Water-sediment interaction in the Arno- and Tiber river catchments (central Italy)

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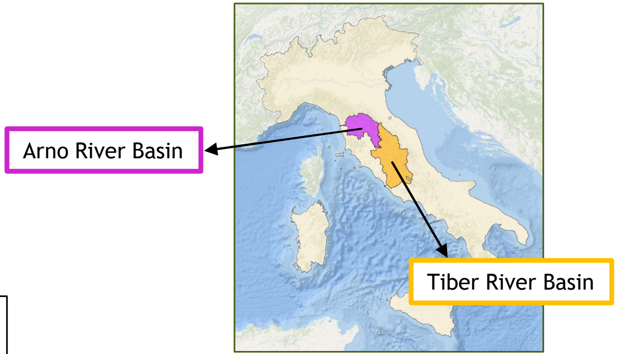
The Arno River Basin



Arno River Catchment

- Size: 8,228 km²
- Fully located within the region of Tuscany (central Italy)
- Second most important river system in central Italy, after it's **neighboring Tiber river catchment**

Arno River

- 242 km long
- Source: Monte Falterona (1,385 m)
- Mouth: Tyrrhenian Sea at Marina di Pisa

Geological Setting

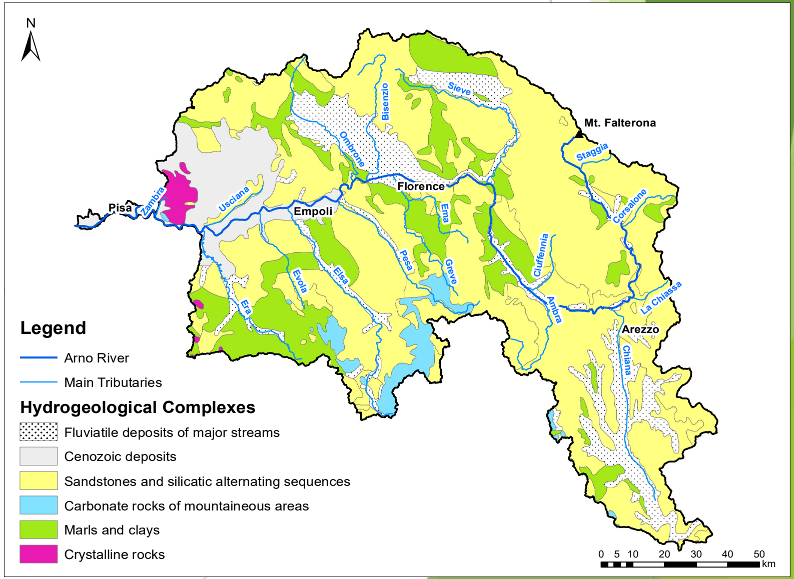
- Dominated by sedimentary rocks → sandstones, marls, clays
- Ophiolitic blocks interbedded in the central and southern parts of the basin
- Limestones, gypsum-anhydrite in southern parts
- Metamorphic rocks in the Monti Pisani area (in the eastern part)

Tiber River Catchment

- Largest basin in central Italy
- It corresponds almost to 1/20th of the Italian territory.
- Size: 17,375 km²

Tiber River

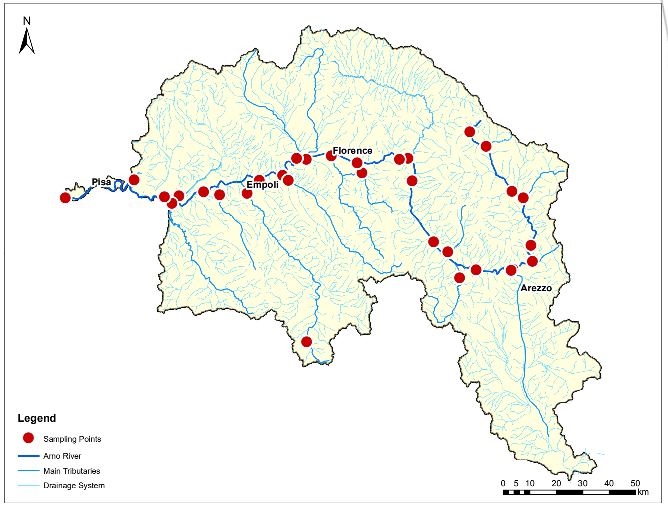
- 405 km long
- Source: Mt. Fumaiolo, 1,278 m
- Mouth: Tyrrhenian Sea near the city of Rome



Sampling methods

- Samples collected in August 2019
- 33 stream sediment samples: 16 from the Arno river, 17 from its main tributaries (taken close to the confluence with the Arno river)
- Representative sample → sediment taken from several places along the river bank (a)

