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BIOCLASTESYS INDUCED FRACTURES AND ROCKFALL ON THE EAST FLANK OF THE RAVINE OF MATERA: PRELIMINARY INVESTIGATIONS

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EXTENDED ABSTRACT

Le "gravine" sono profonde incisioni morfologiche che si sviluppano nella zona del bordo sud-occidentale della piattaforma carbonatica dell'altopiano della Murgia. Sono caratterizzate da fianchi abbastanza scoscesi e da un fondo stretto, con sviluppo planimetrico irregolare e discreta pendenza. Le gravine pur essendo parte del reticolo idrografico non sono interessate da deflussi idrici regolari, ma drenano occasionalmente il ruscellamento generato da eventi meteorici rilevanti e, pertanto, possono essere idrologicamente classificate come corsi d'acqua a carattere effimero o occasionale. Dal punto di vista geologico, le gravine si sviluppano di norma nei litotipi calcarenitici delle Calcareniti di Gravina (Pliocene sup. – Pleistocene inf.) e spesso si approfondiscono fino a raggiungere ed interessare il substrato costituito dai litotipi calcarei della formazione dei Calcari di Altamura (Cretaceo), che affiorano diffusamente su quasi tutto l'altopiano della Murgia. Le calcareniti giacciono in trasgressione con una lacuna stratigrafica sui calcari. Le suddette Calcareniti sono costituite da sabbie medio-fini debolmente cementate, prevalentemente calcaree, a contatto diretto con i sottostanti calcari, con intercalazioni di livelli più grossolani e di livelli sabbiosi più sciolti. Le calcareniti presenti sui fianchi delle gravine, spesso si presentano disturbate e fratturate a seguito di più cause, dipendenti sia da elementi contingenti che dai rilasci tensionali legati al sollevamento tettonico ed all'apertura delle gravine stesse. Fra gli elementi contingenti figurano le azioni antropiche e gli effetti dovuti alla bioclastesi, causata dalla presenza di vegetazione, in particolare alberi di fico.

Il presente lavoro si focalizza sulla diffusa presenza di fratture che interessano i livelli calcarenitici più alti del fianco est della gravina di Matera. Questi presentano diffuse evidenze di passati crolli di blocchi calcarenitici così come molteplici fratture, prevalentemente subverticali, legate a fenomeni di "richiamo al vuoto", alcune delle quali lascerebbero presagire dei fenomeni di incipiente distacco di blocchi di grandi dimensioni. In particolare, sono presentate alcune osservazioni preliminari condotte a seguito della prima attività di rilievo effettuata nella gravina, nell'area interessata da crolli e fratturazioni, che evidenziano come queste ultime sono a luoghi fortemente condizionate dalla presenza di vegetazione. In particolare, alberi a basso fusto (fico), i cui apparati radicali si sono insinuati attraverso piccole fratture o percorsi a bassa resistenza meccanica presenti nella formazione delle calcareniti. Gli apparati radicali favoriscono la fratturazione, allargando le fessure presenti e favorendo il potenziale il distacco di blocchi calcarenitici, questi ultimi richiamati verso il basso dalla gravità. L'analisi dei crolli sui fianchi delle gravine costituisce un'importante attività conoscitiva propedeutica alla tutela e preservazione del paesaggio della Murgia pugliese e materana, considerata l'unicità di tali elementi e la concomitante presenza di testimonianze storico-archeologiche, in particolare sui livelli calcarenitici della gravina. Questi ultimi sono infatti interessati da numerose cavità rupestri, che hanno avuto una lunga frequentazione sin dal Neolitico e contenenti affreschi prevalentemente di epoca alto-medievale, la cui conservazione è seriamente minacciata dai crolli. L'analisi, di tipo geometrico-ricostruttiva, effettuata nel presente lavoro, che riguarda in particolare un'area della Gravina di Matera, che è parte dell'area protetta del Parco della Murgia Materana, è stata effettuata attraverso l'utilizzo di un dispositivo aereo a pilotaggio remoto e di un laser scanner terrestre. L'utilizzo di tali strumenti ha consentito di ricostruire accuratamente la geometria delle aree interessate dai crolli più recenti e di analizzare il quadro fessurativo di un'area circoscritta del fianco della gravina, dove le fratture si sono evolute in tempi recenti.

