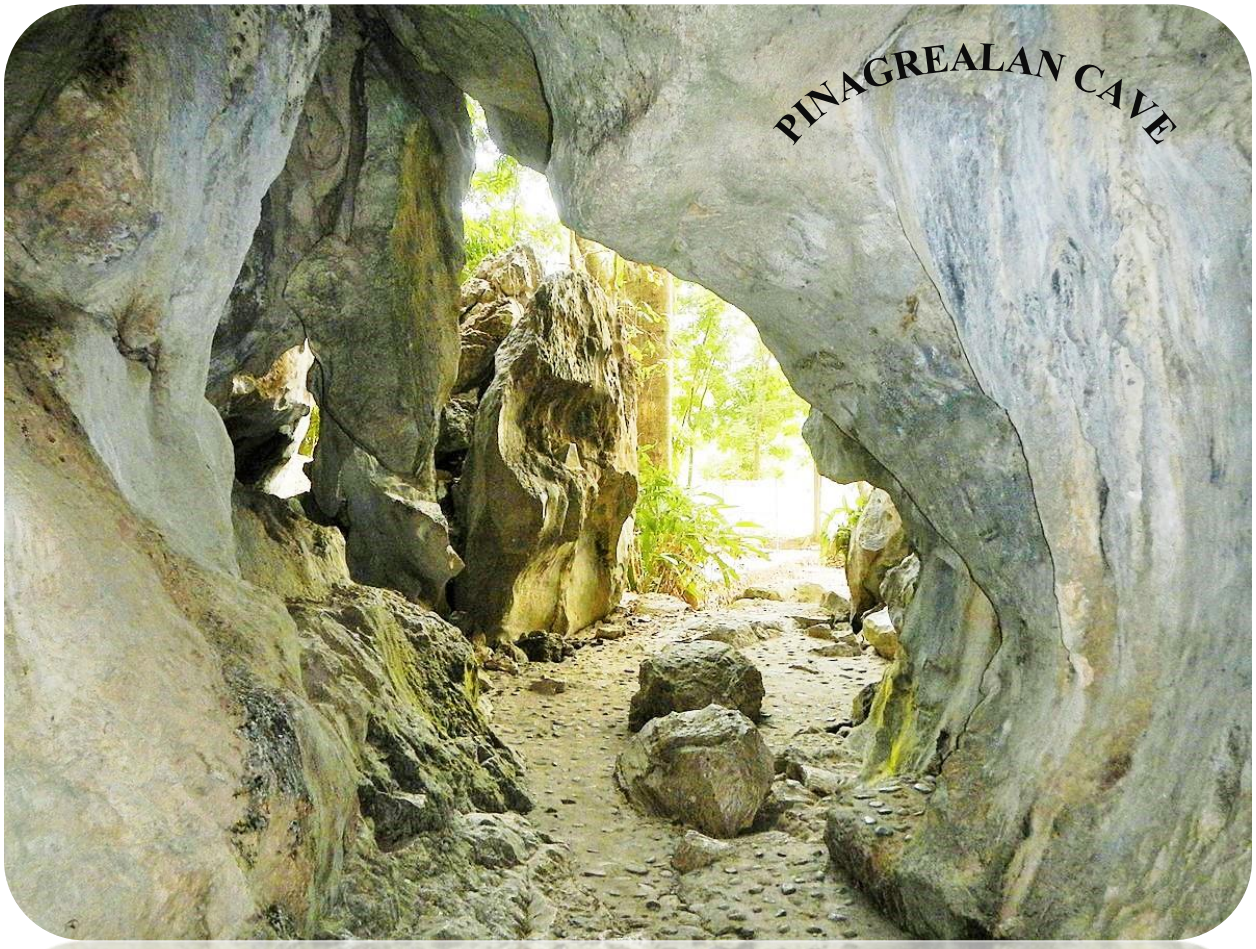
GEOLOGICAL ASSESSMENT REPORT TO EVALUATE THE IMPACT OF THE SPAR MINING QUARRY ABOVE THE PINAGREALAN CAVE



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GEOLOGICAL ASSESSMENT REPORT TO EVALUATE THE IMPACT OF THE SPAR MINING QUARRY ABOVE THE PINAGREALAN CAVE

REGIONAL GEOLOGY OF THE AREA

Geology of the Pinagrealan cave Barangay Bigte, Norzagaray, is majorly comprises of limestone. Pinagrealan is located at the foot of the Sierra Madre mountain range extending more than a kilometer. The famous personalities that once inhabited this cave is Gen. Emilio Aguinaldo and Gen. Pio del Pilar.

The physiographic features of the area is include the volcanic cone of Mount Arayat that is the only elevated feature in the vast plain, the north and south draining river systems, wetland areas including the Candaba Swamp in Pampanga and the Angat Dam in Bulacan, and the Pampanga River delta which drains towards Manila Bay in the south.

