Carbonate Resources in Viet Nam: Exploiting, Processing and Using

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Abstract

Vietnam has a carbonate rock distribution area of about 60,000 km², accounting for nearly 20% of the territory's area. Carbonate rocks in Vietnam are located in many different stratigraphy, their ages from Pre Cambrian to Triassic. Carbonate rocks in Vietnam include limestone, marble, and dolomite. Carbonate rock has been made up for hundreds of millions of years. However, the use of carbonate rock resources in Vietnam is inconsequential, reducing its value. The author of the article introduces an overview of carbonate rock resources in Vietnam, and the reality of exploiting and processing carbonate resources in Vietnam. Since then, gave warnings about illogical in the use of carbonate rock resources. At the same time, it also makes recommendations for the rational use of carbonate rock resources for sustainable development.

Keywords: Carbonate; Marble, Dolomite, Karst; Donggiao formation; Carbon-Permi formations

1. Introduction

Studies of karst (in general) or limestone (in particular) have been of interest to many geologists (Derek and Paul, 2007; Alobadi et al., 2021; Thinh et al., 2022; Institute of Geology and Minerals, 2005). Vietnam has a carbonate rock distribution area, accounting for about 20% of the territory. The carbonate rock resources are inside in karst regions. The distribution area of carbonate rocks is mainly concentrated in the north and north-central region. The south only has Ha Tien, Kien Giang province (Fig. 1).

Carbonate rocks in Vietnam are mostly found in Dong Giao formations, and Bac Son formations. Their age is Triassic and Carbon-Permian. There are many karst studies in Vietnam. But studies only focus on areas such as karst geology (Tuan, 2004; Tuyet et.al., 1998), karst hydrogeology (Tuyet et al., 1998), hazards on karst (Tuan, 2009; Tuan, 2019) and characteristics of karst poljes (Tuan, 2009; Tuan, 2019; Tuan, 2020). Only a few studies on Carbonate resources are in Vietnam's Direction of sustainable development (Khien, 2010; Tuan, 1999). The problem of exploiting and processing carbonate resources has received little research attention. The article deals with the waste of carbonate rock resources in Vietnam and towards the rational use of carbonate resources for Sustainable Development.

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2. Materials and Methods

2.1. Data Collection

Collect all the data on karst geology, karst hydrogeology, limestone mines, and carbonate resource use fields.

![Map of karst regions in Vietnam](image-url)

*Fig. 1. Map of karst regions in Vietnam (Institute of Geology and Minerals. 2005)*

2.2 Analysis of Satellite Images, Topographic Maps

Karst topographic is very specific and can be recognized on satellite images, airplane photos, topographic maps. Analysis of satellite images and topographic maps are simple methods to help us determine carbonate rock distribution areas (Fig 2).
2.3. Field Investigation

We have field investigation and research all the territory of Vietnam. This is the basis for determining the limestone distribution areas (Figs. 3 and 4).

2.4. Sampling and Sample Analysis

Limestone samples were featured for different formations in the territory of Vietnam (Table 1). At marble mines, limestone is also sampled and analyzed (Tables 2, 3 and 4). In addition, in the detailed study areas, the samples were taken from limestone layers of different colors to determine the CaO content.

2.5. Materials and Methods

Data to complete the article includes:
- Materials from the Department of Geology and Minerals of Vietnam, Karst Geology, Karst (DGMVN; Thanh, 2013; Tuyet et al., 1998).
- The results of chemical analysis of limestone (Che, 2005; Huy, 2007; Uu, 2005)
- Materials processing and using limestone (Khoa, 2013).
• Data field investigation and research results of the author from the year 1999 to now (Tuan 1999; Tuan 2009; Tuan 2020; Tuan 1999; Tuye et al., 1998).

3. Results and Discussion

3.1. Carbonate Rock Formation Process

Limestones are formed in shallow and warm marine environments. Limestone formation became different layers, at the beginning they are a Strike of horizontal bedding. Then, the activities of Endogenous geologies make the limestone layers deviation, where there is a Strike of vertical bedding or form folds. Some places are homogeneous limestone from top to bottom, called massive limestone (Figs. 5 and 6).

