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AN INTRODUCTION TO THE EARLY HOLOCENE EOLIAN DEPOSITS OF GROTTA ROMANELLI, APULIA, SOUTHERN ITALY

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ABSTRACT: Due to its geographic position and geomorphological configuration, Grotta Romanelli acted as a sediment trap since at least MIS 5. The so-called 'terre brune' sequence is a deposit mainly of eolian origin bearing upper Palaeolithic artefacts and fossil remains of vertebrate fauna; it was deposited during the Glacial-Interglacial transition and the Holocene. Sedimentology and mineralogy of this deposit are investigated. The stratigraphic sequence provides a promising archive within which both human and climatic impacts can be studied.

KEYWORDS: Grain size, mineralogy, Holocene, Grotta Romanelli, southern Italy

1. INTRODUCTION

Eolian deposits have long been considered a significant resource for the past environment reconstruction. Eolian activity is, in fact, modulated/influenced by global climate changes (Porter, 1989) as documented, for example, in the Chinese Loess Plateau, i.e. one of the longest and most continuous palaeoclimatic records of the Quaternary interglacial-glacial cycles (Ding et al., 2005). In Italy, Quaternary eolian deposits were described in different sites (Sevink & Kummer, 1984; Cremaschi, 1990; Narcisi, 2000; Giraudi et al., 2013; Boretto et al., 2017). Loess deposits in northern Italy and the Adriatic edge of central Italy were associated to periglacial environment, whereas in central and southern Italy their origin was attributed to dust coming from North Africa, where arid conditions during MIS 4 and 2 and in the late Holocene may have enhanced the dust supply in southern Mediterranean sector (Giraudi, 1995; Narcisi, 2000).

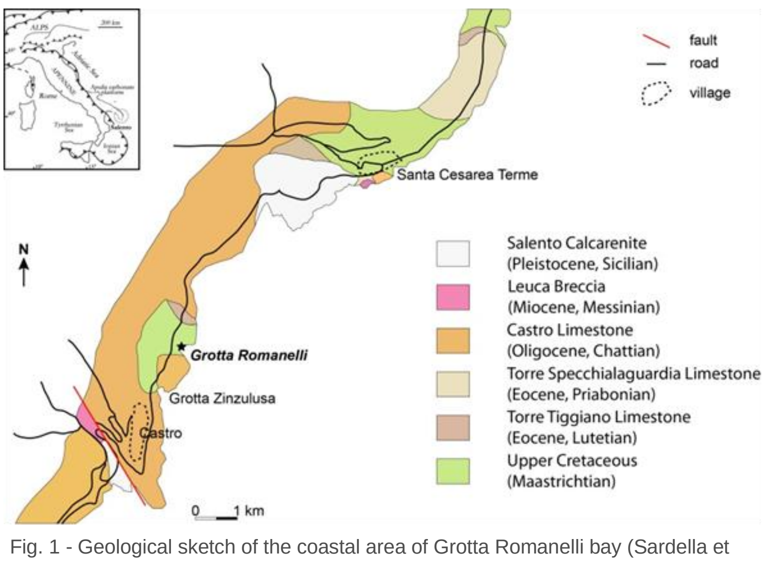

Fig. 1 - Geological sketch of the coastal area of Grotta Romanelli bay (Sardella et al., 2018)

Eolian deposits accumulated in caves can provide archives of past climate and human-induced changes. These deposits are additionally a significant source of information about land-atmosphere transfer processes, atmospheric residence times, land-surface depositional processes (Evans & Soreghan, 2015).