REGIONAL TECTONICS OF THE AREA

Geologic structures that affect the seismicity in area, include the Manila Trench on the west, the East Luzon Trough and Philippine Trench on the east and the Philippine Fault on the northeast. The West Valley Fault is a geologic structure that can affect Metro Manila and portions of Bulacan, Rizal, Cavite, and Laguna provinces.

The Manila Trench is located west of Luzon Island and represents the eastward subduction of the oceanic crust of the South China Sea beneath the Philippine landmass, reaching depths of 5,100 meters. The corresponding Benioff zone is steep on the southern portion but flattens off towards the north. The volcanic arc corresponding to the Manila Trench includes Mounts Pinatubo, Taal and Banahaw and the inactive volcanoes located north of Mount Pinatubo.

The Philippine Trench represents the westward subduction of the Philippine Sea Plate beneath the Philippine landmass. Its shallow Benioff zone corresponding to a maximum depth of 250 km suggest that this subduction zone is young and is presently propagating to the south towards the Moluccas Sea Collision Zone (Aurelio and Peña (Eds.), 2002). The volcanic arc corresponding to the Philippine Trench can be traced from Bicol to Leyte but becomes unclear in Mindanao. The Philippine Fault is a left lateral strike slip fault that extends for 1,200 km from Northern Luzon to Northeastern Mindanao, cutting across the Bicol Region and the Visayas.

METHODOLOGY

I ensure that all content of the report is independent geological consultant review based on the data provided on 6th June 2021. All the results in this review report are made after the observation of the 50 photographs of the Pinagrealan Cave condition (entrance and interior) provided**.**

FOLLOWING GEOLOGIC HAZARDS CAN IMPACT PINAGREALAN CAVE DURING THE SPAR MINING ACTIVITIES

- After detailed study of the tectonics and geology of the Pinagrealan Cave and surrounding areas are tectonically active and comprises on faults and volcanic activities showing in (Figure 1). If the Blasting activates will continued around the Pinagrealan Cave can produced the vibrations and shock waves can cause local ground shaking. Due to local ground shaking to cause cave roofs to crack or collapse. Blasting may cause fracturing of quarry walls, increasing permeability and increasing drainage towards quarry face (Gagen and Gunn, 1987, Gunn and Bailey, 1993).

- The geology of the Pinagrealan Cave is major Limestone and the Limestone is soft and layered sedimentary rocks. By the help of photo geology, I conclude that the major area of the Cave is fractured due to past and present tectonic activities showing in (Figure 2). The area investigated is prone to ground shaking hazards due to the presence of several earthquake generators in the region.

- The distance of Spar Mining Quarry above the Cave approximate is 100 feet which is more vulnerable to perform any further operation. Because the mining operation area is geologically more sensitive and hazardous and cause the major collapse of the Cave.

- Landslide involves the bulk transfer of masses under the influence of gravity. This is usually triggered by prolonged heavy precipitation, and possibly slope excavation in mining area. The Mass movement such as landslides, rockfall and subsidence can cause great casualties and damages to properties. The Cave area is moderate susceptible to

landslide showing in (Figure 3). There were several landslides, rockslide/rock fall prone areas identified during mapping.

- Change in Surface Landform During quarry operation, the construction of hauling roads shall incur minor changes in the topography of the project site. Some backfilling works will be undertaken on some low areas highly susceptible to flooding.

- Limestone mining can affect ground water conditions. Limestone deposits often occur in association with karst, a topography where limestone slowly dissolves away underground. The deposits result in sinkholes, caves and areas of rock fractures that form underground drainage areas. When mining occurs in karst, disruption to natural aquifers, or flows of underground water, can result. Often, mining operations remove ground water to expose the quarrying site, which can lower the water table and change how water flows through the rock formations.

- Sinkholes can develop, where the roofs of underground caverns are weakened or collapse. Collapse can be gradual or sudden. Although natural sinkholes develop over time, man-made ones predominate in mine areas. Sinkhole formation can cease after mine dewatering is stopped and the water table can return to normal levels.

- Subsidence often occurs in karst terrains where the dissolution of limestone can create subsurface voids or caves that can collapse and can cause the overlying material to fall. However, subsidence can occur in areas adjacent to the project site.

Cave Classification: DMC 2007-04 prescribes the following classes of caves in the country.

Class I. Caves with delicate and fragile geological formations, threatened species, archeological and paleontological values, and extremely hazardous conditions. Allowable activities are limited to mapping, photography, educational and scientific purposes.

Class 11. Caves with areas or portions which have hazardous conditions and contain sensitive geological, archeological, cultural, historical, and biological values or high-quality ecosystem. It may be necessary to close sections of these caves seasonally or permanently. It is open to experienced cavers or guided educational tours / visits.

Class 111. Caves generally safe to inexperienced visitors with no known threatened species and archeological. geological, natural history. cultural and historical values. The caves may also be utilized for economic purposes such as guano extraction and edible birds nest collection by (DENR).

