

THE OPTIMAL SOLUTION FOR DOMESTIC WATER ON THE DONGVAN KARST PLATEAU, HAGIANG, VIETNAM

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Abstract: Karst regions are characterized by their intricate topography, abundance of caverns, challenging access, and regular dry-season water shortages. The Dongvan Karst Plateau (DVKP) region is primarily composed of limestone, according to the findings of our research, and it contains karst landforms ranging in elevation from 300 meters to about 2000 meters. Based on their heights, the 300–600 m, 600–900 m, 900–1200 m, 1200–1500 m, and 1500–2000 m cave floors can be distinguished. There are five distinct levels at which karst caves can be found: 300–600 m; 600–900 m; 900–1200 m; 1200–1500 m; and 1500–2000 m. Because the DVKP region frequently experiences a shortage of water during the dry season, it is also known as "the land of thirst".. Geologists have found that the Ma Le cave system at 1150m always has water. Accordingly, the idea of pumping water based on altitude difference was born. When there is water, the lives of people in DVKP are revived. For the first time, DVKP of Vietnam has successfully applied: the "water pumping solution that does not use electricity. The authors would like to introduce the successful research cooperation of Vietnamese, Belgian and German geologists in the DVKP region. The results of this study can be applied to karst areas with similar structures to the DVKP area.

Key words: Ground water, cave, karst, Ma Le cave, **Dongvan Karst Plateau.**

1. INTRODUCTION

North Vietnam's Hagiang province is mountainous, covering an area of roughly 7,945.8 km². It shares boundaries with Tuyen Quang province to the southeast, Lao Cai province to the west, Cao Bang province to the east, and China to the north. With a total area of roughly 2380 km², the DVKP in the province of Hagiang is primarily made of limestone and has a complicated topographical structure with numerous unique cave floors. During the dry seasons, it is commonly

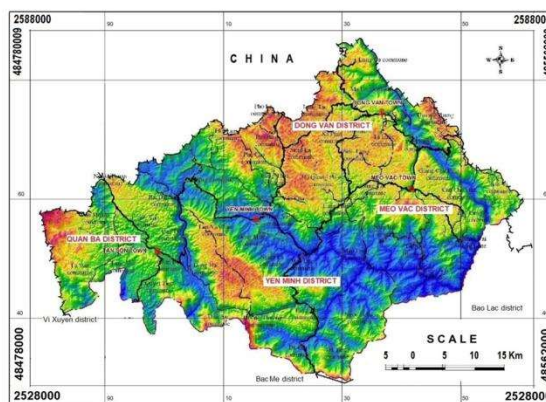


Figure 1. Location of the Dongvan Karst Plateau in Hagiang Province of Vietnam

During the dry seasons, it is commonly

assessed as a place lacking in water (Figure 1). Our purpose is to find water in karst caves, serving the water supply for people in DVKP. Therefore, the limestone area is of particular interest to us.

Research on water resource management for sustainable development has interested many scientists [1, 3, 4, 7, 8, 9]. Finding freshwater in the karst is extremely challenging and sometimes even unsuccessful. There have been many solutions to overcome the water shortage at DVKP, such as building concrete tanks or small hydroelectric dams, but there has been no success so far as building concrete tanks on limestone often causes water to drain out (Figure 2) or water supply for operating small hydroelectric dams is not sufficiently maintained.



Fig 2. *A concrete tank without water during the dry seasons in DVKP*

Geologists have recently found a water source at an altitude of 1150 m in the Ma Le cave system to help DVKP meet water needs for daily life and sustainable development. Finding the existence of karst water at an altitude of 1150m gave geologists an idea: to take advantage of the difference in altitude to design "Water pump does not use electricity".

2. MATERIAL AND METHODS

2.1. Material

The data in this article have been compiled from geological documents on geomorphology, karst hydrogeology, and tectonics of the DVKP region [2, 5, 6, 10, 11].

In addition, the SPOT5 satellite image documents are incorporated as an important input, helping us to build a digital elevation model (DEM).

2.2. Pre-investigations research

This is an important task helping us to orient and locate the important positions that need to be approached when conducting field investigations. Indoor data analysis helps us save time, effort, and money that may be required for field investigations. The indoor approaches include:

- Data acquisition: We reviewed all sources of documents related to the study area. Especially documents related to karst and karst hydrology.

