Antecipa *Ciclo de Webinars*
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Água mole em pedra dura. A água e os materiais pétreos

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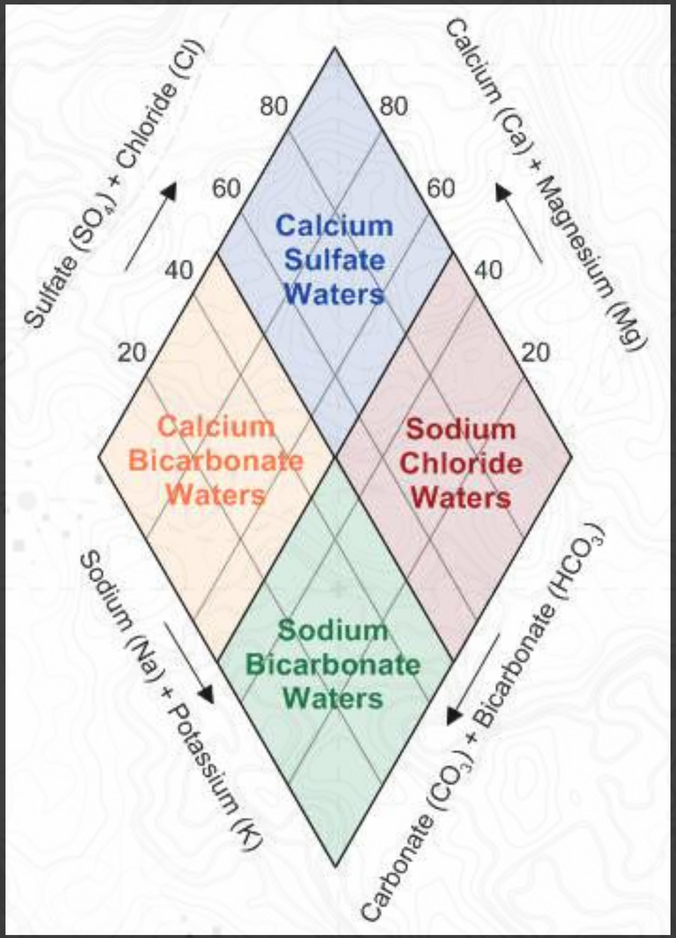
The waters and their physical and chemical characteristics

The chemical-physical characteristics of water depend on meteorological factors and, in the case of source water, on the lithologies on which it flows

Granites: Sodium Chloride waters
Rhyolites: Sodium Chloride waters
Evaporites: Calcium Sulphate and Sodium Chloride
Limestones and marbles: Calcium-Carbonate waters
Soils: Sodium Bicarbonate waters
Dolomites: Magnesium Carbonate waters

Physical features of the waters

pH
Total dissolved solids (mg/l)
Conductibility (µS/cm)
Density (kg/m^3)
Hardness (French hardness degrees)
Temperature (°C, K)



Piper diagram for water hydrogeochemical classification

Natural sources of water

Underground waters:

Circulating waters of deep or superficial aquifers. These are moderately saline waters often with TDS greater than 500mg/l. Their chemism reflects the lithology of the substrate and eventual ingressions of seawater. The pH is variable. Aquifer drinking water must have a $6.5<pH<9.5$

Seawater:

According to the basin, seawater has a variable TDS. In Mediterranean sea the total dissolved solids is $36<TDS<39$g/l. The hydrogeochemical *facies* is Sodium Chloride. The pH is variable between 7.5 and 8.5 even if seawater is often basic

Rainwater:

Precipitation water generally has a $2<TDS<20$ mg/l with values up to 130mg/l. The chemism varies from sodium chloride to calcium sulphate and depends on the wind in charge or on the atmospheric particles. pH is variable, normally slight acid $5<pH<6.2$. Alkaline rainwaters can have a $8<pH<11$.

Interaction between water and stone

Within the stone, the water circulates essentially in three ways:

1) Porosity

Is the most complicated and common way for water circulation. It depends on open porosity, pore tortuosity, pores radius etc

2) Fracturing

The circulation of water by fracturing involved a lot of rocks typology, mainly siliceous. The amount of transported water and the circulation speed by fracturing modality are relatively high

3) Karst

The circulation of water by karst is typical of limestone rocks. The amount of transported water and the circulation speed by Karst modality are very high

Interaction between water and stone

Water-rock interaction does not occur only in large-scale natural environments. This process is also important in architecture where stone is utilised as building material

Water comes into contact with a building through the following ways:

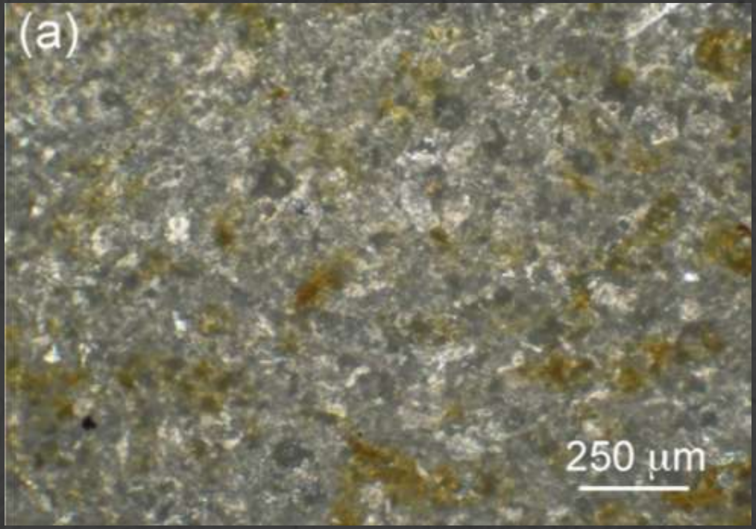
1) Rainwater runoff
2) Capillary rising
3) Moisture and humidity
4) Residual from the moment of building construction
5) Extreme condition: flooding
6) Accidentals
7) Others