Grotta Romanelli, located on the Adriatic coast of southern Apulia (Italy), is considered a key site for the Mediterranean Quaternary for its archaeological and palaeontological content. The cave opens in Upper Cretaceous limestone (Bosellini et al., 1999) at about 7.4 m above sea level, and is filled with thick deposits containing rich fossil remains of vertebrate and a wide variety of artefacts (see Sardella et al., 2018 and references therein). The stratigraphic sequence, as described by Blanc (1920, 1928), schematically consists (from the top to the bottom) of: (i) an upper complex, called 'terre brune' ('levels A-E'), bearing upper Palaeolithic artefacts and vertebrate fauna including *Pinguinus impennis* (= *Alca impennis* in Blanc, 1927); (ii) a thin stalagmitic layer (called 'level F'), dated at 40,000± 3250 years (Fornaca-Rinaldi & Radmilli, 1968); (iii) a deposit called 'terre rosse' ('level G'); (iv) a thick stalagmitic layer ('level H'); (v) a bone breccia ('level I'), and (vi) a beach deposit ('level K') referred to the Tyrrhenian Stage (MIS 5). The 'terre brune' and 'terre rosse' deposits are considered mainly of eolian origin (Blanc, 1920, 1928; Blanc & Cortesi, 1941); according to radiocarbon dates, the 'terre brune' sequence appears to span from about 9.5 to 12 ka (Alessio et al., 1965; Bella et al., 1958; Vogel & Waterbolk, 1963).

In this study we provide the first results of the sedimentological and mineralogical characterization of the 'terre brune' deposit, which may represent a record of the Holocene climate in southern Italy and provide a promising archive within which both human and climatic impacts can be studied.

2. MATERIALS AND METHODS

During September 2016 the stratigraphic section SS1, located in the western sector of the cave, was selected as the representative profile for a multidisciplinary study of 'terre brune' deposit. The SS1, about 2.80 m thick, was cleaned, documented and sampled at a resolution of ca. 3 cm (Fig. 2). Ninety-six samples were collected for sedimentological and mineralogical analyses.

Grain sizes were determined using a CILAS 1064L laser diffraction particle size analyzer (range from 0.04 to 500 μm). The grain size fractions are according to the classification of Wentworth (1922).

Mineralogy was determined using a Philips PW1840 diffractometer (CuKa/Ni: 40 KV and 20 mA) on bulk sediment and on clay fraction of selected samples. Identification of the mineral phases was determined with XPowder12 freeware software.

Fig. 2 - Picture of stratigraphic section SS1.

The calcium carbonate content ($CaCO_3$ %) was measured gas-volumetrically, by addition of HCl in a Dietrich-Frühling calcimeter.

Carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotopes were determined on calcium carbonate contained in sediment sieved to < 20 μm, which reacted with 100% phosphoric acid at 70°C using a Thermo GasBench device connected to a Delta Plus mass spectrometer. Results are expressed in delta per mill versus VPDB standard.

3. RESULTS

Field observation of the section revealed the presence of cross-laminations and large-scale ripples of variable thickness (1 - 10 cm). These structures are made of dark brown, cracked clayey-silt sediment, or silty sand with dull yellowish color. Layers of detrital limestone, generally rich in palaeontological and archaeological remains, are also present.

Laboratory analyses confirmed that the grain size distribution is generally bimodal, with elevated percentages in clay (from 27 to 59%, mean 47%) and silt (from 26 to 54%, mean 44%) grain size fractions; in several samples the sand fractions are also detected. Variations in these proxies along the sedimentary sequence are shown in Fig. 3. The grain size records show three intervals (55 - 75 cm, 90 - 130 cm and 195 - 230 cm) with lower percentage of clay fraction (Fig. 3a) that is counterbalanced by the content of the sand fractions (>63 μm, Fig. 3c-e).

X-ray diffraction shows that samples are mainly composed by quartz and minor amounts of calcite, plagioclase, feldspar. Oriented XRD of the finest fraction of selected samples revealed the presence of clay minerals of the illite and kaolinite groups. The intensity of the main peak of quartz was used for a further stratigraphic record (Fig. 3f). It shows that when sediments are enriched in clay fraction they are depleted in quartz and *vice versa*, because the fine fraction contains higher amounts of clay minerals.

Carbonate contents vary from 0 to ca. 12% (Fig. 3g); of note is that the samples in which carbonate was not detected still contain small amounts of carbonate that are below the detection limit of the method. The interval between 90 and 190 cm comprises the largest amount of calcite particles; this part of the sequence is also particularly rich in palaeontological and archaeological remains.