Sampling points of the Arno River Basin



- Used tools: stainless steel hollow-core sampler (b), plastic showel (c)

Analytical Methods

Sample preparation

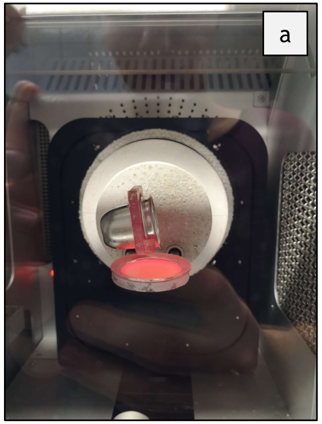
- Drying
- Sieving (0.18mm sieve)
- Milling
- → Powder Sample

XRF-Analysis

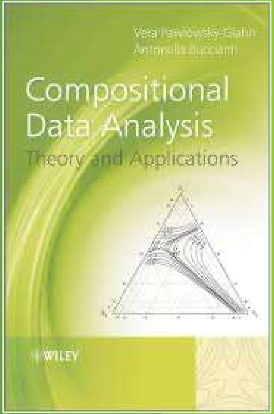
- Powder sample burned in muffle oven at 1050°C for 2h
- LOI determination
- Production of glass beads in a melting oven at 1050°C (use of 1g burned sample + 8g Lithiumtetraborat) (a)
- Analysis of those glass beads (carried out at Montanuniversität Leoben, laboratory of the Chair of Geology and Economic Geology)

Magnetic Susceptibility

- 10g of Powder Sample in plastic cylinder (b)
- Measurement of mass specific susceptibility (carried out at Montanuniversität Leoben, Paleomagnetic Laboratory of the Institute for Geophysics) (c, d)



Statistical methods



Compositional Data theory

- Compositional data are by definition **parts of some given numerical total** which only carry relative information between them (Aitchison, 1986).
- They are known in geology as closed data since, frequently, they sum to a known total typically 100 for percentage data or 10^6 for ppm. They cannot range from $-\infty$ to $+\infty$, since they are always positive and not free to vary independently and they have important mathematical properties extensively discussed by many authors.
- **Geochemical data of stream sediments are compositional data**, thus they need to be analysed in the framework of the Compositional Data Analysis (CoDA) by using data transformations-> e.g. centred log ratio transformation (clr)

Centred log ratio transformation (clr):

$$\mathrm{clr}(x) = \left(\ln \frac{x_i}{g(x)}\right)_{i=1,\dots,D} \quad \text{with} \quad g(x) = \sqrt[D]{x_1 \cdot x_2 \cdots x_D}$$

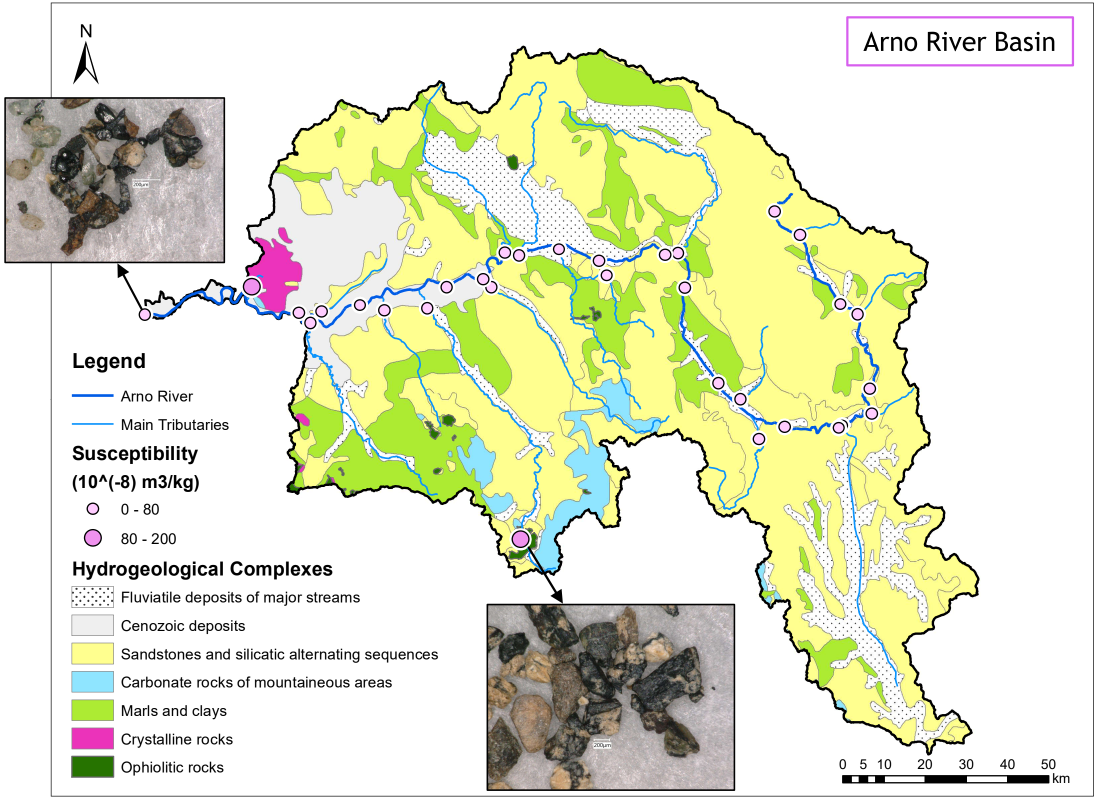
This transformation is obtained dividing each component x_i by the geometric mean g(x) of all the considered parts (in this case chemical elements).

