Application of low frequency georadar antenna to fractures detection and 3D visualization in a new quarry bench.

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1. Introduction

Ornamental stones quarries have to be mined with care as rock mass is characterized by several inherent planes of structural discontinuities (fractures, joints, etc.) which can't be easily and fully recognized before exploitation.

Planes of discontinuities are the main reason for a natural rock block formation or production waste in the exploitation process (Fig. 1). Preliminary fracture detection is a key issue for many decisions and for design and exploitation optimization. In this research we introduce an application of Ground Penetrating Radar (GPR) for detecting and imaging fractures in a sandstone quarry in Tosco-Emilian Apennines.

2. Aims

I. Testing the ability of low frequency GPR antenna to image large apertures fractures surfaces in a new bench.
II. Construction of a 3D fractures Model.
III. Post-processing for quarrying decision and optimization (work in progress).

3. Fractures detection methods

The evaluation of an ornamental stone deposit is deeply linked to the characterization of fractures and joints . The survey of fractures is an essential step to avoid the decrease of the recovery of blocks. Moving sustainably from this concept and after surveying the literature of fractures detection methods, a classification to destructive and non-destructive methods could be obtained (Fig. 2).

Destructive methods may give more accurate information in terms of detecting intensive data such as micro fractures at large depths. They are more expensive, time consuming, and the results represent just the testing area since it is often followed by 3D stochastic modeling of fractures.

On the other hand, non-destructive methods are fast, able to cover wider areas and less expensive. Traditional and non-contact surveying techniques have been used to record and classify sets of fractures in just rock faces and sometimes they are followed also by 3D stochastic modeling. Geophysical techniques can give a realistic 3D image of fractures spatial orientation by applying 3D in-situ cheap data acquisition.

4. Ground Penetrating Radar

It is a geophysical electromagnetic method based on transmission of electromagnetic waves pulses to the rock mass. When the radar waves hit a boundary of two materials of different dielectric properties, a reflection from this boundary is received by the antenna. The maximum penetration depth range mainly depends on the frequency of the antenna since the wave propagation in a medium is described by this equation: velocity (v) = frequency (f) x wave length (λ). There are other factors that control the signal penetration depth (attenuation) such as the water content and homogeneity of the medium. The frequency selection of an antenna depends on the surveying objective. Low frequency antennas allows to obtain greater depth ranges, but with reduction in resolution and vice versa.

5. Methodology and case study

Selection of a fracture detection method is controlled by the application target. GPR has been trusted to image fractures in quarries in several publications [see 1,2,3 among others]. Low frequency GPR antennas can be used for exploring the site geology, such as fractures, and detecting deep buried large objects [4,5]. In applications to detect fractures in sandstone rock mass with 400 MHz GPR antenna, a penetration depth of 3-4 m was just obtained [6,7]. Accordingly, we test the ability and quality of low frequency GPR antenna (70 MHz) to image fractures at a greater depth in a case study of a new sandstone quarry bench in Firenzuola, Italy. The rock mass of this site is horizontally stratified and is characterized by large aperture vertical fractures (2-3cm), see Fig. 3. Low frequency GPR antenna (70 MHz) was used to obtain a deep image of the sub-surface. The data acquisition was carried out in 3D GPR survey grid (7mx12m) over the bench surface with spacing of 1mx1m leading to 21 survey lines. The grid is located in 8m far from the bench face (Fig. 4) to check the entire existence of fractures in x direction.

6. Results and discussion

After wise signal processing using Radan software [8], the GPR cuboid of the surveying grid was produced to facilitate 3D interpretations (Fig. 5 and Fig. 6 show examples of fractures interpretations). A penetration depth of 14m was obtained due to signal attenuation caused by fractures and the wet condition of rock mass. Continuous vertical fractures reflections could be optically interpreted through whole the GPR cuboid while few others are discontinuous (Fig. 5). The discontinuous extensions of few vertical fracture surfaces may refer to higher mechanical properties of a rock horizon or due to the limited resolution of the antenna (under research point).

Using a wide range of frequencies is recommended to make a compromise between penetration depth and resolution.