Calcite contained in the grain size fraction <20 μm has oxygen isotope composition between -15.52‰ and

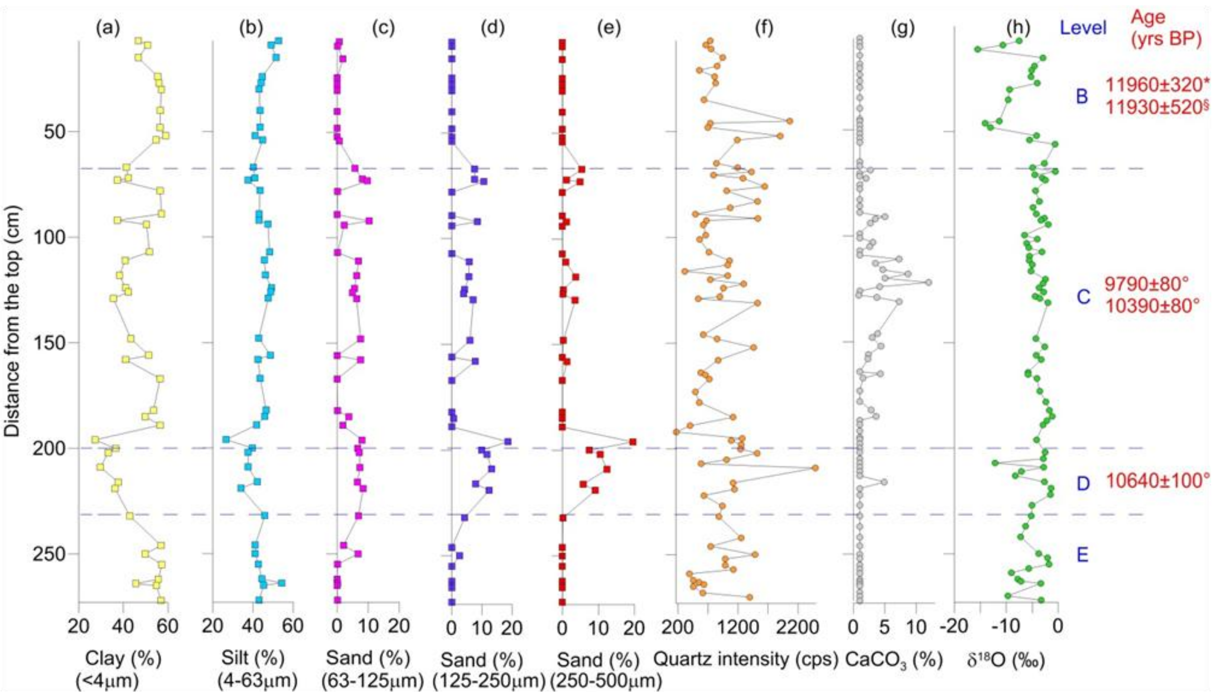

Fig. 3 - (a) Percentage of clay (<4 μm), (b) percentage of silt (4-63 μm), (c) percentage of very fine sand (63-125 μm), (d) percentage of fine sand (125-250 μm), (e) percentage of medium sand (63-125 μm), (f) intensity of main quartz peak (cps), (g) carbonate content ($CaCO_3$%), (e) $\delta^{18}O$ (‰ vs. VPDB) results plotted vs. depth for the stratigraphic section SS1 of 'terre brune. Levels according to Blanc (1920) stratigraphy end published ages (*Alessio et al., 1965; §Bella et al., 1958; °Vogel and Waterbolk, 1963).

-0.55‰ vs. VPDB. The $\delta^{18}O$ record is shown in Fig. 3h; the upper (top - 70 cm) and the lower (200 - 280 cm) parts of the curve show several abrupt shifts towards very low isotopic values, up to -15.52‰ and -12.14‰, respectively. Between 90 and 190 cm the record approximately shows uniform isotopic compositions with an average of -3.65‰; this value would indicate that the carbonate fraction at this level has mainly the contribution of the isotopic signal of the marine carbonates, then it has in prevalence detrital nature.

4. DISCUSSION AND CONCLUSION

The 'terre brune' deposit was mainly considered of eolian origin, due to the mineralogical composition and morphology of quartz grains (Blanc, 1920, 1928; Blanc & Cortesi, 1941). Our data are in accordance with the mineralogical and sedimentological composition presented in the previous studies about Grotta Romanelli, and with studies from other Italian sites where eolian deposits were identified (Narcisi, 2000; 2001; Giraudi et al., 2013).