Capillary rising by foundations: The case study of *San Saturno* Basilica (Italy)

Realised by local biomicrite ashlars, *San Saturno* church is an example of Romanesque-style architecture in Sardinia (Italy)

The church is built on Miocene sediments which have a natural non-artesian aquifer. The depth of the water aquifer at the point of construction varies from 1 to 3 meters.

During the winter, the water table increases its level, flooding the crypt of the church. The water flows through the foundations made of biomicrite reaching the walls of the inhabited area



Thin-section of the biomicrite

Efflorescences on the walls (elevation 13cm)

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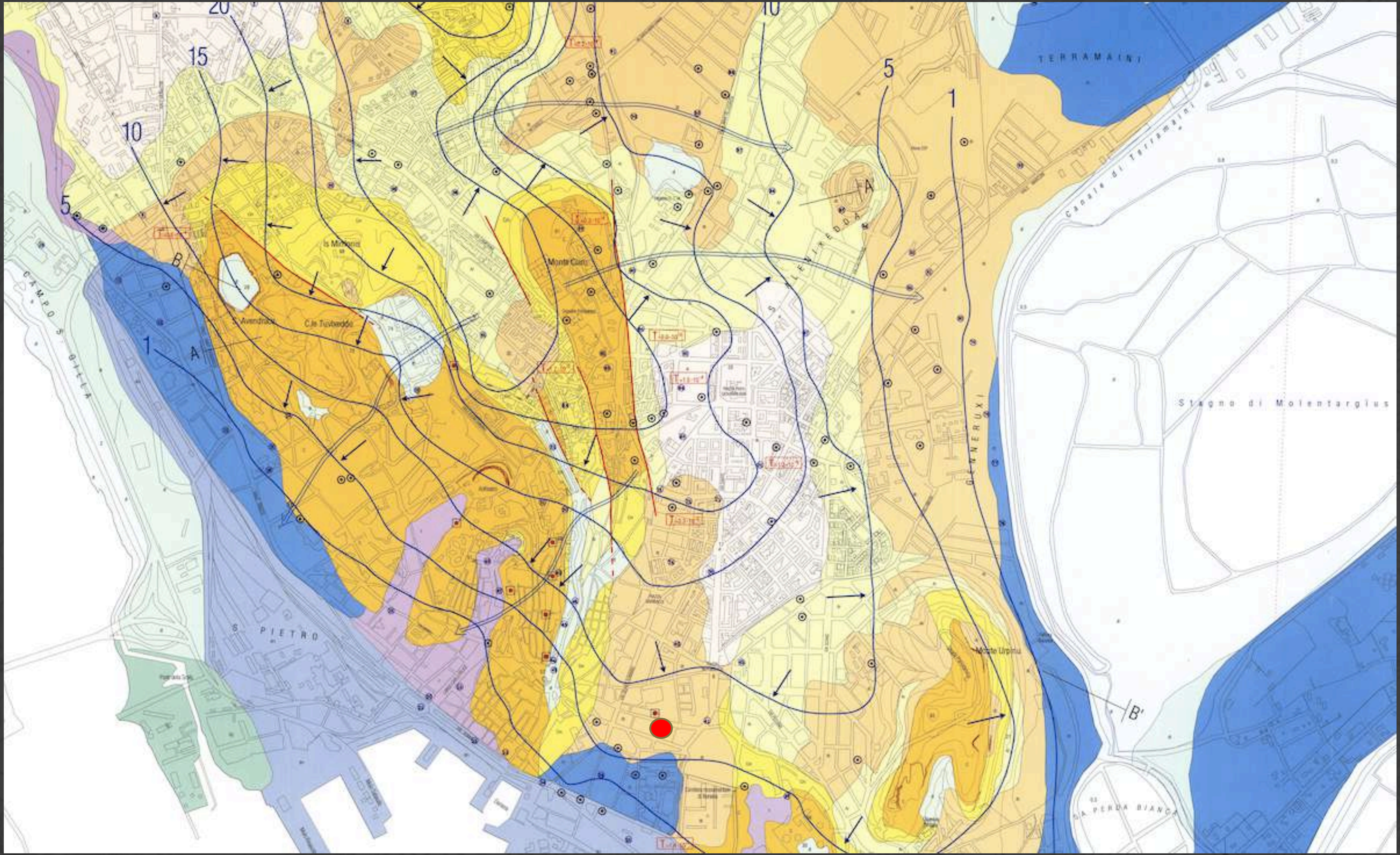
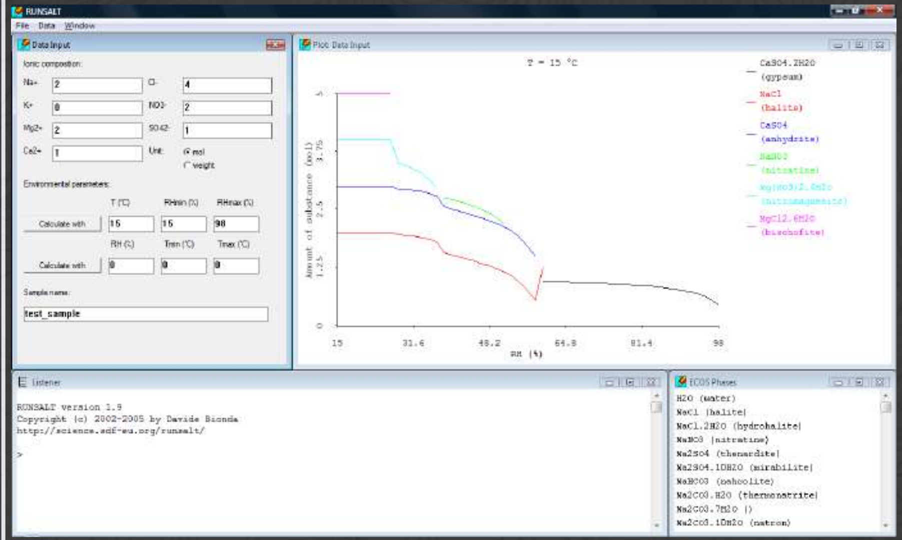