Fig 5. Gray limestone, massive limestone aged Carbon-Permian.

Fig 6. The massive limestones have aged Carbon-Permian in Ha Long Bay, Quang Ninh province.

3.2. Quality of Carbonate Stone

Limestone in Vietnam is distributed mainly in the north, from latitude 17 to the north (Fig. 1). They are present in many different stratigraphies. Karst rocks in the territory of Vietnam are mainly limestone, marble, and dolomite. Limestone is present in stratigraphies of early, mid, late, and early Proterozoic age, has a thin thickness, and often suffers from metamorphosis. In addition, limestone is also found in Cambri, Silur stratigraphy, and most stratigraphy of the age Devonian, Carbon - Pecmi, and Triassic. The total thickness of limestone in Vietnam is about 5,000m; in which limestone has the middle age of Dong Giao formation (T2dgdg) and Muon Trai formation (T2lmt), up to 2,300m thick (Tuyet et al., 1998). Our studies show that carbonate rocks are distributed in 31 provinces and cities of Vietnam. Most of them are in the provinces of Ha Giang, Cao Bang, Lai Chau-Dien Bien, Son La, Quang Binh, Lang Son, Nghe An, Tuyen Quang, Bac Kan. The best quality limestone is carbon-Permian and Triassic aged limestone (Table 1).

Table 1. Results of the analysis of the chemical composition of limestone in Vietnam

<table>
<thead>
<tr>
<th>Main chemical composition</th>
<th>Min</th>
<th>Max</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late Proterozoic rock group – Cambri</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SiO₂</td>
<td>0.18</td>
<td>16.64</td>
<td>4.855</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>0.19</td>
<td>3.58</td>
<td>1.358</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>0.01</td>
<td>1.1</td>
<td>0.317</td>
</tr>
<tr>
<td>FeO</td>
<td>0.04</td>
<td>0.55</td>
<td>0.266</td>
</tr>
<tr>
<td>CaO</td>
<td>22.39</td>
<td>55.5</td>
<td>22.39</td>
</tr>
<tr>
<td>MgO</td>
<td>0.08</td>
<td>21.8</td>
<td>8.866</td>
</tr>
<tr>
<td>losses on ignition</td>
<td>36.02</td>
<td>46.82</td>
<td>42.01</td>
</tr>
</tbody>
</table>
The results of our field investigation and sampling at the limestone and marble quarries in Yen Bai, Nghe An, and Ha Tien provinces show that the quality of marble and limestone is very good. Total sample taken at mine marble, mine limestone and in the boreholes was 520 samples. The results of the summary chemical analysis on Tables 2, 3, and 4.

3.3. Marble of Yen Binh, Yen Bai

| Table 2. Synthesis of chemical analysis results of marble in Yen Binh, Yen Bai |
|---------------------------------|-----|-----|-----|-----|-----|
|                                | CaO | MgO | Al₂O₃| SiO₂| ΣFe |
| Min                            | 54.6| 0.22| 0.20| 0.1 | 0.1 |
| Average                        | 53.28| 0.41| 0.06| 0.04| 0.01|
| Max                            | 55.33| 0.31| 0.48| 0.27| 0.18|

3.4. Marble of Chau Cuong- Nghe An

| Table 3. Synthesis of chemical analysis results of marble in Chau Cuong- Nghe An |
|---------------------------------|-----|-----|-----|-----|-----|
|                                | CaO | MgO | Al₂O₃| SiO₂| ΣFe |
| Min                            | 54.26| 0.12| 0.20| 0.1 | 0.1 |
| Average                        | 53.28| 0.41| 0.06| 0.04| 0.01|
| Max                            | 55.08| 0.31| 0.32| 0.27| 0.18|