Available chronology of the 'terre brune' (Alessio et al., 1965; Bella et al., 1958; Vogel & Waterbolk, 1963) temporally constraints the deposit to the beginning of Holocene, although the lowermost portion has never been dated. Preliminary results of new radiocarbon dating consistently indicate that the investigated section was formed between the late Last Glacial and the early Holocene (Calcagnile et al., 2018), when different climates occurred in the Mediterranean basin. Various proxy data suggested dry and cold climate condition during the Late Glacial, enhanced meteoric precipitation during the transition from the Late Glacial to the Holocene, a general climate amelioration and wetter conditions during early Holocene, and a change toward the present-day dry regime at 6-5 ka BP (Allen et al., 1999; Sadori & Narcisi, 2001; Bar-Matthews et al., 2003; Zanchetta et al., 2007; Martrat et al., 2014).

The sedimentological and geochemical records of the 'terre brune' sequence were used to reconstruct the environmental variations related to climate changes during the late Last Glacial and the early Holocene.

Sediments of the lower part of the sequence (200-280 cm), that may be correlated to 'levels D-E' of Blanc (1920) stratigraphy, are progressively enriched in medium sand and depleted in clay contents; also, the quartz content increases, whereas the carbonate content is low. As the coarsening of eolian input mainly depends on two factors, the wind speed and the distance from the source areas (Muhs, 2013), our data suggest that deposition of this part of the sequence occurred during a period of more intense wind transport. The source of this sediment could have been eolian dust from Sahara regions. Loess formed by quartz of Sahara origin, was identified in several Italian sites, e.g. the Lago di Vico and Lagaccione, maar lakes in central Italy (Narcisi, 2000; 2001; Narcisi & Anselmi, 1998), the island of Lampedusa (Giraudi, 2004), the high mountains of the central and southern Apennines (Frezzotti & Giraudi, 1990; Giraudi et al., 2013). This phase of deposition certainly took place before 12 ka BP. At that time it is likely that a coastal plain in front of Grotta Romanelli was still large and it may have also contributed to the accretion of the 'terre brune'; the coastal plain was evaluated 20 km wide at the Last Glacial Maximum (22 ka BP), and characterized by different environments, from lagoon to wetland, possibly fringed by sand dunes (Cassoli et al., 1979). Palaeontological remains also indicate a terrestrial environment ranging from open semi-arid to an occasionally dried-out mud flat (Sardella et al., 2018).

In the interval going from 70 to 200 cm, possibly corresponding to 'level C' of Blanc (1920) stratigraphy, the grain size distribution shows an increase of fine and very fine sands, whereas medium sand and clay decrease. An average decrease of quartz intensity also corresponds to carbonate content rise (up to 12%). The observed pattern suggests a decreased capacity of eolian energy to transport coarse particles. At this stage it is also possible that the record data respond to a progressive sea-level rise and a consequent reduction of the coastal plain which coincided with the main phase of deglaciation between ca. 11.5 ka BP (the end Younger Dryas) and ca. 8.2 ka BP (Lambert et al., 2014). In particular the increase in carbonate content which is mainly of detrital origin, as isotopes would prove, may be considered the effect of the decrease of the eolian transport and the reduction of quartz mass capacity to dilute other mineral phases. Considering that this part of the sequence is particularly rich in palaeontological and archaeological remains, it is possible to speculate that this detrital contribution could be additionally due to the human occupation.

The upper part of the sequence (70 cm - top) may correspond to the 'level B' of Blanc's stratigraphy. The sediment contains a considerable amount of clay and silt, whereas the sand fractions are virtually absent. Quartz and carbonate content decrease. Overall, this pattern points to a dramatically decline in the energy of eolian depositional mechanism and to an almost complete drowning of the coastal plain which cannot provide further sediments to contribute to the eolian wedge accretion. This is almost the last phase of sedimentation; the uppermost layer of the Banc's stratigraphy, the 'level A', was not preserved, due to both natural erosion and several years of excavations and research (Sardella et al., 2018).

The end of sedimentation in Grotta Romanelli occurred at about 6 ka BP, when 1) the coastal plain in front of Grotta Romanelli was greatly reduced and the sea level was about -7 m below the modern sea level (Lambeck et al., 2004); and 2) prevailing wind directions changed, probably in relation with the termination of the African Humid period (De Santis & Caldara 2015).

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