Carta idrogeologica di Cagliari, (Pala et. al 1997)

Capillary rising: The case study of *San Saturno* Basilica (Italy)

The analysis of groundwater (in the table), associated with the simulation software indicated RUNSLAT that the efflorescences are mainly attributable to mirabilite. XRD analysis confirm the prevision of the software.



Collected water	TDS (mg/l)	Temperature (°C)	pH	Conductivity (μS/cm)	Mg^{+2} (mg/l)	Na^{+} (mg/l)	K^{+} (mg/l)	Ca^{2+} (mg/l)	Cl^{-} (mg/l)	SO_4^{-2} (mg/l)	HCO_3^{-} (mg/l)
Ground water (C_{GW})	491	13.0	8.1	980	12	68	9	28	174	35	104

The groundwater shows a high presence of Na^{+} and Cl^{-} due to a salinization.

The hydrogeological model confirms the presence of marine ingress in the aquifer due to the overexploitation of groundwater for domestic and industrial purposes.

In addition, infiltrations of wastewater from sewerage system and cesspit are present

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Capillary rising: The case study of *San Saturno* Basilica (Italy)

Physical mechanical-parameter of Biomicrite: The following data have been calculated at Hercules and LEM (Laboratório de ensaio mecânicos)

Total porosity = 27%
Open porosity = 22%
Closed porosity = 5%
Imbibition coefficient = 9%
Saturation index = 84%
Hardness = 240 HDL (Leeb D hardness degrees)
Permeability = 14mD (semi-permeable)
Point Load Strength Index = 1.33MPa
Compressional P waves speed = 2880m/s

Contents lists available at ScienceDirect
Construction and Building Materials
journal homepage: www.elsevier.com/locate/conbuildmat
ELSEVIER

Building pathology and environment: Weathering and decay of stone construction materials subjected to a Csa mediterranean climate laboratory simulation

Fabio Sitzia [a,b,*], Carla Lisci [a,b], José Mirão [a,b]

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Construction and Building Materials
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ELSEVIER

Accelerate ageing on building stone materials by simulating daily, seasonal thermo-hygrometric conditions and solar radiation of Csa Mediterranean climate

Fabio Sitzia [a,b,*], Carla Lisci [a,b], José Mirão [a,b]
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Water Runoff

The runoff of water causes the proliferation of biological activities which act as a noble patina. The presence of higher plants, on the other hand, is harmful.

In correspondence with the water dumps, probably with an inadequate maintenance of the gutters, the wall has a surface runoff

This is causing a series of problems for the masonry which is starting to show erosion cavities. Monitoring on a photogrammetric basis takes place every 5 years to evaluate the erosion degree

Rainwater and its corrosive effect

The rain water is naturally slightly acidic ($5.9 < pH < 6.3$) so it has remarkable dissolutive properties especially against limestones.

The dissolution effect is slow and difficult to observe macroscopically. However it can be identified when the surface of the stone has a polished finish

Corrosion of rainwater is essentially due to 2 main reasons:

1) High capacity of (TDS = 3mg/l) rainwater to dissolve atmospheric carbon dioxide forming carbonic acid. More TDS are present in the water, less is the capacity of CO_2 dissolution

2) Strong leaching capacity towards materials, not only natural stone but also plastic polymers, metals and alloys

