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Geological Structure and Geomorphological Aspects in Karstified Susceptibility Mapping of Limestone Formations

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Abstract

Major cavities and underground drainage tend to develop with the aid of massive or thick-bedded and well-jointed limestone whilst porous and soft limestone is more likely to form micro-cavities and localized karst along bedding and close to ground level. This phenomenon wouldprobablybe explained by studying the movement of water circulating through the pores in the limestone. Strong correlations between fracture patterns and drainage lines/cavity zones have been long suspected by many researchers in the past (Mayer, *et al.*, 2003). An assumption has been made that fractures offer lines of decreased hydraulic resistance to groundwater flow and therefore they are more easily exploited by weathering and erosion processes than their adjacent rock (Sower, 1975 and Ericson *et al*., 2004). The end product of the weathering and erosion process is a river channel or active cavity, developed along fractures orientation. Thus, the karstic surfaces are consistently developed along the joint sets orientated at limestone is strongly fractured with the dominant joint orientations.In this paper, a methodology for karstified susceptibility assessment of three selected limestone formations is presented specifically looking at tectonic history, joint pattern, and topographyand karstification intensity. Structural analysis, based on rose diagram and stereographic equal-angle projection method have been used to analyze the joint orientations.

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1. Introduction

A great numbers of variables that involved in the process of karstification have strongly influenced the character of the developed karstic features; this is demonstrated by the existence of a huge variation of karst from one place to another.As in Waltham and Fookes (2003), a functional combination of climate and historical geology (sedimentation and structural history) broadly influenced the karst classification system, and it must therefore be borne in mind that the level of karst complexity also increases in heavily tectonized rock.

In Waltham and Fookes system, karst formation is classified into five different progressive classes: kI – juvenile karst; kII – youthful karst; kIII – mature karst; kIV – complex karst and kV – extreme karst. Karst kI is the youngest form of karst landscape, often only to be seen in deserts and periglacial zones and considered to show little potential for producing engineering hazard. In contrast, karst kV is the oldest and most hazardous from the engineering point of view, as it exhibits a complex cave system; it is usually encountered in wet tropical regions. In Malaysia, karst in most of limestoneformations are dominated by its highly variable rockhead and is thus classified as extreme karst (kV) under the Waltham and Fookes (2003) system. Karst landscape of kV, i.e. as seen above the ground level, will assist in visualising the true extent of sub- surface karst in parts of Malaysia, otherwise only revealed by borehole cores.

Bedding planes and tectonic structure such as faults, folds and joints, have been frequently linked to the development of karst systems and in some cases, are given as the single most important factor that determines the variety of karst seen today (Waltham *et al*., 2005). In karst systems, horizontal or vertical cave passages are often developed preferentially within these lines as they are less resistant towards dissolution compared to the adjacent intact rock mass. The bedding plane in a sedimentary rock is a primary structure, originally planar and of low dip, characterised by differences in sediment composition, structure and texture. The variation caused by these changes, developed at deposition, might come in the form of the grain size or mineral content. In contrast, tectonic structuressuch as faults and joints are secondary planes, formed in response to tectonic forces and occur after lithification. In this study, the effect of parameters cited towards the intensity of karstification were based on field data mapped from three different sites, the SMART tunnel site of the Kuala Lumpur Limestone Formation, limestone quarries in Kinta Valley, Perak and Kangar, Perlis for both the Kinta Limestone Formation and the Chuping Limestone Formation.

2. Methodology

Detailed geological mapping were carried out at three localities of rock formation. In this exercise, detailed measurement of the orientations (orientation of strike and angle of dip) of bedding planes, fractures (joints and fault planes) and karst surfaces developed in the exposed limestone and measured as separate entities. This is because not every joint is karst, and it looked as if the groundwater flow is choosing its own orientation in which to develop karst. A reconnaissance of mapping areas was carried out during the first few days of the mapping to quickly assess the quality and the level of weathering of the limestone outcrop. The accumulation of fracture line directions was then displayed, measured from Grid North (which is within 0° 3' East of Magnetic North in this area), by using a rose diagram to produce percentages in any given direction grouped in batches of 10° from North. The details below are the finding of each exercise carried out at, as the following:

2.1. Kuala Lumpur Limestone Formation

The limestone formation outcrops on the floor of the Klang Valley, elongated in a north-south direction with broad exposure in the north, up to 10 km. The limestone is composed almost entirely of carbonates minerals ($CaCO_3$) with few impurities, dominantly calcite but frequently containing a small percentage of magnesium (Mg). Locally dominant in certain areas is dolomitic limestone and dolomite. The types of limestone mapped in the area are described as follows, first is calcitic limestone – the recrystallized calcitic limestone ranges from white, cream, grey and less frequently, pink in colour, depending on the non-carbonates content of the formation. The rock has a granular texture with a size crystal from 0.2 mm to 1 mm and up to 5 mm adjacent to the aureole of the granite. Weathered limestone is characteristically soft/weak white sugary rock. Distinct calcite crystals are found near to