3.5. Limestone of Hà tien- Kienggiang

| Table 4. Synthesis of chemical analysis results of limestone of Hà tien- Kienggiang |
|---------------------------------|-----|-----|-----|-----|-----|
|                                | CaO | MgO | SiO₂| Al₂O₃| ΣFe |
| Min                            | 50.82| 1.85| 0.52| 0.004| 0.1 |
| Average                        | 51.09| 1.50| 3.24| 0.085| 1.12|
| Max                            | 51.39| 1.94| 15.15| 0.240| 0.241|

3.6. Exploiting Carbonate Stone

Provinces with many active carbonate quarries are Ha Nam, Yen Bai, Nghe An, Ninh Binh, etc. Places recognized as geological heritage must be protected, this is the prohibited zone. However, in Cam
Pha district, Quang Ninh province, lying next to Ha Long city is the place where UNESCO is the world's heritage workers, but the limestone quarries are still being exploited (Figs. 7 and 8).

**Fig 7.** Limestone exploitation in Cam Pha, Quang Ninh

**Fig 8.** Limestone exploitation in Cam Pha, Quang Ninh

Many limestone mountains in Ha Nam and Ninh Binh Provinces have been flattened (Figs. 9 and 10).

**Fig 9.** The limestone blocks are flattened

**Fig 10.** National scenic spots Kemtrong in being exploited for construction stone

In Vietnam, on karst areas are exploited violently, depriving resources and environmental pollution. Exploited limestone is mainly used as raw material for Cement production, paving roads. In many places, limestone content as high as 98% CaCO$_3$ content, but not classified, and still exploited as building materials.

According to incomplete statistics, up to now, there are hundreds of carbonate quarries under the Ministry of Natural Resources and Environment and licensing provinces. Currently, the Ministry of Natural Resources and Environment licenses 87 carbonate quarries, including 38 marble quarries. The marble mines are mostly in Yen Bai, Nghe An, Bac Kan, Tuyen Quang, and Ha Nam provinces (Figs. 11, 12, 13 and 14).
In Vietnam, the processing of carbonate stone is not popular. Carbonate stone is mainly used in raw materials for the construction industry. Firstly, there must be a strategy for exploiting and processing limestone, serving for sustainable development. Some provinces, including Yen Bai province, have imported equipment from China, India, Germany, the US, and Spain for deep processing. In 2020, the People's Committee of Yen Bai province in cooperation with the Joint Stock Company exploiting and processing minerals Vu Gia has started a factory building and processing Vu Gia marble. To produce products from carbonate stones of different sizes from raw to fine-grained and super smooth. Estimated output is 350,000 tons/year. Products are supplied to the domestic market and exported to foreign markets such as India, China, Italy, and some European countries.

According to the Department of Geology and Minerals of Vietnam, Vietnam currently has about 98 white limestone production and processing in operation (Table 5) (DGMVN).

Table 5. White limestone processing facilities in Vietnam

<table>
<thead>
<tr>
<th>No</th>
<th>Province / city</th>
<th>Number of processing facilities</th>
<th>Reserves</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yên Bai</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Nghe An</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Bac Kan</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Tuyên Quang</td>
<td>1</td>
<td>200,000 m³</td>
</tr>
<tr>
<td>5</td>
<td>Hà Nam</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Products of white marble include Calcium Carbonate (CaCO₃) uncoated, coated Calcium Carbonate (CaCO₃), Plastic filler (Tactical), light powder CaCO₃, Limestone powder (CaO),
Quicklime, etc. From carbonate rock created products for industries such as the glass industry, glass production, Ceramics industry, Plastic industry, rubber, Detergent manufacturing industry, Environmental treatment industry, and Livestock industry.

Limestone products have been used in many different industries. In the construction industry, limestone is used to produce cement. In the paint industry, calcium carbonate accounts for more than 60%. Besides, limestone will help enhance anticorrosion, etc. In the medical industry, limestone is used as a calcium supplement, which acts as a deoxidizer in the industry medicine. Limestone is also capable of absorbing gases such as NH₃, H₂S, CO₂, etc. cleaning the water environment, whitening porcelain, making chalk for school use, etc.