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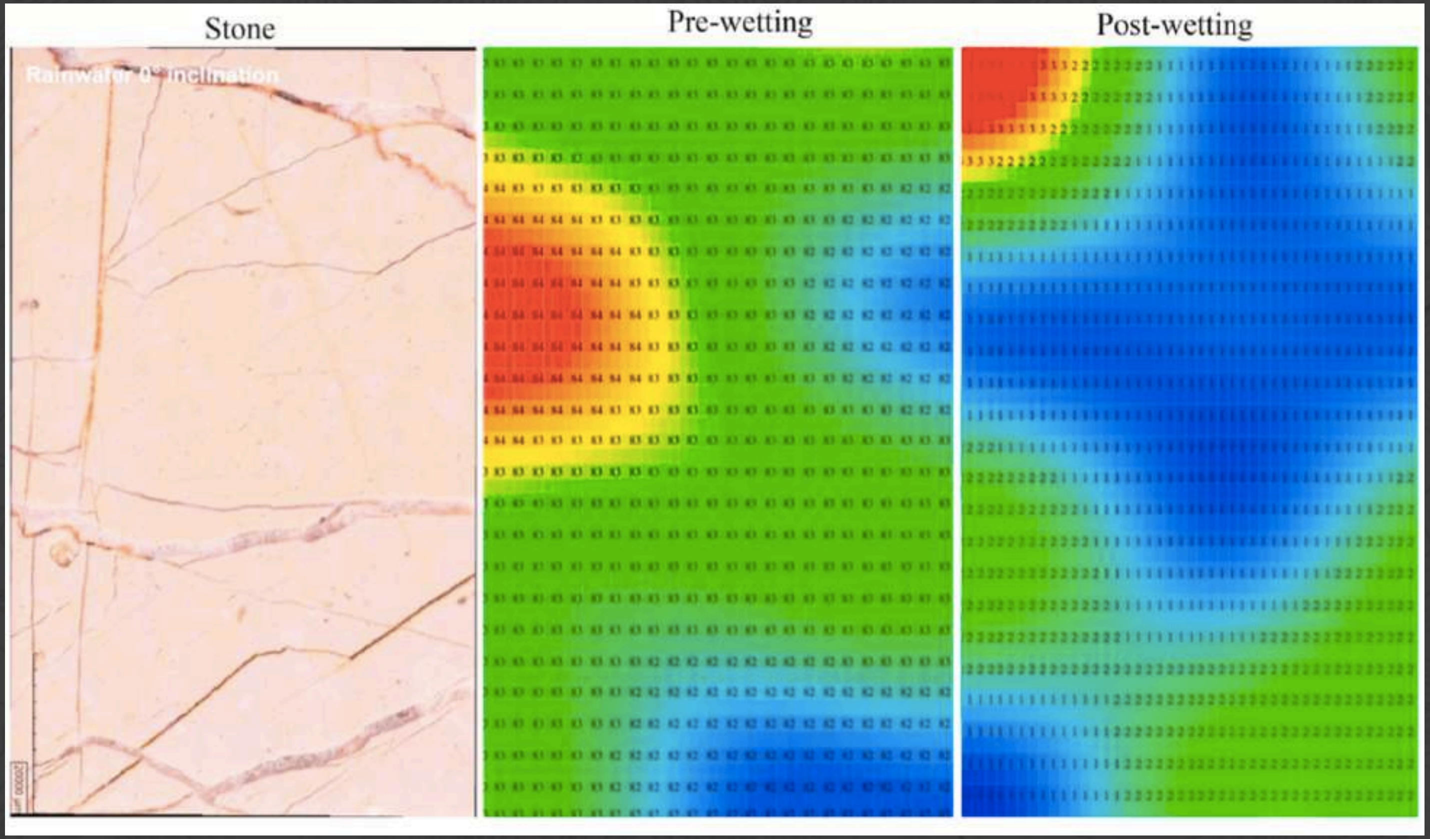
Rainwater and its corrosive effect

The rainwater effect has been reproduced in laboratory (Hercules)
Polished stones were subjected to wetting by manual spraying



After 30 days of spraying the gloss of the stone changes from 82 to 1

More information at:


Contents lists available at ScienceDirect

Journal of Building Engineering

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ELSEVIER

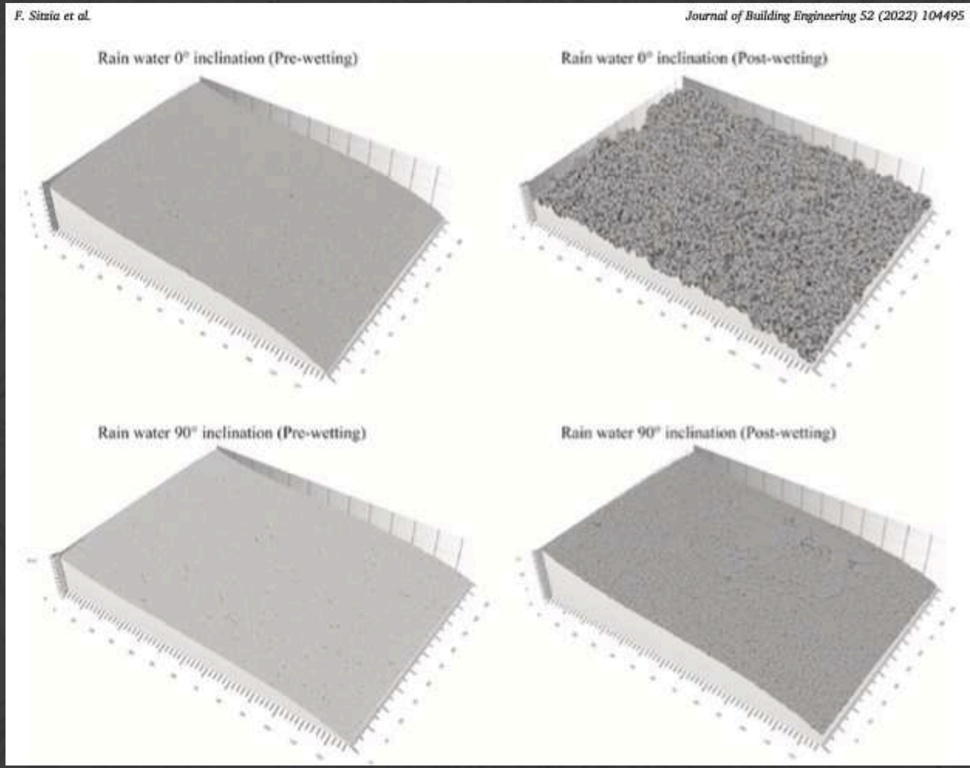
The interaction between rainwater and polished building stones for flooring and cladding - Implications in architecture

