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Geoheritage values of the Dong Van Karst Plateau Geopark: A quantitative geomorphological and topographic analysis

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Abstract: The main purpose of this study is to analyse the geomorphological charactertistics of the Dong Van Karst Plateau Geopark (DVKPG) in the Ha Giang province of Vietnam. A digital elevation model (DEM) was generated using SPOT5 imagery and elevation and slope maps were then extracted from the DEM. A geological map at the scale of 1:200,000 was constructed and used for analyzing and visualizing the carbonate rock in three dimensions. The results show that there are two types of topographic development in the study area. The first, formed by tectonic movement and affected by major faults, is distributed in a NW–SE direction. The second was formed by exogenous geomorphological processes and influenced by both major and faults. It is distributed mainly in a NE–SW direction. Geological analysis indicates that ten stratigraphic formations crop out in the study area but only six of these have correlations with karst landscapes. Carbonate rocks are mainly distributed in the Dong Van district. They cover an area of 329.7 km^2 (71.7% of the entire district and 36.5% of study area). In constrast, there is few carbonate rocks in the Quan Ba district. In the case of slope, the slope angels from 15–30° cover about 53.5% of the study area. There are 1261 karst sinkholes in the study area with an average density of 1.4 sinkholes per km^2.

Keywords: Dong Van, Ha Giang, karst plateau, geopark

INTRODUCTION

The Global Network of National Geoparks was established under the aegis of UNESCO in 2004 aimed at protecting some of the world's most spectacular and important geological sites. A geopark is defined as a a nationally protected area containing a number of geological heritage sites of particular significance, rarity or aesthetic appeal and these heritage sites are developed as part of an integrated concept of conservation, education and sustainable development (UNESCO, 2006). According to Azman *et al*., (2010), the main objectives of a geopark are (1) protection and conservation, (2) tourism-related infrastructural development and (3) socio-economic development. Therefore scientific studies in these geoparks may present opportunities to understand important events in their geo-history and supply additional information on permanent and protected sites where scientific ideas can be tested for generations to come (Kusky *et al*., 2010). The main objective of this study was to undertake quantitative analyses of the geomorphology and topography of the geoheritage of the Dong Van karst plateau in the Ha Giang province of Vietnam.

STUDY AREA

The Dong Van karst plateau Geopark (Figure 1) is located in Ha Giang province, in the northwesten part of Vietnam. It covers an area of 2380 km^2 in four administrative districts: Dong Van (460 km^2), Meo Vac (577.6 km^2), Yen Minh (785.2 km^2), and Quan Ba (557.2 km^2). The altitude varies from 174 to 2,265 m.

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DATA AND ANALYSIS

Digital elevation model and derivatives

A digital elevation model was generated from SPOT5 satellite imagery with a resolution of 15 m. Based on the DEM, geomorphometric data was extracted using ArcGIS 10. 0 software. The elevation map was constructed with elevation seven classes: 100–300 m; 300–600 m; 600–900 m; 900–1200 m; 1200–1600 m; 1600–2000 m and >2000m. The characteristics of the elevation classes are shown in Table 1 and Figures 2 and 3.

Table 1: Characteristics of elevation classes.

No	Elevation classes (m)	Area (km^2)	Percentage
1	178 - 300	37. 2	1. 6
2	300 - 600	376. 3	15. 8
3	600 - 900	549. 1	23. 1
4	900 - 1200	623. 6	26. 2
5	1200 - 1500	592. 4	24. 9
6	1500 - 2000	197. 8	8. 3
7	2000 - 2260	3. 4	0. 1

The three elevation classes (600–900 m; 900–1200 m; 1200–1500 m) cover an area of 1,765 km^2 (74.2% of the study area) and contain impressive landscape characteristics. In contrast, the elevation class >2000 m covers an area of only 3.4 km^2, distributed mainly in the rear of the plateau. The elevation class of 600-900 m contains terrestrial (non-karstic) landscapes with residual towers and cones on the