7. Conclusions

Among different fractures detections methods, GPR is recommended for fast, easier, reliable and non-destructive data acquisition particularly when the surveying area is accessible. Low frequency GPR antennas can be used to image subsurface large aperture fractures in applications to stones deposits exploration since deep imaging is time-saving and gives a wider impression to the exploration zone. An intensive 3D survey grid is recommended with low frequencies GPR antennas since interpolation between survey lines can clarify more the results.

Fig. 1. An extracted stone block was considered as waste because of a fracture plane.

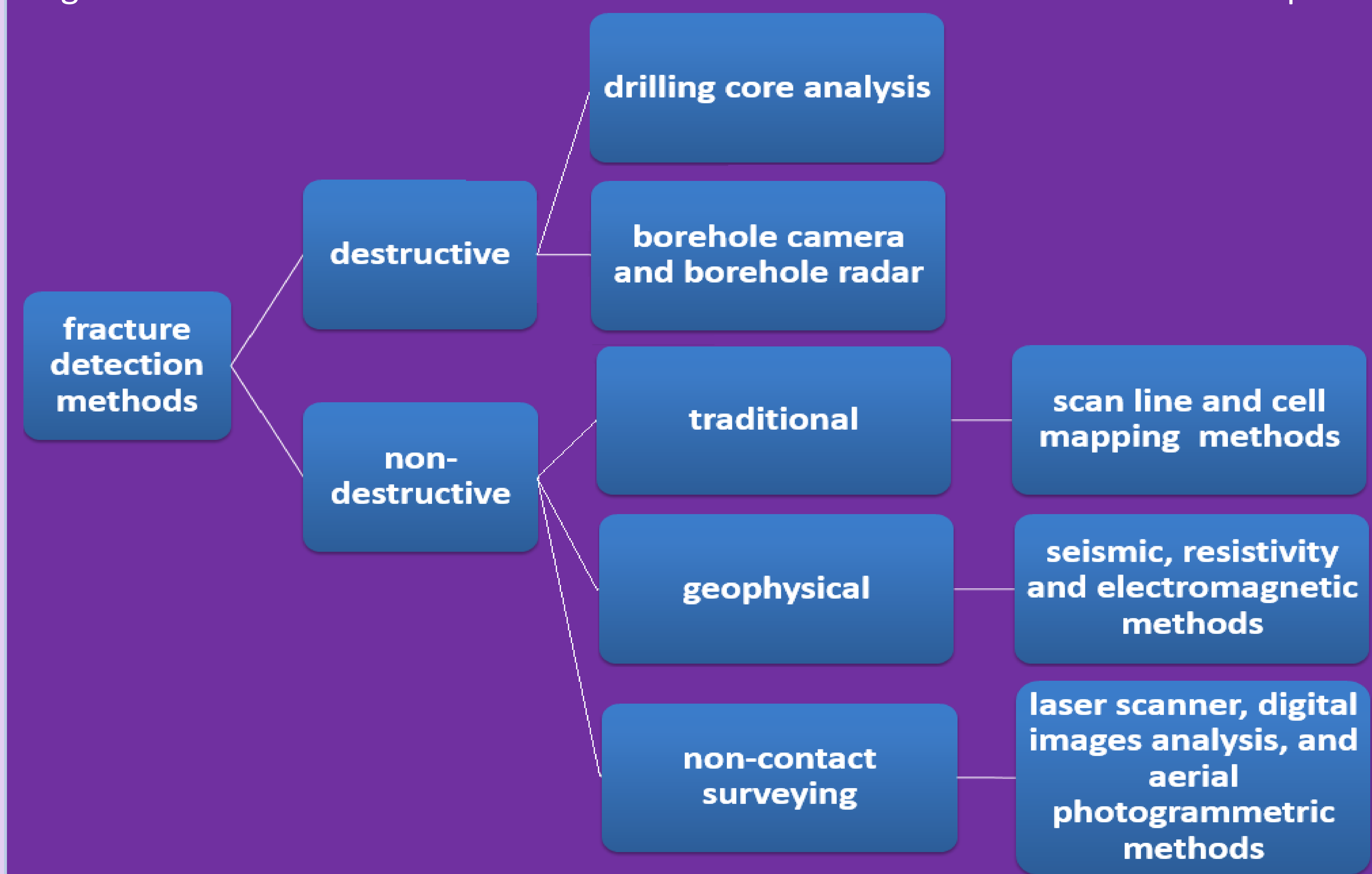

Fig. 2. A classification survey to fracture detection methods, see a sample from the surveyed publications in [1,2,3,6,7,9,10,11,12,13,14].

