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Evaporite sinkholes in the Friuli Venezia Giulia Region (NE Italy)

Stefano Devoto[1], Chiara Calligaris[1], Luca Zini[1], Franco Cucchi[1]

1) Dipartimento di Matematica e Geoscienze, Università degli Studi di Trieste, Via Weiss 2, Trieste, 34128, Italy

sdevoto@units.it

ABSTRACT

Sinkholes in evaporite karst areas occur worldwide and can cause severe damages to human structures such as buildings and roads. This type of geo-hazard affects several Mediterranean countries such as Spain, Algeria, Albania, Turkey and Italy.
This work presents the outputs of a multidisciplinary approach for the investigation of hundreds of karst sinkholes located in the Friuli Venezia Giulia Region, which is situated in the NE sector Italy. Most of them are associated to the presence of Permian and Triassic evaporites, which act as tectonic lubrificant of main regional faults.
Identification techniques included traditional activities. Preliminary investigations comprised collection and analysis of aerial photos and reports. The outputs of above-mentioned analyses were validated by field activities, which permitted to detect and mapping sinkhole phenomena. The latter were classified using the classification developed by Gutiérrez et al (2014).
The main output obtained by investigations carried out by the researchers of the Department of Mathematics and Geosciences of the University of Trieste was the production of a detailed sinkhole inventory containing the main features of sinkholes, such as type, size, etc. All the data were inserted and stored in a GIS, which represents the first sinkhole inventory related to the evaporite karst environment in Friuli Venezia Giulia Region.
Its future integration with analysis of predisposing factors can permit to produce sinkhole susceptibility maps, which can represent an essential tool for the assessment of subsidence phenomena risk zonation.

