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Ground penetrating radar and structural geological mapping investigation of karst and tectonic features in flyschoid rocks as geological hazard for exploitation

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A B S T R A C T

We evaluated the use of ground penetrating radar (GPR) in detecting karst cavities and discontinuities that could form potential landslide surfaces in flyschoid rocks of the Rodež open pit mine in Anhovo (W Slovenia). We recorded 21 GPR profiles in three consecutive benches with the unshielded 50 MHz rough terrain antenna (RTA) system, and correlated them with the results of detailed structural and lithological mapping of the area. We located several karst cavities and confirmed the presence of discontinuities with the interpretation of GPR profiles alone. However, their correlation with geological and structural data gave a more precise insight into the structural setting of the studied area. The different discontinuity families specified in the Rodež open pit mine are mainly the result of the strike-slip tectonics and gradual anisotropic lithology. The complexity of the intersections of structural discontinuities and the mechanical properties of rocks contribute to the formation of sliding surfaces and the developing of karst features. Cavities and phreatic channels develop in the vadose zone in calcarenites and result from complex structural deformation and karstification factors at the open joints or larger structural fractures.

1. Introduction

Altering sedimentological characteristics and complex geological structures (e.g. joints and faults) of rock massifs make orientating and positioning of slopes a major challenge in designing an open pit mine. The initial movements in the slope are often associated with stress relaxation, i.e. linear elastic deformation caused by unloading mining works. The first clear evidence of such instability in an open pit is the activation of sliding surfaces. The development of a complete geotechnical model that consists of four interlinked components (geology and structure of the ore body, open pit rock mass characteristics and hydrogeology) can prevent such hazardous incidents from happening. In this study we focused our research on the structural and geological properties of the Rodež open pit mine, developed in flyschoid rocks (Fig. 1).

The Rodež quarry is the main source of raw material for the production of cement in the company Salonit Anhovo, which is the largest cement producer in Slovenia. The quarry is located in the Soča Valley (W Slovenia), 10 km north of Nova Gorica, on the west side of Mt. Jelenk at the margin of Banjščice plateau. The open pit is developed in 14 benches and spans 300 m in elevation. The Palaeogene flyschoid sedimentary rocks in the studied area belong to the Lower and Middle Palaeocene [1]. Detailed geological mapping revealed a complex structural heterogeneity of the beds.

Structural discontinuities are related to the formation of several karst features (e.g. small cavities) in the carbonate units of the Rodež megabed. The possible occurrence of hidden underground cavities is very hazardous for exploitation, and can lead to dangerous and costly accidents like collapses under quarry machines (Fig. 2). In most cases, the underground karst structures develop in the vadose zone and result from complex structural deformation and karstification factors [2] at the open joints or larger structural fractures. To reveal the spatial occurrence of cavities, it is necessary to obtain a detailed insight into the distribution of structural discontinuities for each part of the mining area. The same discontinuities can also develop into sliding plane structures and, depending on their orientation, can cause slope failure during mining (Fig. 3).

For this reason, we decided to study the structural and karst phenomena in the area with the low frequency ground penetrating radar (GPR) method, which has been proven effective in many different case studies (e.g. [3,4]). Using geophysical investigations, we wanted to prove the existence of underground

