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A cura di: Domenico Calcaterra & Silvia Fabbrocino

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Preliminary outcomes from a catalogue of natural and anthropogenic sinkholes in Italy, and analysis of the related damage

MARIO PARISE (*), CARMELA VENNARI (*), FAUSTO GUZZETTI (**), IVAN MARCHESINI (**) & PAOLA SALVATI (**)

RIASSUNTO

Risultati preliminari di un catalogo su sprofondamenti di origine naturale ed antropica in Italia, e analisi dei relativi danni.

Il presente lavoro illustra i primi risultati derivanti dalla raccolta di dati su eventi di sprofondamento (sia di origine naturale che antropica) sul territorio italiano. Un catalogo cronologico è stato strutturato e popolato a tale scopo, con il preciso obiettivo di raccogliere informazioni sulle date di occorrenza degli sprofondamenti, come primo e fondamentale elemento di conoscenza per la definizione della pericolosità connessa a questo tipo di fenomeni, ai quali non sempre viene dato il giusto risalto nella valutazione dei rischi geologici in Italia. I dati sinora raccolti (consistenti in circa 700 eventi, distribuiti sull'intero territorio italiano) evidenziano una particolare concentrazione in alcune regioni, che però è anche derivante dalla maggiore attenzione rivolta agli sprofondamenti in alcune zone (significativi, in tal senso, gli esempi delle città di Roma, Napoli e Palermo).

KEY WORDS: *Catalogue, damage, hazard, Italy, sinkholes.*

INTRODUCTION

Landslides, floods, volcanic eruptions and earthquakes represent the main geohazards that are generally taken into consideration in the assessment of geological risk in Italy. Sinkholes related to both natural and anthropogenic processes, on the other hand, are often underrated, so that these phenomena are not typically included in risk assessment analysis. Nevertheless, sinkholes are widespread in Italy, representing in some regions the most frequent hazard, and a severe cause of economic losses to society.

In order to give to sinkholes the due attention within the framework of multi-hazard evaluation programs in Italy, we have compiled a chronological catalogue of natural and anthropogenic sinkholes. The main constraints considered for populating the catalogue are represented by availability of a date of occurrence, and knowledge of the location of the sinkhole. In this article, we briefly describe the catalogue, and the data so far collected, present some considerations on distribution and frequency of sinkholes over the Italian territory, and carry out a preliminary analysis on the deriving damage, aimed at contributing to the evaluation of the societal losses produced by geohazards in Italy.

NATURAL VS. ANTHROPOGENIC SINKHOLES

Sinkholes can have a natural or anthropogenic origin. Natural sinkholes are common where: the rock below the land surface is soluble (carbonates, evaporites) and karst processes are or have been active in producing natural cavities, even of great size (PARISE, 2008); in plain areas where thick sequences of heterogeneous alluvial sediments are present (DEL PRETE *et alii*, 2010); and along coastal areas generally characterized by carbonates of recent age (BRUNO *et alii*, 2008).

In general, most of natural sinkholes occur due to processes related to solution of rocks by the underground water circulation. Natural sinkholes have typically a low impact on the built-up environment, mostly affecting rural areas; however, they can locally involve inhabited areas (see, for instance, the case at Camaiore, Tuscany, in 1995; BUCHIGNANI *et alii*, 2008).

Anthropogenic sinkholes are related to the long history of Italy, where in different epochs artificial cavities have been realized underground by man for a variety of purposes (CAPPA, 1999; CASTELLANI, 1999). In many cases, following their use during a certain period of time, these cavities have been later on abandoned, and knowledge of their precise location got lost in time. As a consequence, in recent decades the areas above them have often been included in the newly developed parts of towns, thus creating a serious risk to the human life. Among the many different typologies of man-made cavities, underground quarries seem to represent the most dangerous category, in relation to sinkhole occurrence (PARISE, 2012; PEPE *et alii*, 2013).

In general, there are more detailed information about anthropogenic sinkholes than for those of natural origin. This because the first category generally affects built-up areas, and produce direct damage and negative effects to the society (blockage of roads and communication routes, disrupting lifelines, etc.). At least some of these effects are typically reported, which helps in defining the time and site of occurrence of the phenomenon.