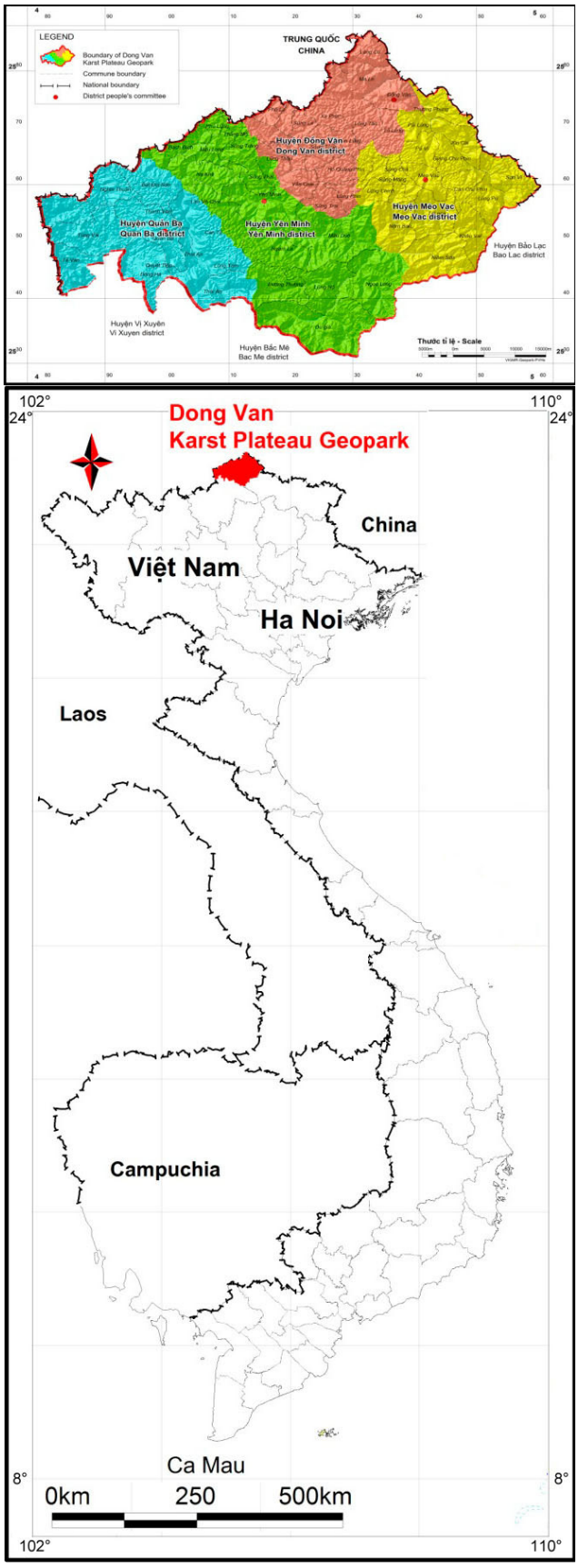

Figure 1: Location of study area.

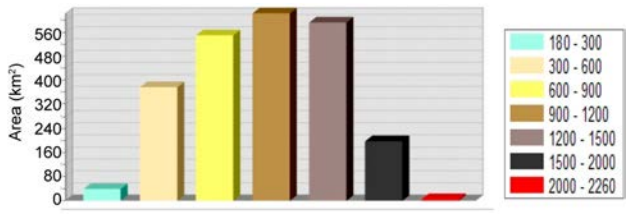

Figure 2: Frequency distribution of elevation classes in the studied area.