Fabio Sitzia [a,b,*], Carla Lisci [a,b], José Mirão [a,b]

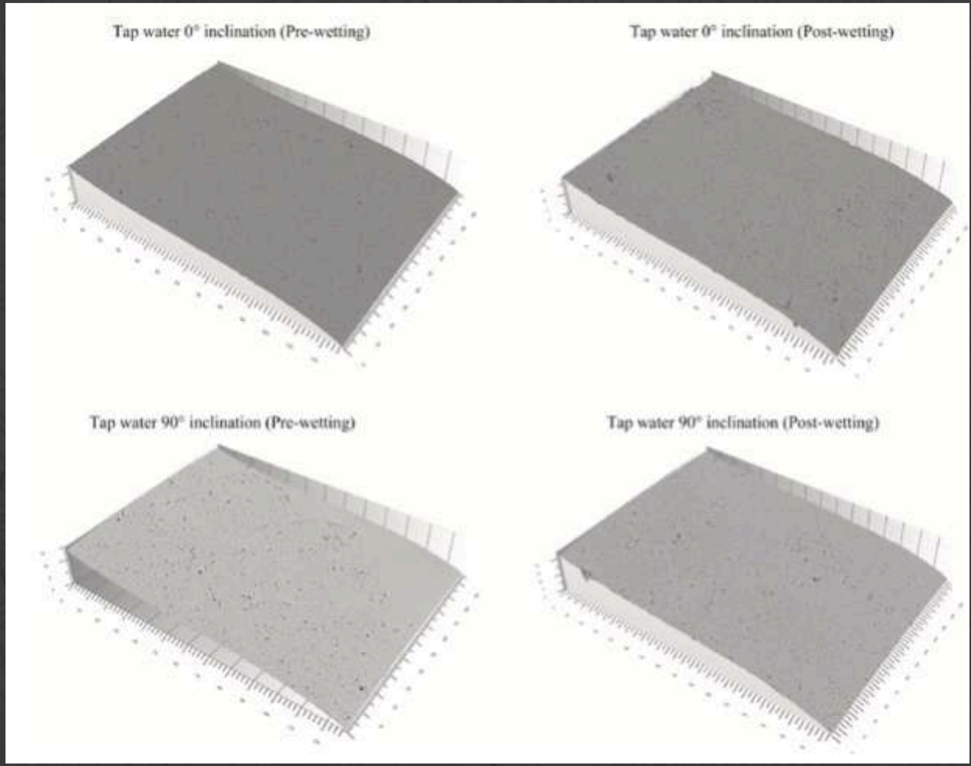
Rainwater and its corrosive effect

Rainwater and tap water were used for the experiments
Experiment was carried out in a controlled environment at 15°C and 60% relative humidity

Rainwater TDS = 3mg/l



Tapwater TDS = 193mg/l



Micro-Photogrammetry by SEM microscope (Hercules Laboratory)