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ABSTRACT

Ravines are typical morphological elements of the landscape of central Apulia and south-east Basilicata, in south Italy. These are deep narrow valleys located at the south-west bound of the Apulian foreland, namely Murgia. Ravines mainly carve the poorly cemented Plio-Pleistocenic sandy levels, belonging to the unit of the Gravina Calcarenites and the underlying cretaceous limestone of Murgia platform. In particular, the upper levels of ravine flanks show collapses and fractures, which alter the landscape of ravines. This work focuses on the geometric reconstruction of the fractures and collapses on the calcarenitic levels of the east flank of the ravine of Matera. This shows a number of fractures, some of them are very recent, which are modifying the flanks, damaging the archeological heritage and precluding the access to the ravine. Therefore, identifying the open fractures and their potential triggers is important for planning a strategy of preservation of this peculiar landscape.

***Keywords**: fractures, ravine, calcarenites, collapses*

INTRODUCTION

The landscape of western central Apulia on the bound with Basilicata, is characterized by the passage from the calcareous platform of the Apulian foreland, to the foredeep domain of the Bradanic trough. On the bound of the Apulian foreland there are deep narrow valleys locally named: "gravine". These are ravines carved in the relatively soft and poorly cemented Plio-Pleistocenic calcareous sandstone, named calcarenites (Cotecchia & Grassi, 1975; Cherubini *et alii,* 1996), outcropping in the upper layers of their flanks, overlying the Cretaceous limestone platform (Doglioni & Simeone, 2019; 2020; Festa *et alii*, 2018). Ravines mainly follow NNW-SSE direction, i.e. parallel to the Apennines trend, with steep and quite winding paths that can be considered as pseudo-meanders. Ravines have depths ranging between few tens of meters and about 200 m. They are ephemeral streams, since they drain runoff generated by extreme rainfall events, otherwise they are dry (Doglioni *et alii,* 2012). The genesis of ravines is likely related to the uplift of the Apulian foreland, due to the orogenesis of the Apennines (Doglioni *et alii*, 1994). Indeed, the back outcropping part of Apulian foreland cracked generating these deep straight valleys, which likely became working as drains of runoff (Doglioni *et alii*, 2012; Doglioni *et alii*, 2020).

The cracks opened during the Pleistocene, therefore the upper Pleistocenic levels were stressed and weakened. For this reason, they are prone to collapse besides being vulnerable to external stresses like human and natural factors (Doglioni & Simeone, 2020). In fact, the continuous human presence since prehistoric age caused a continuous digging and reshaping of the flanks of ravines, together with a continuous maintenance (Cotecchia & Grassi, 1975; Simeone *et alii* , 2019). The instability of calcarenites related to digging caused occasional collapses, which were immediately repaired in order to limit the propagation of damages. The flanks of ravines were also used for cropping on small artificial terraces. These activities ruled the presence of vegetation, thus limiting the proliferation of roots, which could potentially crack the calcarenites. The progressive abandonment of the ravine by its inhabitants, caused a lack of maintenance and a proliferation of small vegetation, which expanded on calcarenites, enlarging the cracks and triggering new collapses. Such phenomenon can be observed in an area of the eastern flank of the ravine of Matera. There, the roots of bushes and small trees, like figs, penetrated and cracked the calcarenite, thus favoring or causing diffuse collapses, specially where there were artificial caves. A recently generated crack is here investigate. According to observations and surveys on the site, it is due to the proliferation of the roots of some fig trees, which insinuated through the rock weakness surfaces crating cracks, thus stressing and enlarging them. The investigation of these phenomena is important for the preservation of the landscape and particularly of the ravines. In fact, these are important both from the landscape and archeological points of views.