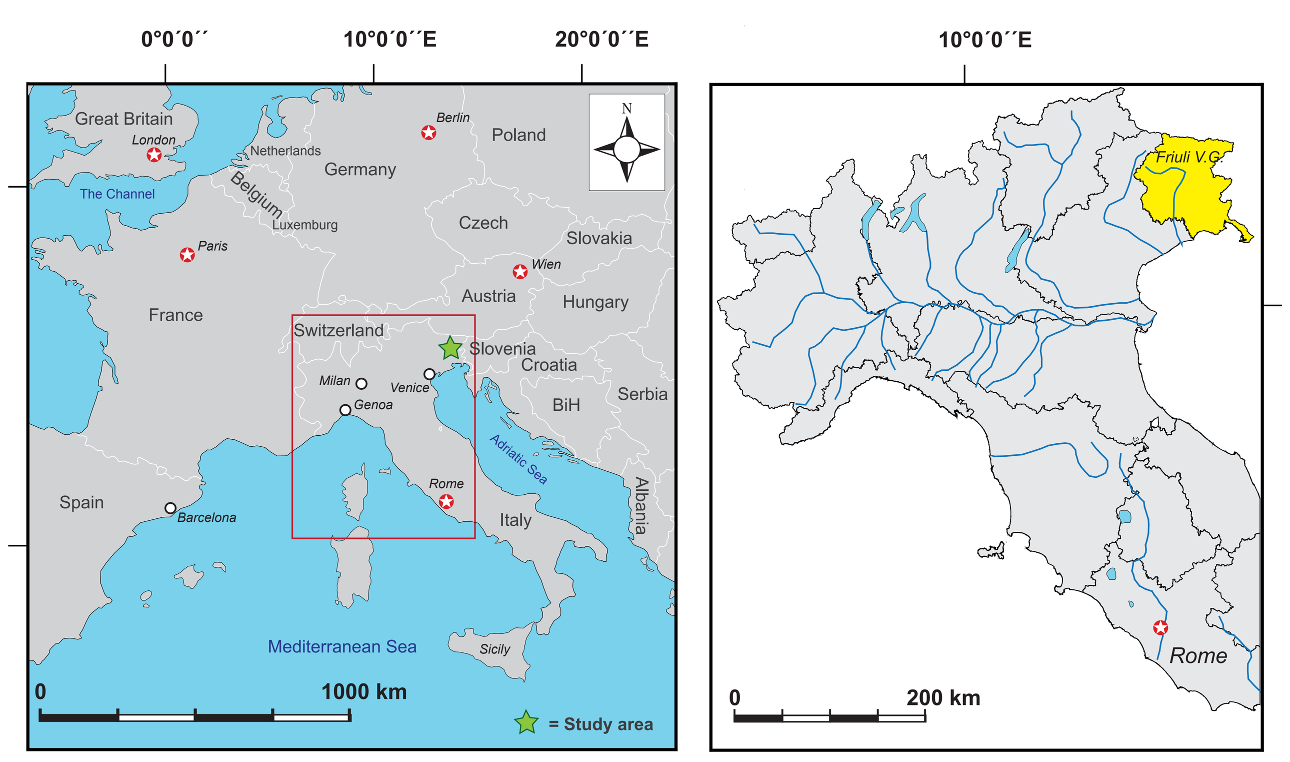

Figure 1: location of the study area

Introduction

In using the term sinkhole researchers indicate a natural closed depressions reaching as far as tens of meters in depth and sometimes exeeding 100 m in diameter. Ground subsidence phenomena and sinkholes associated with the presence of evaporites were recognised and classified in several European countries such as England (Cooper et al 2011), Lithuania, Spain (Galve et al 2008; 2009), and Albania (Parise et al. 2004).
According to Nisio et al (2007) and Caramanna et al (2008) ground subsidence phenomena are also common in Italy . These landforms have been recognised in many regions such as Sicily, Apulia, Campania, Sardinia and Friuli Venezia Giulia.
Sinkholes of Friuli Venezia Giulia (Figure 1) are mainly associated to the presence of evaporite rocks deposited during the Permian Age (Bellorophon Formation) and in the Carnian age (Raibl Formation).
The first studies, which were performed at the end of 1800s in the northern part of Tagliamento River Valley, reported sinkhole phenomena and were connected to events which occured in the Quaternary alluvial deposits overlying evaporite rocks (Gortani 1965).
Recently there has been reneawed interest (Zini et al. 2015) aimed at gaining better knowledge of the territory and its geohazard. The Regional Geological Survery funded a subsidence sinkhole inventory of the entire Region. This inventory contains historiacal, geological and geomoprhological information of 600 sinkholes. Most of them are associated to evaporite rocks and are located in the NW sector of Friuli Venezia Giulia Region, where evaporite rocks are abudant.

Karst areas of Friuli Venezia Giulia Region

The Friuli Venezia Giulia Region is a small territory of 8,000 km2, where about 5,000 km2 are mountainous or hilly areas. Approximately 1,900 km2 of the above-mentioned region is characterised by outcropping carbonate rocks , in facies that vary in lithology from limestones to dolostones allowing manifold manifestations of karst landforms, often notable also thanks to the very high rainfall rate typical of the Alpine and pre-Alpine areas. This means that almost the 40% of the regional territory is karstifiable and/or karstified.
In addition to carbonate rocks, the NW part of the Friuli Venezia Giulia Region hosts further karst areas developed in the evaporite of the Permian and Triassic ages. The outcrop percentage of evaporite karst is close to 1% but becomes even higher if the wide intermountain valleys of the NW part of Friuli Venezia Giulia, characterised by the presence of thin alluvial sediments, are taken into account. One such example is the Tagliamento Valley, where extensive subsidence phenomena are associated with the presence of evaporites mantled by alluvial deposits (Zini et al. 2015). In these areas are also several small villages which have seen this type of hazard over the last 50 years.

PERMIAN EVAPORITES

The evaporites of the Permian age are abundant in the areas of Sauris, Val Pontaiba, Prato Carnico and Ovaro. They are included in the Bellerophon Formation, typical of the transgressive sequence where the gypsum, characterised by micro and saccharoid crystals layered and interbedded with black limestones and dolostones, overlies the continental deposits of the Arenarie della Val Gardena Formation. Moving upward in the stratigraphic sequence, gypsum are replaced by limestone-dolostone-gypsum vacuolar breccias, by dolomitic limestones forming the mean member of the vacuolar dolostones

