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CAMPANIA GREY TUFF AND ANTHROPOGENIC TUFF CAVITES IN THE SOUTHERN METROPOLITAN AREA OF CASERTA (SOUTHERN ITALY)

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ABSTRACT: The Late Quaternary geological evolution of the northern Campania Plain was affected by the volcanic activity of the Phlegrean Field. The geological features of the Campania Grey Tuff (CGT, ~39 Ky), deposited on the whole Campania Plain, were reconstructed along a transect from the northern boundary of the metropolitan area of Naples up to Caserta. Since the tuff has good mechanical properties, it was involved since historical times in an extensive mining activity, from which a very dense network of quarries and underground cavities was inherited, strongly related to the lithofacies distribution. We provided a first geological underground database of the metropolitan area of Caserta, north of Naples, and analyzed the hazard aspects related to the mining activities.

KEYWORDS: Campania plain, Campania Grey Tuff, urban data management, database, tuff cavity

1. INTRODUCTION

The Late Quaternary geological evolution of the northern Campania Plain has been affected by the volcanic activity of the Phlegrean Field. Among the volcanic events that have characterized this area, the one that emplaced the Campanian Grey Tuff (~39 Ky; De Vivo et al., 2001) was the most important. Thick pyroclastic flow deposits blanketed the whole plain and represented the substrate for the following Holocene sedimentation, with thicknesses of tens of metres and a depth from the ground level reducing toward north-east, close to the Apennines foothills (Ortolani & Aprile, 1985; Bellucci, 1994; Putignano et al., 2007; Ruberti et al., 2014).

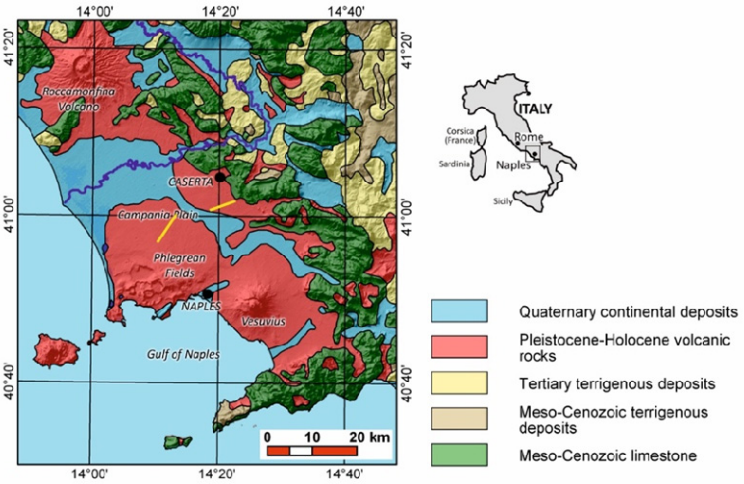

Fig. 1 - Geological map of the study area (modified from Ruberti et al., 2014). Yellow lines indicate the geological profiles in Fig. 2.

The Campanian Grey Tuff shows different lithofacies both laterally and with depth (Di Girolamo, 1968; Cappelletti et al., 2003; Ruberti et al., 2014). Since the tuff has good mechanical properties, it was involved since historical times in an extensive mining activity, from which a very dense network of quarries and underground cavities was inherited, strongly related to the lithofacies distribution.

In many urban centers of the Campania Plain (e.g., Naples, Aversa and surroundings), cavities have been reported in specific geological investigations although their real extent is almost unknown. In these towns the underground mining activities were performed to extract tuffs for buildings. The urban development has sealed every signal of the presence of cavities, which thus represent a geological hazard and contribute to subsoil instability in many places (Brinkmann et al., 2008; Parise, 2010; Scotto di Santolo et al., 2018). In a correct urban management, the knowledge of the city subsoil is a priority, as the presence of cavities may easily trigger the collapse of the shallow or deeper soils (e.g., Ciotoli et al., 2015; Guarino et al., 2017).