REGION/ PROVINCE	NAME OF CAVE	LOCATION	CLASSIFICATION
	2. Nagbukel Cave	Brgy. Cabaruan, Diffun	Class III
***Region 3* (2)**			
1. Bulacan	**1. Puning Cave**	Brgy. Bayabas, Doña Remedios Trinidad	Class II
	2. Pinagrealan Cave	Brgy. Bigte, Norzagaray	Class II
***Region 4A* (4)**			
1. Rizal	**1.Pamitinan Cave** (Pamitinan Protected Landscape)	Brgy. San Rafael, Rodriguez	Class II
	2. Bat Cave	Brgy. San Rafael, Rodriguez	Class II
2. Quezon	**1. Palale Cave**	Brgy. Ibabang, Palale,Tayabas	Class II
3. Laguna	**1. KwebangPuti**	Brgy. Paowin, Cavinti	Class I

CONCLUSION

The Spar Mining Quarry exists approximate 100 feet above the Pinagrealan Cave and may cause several geological and environmental impacts on the cave. The Mining Quarry operation activities such as rock blasting, drilling and slope excavation may cause seismic impact on the cave structure. The vibration generated by construction or quarry blasting may have an adverse impact on the environment (Mesec et.al, 2018).

As we know that the Cave area is consisted on rock fracture, rock joints, caverns and sinkhole which is susceptible to Cave collapse and failure due to uncontrolled blasting. Due to the continuing blasting and mining operation above the Pinagrealan Cave can cause the joint and fracture opening to be widened. This phenomenon may lead to cave collapse. Finally, the Spar Mining Quarry activity needs to reduce the risk of the rock failure/collapse inside the cave.

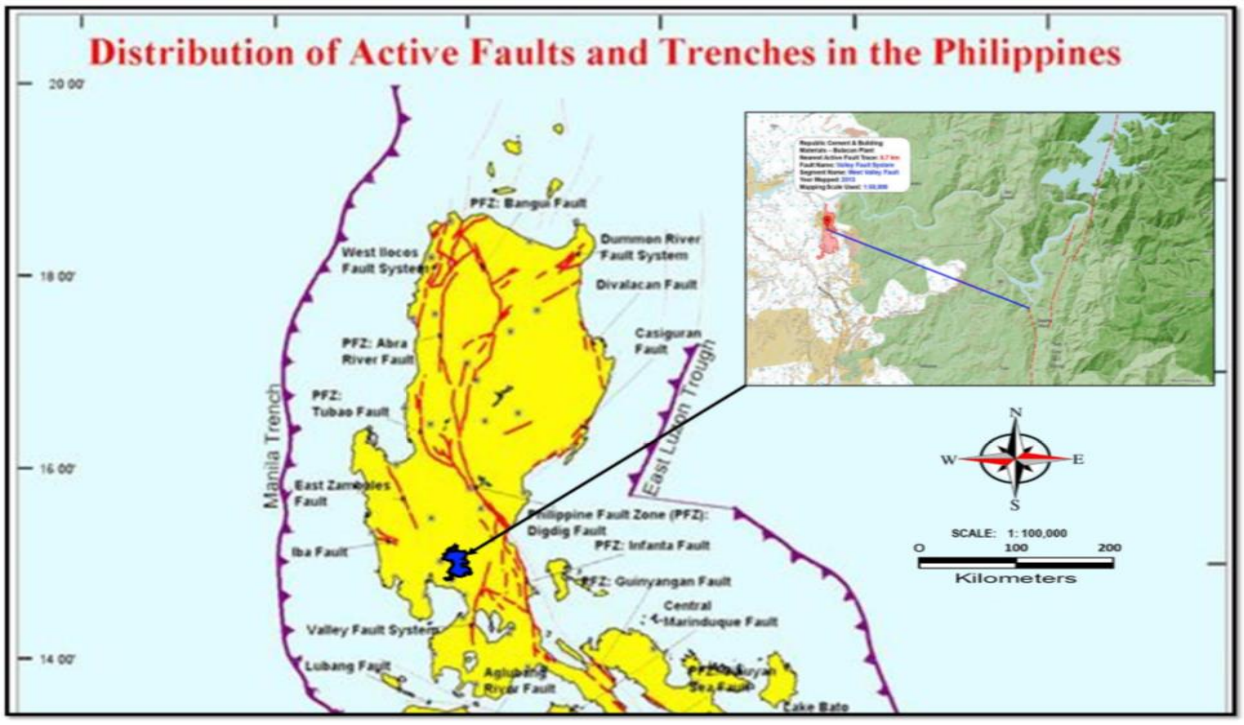

Figure.1. Showing the tectonic activity around the Pinagrealan Cave.

Figure.2. Showing the rock fracture of the Pinagrealan Cave.