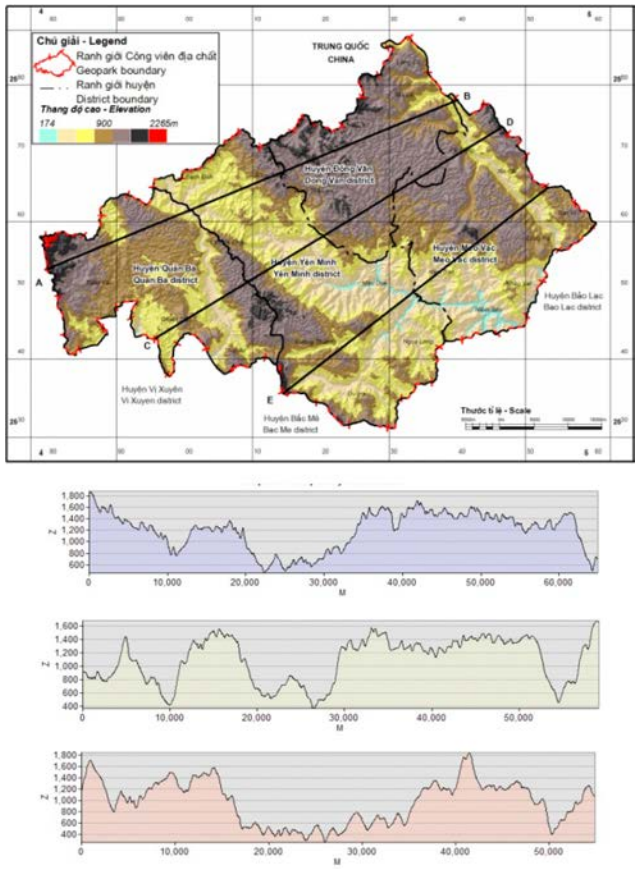

Figure 3: Elevation map of the studied area and NW-SE Cross-sections, A-B (upper), C-D (middle) and E-F(lower).

slopes, and carren slopes. This elevation class is adjacent to karst areas and terrestrial landscapes make a contrast to surrounding karstic landscapes. For the elevation classes 900-1200 m and 1200-1500 m, karstic landscape features are mainly steep cliffs, cones and towers that are distributed on the top of mountain chains. In order to show the variation of elevation in the DVPKG, three NW trending cross-sections (Figure 3) were constructed.

The slope angle map (Figure 4) was constructed with 7 classes. Characteristics of the slope angle classes are indicated in Table 2.

The areas of steep slope (15°-30°) account for 53. 9% of the study area. They are characterised by limestone mountains with non-karst landscapes, stone forests and residual cones on the slopes. The inclined slope (5°-15°) and comparatively steep slope (30°-45°) cover areas that account for around 21.9% and 16. 5% of the study area, respectively. The very gradual slopes (0° - 2°) and gradual

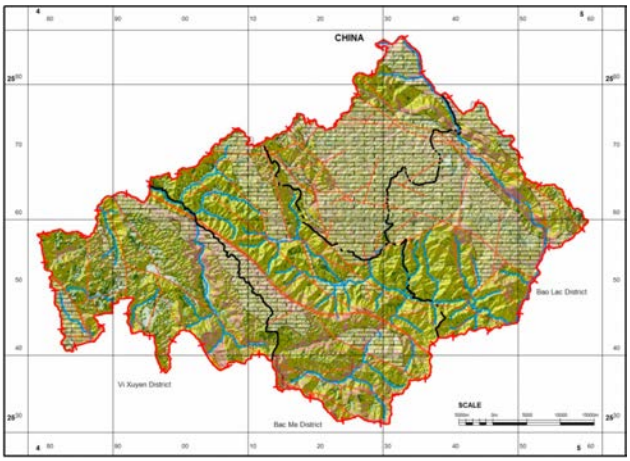

Figure 4: The slope angle map of the studied area. Refer to Figure 5 for legend of slope classes.