It is herein reported a preliminary study carried out on the small area of the Campania Plain, north of Naples, along a transect from the northern boundary of the Naples Municipality to Caserta. The study area is characterized by a flat topography and was interested by the volcanic activity of the Phlegrean Field. Tuffs and cinerites are the main lithologies recognized in the first tens of metres. Since the tuffs have good mechanical properties (i.e. high compression strength, low specific weight) and are found at a shallow depth from ground level, they were involved since historical times in an extensive underground mining activity. Towards the Apen-

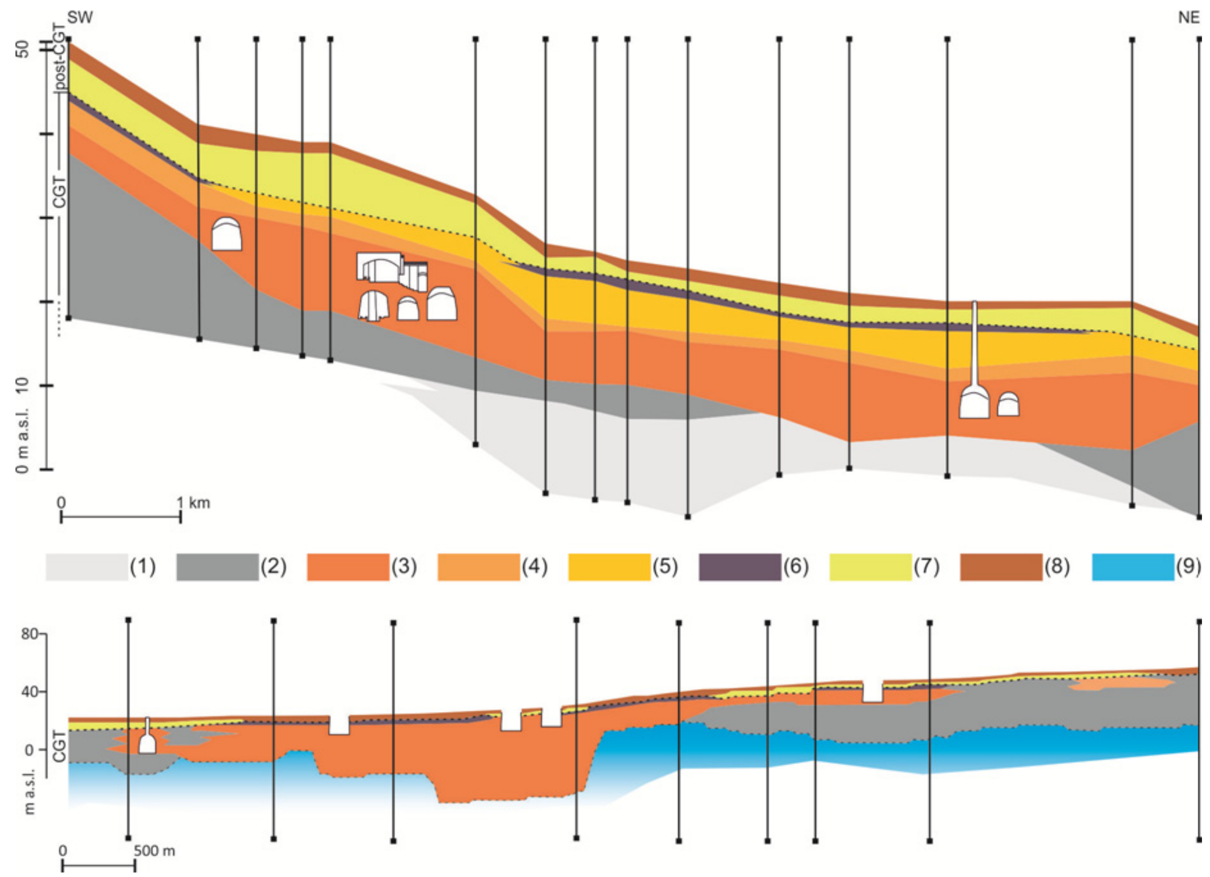

Fig. 2 - Geological cross-sections (tracks in Fig. 1): (1) *cinerite*,(2) grey tuff, (3) zeolitic yellow tuff, (4) pebble tuff, (5) incoherent facies of CGT, (6) paleosoil, (7) pyroclastic deposits younger than CGT, (8) soil, (9) pre-CGT deposits. Quarries and cavities are not to scale. Dotted line indicates the upper and lower limits of the CGT deposits.