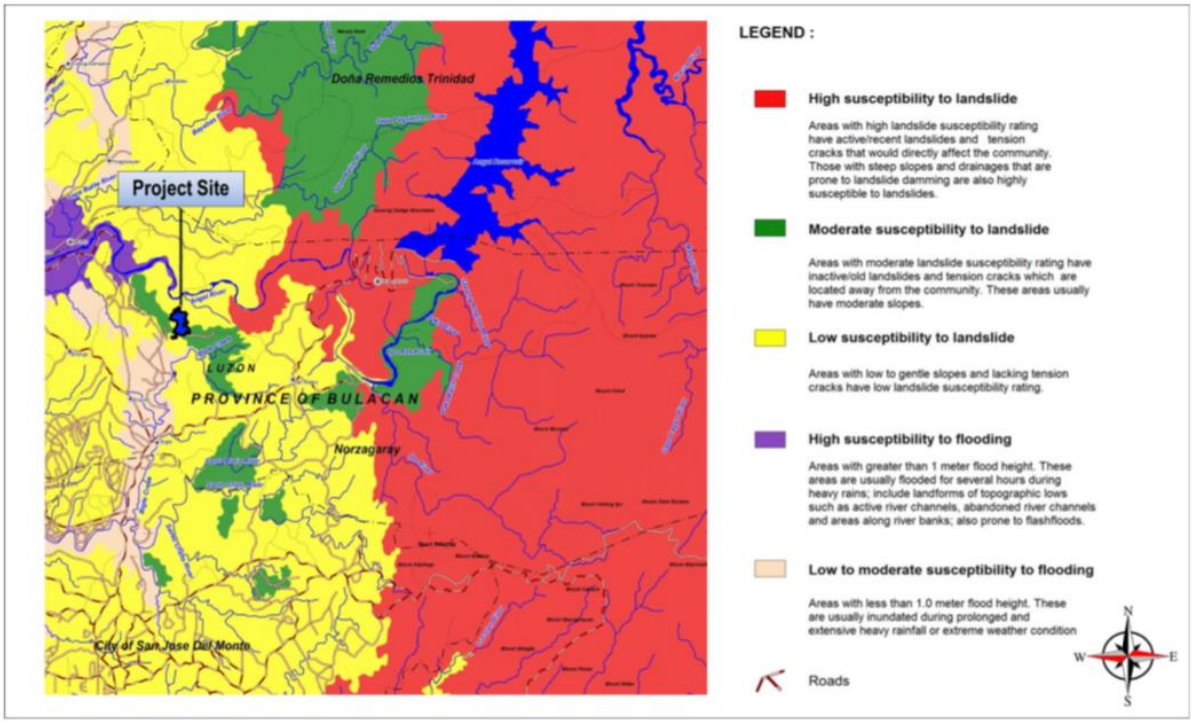

Figure.3. Showing the landslide around the Pinagrealan Cave.

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The impact of SPAR's mining on Pinagrealan Cave

Based on the Department of Environment and Natural Resources report in 2017, the Philippine government commits to provide a competitive investment climate and adequate protection of the rights and privileges of mining investors, as a form of supporting the acceleration of economic growth. Then, the Philippine government promotes the rational exploration, development, utilization and conservation of mineral resources guided by its commitment to responsible minerals development. Spar Development Co., Inc. (SDCI) is one many mining company that managing cement, manufacturing and processing in Norzagaray, Bulacan, Philipines with contract since June 17, 2004 to June 18, 2029. The total working area is around 24 ha or 0.077% of Norzagaray's total land areas.

This is contrary to the previous Department of Environment and Natural Resources (DENR) Memorandum 1991, where SPAR has been mining less than 320 m from Pinagrealan Cave, because it can damage the natural condition of the cave. In 2012, issued a report that aims to preserve, protect and regulate caves in the Philippines with cave classification methods including geological formations, endangered species, archeology, fossils, natural hazards, and other historical values, of which Pinagrealan Cave is included.

Fig. 1 *Location of Pinagrealan Cave and the existing quarry site. Source: Google Earth*

Although spar has said that they have set aside PhP179,0000.00 (2017) for Environmental Protection and Enhancement Program, PhP90,402.30 (2017) for Social Development and Management Program, and PhP155,000.00 (2017) for the Safety and Health Program, still the mining process does not comply with the procedures and violates the agreed rules. Mining location can be seen in Fig. 1.

1. Pinagrealan Cave

Pinagrealan Cave located in Norzagaray, Bulacan, Philippines which is two hours away north of Manila is one example of a problematic cave and has been the center of attention until now. Pinagrealan

cave was used as hideout for the revolutionaries against Spain in 1896 and Filipino-American war in 1898 which was also the hideout of Gen. Emilio Aguinaldo, the first President of the Philippines. During the Filipino-Japanese era, it was then used as a sanctuary by the Japanese Imperial Army by the time the Philipines was liberated by American Forces.