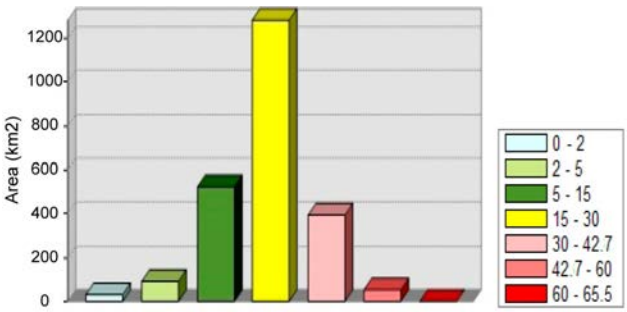

Figure 5: Frequency distribution of the slope classes.

Table 2. Characteristics of the slope classes.

No	Elevation classes (m)	Area (km^2)	Percentage
1	Very gradual (0^0 - 2^0)	31. 3	1. 32
2	Gradual (2^0 - 5^0)	92. 4	3. 88
3	Inclined (5^0-15^0)	522. 3	21. 94
4	Steep (15^0- 30^0)	1,283. 8	53. 94
5	Comparatively steep (30^0-45^0)	392. 5	16. 49
6	Very steep (45^0-60^0)	56. 8	2. 39
7	Abrupt (> 60^0)	0. 8	0. 03

slopes (2° - 5°) are mainly located in alluvial flats and terraces along the Mien river. These areas contain karst valleys. Generally, the slope angle map represents a high contrast of landscape within the geoheritage area.

Geological map

The geological map (Figure 6) was constructed using the Bao Lac and Ma Quan geological sheet maps at the scale of 1:200.000 and was used for analyzing the distribution of carbonate rocks. Lithological formations in the map were updated using the SPOT5 satellite images. Fieldwork was conducted to verify the results. A total of 10 lithological formations were represented. They are Chang Pung (€$_3$*cp*), Lutxia (O$_1$*lx*), Song Cau (D$_1$*sc*), Mia Le (D$_1$*ml*), Na Quan (D$_{1-2}$*nq*), Toc Tat (D$_3$*tt*), Bac Son (C-P *bs*), Dong Dang (P$_2$*dd*), Hong Ngai (T$_1$*hn*) and Song Hien (T$_1$*sh*).

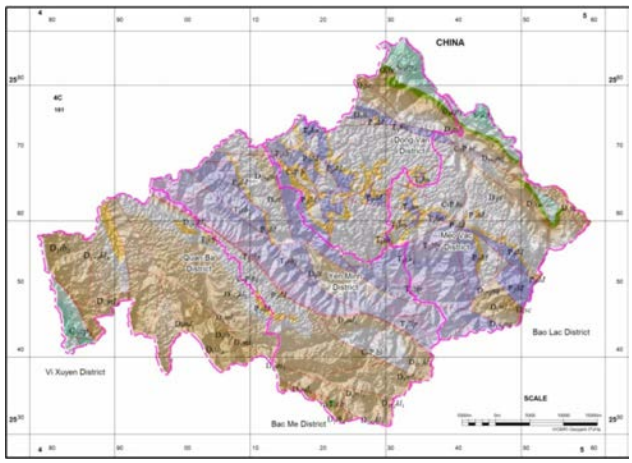

Figure 6: Geological map of the studied area.

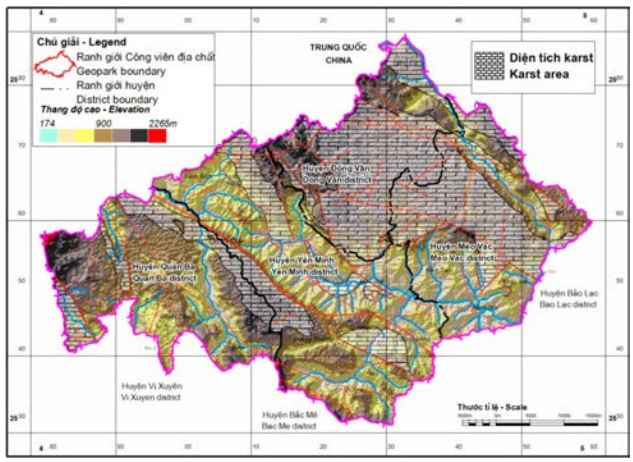

Figure 7: Distribution of carbonate rocks.