- Analyzing satellite images, geological maps, and topographical maps

- Research geological, hydrogeological, and geomorphological documents and the available results of cave investigations.

- Building DEM

From the DEM model combined with satellite image analysis, we build component maps such as:

- Slope map;

- Lithological map showing the distribution of rock types;

- Terrain sections;

- Distribution of sinkholes and caves.

2.3. field investigations

- We investigated and researched on geological structures, hydrogeological characteristics, and distribution of caves were conducted throughout the study area to classify karst caves according to different elevations.

- From the results obtained, we identify capacity areas of water storage, flow measurement, and investigations of the water quality that were implemented to serve the water supply for DVKP.

2.4. Cave investigations

Fieldwork in our DVKP area includes searching for water in the cave and taking samples.

3. RESULTS

3.1. Geological setting

The DVKP area has a complex geological structure. Participating in the geological structure of the DVKP area includes karst and non-karst rocks. The main karst rocks are limestone of the Bac Son formation (C-P *bs*), Dong Dang formation (P₃*đđ*), the no karst rocks include those of the Chang Pung Formation (Є 3 *cp*), Lutxia (O₁ *lx*), Song Cau (D₁*sc*), Hong Ngai (T₁ *hn*) and Song Hien Formation (T₁ *sh*) [2; 5].

Our research object is the limestone area, so all the above geological formations are divided into 2 groups of rocks: the karst rock group and the non-karst rock group (Figure 3). Figure 3 is obtained from the DEM.

3.2. Distribution of limestone and karst caves

Our purpose is to find water in karst caves, serving the water supply for people in DVKP. Therefore, the limestone area is of particular interest to us. From geological data, combined with satellite images, the limestone distribution area of DVKP is obtained from the DEM (table 1).

Table 1. Statistics of carbonate rocks in the study area.

No	District	Area (km ²)	Areas with carbonat rocks (km ²)
1	Dong Van	460.0	329.7
2	Meo Vac	577.6	287.1
3	Yen Minh	785.2	178.2
4	Quan Ba	557.2	108.5
	Total	2380	903.5

Thus, limestone accounts for 40% of the total area of DVKP.

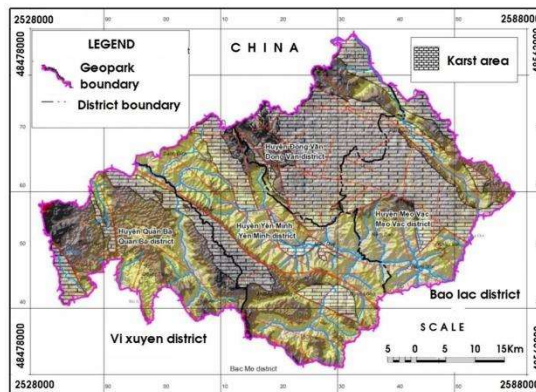


Fig. 3. Distribution carbornate rocks

Based on the available research results, the number of karst caves and sinkholes was also determined by DEM (table 2).

Table 2. Distribution of sinkholes according to height classes

Height class (m)	Number of caves	number of sinkholes
0-300	0	0
300-600	20	15
600-900	17	53
900-1200	31	391
1200-1500	28	652
1500-2000	17	188
Sum	103	1299

Thus, the karst caves are concentrated at 2 elevation levels: (1) from 900 to 1200m and (2) from 1200 m to 1500 m.

3.3. Results of karst cave investigations

With the efforts of Vietnamese and Belgian geologists, we have found the Ma Le cave system distributed at an altitude of about 1150 m [6, 10, 11]. The wonderful thing is that the Ma Le cave system has water all year round. This is where the freshwater supply serves the needs of the DVKP area. Nho Que river is at an altitude of 350-400 m (depending on different locations), so the height difference between Ma Le cave system and the Nho Que river ranges from 750 to 800 m. People live in the DVKP area where the highest point is about 1200 m. Therefore, Ma Le cave system completely meets our requirements.

Our survey shows that, in the dry seasons, the water flowing from Ma Le cave to Seo Ho Stream reaches 101 l/s to 137 l/s. The water will be collected, flowing into the drainage ditch to return to the clarifier. (fig 4. Fig 5).