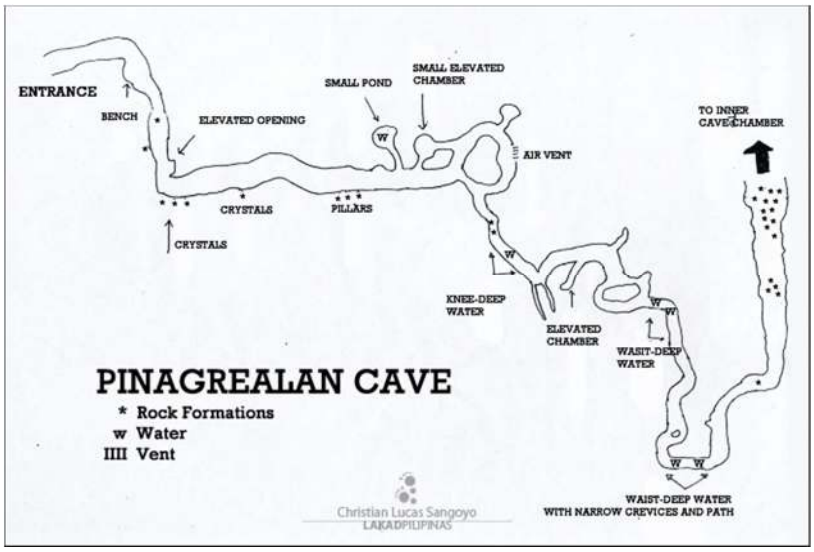

Fig. 2 *Pinagrealan Cave morphology map*

Fig. 3 *Fracture of Pinagrealan cave*

Pinagrealan is one of the many caves in the Philippines that is used as a tourist attraction because of its attractive landscape and complex ecosystem. The following is one of the stories of local people who have visited the cave in Trip Advisor site "Parking is close to the mouth of the cave and a guide will be assigned to you or your group before you enter. The guide will require you to have a helmet and light for the exploration. I recommend that you bring your own headlamp. The lamps they provide are dim and it is

an understatement to say the cave is dark. I'm impressed by the briefing as the guide talks about the historical value of the cave, cave etiquette, what to expect and asked if any of us were claustrophobic. You should never break away from the group.It can cost you your life when you get lost in the complicated and confusing underground network. Leave that to the professional spelunkers. He added that we shouldn't touch the crystals on the cave walls and avoid being noisy when we are inside. The residents of the cave are nocturnal and they sleep during the day. The bats will be disturbed unnecessarily if we make loud noises inside their home. The temperature swiftly went down with a cool breeze that wafted from a partition at the top. There are areas where you can see water dripping along the walls. Nature sculpts caves through water. As it trickles through the soil, rainwater picks up carbon dioxide and turns into acid. This causes limestone to fracture along joints. As more rainwater trickles through, it creates gaping holes that we call grottos or caves. It can take decades to a century to form these large intricate networks, a humbling reminder of how powerful Mother Nature can be. Best not to anger her. She can be temperamental as she is kind to humanity. One of our companions didn't bring an extra set of clothing to change in and we had to back at the point where the water goes waist deepl. Just the same, we were happy to see nature's grand formations, little crabs, shrimps and tiny catfish in step pools of water. Caves are visually dramatic and will linger in your memory. There were signs of vandalism on the cave walls. This makes me even more glad that the LGU is making an effort to provide awareness and education to preserve it's historical and natural beauty".

2. Geology of Pinagrealan cave

This cave belongs to the Angat formation. This cave belongs to the Buenacop Limestone (upper member of Madlum Formation) and Angat Limestone or Angat Formation, which is The Angat Formation unconformably overlies the Bayabas Formation. It consists of a lower calcareous shale and sandstone member and an upper limestone member. These rocks are distributed along Angat River, on the western flank of the southern Sierra Madre, and in the Norzagaray and Camachile areas of eastern Bulacan. The Angat Formation is dated Early Miocene.

Conformably overlying the Angat Formation is the Middle Miocene Madlum Formation which consists of a lower clastic member (sandstone, silty shale), the middle Alagao Volcanics (andesite flow, pyroclastic breccia, tuffs, graywacke, argillite), and the upper Buenacop limestone. These rocks are exposed in the area between the Angat and Peñaranda rivers and in San Ildefonso, Bulacan.

Karst landscapes, in which dissolution of bed rock by water is one of the dominant geomorphic processes, occupy ~10-20% of earth's land area. Nearly all major surface karst feautures owe their origin to internal drainage, subsidence, and collapse trigerred by the development is essential to the hydrologic or geomorphic interpretation of any karst region, and in assessing aquifer yield, contaminant migration, and soil and and bedrock stability (Palmer, 1991). Then karstsification can cause advantages and disadvantages for the surrounding community, if not managed properly. The cave is one of the formations by the karsification process, which can be observed in the Fig 3.