Fig. 3. Out-cropping large aperture vertical fractures in the bench surface.

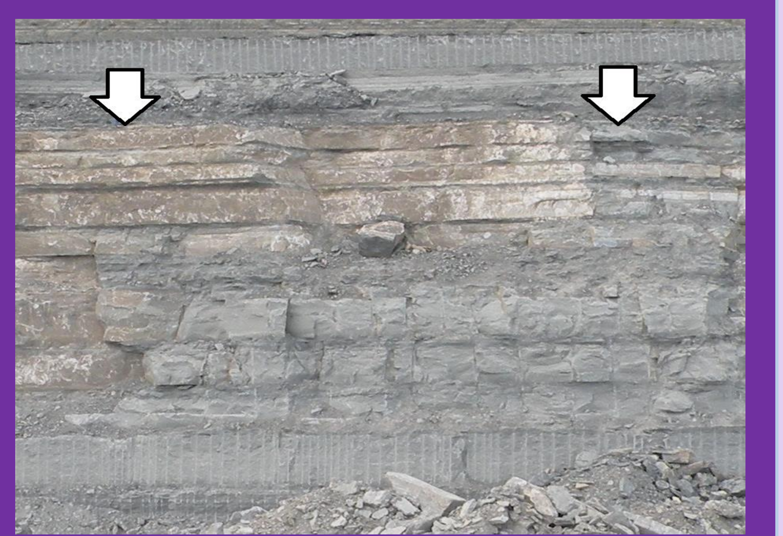

Fig. 4. A front view of the bench face. The arrows refer to the survey grid limits, 8m far from the face.