Fig 4. Water from Ma Le cave system flowing into Seo Ho stream in the dry seasons reaches 120 l/s



Fig 5. A water channel from Ma Le cave system to clarifier

Water samples in the Ma Le cave system were also collected during the survey. The results of the analysis of indices such as pH, TDS, CaCO₃, Fe, Chlorite, Pb, and COD have been evaluated to meet Vietnam's water standards.

3.4. Water supply plan for DVKP area

Research on karst geology has been conducted by Vietnamese and Belgian geologists since 1995. The idea of finding a karst cave with water at DVKP has been cherished by us

for a long time, now come true. This is the basis for us to implement the science and technology cooperation project with Germany in finding solutions for sustainable water supply in high mountains and for water scarcity in Hagiang province. All work such as designing water pumps, water tanks, and pressure tanks has been done by the Kawatech project and completed since 2019. The KaWaTech project has a power of 19 liters/s, providing about 1,800m³ of water/day, the pressure pipeline is about 2.5km long. The diagram illustrating a non-electric water pump solution at DVKP is presented in figure 6.

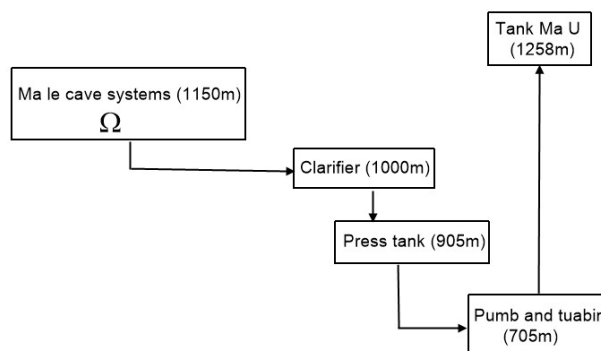


Fig 6. The diagram illustrating a non-electric water pump solution at DVKP, Hagiang, Vietnam

3.5. Why does Ma Le cave system at an altitude of 1150m often have water even in the dry season?

Section 3.1 shows that the DVKP region is an area with a complex geological structure, with many different types of rocks. The no -karst rocks are distributed in the north of the male cave system at altitudes from 800m to 1700m (fig 7). The characteristics of karst areas are water shortage in the dry season and water abundance in the rainy season, but the water drains very quickly through fault systems, caves, fractured, dolines and vertical shafts, going down into underground caves. However, the Male cave system always has water because the water is supplied from the no- karst area.

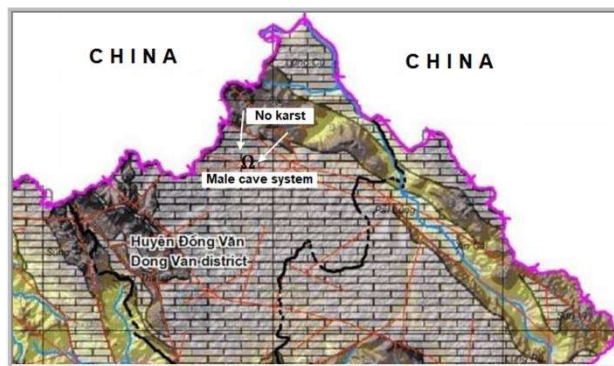


Fig 7. Male cave system is supplied with water from the no -karst area

The no-karst area is located at an altitude of 800m to 1700m, formed from rocks of Mia Le formation, and Song Cau formation, mainly composed of clayish siltstone, marlaceous shale, conglomerate, sandy siltstone, and clay shale. Thus, the diversity and complexity of geology is the reason why Male cave system has water all year round.

4. CONCLUSION

Research on the distribution of karst caves at DVKP serving the search for freshwater has become real. The existence of 5 levels of caves has created enough potential energy to lead water from the Ma Le cave system to a height of 1258m. The Ma U reservoir at this altitude

is where water is distributed to the Dong Van Karst Plateau, overcoming water shortages in the dry season. Currently, Dong Van Karst Plateau has been given the new name "Dong Van Karst Plateau Geopark", Non-electric water pumping solution can be applied to limestone mountain areas with similar geological structures as the Dong Van Karst Plateau. This is an optimal solution, serving environmental protection and sustainable development.

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