In this study, the lithological formations were divided in to 2 groups: 1) carbonate rock with karst landscape including Chang Pung (€$_{2-3}$ cp), Lutxia (O$_1$ lx), Toc Tat (D$_3$ tt), Bac Son (C-P *bs*), Dong Dang (P$_2$*dd*), and Hong Ngai (T$_1$*hn*) formations and 2) non-carbonate rock with non-karst landscape. Using DEM, the distributions of different types of rock in correlation with the elevation classes was analysed. Distribution of the carbonate rocks are shown in Figure 7. The carbonate rock covers of 71.7% area of the Dong Van district, but only 19.5 % in the Quan Ba district (Table 3).

Table 3. Statistics of carbonate rocks in the study area.

No	District	Area (km^2)	%	Areas with carbonate rocks (km^2)	%
1	**Dong Van**	460. 0	71. 7	329. 7	36. 5
2	**Meo Vac**	577. 6	49. 7	287. 1	31. 8
3	**Yen Minh**	785. 2	22. 7	178. 2	19. 7
4	**Quan Ba**	557. 2	19. 5	108. 5	12. 0

The carbonate rocks with karst landscape cover an area of 903.5 km^2, distributed mainly in Dong Van and Meo Vac districts. Carbonate rocks interbedded with non-

Table 4: Distribution of sinkholes and caves in correlation with elevation classes.

No	Elevation classes (m)	Number of caves	%	Number of sinkholes	%
1	0-300	0	0	0	0
2	300-600	18	29. 0	9	0. 7
3	600-900	13	21. 0	43	3. 4
4	900-1200	9	14. 5	281	22. 3
5	1200-1500	16	25. 8	742	58. 8
6	1500-2000	6	9. 7	186	14. 8
7	> 2000	0	0	0	0

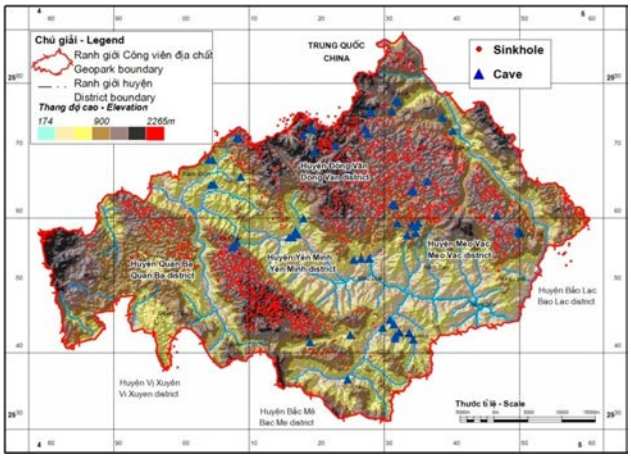

Figure 8: Location of karst sinkholes and caves in the studied area.

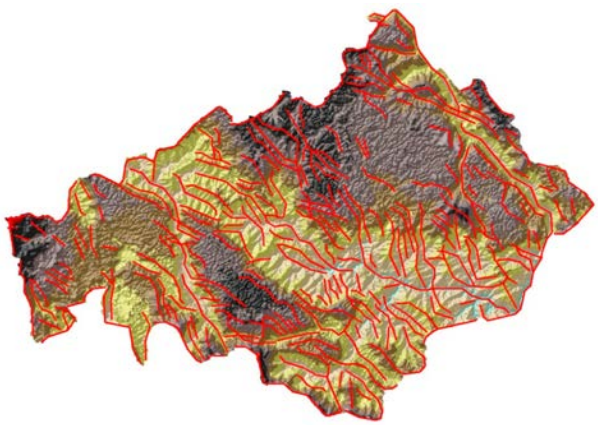

Figure 9: Possitive lineaments map of the studied area.