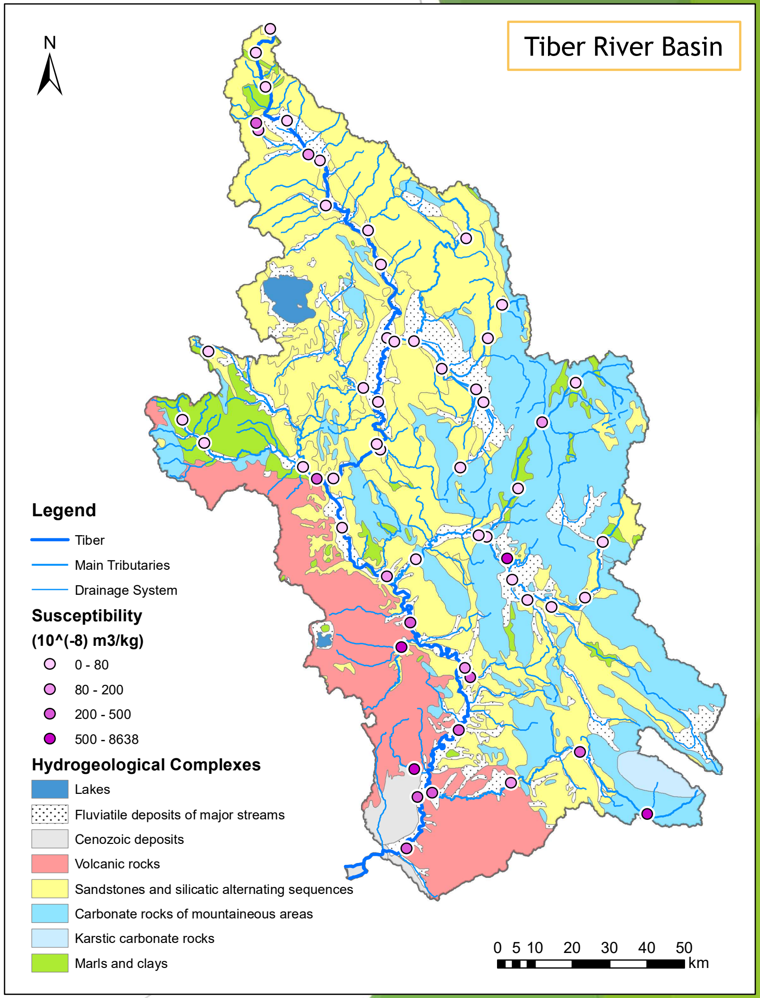
Correlation analysis and clr variance

- A correlation analysis for compositional data based on the non-parametric Spearman correlation coefficient was performed in R for the stream sediment data of both catchments according to method developed by Kynčlová et al. (2017).
- The results are visualised by means of the so-called "heatmap", in which chemical variables are rearranged according to their similarity using a hierarchical cluster analysis.
- The clr variance was calculated using the software CaDaPack by producing a compositional statistics summary related to logratios, which also includes the Variation Array and Total Variance.

Results: Susceptibility

Comparison of the Susceptibility of the Arno & Tiber River Basins including selected pictures of the magnetic fraction.