CARNIAN EVAPORITES

The evaporites of the Carnian age are common in NW Friuli. They belong to the transgressive sequence that represented a climatic event on the regional global scale at the end of the Upper Carnian. The most characteristic lithology is represented by grey and pink- colored saccharoid gypsum, rich in clayey impurities, often in mm-thick rhythmic laminae, typical of evaporitic lagoon deposit

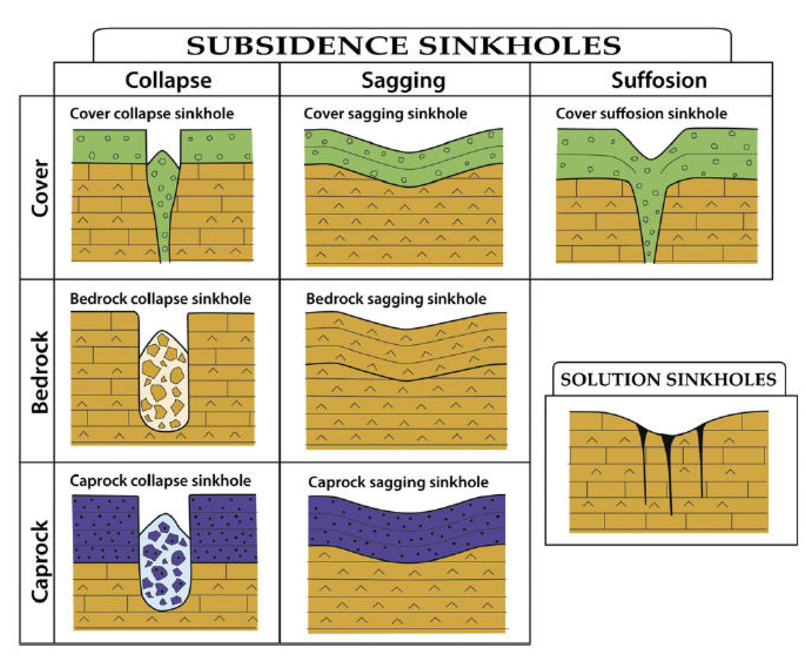

Figure 2: sinkhole classification used

Figure 3: impressive bedrock collapse sinkhole

Sinkhole recognition and classification

We recognised and classify 552 subsidence sinkholes. Only four types of the classification developed by Gutiérrez were recognised in the Friuli Venezia Giulia. Most of them are collapse sinkholes (42%) and involves different types of material. Graph 1 lists the different types and their percentages.

