HYDROGEOLOGICAL INSTABILITY, AN ITALIAN CASE STUDY: CIVITA DI BAGNOREGIO

O. Corapi[1], G. Fanali[1], L. Paolini[1], P. Passaniti[1], G. Talucci[1], G. Teti[1], A. Lattanzi[2] , A. Berardi[3]
[1]Students: Liceo Vittoria Colonna (Rome)
Teachers: Dipartimento di Lingue[2] and Dipartimento di Scienze Naturali[3] , Liceo Vittoria Colonna (Rome)

INTRODUCTION

'*Hydrogeological instability*' defines different processes that have a destructive action on the soil. Some manifest themselves in a slow and general way (such as surface *erosion*) others can be sudden and catastrophic (such as *landslides* and *floods*). Hydrogeological instability, as well as seismic and volcanic risk, is related to the geological history of Italy and needs to be studied also with the goal of predicting and preventing potentially destructive natural events.

OBJECTIVES

In this work we have chosen as *a case study* Civita di Bagnoregio, a place where the morphology and geology of the territory match the suggestive location of the small town center creating a "*dangerous beauty*". We have conceived a path to study individual cases of geological sites of interest, including analysis of online databases and laboratory simulations of permeability and landslides.

MATERIALS and METHODS

GEOSITE DATA AND MAPS COLLECTION
Internet open source data bases:
- EU Flood risk area viewer
- European Spatial Planning Observation Network
- Inventario Nazionale Geositi (*ISPRA*)
- Google Earth
- Inventario Fenomeni Franosi Italia (*ISPRA*)

LABORATORY PERMEABILITY TEST (fig.1)
Different soils and laboratory materials:
- Lithoid tuffs* / Stratified tuffs* / Sand / Clay
**Tufaceous soils recovered in the area of Viterbo – Italy*
- H_2O
- Glass funnels

SIMULATION OF LANDSLIDE (fig.2-4)
Different soils and laboratory materials:
- Lithoid tuffs* / Stratified tuffs* / Sand / Clay
**Tufaceous soils recovered in the area of Viterbo–Italy*
- H_2O
-Wooden scale model


Fig.1


Fig.2


Fig.3


Fig.4

RESULTS and DISCUSSION

GEOSITE DATA AND MAPS COLLECTION
1. Flood and Landslide Risk in Europe and Italy (fig. 5-6)

Italy faces significant flood risk and high landslide hazards, similar to many other European countries.


Fig. 5 from EU Flood risk area viewer

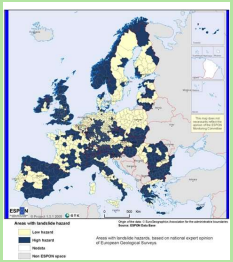
Fig. 6 Landslides hazard map ESPON

2. Geolocation and Geological features:
Geolocation data from Google Earth (fig. 9-10) and Inventario Nazionale Geositi (fig. 7-8) show that Civita di Bagnoregio is located in Italy, Lazio, Viterbo at an altitude of 443 meters, 42°37'48"N 12°05'21"E; it belongs to the geological area called "Ignimbrite di Orvieto-Bagnoregio". The area known as "Calanchi di Civita di Bagnoregio" is particularly appreciated for its landscape value and geological features.


Fig. 7


Fig. 8


Fig. 9

Fig. 10

3. Landslide Risk in Civita di Bagnoregio:
According to the Italian Landslide Inventory (IFFI), there are a total of 54 landslides in the Bagnoregio area, with various types of movements recorded. The presence of active landslides and the categorization of the area as having a very high geological risk for landslides (fig. 11) need continuous monitoring


Fig. 11

RESULTS and DISCUSSION

LABORATORY PERMEABILITY TEST and SIMULATION OF LANDSLIDE
1. Reconstruction of the different geological layers of Civita di Bagnoregio was set up according to literature data (fig. 12-14) to test water permeability (fig. 15-16).
2. Experimental data analysis (fig. 15-16 and Tab. 1) demonstrated that clay reduces permeability (as in Sample C - tuff, sand, clay) in fact the presence of clay tends to retain more water and drain slowly.
3. Simulations of landslide in a reconstructed model of Civita di Bagnoregio (fig. 17-19) indicated that merely wetting the clay lower layer isn't enough to cause erosion; increased water and stress -as in the case of extreme weather phenomena- are needed to trigger "landslides" of the upper tuffaceous layers.

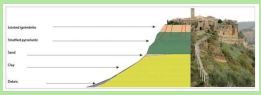
Fig.12 (from Margottini e Di Buduo, 2016)

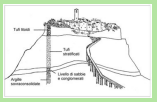
Fig.13
from Margottini e Serafini, 1990


Fig. 14
Our laboratory model

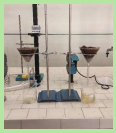
Fig. 15


Fig. 16

SAMPLE	Layers	H_2O initial volume	Time 1st drop	Time last drop	H_2O eluated volume
A	Sand	250 ml	5 sec	1 min 36 sec	88 ml
B	Lithoid tuffs / Stratified tuffs / Sand	250 ml	2 min 9 sec	29 min 57 sec	170 ml
C	Lithoid tuffs / Stratified tuffs/ Sand / Clay (Civita's stratification like)	250 ml	4 min 8 sec	42 min 36 sec	150 ml
D	Lithoid tuffs / Clay	250 ml	1 min 54 sec	42 min	22 ml

Tab. 1


Fig. 17


Fig. 18


Fig. 19

CONCLUSIONS

In Italy there are several regions presenting hydrogeological instability. Civita di Bagnoregio stands out as a geosite of exceptional interest, presenting a very high landslide risk. Our research emphasizes the critical role of soil composition in this context, particularly the interaction between clay and tuff layers. For their ability to retain water and slow drainage, clay layers could play a key role in the upper rock layers' stability. Therefore, monitoring and prevention strategies - including water management – are essential to mitigate risks and to safeguard this unique landscape and its communities.

References
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