nines the tuff lies only a few metres below the ground level. This resulted in a strong development of quarrying through open pits (Ruberti et al., 2014).

The present investigation tries to address the complex interaction between geological framework and anthropic activities related to urban subsoil of the metropolitan area of Caserta, north of Naples; data were managed in a GIS so as to provide a first geological underground database and a preliminary analysis of the hazard aspects related to the mining activities.

2. STUDY AREA

The examined area, about 54 km^2 wide, corresponds to the central part of the Campania Plain (Fig. 1), north-east of the Phlegrean Fields, that is characterized by a flat morphology between 95 and 20 m a.s.l. In this area the subsoil is formed by the succession of different units composed of volcanoclastic deposits, in particular related to the Campania Grey Tuff (CGT; 39 ky B.P; De Vivo et al., 2001) and Neapolitan Yellow Tuff (NYT; 15 ky B.P.; Deino et al., 2004) pyroclastic eruptions.

The CGT deposits were settled on the whole Campania Plain, giving rise to a thick (up to 40 m), laterally continuous, volcanoclastic unit. Different lithofacies can be recognized within the CGT mostly basing on the different mineralogic composition (Di Girolamo 1968; Cappelletti et al., 2003; Morra et al., 2010). On the whole, from top to bottom the succession of CGT lithofacies is characterized by an upper incoherent part, represented by the *cinerazzo* (cz) followed by the coherent zeolitic yellow tuff (tgz) and/or grey tuff (tg), piperno tuff (tp), and pipernoide (pp) ones. Close to the bottom of the unit, a soft lithofacies occurs, called *cinerite* (cn). These lithofacies greatly vary in thickness and occurrence vertically and laterally toward east or north from the source area. The uppermost unit of the reconstructed stratigraphic succession is represented by the thin grey, loose ashy deposits of the NYT, which are locally separated from underlying CGT by a paleosol (Putignano et al., 2007; Santangelo et al., 2010; Ruberti et al., 2014).

The good mechanical characteristics of the tuff lithofacies justify the presence of numerous quarries and/or cavities, according to the availability of adequate thicknesses of coherent lithofacies (i.e. tgz, tg).

3. METHODS

The main geologic features of the study area were obtained using lithostratigraphic logs from boreholes

Fig. 3 - Example of cave dug into the tuff. a) view of a chamber with an access well on top; b) details of access realized with steps directly carved into the tuff.

reaching the depth of 30–35 m, available from different sources (environmental agencies, municipality offices, professional studies, unpublished researches, etc.), and from the analysis of quarry walls (in the northern part of the study area) exposing 15–20 m of deposits. The marker key to correlate the different units was represented by the CGT volcaniclastic deposits.

The lithological data were collected into a relational geodatabase of well-log stratigraphies, which were further interpreted and homogenized in terms of lithologic units, also containing the related thickness and upper- and lower-boundary elevations a.s.l, with the aim of facilitating the development of a 3D geological model (Putignano et al., 2007; see also methods in Velasco et al., 2012).

Previous studies have highlighted the presence in the area of numerous cavities. In a first step, a database was elaborated to organize previous data and the results of new, specific investigations. A GIS project was designed to manage the georeferenced database and plot the cavity distribution on the numerical cartography in 1:5000 scale. Many cavity maps were digitized, georeferenced and imported in the GIS environment. In such way, they can be easily located under the built areas. Where plan views were not available, the cavities and/or the access wells were reported only as points. The shallow quarries have been located through interpretation of aerial multitemporal photos and analysis of historical cartography (see also Ruberti et al., 2014).