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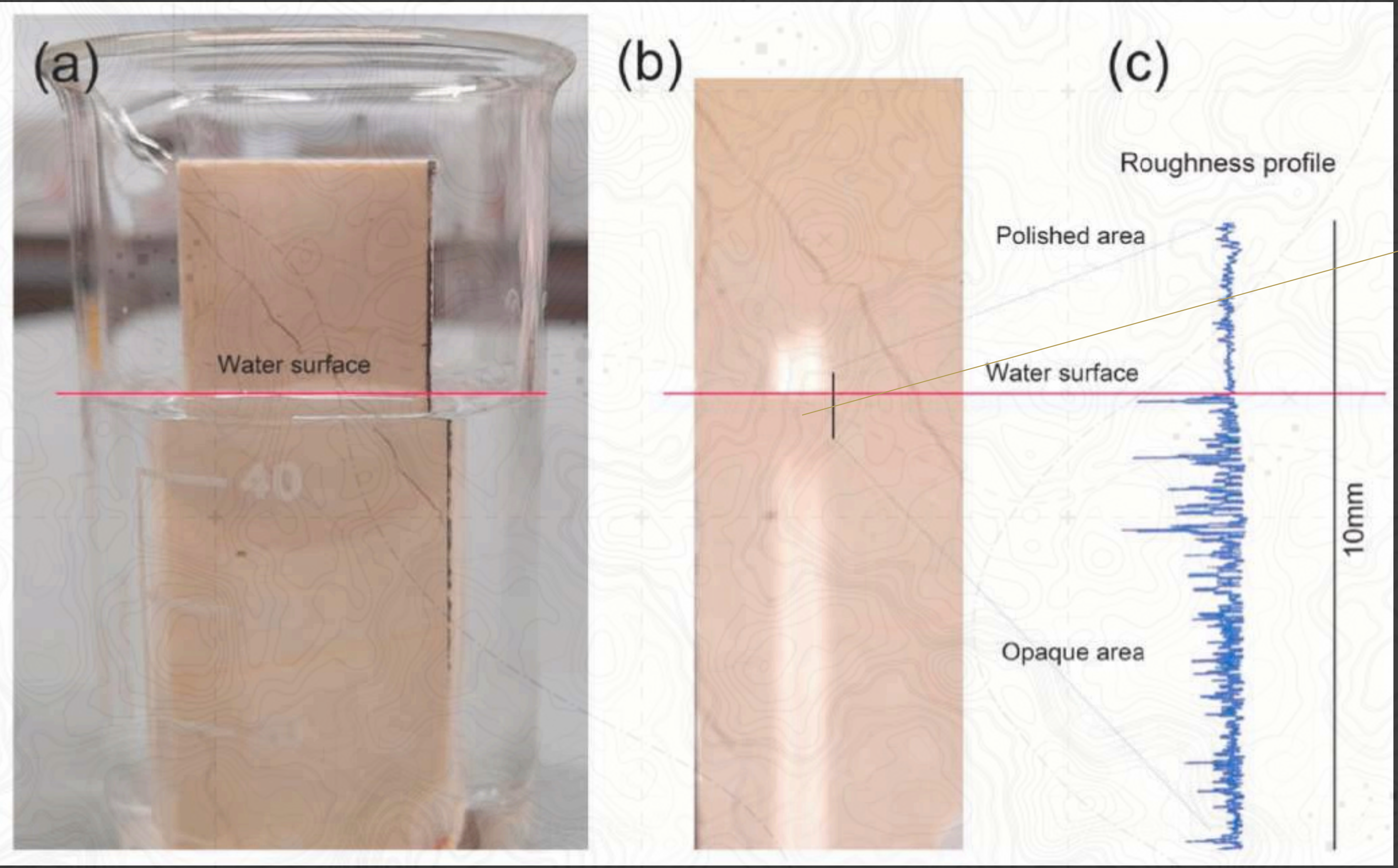
Rainwater and its corrosive effect

Carla Lisci's rainwater experiment



Area of greatest production of carbonic acid H_2CO_3

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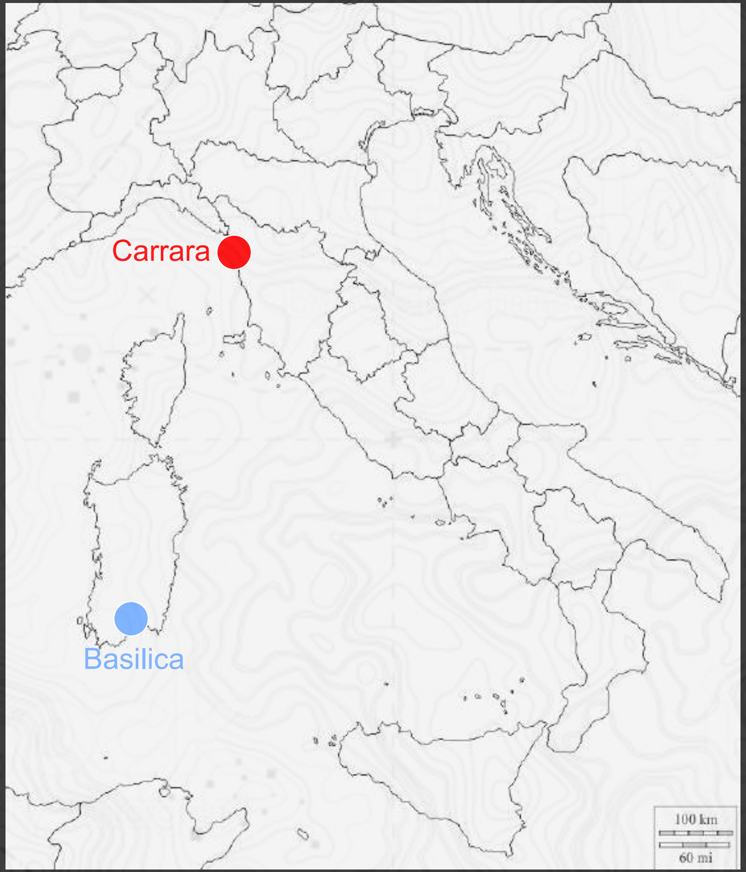
Residual water from the moment of building construction

The colonnade of the San Saturnino Basilica

A marble columns inside the basilica of San Saturnino (XII Cent. AD, Cagliari, Italy) are subject to severe degradation due to granular disintegration: The process is also called CSC or Crystal Sugar Corrosion. Marble has a saccharoid structure that disintegrates by crystalline decohesion



Isotopic analysis show that the column is realised with Carrara marble

The analysis are in still in progress but archaeometric hypothesis say that the column was submerged with seawater at the moment of sea transportation