In case of natural sinkholes, especially when they occur in rural areas, the related surface effects may go unnoticed; further, land owners often prefer not to spread the news, in order to avoid loss of value of the land.

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THE CHRONOLOGICAL CATALOGUE

The catalogue on Italian sinkholes has been structured giving a crucial role to the information on time of occurrence of the sinkhole, and, in addition, clearly expressing a level of accuracy about these specific data. The main constraints considered for populating the catalogue were therefore represented by availability of a date of occurrence, and knowledge of the location of the sinkhole.

In the collection of sinkhole data, we used a variety of source of information: newspaper clips, scientific literature, history books, transcriptions or translation of old chronicles, reports by regional or local technical offices, direct surveys. Existing databases on sinkholes (ISPRA, University of Rome Tre, other websites dedicated to the topic, etc.) have also been interrogated and critically examined. With reference to these databases, it has to be pointed out that our catalogue differs from the existing lists of sinkholes, being specifically addressed to time of occurrence, as such information is considered crucial for the real assessment of the sinkhole hazard.

Given the focus of our work on time of occurrence of the events, to include a sinkhole in the catalogue the knowledge of a temporal reference is required: ideally, the date of occurrence is complete when hour/day/month/year of the event are all available, which is the best situation, corresponding to high accuracy (Fig. 1). When the information about time of occurrence is more limited (for instance, comprising only month and year, or a few generic information), the accuracy is ranked as having progressively lower degree (medium, medium-low or low).

The present version of the catalogue comprises so far about 700 events; they cover a time span from 276 B.C. to the present day.

More than 50 % of sinkholes have an anthropogenic origin, about 25% are related to natural caves, whilst for the remaining cases there are no information useful to ascertain the natural or anthropogenic origin; therefore, they have been provisionally inserted as of unknown origin (Fig. 2).

As concerns the geographical location, sinkholes have been ranked in different levels of certainty, depending on the precision in location of the site of occurrence. Accuracy in the geographical location generally decreases going back in time; nevertheless, some historical documents and chronicles resulted to be very accurate in providing figures for site of the sinkholes, as well as for casualties and damages produced by the event. Overall, most of the sinkholes in the catalogue (about 70%) have a precise location, that is the real site of occurrence of the sinkhole is well known (even for those that have later on been filled or masked by man's activities). As for the remaining cases, they have some degrees of uncertainty, but only in a few cases (exactly, 47 sinkholes) very generic indications about the site of occurrence are available.

In addition to data on time and place of occurrence of the sinkholes, the catalogue also reports, when available, further information as the triggering factor (rainfall or seismic events, man-made works such as realization and/or maintenance of pipelines, quarrying activities, etc.), morphometric data (depth and width), and indication of the occurrence as first-time event, or re-activation of an already known phenomenon.

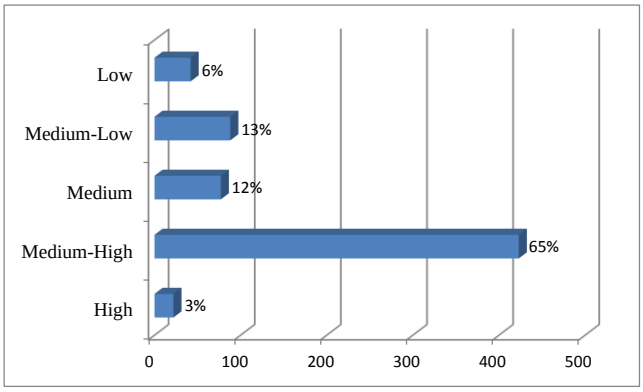

Fig. 1 – Histogram showing the accuracy in the temporal occurrence of the sinkholes in the catalogue.

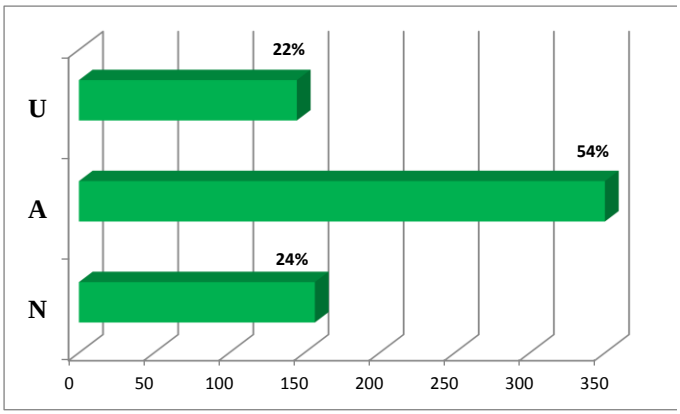

Fig. 2 – Origin of sinkholes in the catalogue: N = natural sinkholes; A = anthropogenic sinkholes; U = sinkholes of unknown origin.