One of the best enterprise processing products from carbonate stone in Vietnam is the joint-stock company Yabashi Holdings. From carbonate stone, Yabashi Holdings processed the following products (Table 6):

**Table 6. Products processed from carbonate stone of Yabashi Holdings Joint Stock Company**

<table>
<thead>
<tr>
<th>Product Type</th>
<th>Description</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone / Crushed Stone</td>
<td>We mine limestone of good quality in the method of bench cut mining by throwing stones into a vertical shaft.</td>
<td>the raw material of quick lime / raw material of calcium carbonate / auxiliary raw material of iron manufacture/aggregate for civil engineering</td>
</tr>
<tr>
<td>White limestone</td>
<td>Manufactured by crushing and grinding and screening limestone of high whiteness yielded in Vietnam. It is used in the chemical field such as paper making. These days it is receiving a lot of attention that it is expected to have the effect to increase the power generation of solar power.</td>
<td>paper making / solar power / For gardening</td>
</tr>
<tr>
<td>Heavy Calcium Carbonate (Granule)</td>
<td>The Limestone is dried and sorted to adjust granule size according to different usages 0.3-1.0mm, 1.0-3.0mm, 4.0-6.0mm</td>
<td>Basicity adjustment for slug / Fluorine gas adsorption / Fluidised bed boiler / Animal</td>
</tr>
<tr>
<td>Heavy Calcium Carbonate (Powder)</td>
<td>It is manufactured by crushing and screening limestone. We can produce various sizes of particles from superfine ground products to granular products to adapt to various use. It is mainly used for rubber, resin, and paint.</td>
<td>paper making / rubber • resin / paint / glass / asphalt / flu gas desulfurization / steel manufacture / fertilizer</td>
</tr>
<tr>
<td>Product Type</td>
<td>Description</td>
<td>Uses</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-------------------------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Quick Limestone (Lump)</td>
<td>This product has very few impurities and you can choose grain size and reactivity freely. We are especially good at quick lime with high reactivity.</td>
<td>Pig iron and iron manufacturing / paper/ pulp / general chemistry industry / civil engineering / desiccant / the quality of water and bottom material improvement / fertilizer</td>
</tr>
<tr>
<td>Quick Limestone (Powder)</td>
<td>The main component of this product is calcium oxide (CaO) and it is a white powder. Limestone mined from the mine is washed with water and screened. And after that quick lime is produced by burning limestone at a high temperature of over 1000 °C in the kiln.</td>
<td>Pig iron and iron manufacturing / paper/ pulp / general chemistry industry / civil engineering / desiccant / the quality of water and bottom material improvement / fertilizer</td>
</tr>
<tr>
<td>Slaked Limestone</td>
<td>It is used mainly in the neutralization of acids, for example, the neutralization of exhaust gas and wastewater.</td>
<td>Garbage incinerator / exhaust desulfurization / waste water treatment / treatment of fresh water and sewage / civil engineering / fertilizer</td>
</tr>
<tr>
<td>Slaked Lime (Slurry)</td>
<td>It is used to neutralize the acidic waste solution and we can adjust the concentration to fit your needs</td>
<td>Waste Water neutralization / General chemical industry usage/Semiconductors</td>
</tr>
<tr>
<td>MICROSTAR T slaked lime</td>
<td>slaked lime fine powder of high purity produced from carefully selected limestone having very little impurity. It conforms to JIS K8575 special grade reagent and food additives standards.</td>
<td>reagent / industrial use</td>
</tr>
</tbody>
</table>
| **High reactive slaked lime** is the slaked lime with increased specific surface area and pore volume more than “JIS special grade slaked lime” to improve drastically reactivity. Its improved flow ability can reduce troubles in silo and transport systems.  
**Uses:**  
garbage incinerator |
|---|
| **Precipitated Calcium carbonate** is synthesized by reacting slaked lime slurry with carbon oxide gas. The product with high whiteness or products with various particle shape which is suitable for each user will be manufactured by changing its synthesis method variously. We have slurry products and powder products and they are used in various fields such as paper making etc. We are only one production plant of precipitated calcium carbonate in the Chubu Region.  
**Uses:**  
paper making / rubber • resin / paint / food additives |
| **Precipitated Calcium Carbonate (Slurry) “Choral bright”** is synthesized fine precipitated calcium carbonate in high conc. slurry form. (High whiteness, high gloss, low viscosity) Maximum solid 70%  
**Uses:**  
Papermaking/ paint |
| **CALSIP lime-based desulfurizing agent** for refining is manufactured by various quick lime mixing with auxiliary raw materials (Al ash, Sic, and Si, etc.), and it has powder type, granular type, and briquette type. We manufacture various components and various kinds of refining agents to deal with customers’ needs. It is used for the improvement of refining ability and the reduction of refining time. In recent years, it has come to be used for refining without fluorine as the replacement of fluorite.  
**Uses:**  
steel manufacture / cast iron |
| **THREAD LIME lime-based fixation agent** is a fixation agent to adapt to the nature of the target soil by mixing various lime and auxiliary raw material. Especially it is effective in the improvement of soft ground. It is a natural material, so it is an environment-friendly product. We have a powdery product, dust proof powder product, and briquette product, and it is used in the construction and civil engineering field.  
**Uses:**  
improvement of soft ground/road works / residential land development/foundation work of railways, airports, buildings / surplus soil recycle |
Geolime is developed by Yabashi's original lime-based solidifying agent added to the soil that is extracted upon mining limestone to use the soil as a recycled resource.