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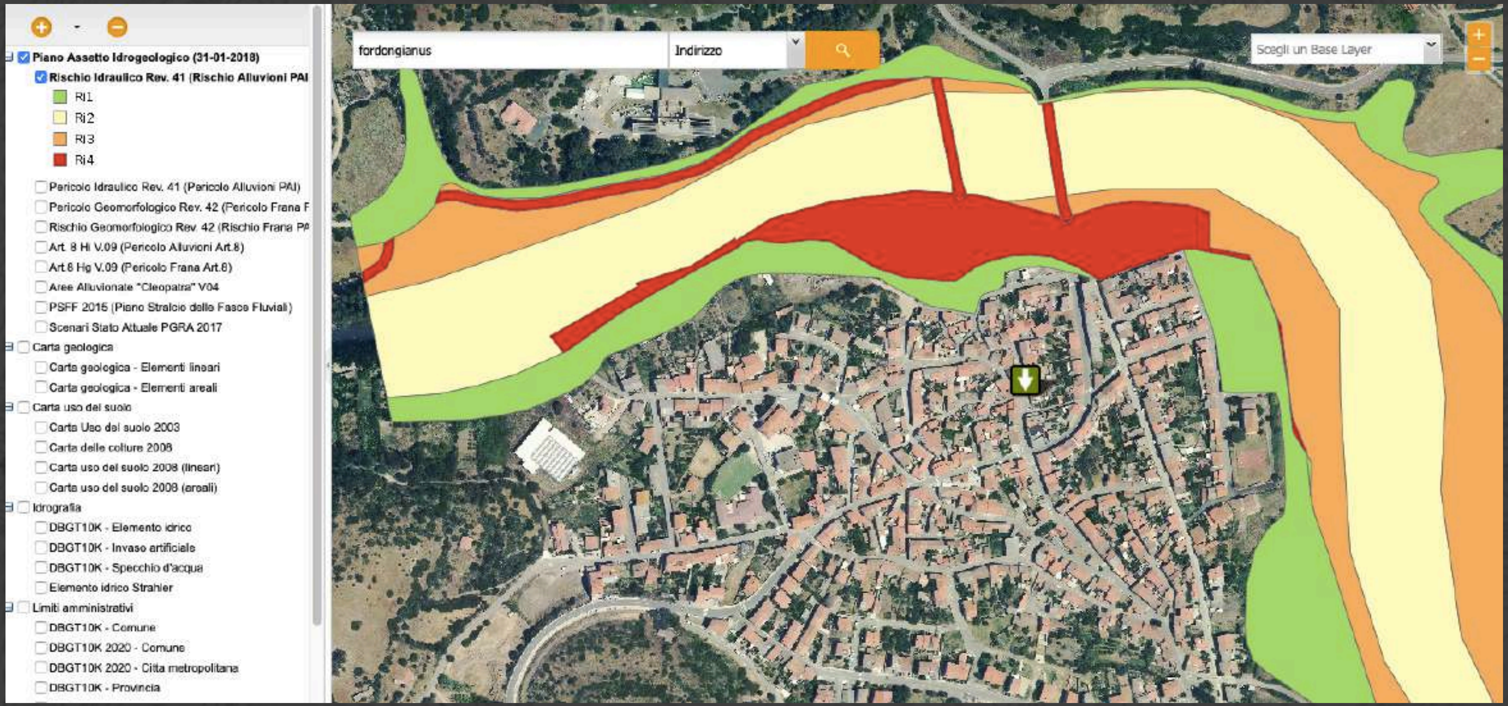
Extreme condition: flooding

The case study of Forum Traiani archaeological settlement

They are infrequent processes which however have a high harmful potential. Flooding event on urban centres have been monitored in the time to create hydrogeological risk maps.

Although flood events have long been known, they have increasingly shorter return times due to the intensification of cloudbursts



Hydraulic risk = Natural hazard x elements under risk x vulnerability

Extreme condition: flooding

Natural hazard:

Class P4: very high danger for return time T = 50 years

Class P3: highly dangerous, for return time T = 200 years, water height of 0.9m and speed of 2 m/s;

Class P2: medium hazard, (T = 200 years) water height <0.9 m, and current speed <2 m/s

Class P1: moderate hazard, in correspondence with flooded areas with T = 500 years.