Fig. 4 *Raw limestone material of Rhino $ Lioness Rock Formation*

These rocks are used as raw materials for the manufacture of cement and other building materials. Fig. 4 shows the the raw material of Rhino's Lioness Rock Formation, where raw materials for cement production are sourced. The upper rock layers consist of shale while the lower rock layers consist of limestone. The quarry started operating in 1997 at an elevation of about 67m. The quarry is now at 62m elevation.

(a) Stalactite and calcite straw (b) Rimstone

Fig 5. *(a) Stalactite is a mineral formation that hangs from the ceiling of caves, and calcite straw is on of stalactite feature, (b) Rimstone, also called gours, is a type of speleothem in the form of a stone dam.*

3. Geologic hazards

The geologic hazards discussed in this section include seismic hazards, volcanic hazards, mass movement hazards and flooding hazards. Seismic hazards are associated with potential earthquakes in a given geographic area and include related earthquake-related hazards such as ground shaking, ground rupture, liquefaction. Location and distance of the project site to the nearest active fault based on the PHIVOLCS fault finder web application is shown in Figure 6: EL-10 and Figure 7: EL-11. As shown on the map, the nearest seismic generator to the project site is the West Valley Fault that is located about 6 km east-southeast of the project site. Ground shaking with an estimated PGA of 0.39g will affect the project site during a strong earthquake (Quebral, et al, 2013). Liquefaction has a low probability of occurrence considering the absence of liquefiable materials in the project site (Figure 8: EL-13).

Fig. 6: EL-10. *Distribution of geological structures in the northern part of the Philippines.*