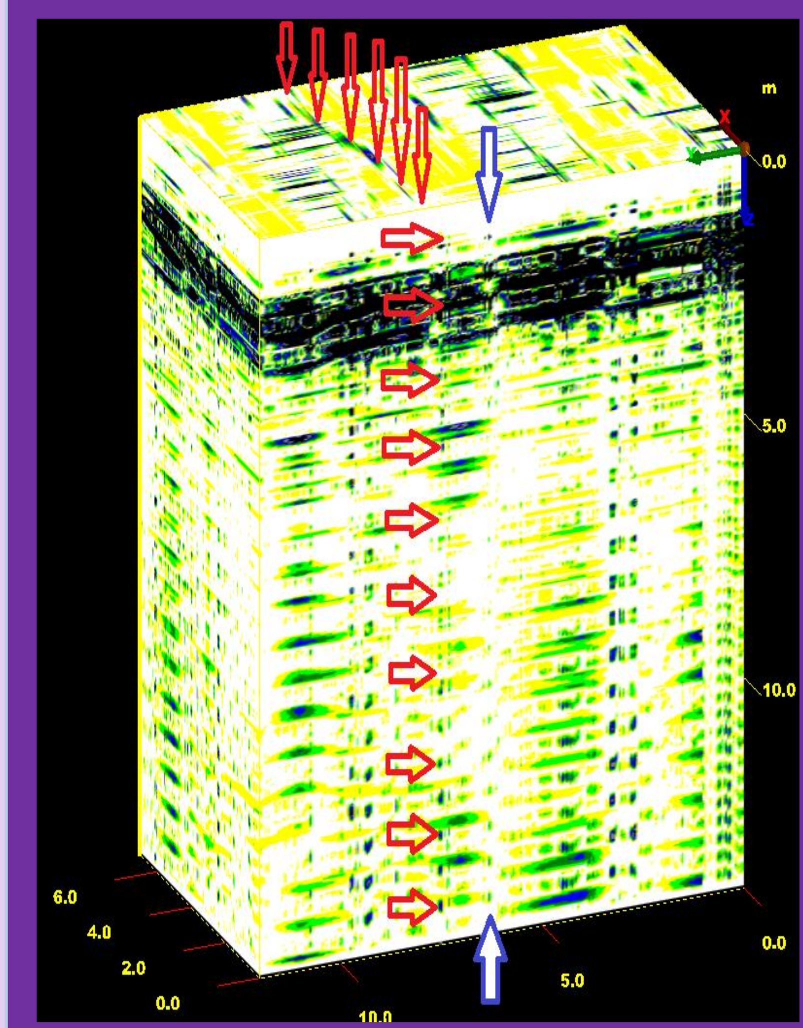

Fig. 5. Full GPR cuboid
RED ARROWS: a tracing of a fracture surface.
WHITE ARROWS: indicate a fracture surface with a discontinuous extension between 5-10 m depth.

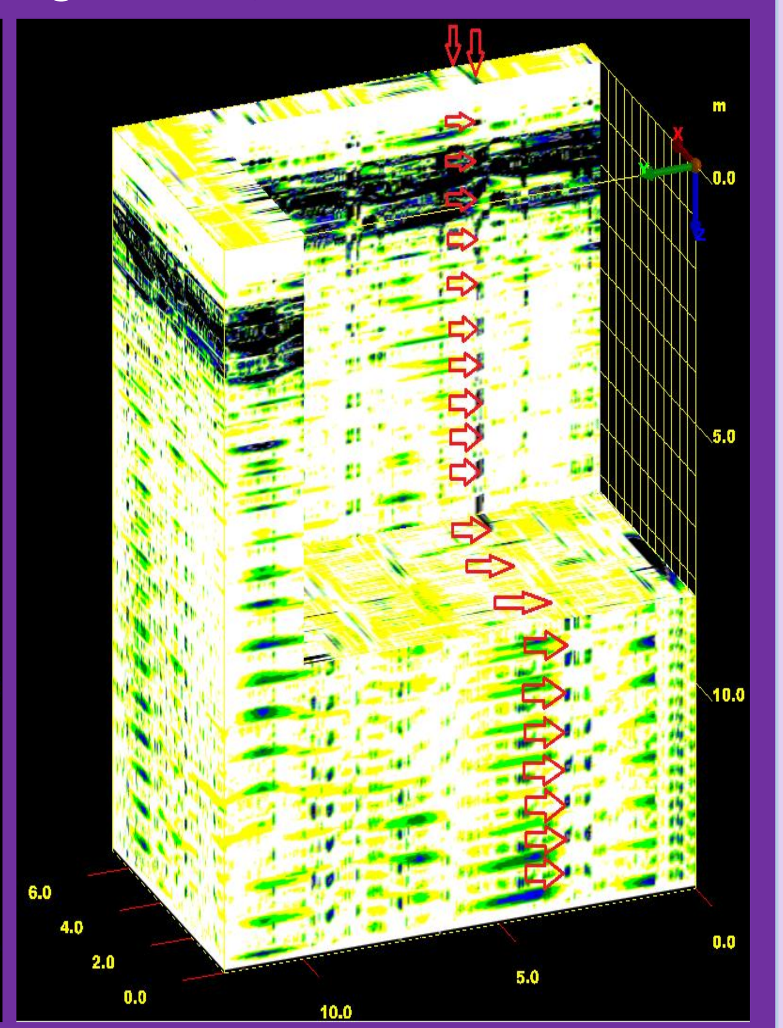

Fig. 6. A 3D cross-section
RED ARROWS: a tracing of a fracture surface in the entire volume of the rock mass.

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Acknowledgement

The authors are grateful to "La Borghigiana" quarrying company for allowing carrying out this research and providing us with all the in-situ needs. Furthermore, authors really thank EU-METALLIC II - ERASMUS MUNDUS program that funds the PhD scholarship of the lead author, Mohamed Elkarmoty.