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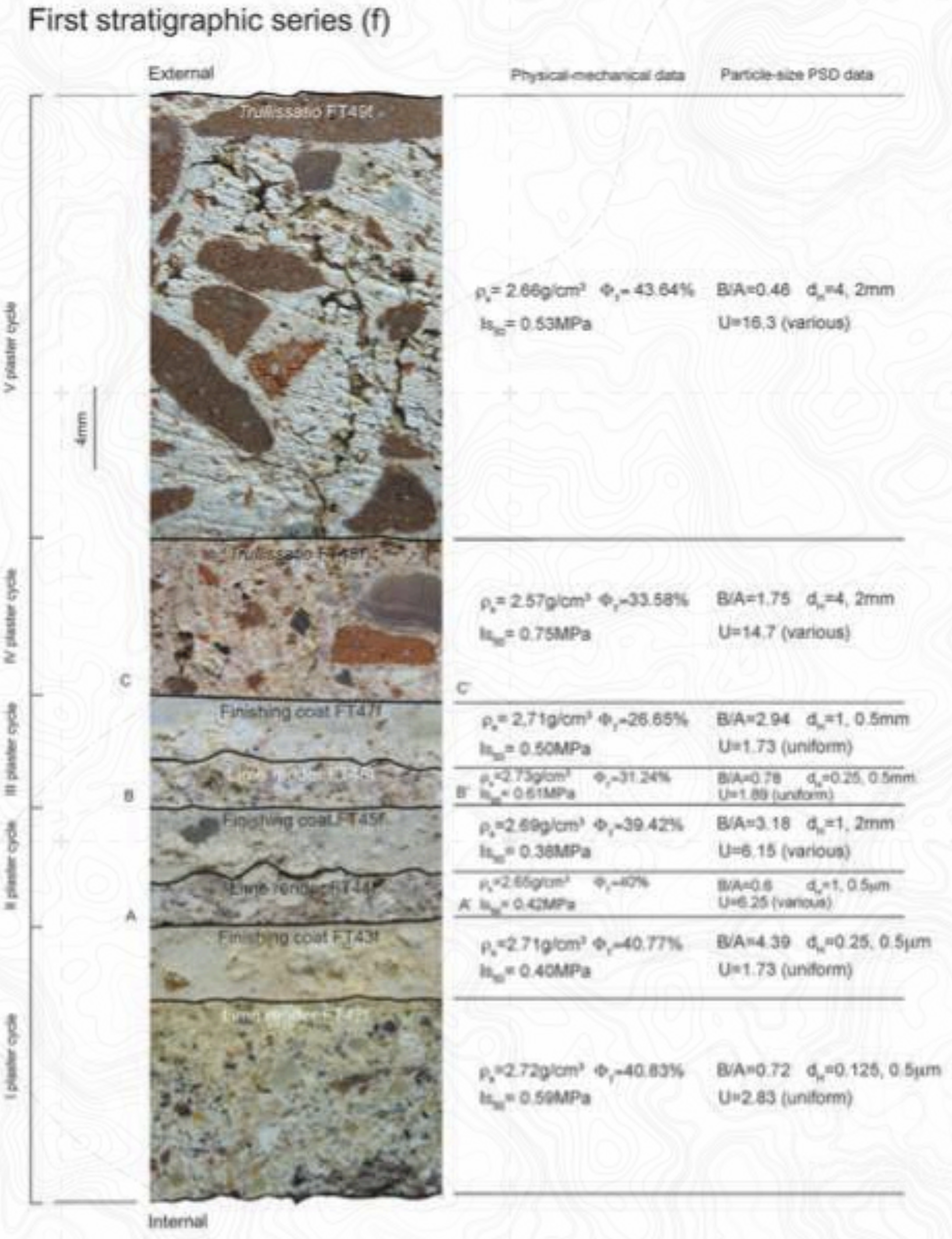
Extreme condition: flooding

Thermal water source

Tirso river



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Extreme condition: flooding

Archaeological and Anthropological Sciences (2020) 12:147
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ORIGINAL PAPER

Ancient restoration and production technologies of Roman mortars from monuments placed in hydrogeological risk areas: a case study

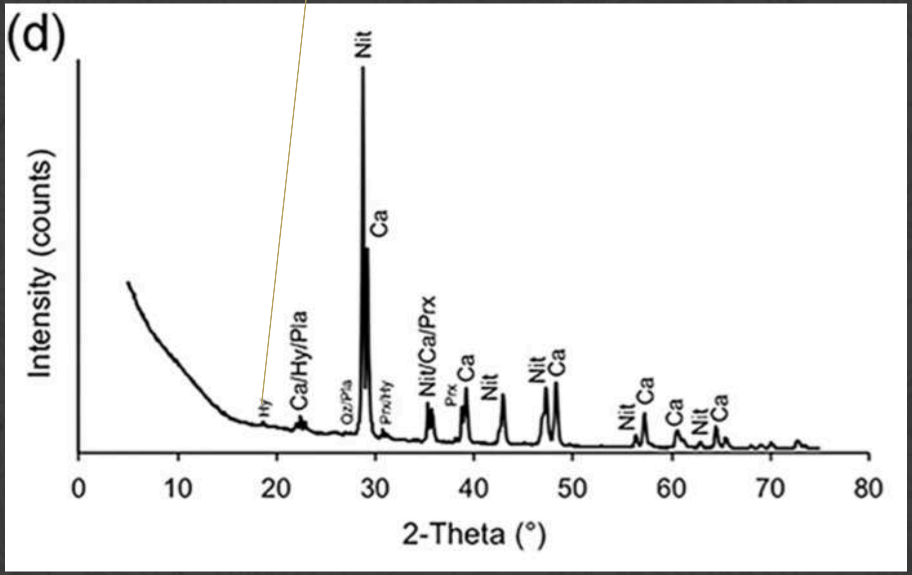
Sitzia Fabio[1] · Beltrame Massimo[2] · Columbu Stefano[1] · Lisci Carla[2,3] · Miguel Catarina[2] · Mirão José[2,3]

Temperature	52,5°C
pH	8.9
Conductibility	1150 µS/cm
TDS	715 mg/l
Calcium	33 mg/l
Magnesium	4 mg/l
Sodium	199 mg/l
Patassium	185 mg/l
Ammonium	< 0.1mg/l
Iron<0.05 mg/l	< 0.05 mg/l
Nitrate<0.01mg/l	< 0.01mg/l
Phospate	traces
Sulphate 47.2mg/l	47.2mg/l
Chloride 305 mg/l	305 mg/l
Manganese <0.01mg/l	< 0.01mg/l
Fluoride 8.7mg/l	8.7mg/l
Silice 40.9 mg/l	40.9 mg/l

Hybrid hydrogeochemical features

1) Sodium-Chloride
2) Calcium sulphate

Presence of Hydrocalumite on mortars
$Ca_4Al_2(OH)_{12}(Cl,CO_3,OH)_2 \cdot 4H_2O$



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That's all folks!

Thanks