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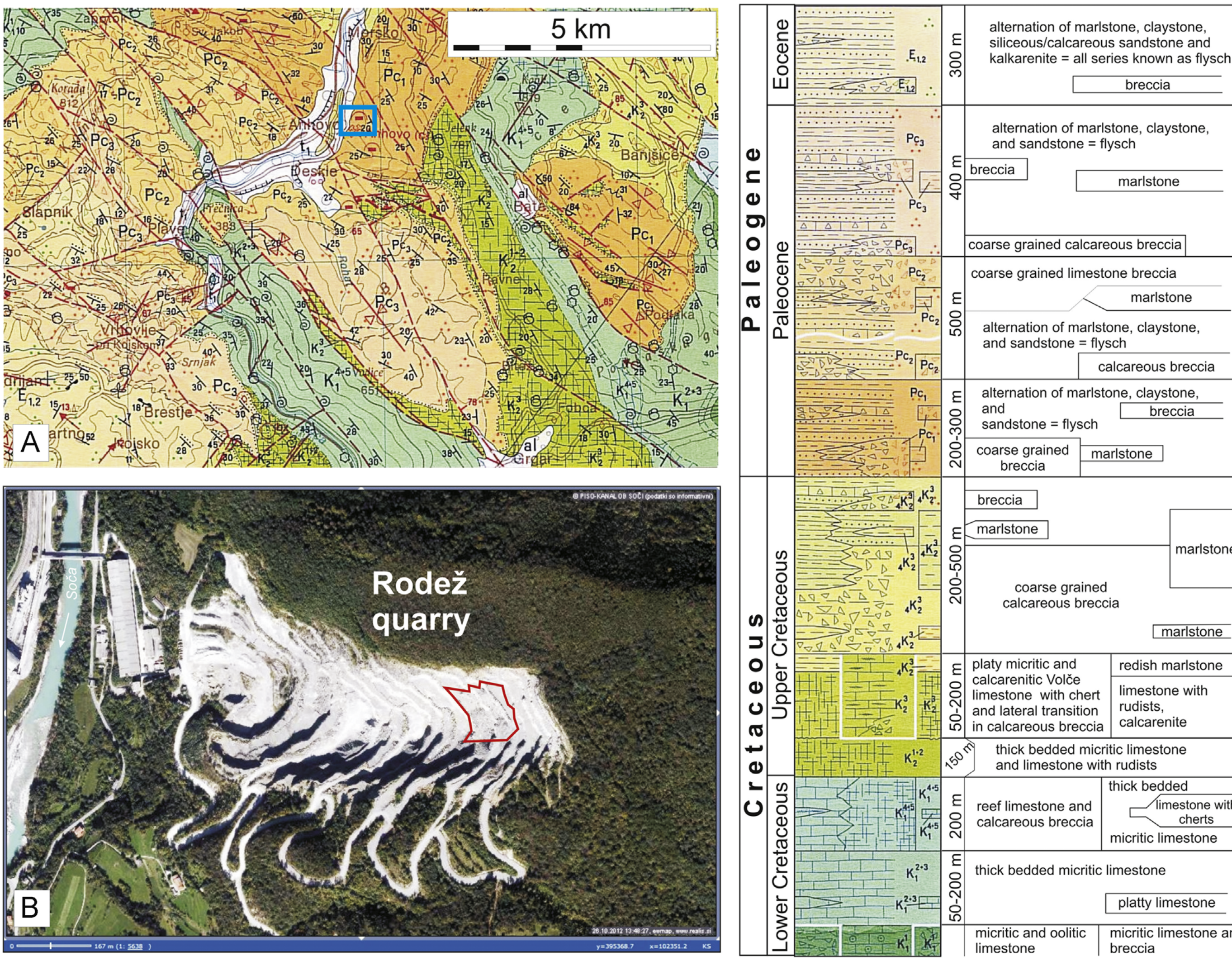

Fig. 1. (A) Geological position of studied area (blue area) [8] with corresponding lithostratigraphical interpretation. (B) Red polygon indicates area shown in Fig. 5. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

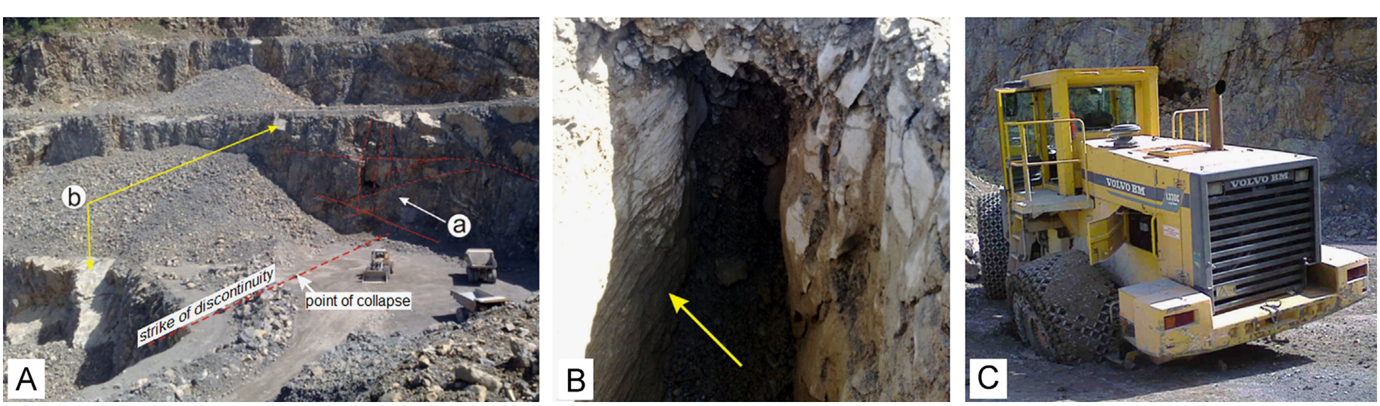

Fig. 2. Work accident during loading of raw material at E255 bench. (A) Roof collapse of phreatic channel along discontinuity (a) and joint structures, some with the same dip as bedding plane (b); (B) karst channel with visible flow direction (yellow arrow); (C) sinking of loader wheel into karst cavity. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

geomorphological structures (cavities, phreatic channels, etc.) in anisotropic lithological horizons, which are related to gradual bedding. On the basis of the conducted research, we evaluated the suitability of the GPR method for tracking karst structures and potential landslide surfaces or other geomechanical instabilities related to the structural discontinuities within gradual anisotropic lithology. We correlated the GPR results with the results of structural and lithological mapping.