SINKHOLE DISTRIBUTION IN ITALY

The about 700 events included in the catalogue are not homogeneously distribuited over the Italian territory; this is due to several reasons, including the different type and detail of information source, and, above all, the different geological and morphological conditions.

The sinkhole distribution is mostly linked to presence of soluble rocks or alluvial deposits as regards the natural sinkholes, whilst the location of the anthropogenic sinkholes is essentially dependent upon the presence of man-made cavities.

The overall distribution of sinkholes events in Italian regions is shown in the histogram of figure 3, where it can be appreciated that the regions with the highest number of documented sinkholes are: Campania (246), Sicily (117), Latium (107) and Apulia (88). Only two Italian regions (Molise and Valle d'Aosta) so far are not present in the catalogue with any documented sinkhole.

The high number of events documented in some areas of Italy is related to dedicated studies carried out, for instance, in

specific towns where the presence of man-made cavities is particularly object of attention, given their high frequency. This is certainly the case for Rome, but also for towns as Palermo and Naples, where recently a great amount of research has been carried out, with particular reference to the issue of anthropogenic sinkholes (respectively, SOTTILE, 2010, and GUARINO & NISIO, 2012).

As noted by previous scholar dealing with natural hazard catalogues (GUZZETTI, 2000; GUZZETTI *et alii*, 2005; SALVATI *et alii*, 2010) it is very difficult to quantify the incompleteness of non-instrumental records of natural events. The lack of occurrence of events in a given period and/or in a given zone may be due to the incompleteness of the catalogue or at change or absence of the conditions which led to triggering the event.

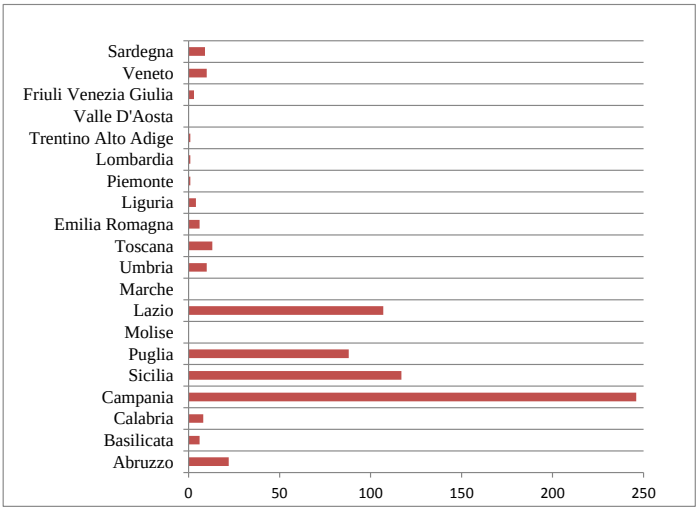

Fig. 3 – Distribution of sinkholes events in Italy (updated to December 2012).

ANALYSIS OF THE DAMAGE

Notwithstanding the sinkholes are rarely considered in the assessment of geological hazard, they represent a real risk for the population, considering also their high frequency in some sectors of the country. Sinkholes have repeatedly caused in Italy heavy damage to the society. Water supply systems, sewer systems, roads and other communication routes have often been hit; in addition, damage and/or collapse of buildings, with the deriving casualties, had also to be registered in several circumstances.

In the time span covered by the catalogue, casualties (which include deaths, missing persons, and injured people) are reported in 3.5 % of the events, whilst damage are documented in 32.6 % of the cases. These numbers are underestimated, because most of the sources typically provide generic information, as occurrence of an unspecified number of deaths and injured people (especially in the oldest reports). This, together with the ancient date of many events, is at the origin of the difficulty in precisely quantifying the intensity of the sinkholes, in terms of their effects on the society.

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