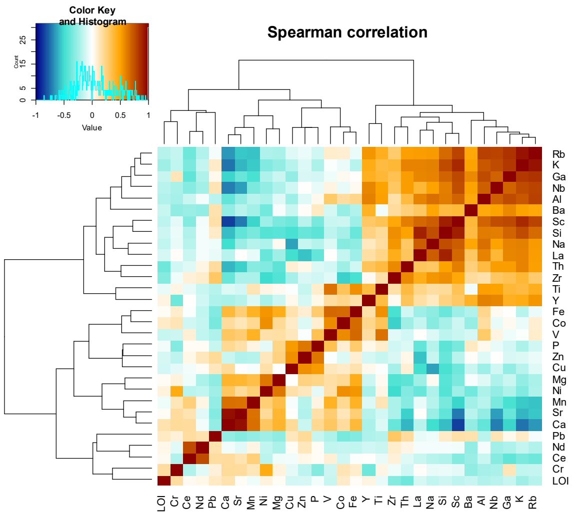


Data source: Gozzi (2020)

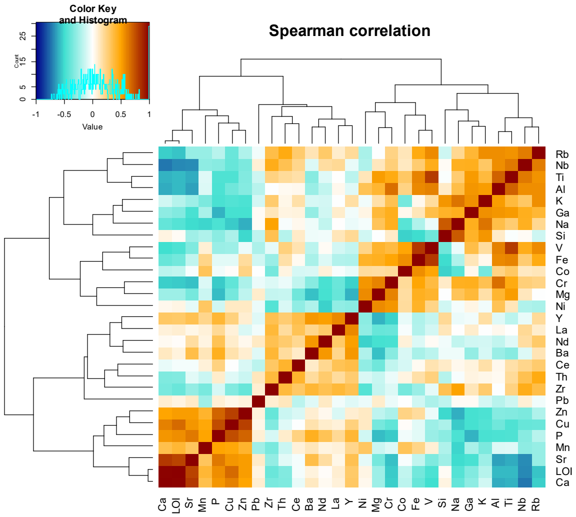
Results: heatmaps and clr variability

- Comparison of the Plotmatrices for the Arno & Tiber River Basins

Arno River Basin



Tiber River Basin



Data source: Gozzi (2020)

The Tiber river catchment shows more elemental associations compared to the Arno river, which has only two major groups
→ Effect of **higher geological homogeneity** of the Arno River Basin

Comparison of clr variance

Elem.	clr variance Arno River Basin (%)	clr variance Tiber River Basin (%)
Si	0.84	0.99
Ti	0.24	0.45
Al	0.21	0.44
Fe	0.40	0.88
Mn	3.05	1.93
Mg	1.08	2.29
Ca	13.75	11.73
Na	11.03	30.66
K	1.00	0.71
P	1.92	1.95
Cu	9.22	1.48
Ce	4.36	1.01
Nb	1.21	1.64
Zr	1.29	1.00
Y	0.90	0.35
Sr	6.90	4.36
Rb	1.36	0.98
Th	1.96	1.96
Pb	9.40	6.23
Ga	5.14	1.09
Zn	2.44	1.57
Ni	2.06	3.97
Co	3.77	3.17
V	0.32	0.75
La	0.28	1.49
Ba	2.02	2.55
Sc	2.69	1.93
Cr	4.90	8.02
Cs	0.28	0.82
Hf	3.37	0.97
Nd	2.61	2.63

Similarly high Ca variability for both catchments

High variability for Na in Tiber River Basin

Chiana valley: Anthropogenic influence (agriculture) causes elevated Cu concentrations

Pb variablity is important in both basins (Anthropic influence?)

Higher Cr variability in Tiber catchment
→ weathering of ophiolitic outcrops

Conclusions

•The mineralogical and geochemical composition of the stream sediments is related to the corresponding lithological composition of the hydrological catchment and to physical weathering within the river basins

•In general, the stream sediment data of the Tiber River Basin show a higher clr variability than those of the Arno River Basin, which is a result of a more homogenous geological setting of the Arno River Basin. When comparing the clr variances for both basins, significant differences (e.g. Na, Cu) and similarities (e.g. Ca) can be seen

•Locally, anthropogenic processes overprint the natural signature → magnetic properties of the sediments provide effective data to map those areas:

→ The range of susceptibility for the Arno river catchment is rather low compared to the Tiber river → more heterogeneity in Tiber river catchment

Future developments

•The application of multivariate robust statistical techniques on the combined dataset (river waters and stream sediments) to evaluate the water-sediment interaction and their spatial properties in central Italy.

References

- Aitchison, J., 1986. The Statistical Analysis of Compositional Data. Chapman and Hall, London, 416pp
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- Kynčlová, P., Hron, K., Filzmoser, P., 2017. Correlation between compositional parts based on symmetric balances. Mathematical Geosciences 49, 777–796.