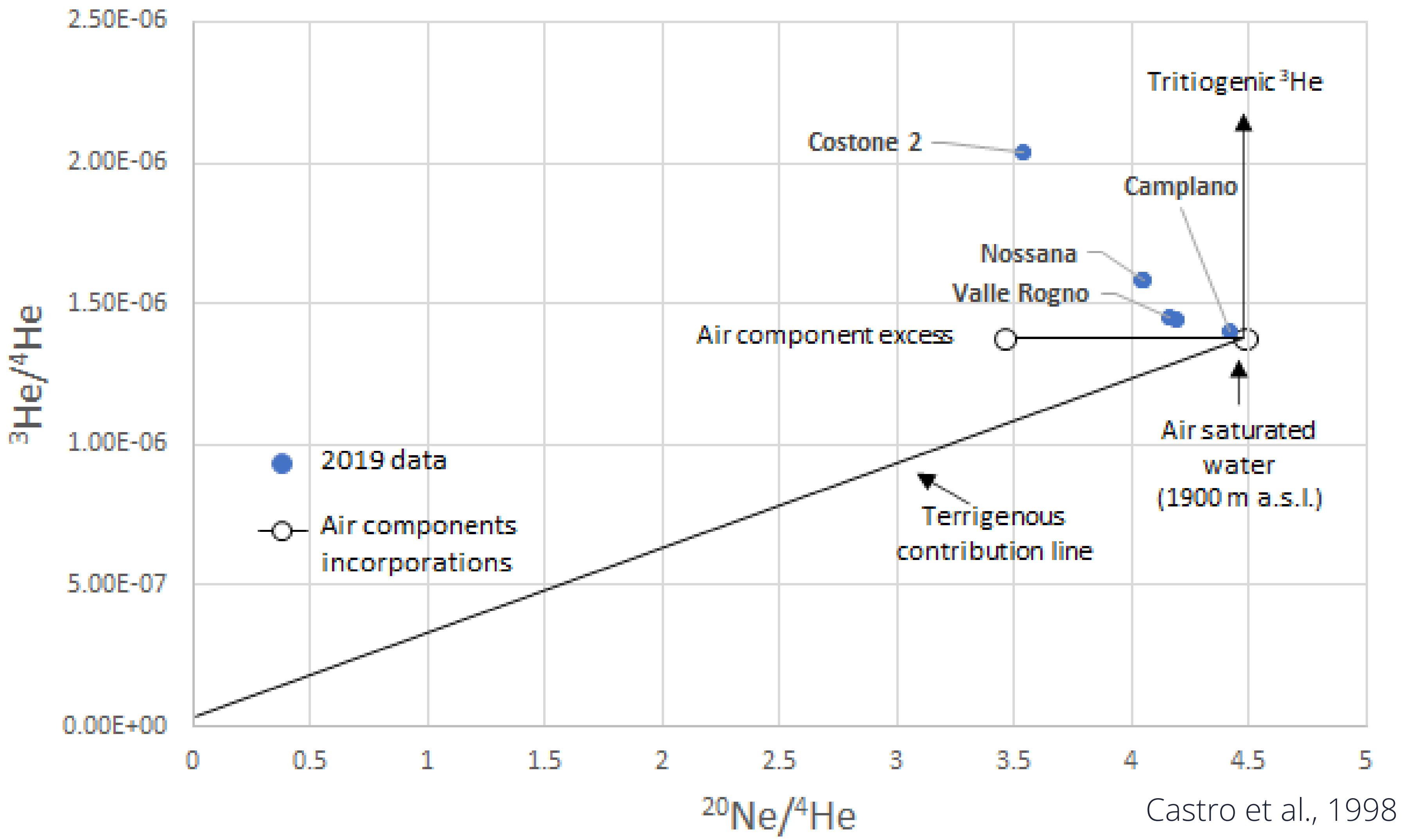
	Sampling 2015		Sampling 2019	
Spring name	Age (years)	Recharge year	Age (years)	Recharge year
Camplano	1.50	2014	0.96	2018
Valle Rogno	8.10	2007	5.24	2014
Nossana	7.90	2008	13.10	2006
Costone 2	29.30	1986	32.48	1987



$$t[years] = \frac{1}{\lambda} ln\left(\frac{^3He_{tritiogenic}}{^3H} + 1\right)$$

λ = 0.056/years

- **10 years for Nossana, 30 years for Ponte del Costone**
- For the main springs **cyclical renewal** of the resource is **not clear**
- The results can be explained as an effect of the incorporation of air components (**turbulent flow**, typical in karst phenomena) and the decay of ^3H into ^3He.