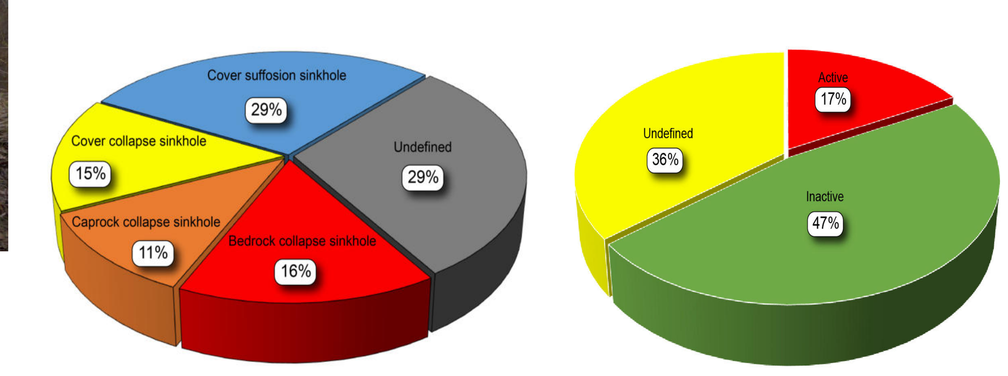

Figure 4: caprock collapse sinkhole

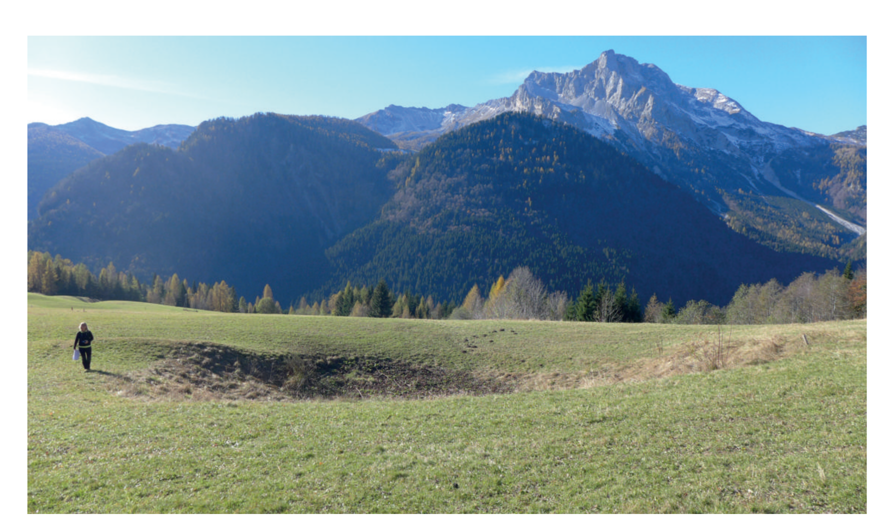

Figure 5: view of a caprrock collapse sinkhole

Figure 6: cover collapse sinkhole (Photo Potleca)

Figure 7: cover suffosion sinkhole

- **Bedrock collapse sinkhole** : their evolution is linked to the presence of cavities in the evaporitc subsurface. They are characterised by steep walls and often host a pond at the bottom (Figure 3). They are very common in NW Friuli and can represent a severe geo-hazard for population and infrastructure

Caprock collapse sinkhole : they involve not karstic material and are very common in the montain ranges of Sauris Village (Figures 4 and 5)

Cover collapse sinkhole : their evolution is linked to the brittle behavior of the cover materials such as Quaternary deposits (Figure 6). They occur suddenly and for this reason they represent a severe geohazard, as witnessed in the Tagliamento River floodplain where several sinkholes affect the village of Quinis, as reported by Zini et al. (2015)

Cover suffosion sinkhole : their evolution is linked to the nature of the cover that behaves as a ductile or loose granular material which gradually settles producing continuous deformations that generate funnel or bowl shaped landforms. They are dominant reaching the 29% of the total and are very common in the NW part of Friuli, near Enemonzo Village. Figure 7 shows an alignement of these sinkholes

Undefined sinkhole : we included in this class those phenomena, which were detected by desk activities and were not surveyed or not identifiable in the field. In some cases, even if they were recognised in the field, it was not possible to assign them an evolutionary process

For each sinkhole we also surveyed state of activity, shape and size. Most of them were classified as inactive, whereas for others was impossible to assign a catergory of activity. All the inventoried sinkoles now populate a GIS developed by Department of Mathematica and Geosciences

Methods

Preliminary research activities were devoted to the collection and analysis of reports, photos and maps located in the archives of the Regional Geological Survey, municipalities and those owned by the Department of Mathematics and Geosciences of the Trieste University.
The outcomes of these analysis supported by the interpretation of aerial photos and DTMs permitted to detect possible areas affected by sinkhole phenomana.
On the basis on these results, we performed extensive field surveys, which permitted to classify hundreds of sinkholes.
Sinkholes were classified using the methodology developed by Gutiérrez et al. (2014). This classification is similar to famous landslide classification of Varnes. In fact it is made up of two terms: the first considers the material involved whereas the second term is related to the type of subsidence processes. Figure 2 (souce Gutiérrez et al. 2014) displays clearly the different types of sinkholes

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Final Remarks

- ✓ The combination of desk activities permitted to recognise more than 550 evaporite sinkholes in Friuli Venezia Giulia, which can be considered one of the most hazardous Italian Region for this type of geohazard
- ✓ From a geomorphological point of view, bedrock collapse sinkholes are rare but spectacular, reaching diameter of about 110 m and depth which can exceeds 35 m
- ✓ We produced a detailed Sinkhole Inventory Map and we are implementing a Susceptibility Sinkhole analysis