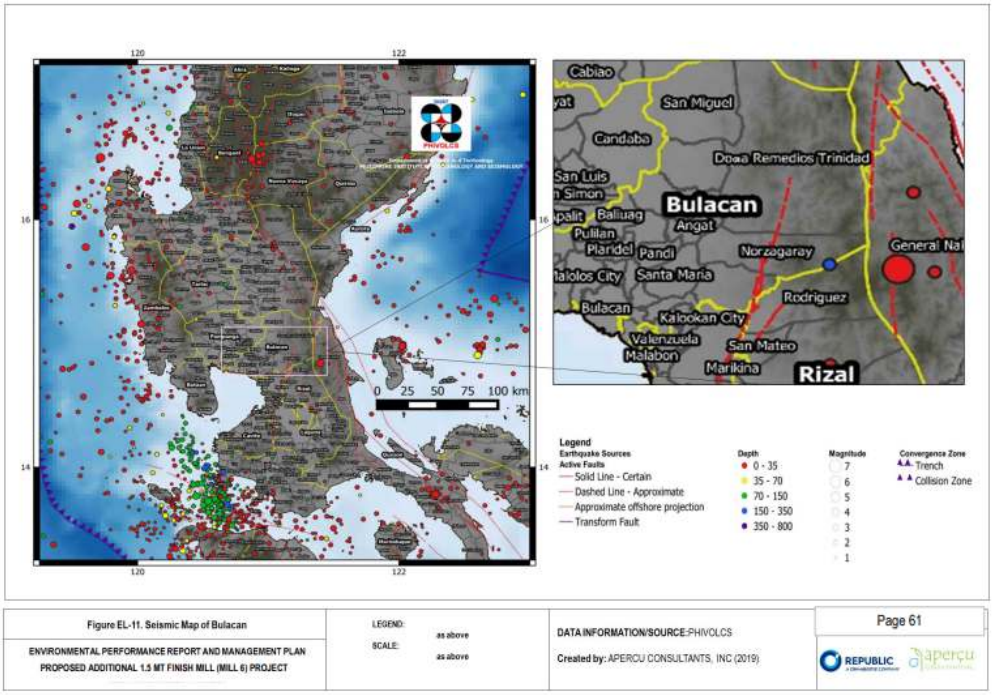

Fig. 7: EL-11. *Bulacan seismic map or subsurface conditions.*

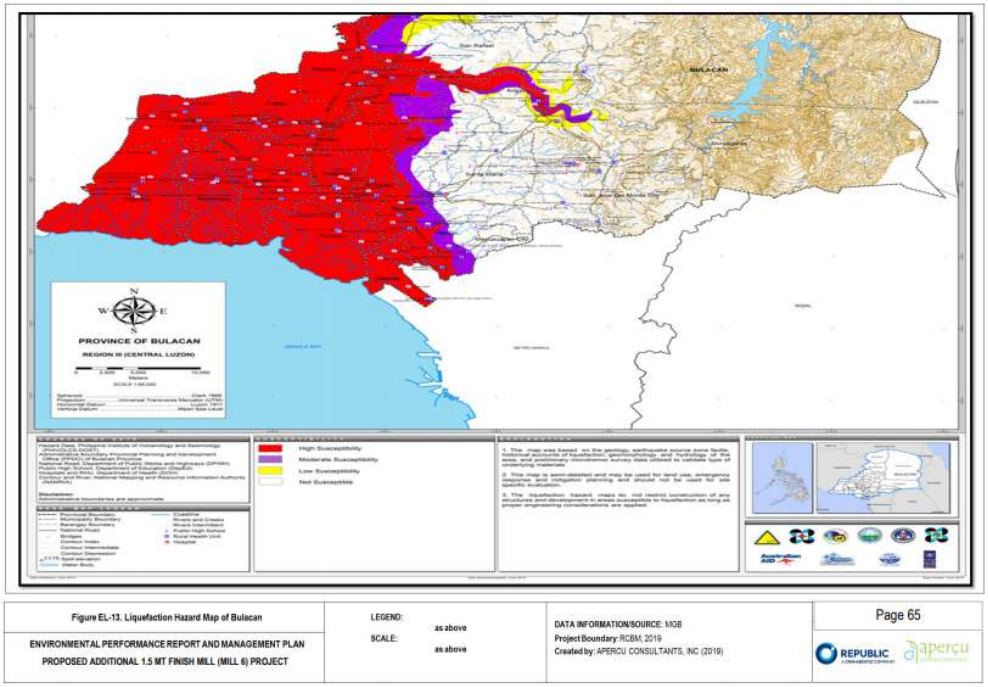

Fig. 8: EL-13. *Potential for liquefaction with high susceptibility to non susceptibility in Bulacan Province.*

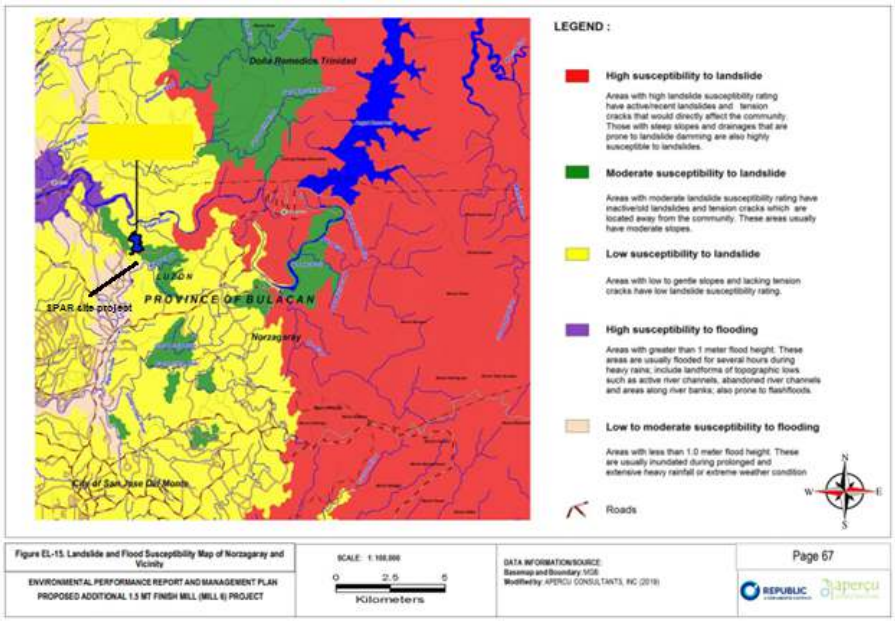

Fig. 9: EL-15. *Potential for liquefaction with high susceptibility to non susceptibility in Bulacan Province.*

a. Landslide vulnerability level

Landslide and Flood Susceptibility Map of Republic Cement & Building Materials:

- Moderate susceptibility to landslide (areas with moderate landslide susceptibility rating have inactive/old landslide and tension cracks which are located away from community. These areas usually have moderate slope
- Low susceptibility to landslide (area with low to gentle slopes and lacking tension cracks have low landslide susceptibility rating)

Subsidence often occurs in karst terrains where the dissolution of limestone can create subsurface voids or caves that can collapse and can cause the overlying material to fall. Although subsidence has not been reported in areas adjacent to the project site, but it will definitely happen because subsidence due to excessive groundwater withdrawal. The possibility of erosion and rockfall will also occur together, due to the fracture (Fig. 3) and high level of rainfall.

For the quarry area, continuous monitoring of the exposed slopes and benches should be done for any indications of possible landslide and rockfall. This can be done by the RCBM geologist (if any) or an independent geologist at least once during the peak of the rainy season. Rainfall monitoring data should be correlated to the occurrence of landslides to determine the approximate amount of rainfall that triggers or causes landslides. Fig. 9: EL-15 shows the landslide and flood susceptibility map of Norzagaray and vicinity. As shown on the map, the project site has low-moderate susceptibility to flooding and landslides. Quebral et al (2013).

b. Soil in Pinagrealan cave

Erosion is one of the factors that can trigger landslides. This process is influenced by its constituent components, namely soil. The land in the project site is divided into several levels (Fig 10), where there are different levels of erosion.