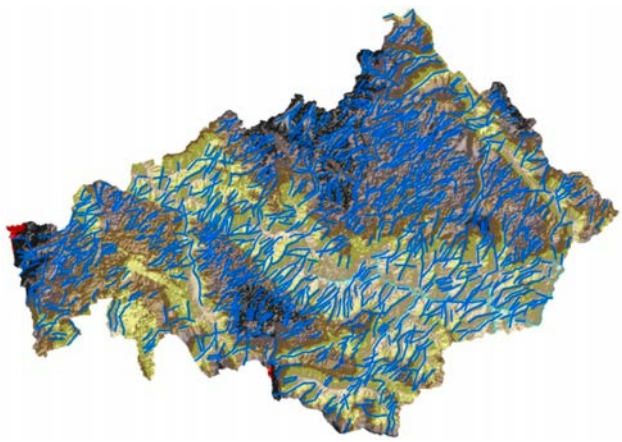

Figure 10: Negative lineaments map of the studied area.

carbonate rocks are distributed in the districts of Quan Ba and Yen Minh. These areas are characterized by diversity in landscape, geological history and cave development and therefore represent the geoheritage values of the DVKPG.

Distribution analysis of karst sinkholes and caves

Karst funnels were interpreted by using SPOT5 imagery, DEMs and topographic map. The location and shape of caves were checked and mapped in field surveys by experts from the Vietnam Institute of Geosciences and Mineral Resources (VIGMR) and Belgian colleagues. A total of 1261 karst sinkholes and 62 caves were identified in the study area (Figure 7). An average density of karst sinkholes per 1 km^2 is 1.4. The distribution of sinkholes and caves in correlates with elevation classes as shown in Table 4.

The elevation class of 1200 – 1500 m has the highest density of sinkholes (58.8%) and a high density of caves (25.8%). The highest density of caves is in the elevation class of 300-600 m. In constrast, there are no caves or sinkholes in the elevation classes of 0-300 m and >2000 m.

Lineament analysis

In order to explore the trend of topographic features in the study area, a lineament analysis was carried out. Using the DEM, eight hillshade maps were created and used to extract lineaments in the study area. This process was carried out using PCI solftware.

Figure 9 shows positive lineament map of the study area. The positive lineament map represents elevated topography, topographic ridges and tectonic cliffs. In general, the positive lineaments trend NW. This is the direction of trend of fault scarps and lithological boundaries in the study area. This is also the major trend of topographic development and tectonic features in Vietnam.

A negative lineament map that represents topographic featuress such as valleys, rivers and streams is shown in Figure 10. In general, the density of negative lineaments is higher than that of positive lineaments. The negative lineaments are mainly short and discontinuous and trend in a NE direction. This indicates that the topography was formed by exogenous geomorphological processes (such as slope erosion processes) or formed by a combination of small faults (trending NE) with major faults (trending NW).

The DEM is also used as a basic data layer to show the distribution of geoheritage sites in three dimensions in the study area (Figure 10).

CONCLUSION

In this study, the geoheritage characteristics of the Dong Van Karst Plateau Geopark were investigated through geomorphological quantitative analysis. A digital elevation model, elevation map, slope angle map and geological map were used in the analysis. The results show that the study area mainly lies within the three elevation classes (600-900 m; 900-1200 m; 1200-1600 m) which have special landscape characteristics. There are 10 lithological formations that crop

Figure 11: Distribution map of geoheritage sites in the study area.

out in the study area but only six of these were determined as karst landscape-forming areas. Carbonate rocks are mainly distributed in the Dong Van district.

Areas of steep slopes (15° - 30°) cover about 53.5% of the study area and display impressive plateau characteristics. There are 1261 karst sinkholes and 62 caves distributed in the study area. Topography in the study area was influenced by tectonic movement including major faulting and exogenous geomorphological processes.

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