THE RAVINE OF MATERA

The ravine of Matera, Fig. 1, is part of the stream named Torrente Gravina di Matera. It is 59.6 km long and is tributary to river Bradano. The catchment has an area of 430 km^2, it covers part of the south-west margin of Murgia. From a geological viewpoint, Cretaceous limestones diffusely outcrop in the east catchment, while Plio-Pleistocenic deposits characterize the west part of the catchment. The substratum of Cretaceous limestone is covered by a sequence of Pleistocene transgressive and regressive poorly cemented sands (Cherubini *et alii*, 1996; Simeone *et alii*,

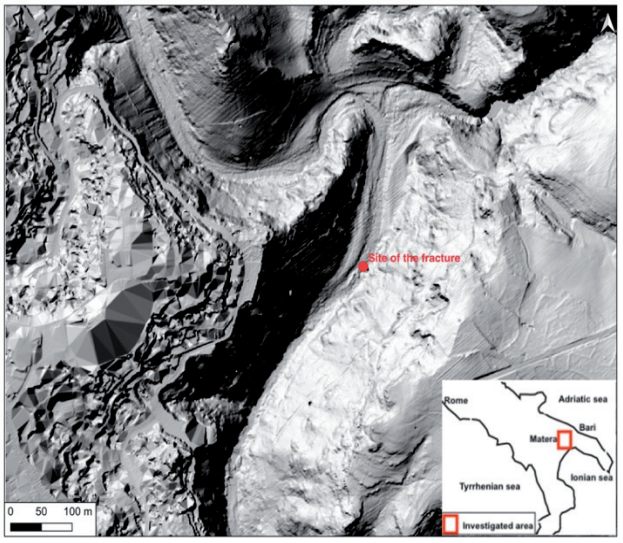

Fig. 1 - Location of the fractured front on 1m-resolution LiDAR of the area

2019). The base of the transgressive deposit is a weak calcareous sandstone rock called calcarenite, easy to be carved and used as building material. It outcrops on the upper part of the flank of the valley, showing manifold morphological terraces. Due to human activity of reshaping and modeling of the flank of ravine, calcarenitic levels were exploited according both to the horizontal and vertical directions. Fig. 2 shows a simplified transect of the ravine of Matera, representing the zone where fractures and collapses show. The central part of the ravine shows an apparent meandering path, see fig. 1, which seems to be due to the irregular consequences of a tensile fracture (Doglioni & Simeone, 2019).

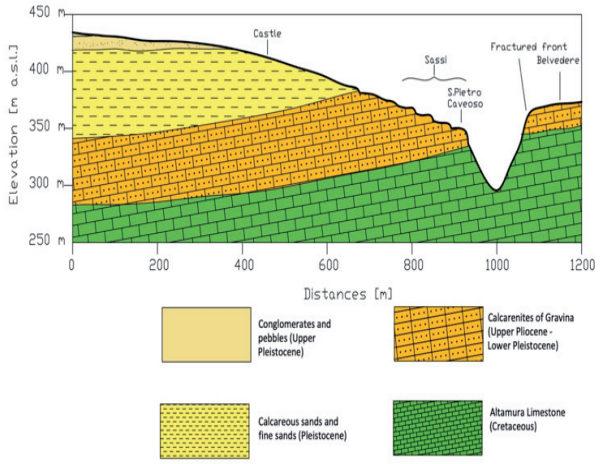

Fig. 2 - Simplified transect of the ravine, with the front affected by fractures

INVESTIGATION ON THE FISSURES AND CRACKS

The site of the fractured was surveyed, using a UAV, in order to have aerial views of those details which were not visible from the ground. The aerial view of the east flank of the ravine of Matera, in front of the urban area, shows a number of collapsed calcarenitic blocks (Fig. 3a).