4. RESULTS AND DISCUSSION

The analysis of geological data has revealed some common features for the considered area (Fig. 2):

i) the occurrence of coherent zeolitic yellow tuff was the main trigger for cavity development, mainly for extraction purpose; mean thickness is 8 m. The zeolitized yellow welded tuff is formed by ashy matrix with rounded lapilli and dispersed block pumice clasts. Locally, few and scattered coarse scoriae are present;
ii) below the zeolitic yellow tuff, slightly welded pyroclastic soils and ash layers occur showing different compaction.
iii) in the slightly lithified upper part ash is characterized by abundant pebbles/breccias of volcanic tuff (*cappellaccio* or pebble tuff);
iv) a metre thick paleosoil underlines the upper limit of the CGT. The former is formed by brown, silty-sand, pyroclastic unit with small rounded and altered pumices. The upper deposits mainly consist of white-yellowish and greyish cinerite in which whitish pum-

Fig. 4 - A quarry pit showing typical vertical walls, partially filled for agricultural purpose.

ice layers intercalate, mostly related to more recent eruptions of the Phlegrean Fields. Towards East the thickness is reduced to a few metres (about 2 m).

On the whole, the development of artificial cavities and quarries was strongly linked to the lithology of the CGT and the related thickness. In the southern part of the study area a dense cavity network characterizes most of the historical town centers whereas towards east the cavities are associated with and/or replaced by open pits developing for almost 10-15 m down from the surface.

The cavities develop within the yellow tuff in which large scoriae, pumices and lava blocks can be recognized. Pipes are common and very often the weak, loosely packed deposits favoured the beginning of the quarring activity (Fig. 3).

The digging of cavities initially involved an excavation carried out as a "bottle" or a "bell" from the ground level down to the tuff unit, developing at depth according to its thickness. During excavation, access points were realized (Fig. 3a) through the poorly lithified or loose deposits, with a square or pseudo-circular cross-section; sometimes they were supported by containment walls made of tuff bricks resting on the lower lithoid tufaceous bank. A single vertical excavation is sometimes added at certain distance, so as to determine in depth the coalescence of several chambers, also through the construction of narrow tunnels or wide passages. Access shafts were often realized with a system of stairs with one or more ramps, with steps directly carved into the tuff (Fig. 3b).

Eastwards, the reduced thickness of the post-CGT deposits allowed the easy mining of tuff in open pits from the ground surface. All the quarries are almost similar: they are rectangular holes about 1–4 hectares large with almost 20-m high, vertical steep walls. A previous study (Ruberti et al., 2014) has highlighted that most of these quarries are nowadays partially filled with earthy materials and used for agricultural purposes, whereas others are sites of illegal waste disposal; some of them lie buried in the present urban area.

The mining activities were responsible for the reduction, up to the complete removal, of the yellow tuff. Moreover, the tuff mining resulted in the reduction of the depth of the quarry bottom in respect to groundwater, leading to a further critical environmental condition.

5. CONCLUDING REMARKS

The study provides a first database of the geological underground in the metropolitan area of Caserta, north of Naples. The database is designed to be managed into a GIS environment in order to provide a detailed 3D geological reconstruction.

The GIS project was implemented with data on tuff cavities and quarries from the same area. Quarrying for building materials was the main trigger for cavity development in the historical center of the towns and their occurrence is linked to the availability of underground well-lithified materials. The analysis of the urban expansion since the beginning of the 19th century has revealed a close relationship between the occurrence of cavities in the subsoil and the expansion of the city until the 1970s, when the use of cement completely replaced the extraction of tuff.

The knowledge of such underground system represents a useful contribution to the hazard evaluation in densely urbanized areas. On the other hand, the recognition of the open pits for tuff extraction and the assessment of their current use provides information for land management and allows the assessment of possible pollution hazard.

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