Castro et al., 1998

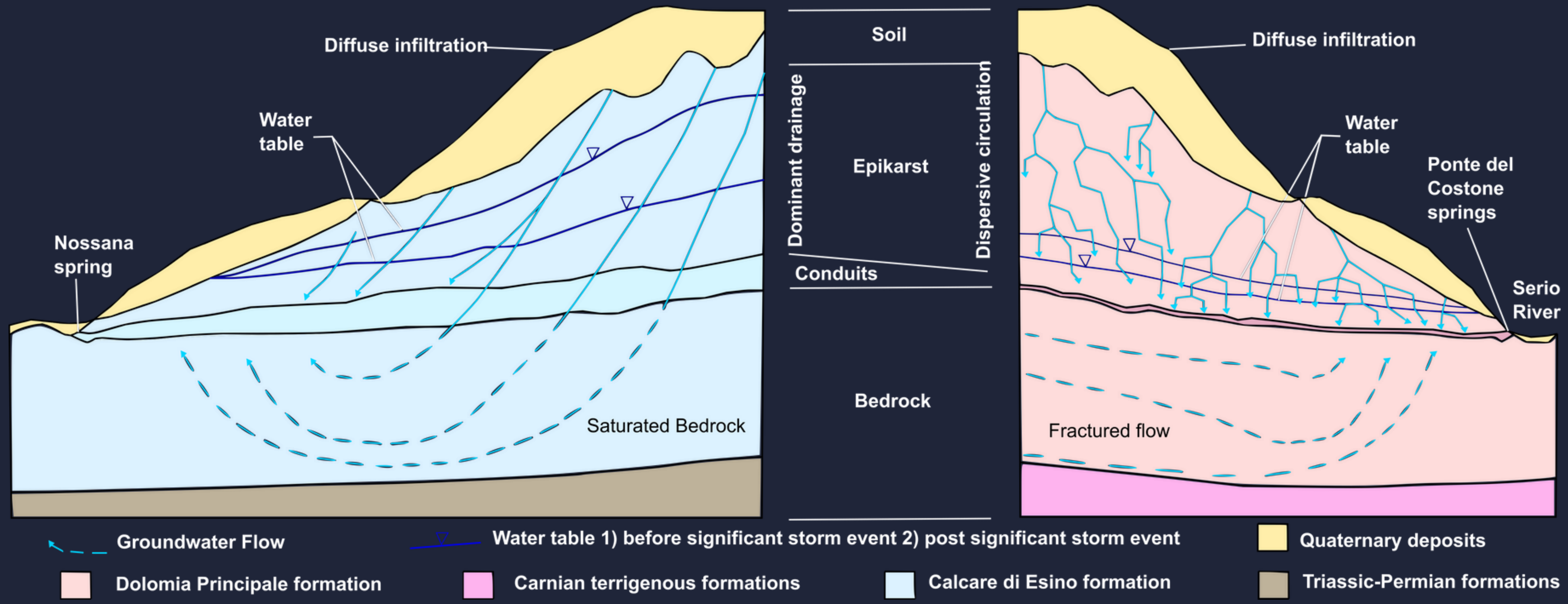
Concluding remarks

- The chemical composition of the waters reflects the carbonate context and is completely controlled by the **spatial distribution** of the different geological formations, by the **different degree of susceptibility to karst dissolution** of the rocks that characterize the study area, and by the **altitude**.

- It was estimated the age of the reserve (or **residence time**) for **Nossana** of about **10 years**, while for the **Ponte del Costone** springs of about **30 years**
- For these main springs, **the cyclical renewal of the resource is not evident;** rather, the water reserve ages in the 2015 - 2018 comparison.

Nossana and Ponte del Costone can be simplified with **hierarchical models** (Asante et al., 2018, White, 2002):

- Piston effect controlled by the amount of precipitation
- Diffuse infiltration in very different timing due to the different response to karst dissolution of the encasing rocks



modified from Asante et al. (2018) and re-elaborated from White (2002)

Thank you for attention

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