These collapses are not documented, thus their occurrences is unknown. However, looking at the alteration of the detached blocks, it is reasonable to assume that they moved during the last 30-50 years. It is noteworthy that rupestrian settlements of ravine suffered during all their history of precarious stability conditions. Their fragility was due to the irregular distribution of voids and solids of calcarenite related to quarrying activity. Calcarenites are characterized by severe differences due to variation of the deposition environment, with sudden variations in facies, porosity and diagenesis degree (Doglioni & Simeone, 2020; Festa *et alii*, 2018). The calcarenitic rocks are characterized by a severe system of fractures, mainly parallel to the flank of the ravine, induced by the opening of the ravine for the tectonic uplift and the induced stress relief. Artificial hollows made it prone to collapse phenomena due to the excavation or to overload. The collapses of

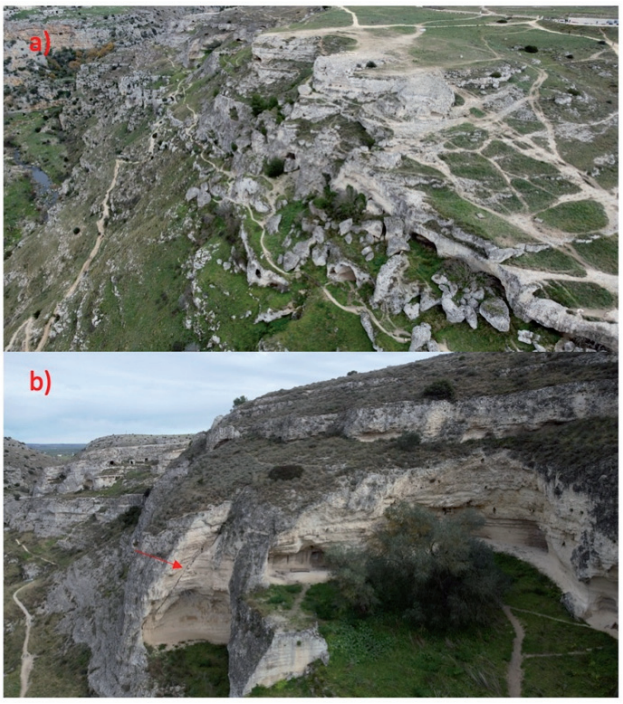

Fig. 3 - a) View of the calcarenitic front where collapses and fracturing occurred. b) Investigated recently opened fracture

rock masses induced tensile releases, which evolved within the hollows. A lot of them show fractures and discontinuities parallel to the excavation front giving indications of the tensile release induced by digging with fracturing in macro blocks.

In addition, the rock joints constitute mechanical discontinuities that are preferential paths of water infiltration and degradation. Their presence is due to quaternary uplift and tectonic activity. These joints are particularly vulnerable to bio-clastic and cryo-clastic phenomena. The presence of bushes and small trees causes a proliferation of roots, penetrating into the joints of calcarenites, thus opening and widening fractures, like shown by the aerial view shown by Fig. 3b. This is the case of a recent fracture, which opened on the front of the flank of the east side of the ravine. It is likely a widening of an existing fracture; its presence was reported at the end of 2022 by people who usually walk the near path. This fracture made a large block of calcarenite potentially prone to collapse, creating a risk condition for the path used by excursionists and threatening the presence of some ancient rupestrian cave. A detailed geometric reconstruction of the site as well as of the fractures is here attempted using a point cloud of the side obtained by a 3D terrestrial laser scanner. The accuracy of the scan is 6 mm at 10 m of distance from the scanner. A point cloud made of 54 million points was obtained by integrating five scans, in order to have a complete reconstruction of the front where the fracture opened. The fracture is averagely

5 cm width, with a maximum aperture of 8 cm. It is 17.5 m long and it has a dip angle of 61.5 degrees. Fig. 4 shows detailed cross section in the order from south and north, corresponding to the main vertical fracture. Fig. 4 clearly shows the presence of two small trees coming out from the fracture. Looking at fig. 4 it is evident the role of the roots of the small tree, which penetrating through the fractures stresses the front of the flank. The flank where the fracture is located shows other discontinuities, which share similar orientations, as shown by the stereogram of the facets in Fig. 5. The average dip of the discontinuities is 81 degrees, while the average dip direction is 88 degrees.