**Uses:**
Landscaping material for factories, residential areas and other facilities

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Calsand

The product's main ingredient is crushed limestone in which the particle distribution has been adjusted to use as the paving material.

**Uses:**
Paving material for ground, parks, and other multi-purposed plaza

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Processing and using carbonate stones (in general), and marble (in particular) in Vietnam have not achieved high efficiency, causing waste of resources. Compare with Fig. 15 (Foundations of Mendip (British Geological Survey) - Stone as a resource). We see the role of carbonate resources is very large, but in Vietnam, it has not been fully utilized.

![Diagram of stone uses](image)

**Fig. 15.** Foundations of Mendip (British Geological Survey) – stone as a resource
4. Reasonable Use of Carbonate Stone Resources for Sustainable Development

To develop karst areas in Vietnam, it is necessary to have a detailed plan, which delineates the mining areas, the limestone, and marble processing areas for socio-economic development; and forbidden area to preserve geological heritage, environment, landscape, or serve national security and defense etc.

Limestone is a nonrenewable resource. Therefore, we must use it economically, and reasonably, to serve the national sustainable development. Here are some suggestions:

4.1. Exploiting Problem

First of all, it is necessary to plan and zone for carbonate mining, including zoning for quality limestone. Mining technology must be improved to minimize resource loss and environmental pollution.

4.2. Processing Problem

Vietnam must import the advanced carbonate stone processing technology. The non-executing business will be forbidden. The goal is deep processing, creating competitive products with the market, increasing the number of carbonate stone processing factories to meet market demand.

4.3. Environment Protection Problem

The environment in the exploitation and processing areas of limestone carbonate is polluted. The pollutions that are easy to see are noise and dust (Figs. 16 and 17). Problems such as smoke, dust, noise, water pollution, and soil pollution need to be addressed soon in the exploitation and processing of carbonate rocks in Vietnam.

5. Conclusions

Carbonate resources are nonrenewable resources, Vietnam needs to have plans for zoning exploitation areas, prohibited zones for Sustainable Development. The use of raw materials needs to be minimized, and deep processing of limestone and marble minerals should be prioritized. The urgent requirement now is to change limestone exploiting and processing technology in Vietnam as soon as possible. Adopting advanced technology to exploit and process limestone in Vietnam not only increases the value of processed products of limestone but also contributes to the environmental protection, resources preservation, and sustainable Development of the country.
Acknowledgements

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