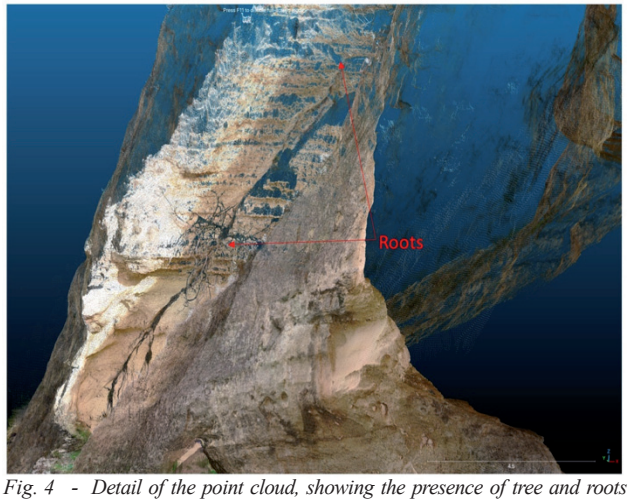

Fig. 4 - Detail of the point cloud, showing the presence of tree and roots penetrating through the fracture

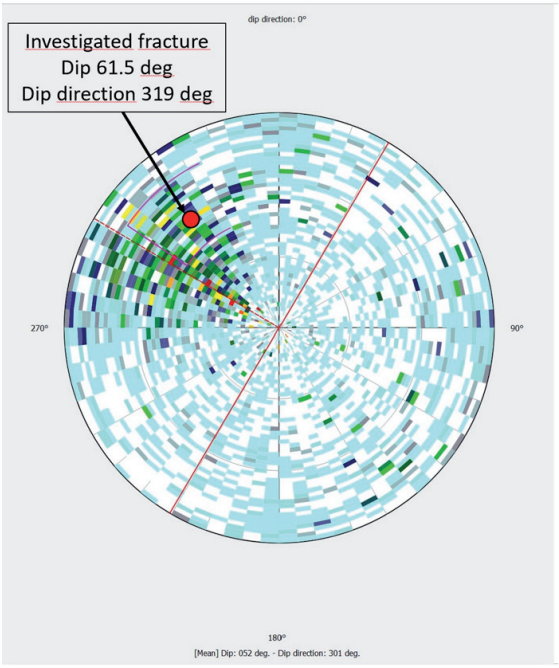

Fig. 5 - Stereogram of the facets reconstructed on the point cloud of front and position of the surface of the main fracture

CONCLUSION

A preliminary investigation of fracturing and collapse phenomena involving calcarenite levels of the ravine of Matera was presented. This work focuses on a recently generated fracture, which cracked a calcarenitic front, weakening the upper side flank of the ravine and causing a potentially critical scenario. This kind of fractures is not new, since calcarenitic levels of the ravine show a lot of fractures and past collapses. However, the presented case is of particular interest, since it is evident how the roots of the trees widened the fracture, thus making it propagating. The uncontrolled presence of wild vegetation threatens the stability of the quaternary upper levels of the flank of the ravine as well as the preservation of the rupestrian habitat. Therefore, this work aims at introducing a different point of view for the prevention of collapses, which focuses on an accurate study and reconstruction of the fractures and of their stress factors. Such approach, based on remote sensing, is relatively cheap and can be implemented on large areas in reasonable times. Therefore, it can be extended to the whole front where quaternary deposits outcrop and can be potentially exposed to fractures and collapses.

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