Table EL-8
Soil type distribution in Norzagaray (Norzagaray CLUP 2011-2020)

Soil Type	Area (hectares)	Percentage	Soil Characteristics
Buenavista silt loam	132.52	0.43	Fair and good lands suitable for limited cultivation; inherent moderate fertility and slightly acidic
Novaliches clay loam	12,466.28	40.45	Located in upland, rolling and hilly areas; soils are steep, well drained and shallow; severely eroded if cultivated; coarse fragments are present in the subsoil
Novaliches loam	3,269.90	10.61	Composed of highly weathered tuffaceous material; Diversified farming with upland rice as main crop
Novaliches soil (undifferentiated)	12,694.35	41.19	Found in forested areas and has no agricultural importance
Prensa clay loam	277.37	0.90	Underlain by volcanic tuffaceous materials where upland field crops can be grown; acidic soils with moderate inherent fertility; soils are sticky when wet and becomes hard when dry
Sibul clay	1,978.58	6.42	Found in lowlands and rolling areas where soils are steep, well drained, shallow and prone to severe erosion if cultivated; lowland recommended for planting rice and corn while rolling areas are good for grazing; limestone fragment can be present at the topsoil
Total	30,819.00	100.00	

Fig. 10 *Soil type distribution in Norzagaray.*

Soil types in Pinagrealan cave are Sibul and Novaliches series. The Novaliches soils series consist of the majority of soils found in Norzagaray and are found in rolling topography. Risk of erosion is high while coarse fragments can be present in the subsoil. A small portion of Norzagaray has soils belonging to the Sibul series where soil is shallow due to erosion. The Sibul soils are found in undulating to steep topography and limestone fragments can be present in the topsoil. This soil type is not suited for irrigated lowland production because of irrigation concerns. A very small portion of the municipality has soils belonging to the Buenavista and Prensa series, which are suitable for paddy rice production.

Fig. 11 *Material that has been crushed by a crushing machine*

If the presence of beryllium, mercury, and selenium later in the soil is abundant, then the mining process around the project area has been polluted. The mining process through Fig. 11 can trigger the presence of these elements.

c. Groundwater Quality

Groundwater quality is one of the requirements for mining companies in the process of managing mining products to find out, a geochemical analysis is needed, such as that carried out by the Republic Cement and Building Materials (RCBM) company Fig. 12. However, at the company Spar Development Co. the results of the groundwater test report document are not attached.

Physico-Chemical Parameters	GW Quality	Standard: DAO 2016-08
pH, range	6.8	6.5-8.5
Temperature, °C	28.4	26-30
Salinity, ppm	0	-
Turbidity, NTU	16.34	-
DO, mg/L	4.12	-
BOD, mg/L	ND	-
TSS, mg/L	5.0	65
TDS, mg/L	639	-

Physico-Chemical Parameters	GW Quality	Standard: DAO 2016-08
Oil & Grease, mg/L	ND	1
PO_4, mg/L	ND	0.5
NH_3, mg/L	ND	0.05
Cr^{+6}, mg/L	0.00627	0.01
As, mg/L	<0.00416	0.01
Cd, mg/L	<0.000727	0.003
Pb, mg/L	<0.00517	0.01
Hg, mg/L	0.00020	0.001
Total Coliform, MPN	11.0	-
Fecal Coliform, MPN	6.80	100

Fig. 12 *RCBM Groundwater Quality*

RCBM said there is no impact on groundwater quality. As indicated by the hydrology study the estimated annual groundwater recharge at the study area is sufficient and there will be no depletion which in term could cause a change in quality.

4. Conclusion

The mining process is one of the effective ways to support the acceleration of income growth in an area, as well as the surrounding community who can get jobs. However, illegal and/or inappropriate mining can lead to excessive environmental damage such as cave morphology; stalactite, stalacmite, air or water vent, rimstone, calcite straw, etc., and flora and fauna ecosystems: bats and unidentified birds, because it will accelerate the destruction. The construction and operation phases of the proposed project probably have impacts on subsurface geology and probably induce subsidence, liquefaction, landslides, and debris flow.

Therefore, sustainable methods are needed such as reduced use of fossil fuel, hence reduced CO2 and other greenhouse gas emissions, maximize energy recovery from industrial by-products and qualifying wastes, use of RDF and plastic derived fuels will divert volumes from sanitary landfills, minimize flooding caused by improper disposal of garbage, and conserving natural resources and energy.

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THE IMPACT OF QUARRY ACTIVITIES TOWARDS THE PINAGREALAN CAVE

INDEPENDENT GEOLOGICAL REVIEW REPORT

JUNE 2021

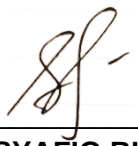
Table of Contents

AUTHENTHICATION OF INDEPENDENT REVIEW REPORT.

I ensure that all content of the report is independent geological review based on the data provided on 6th June 2021. All the findings in this review report are according to the observation on the photograph of the Pinagrealan Cave condition (entrance and interior) provided.

Thank you.

Yours Thruthfully,



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1.0 INTRODUCTION

This report is an independent review regarding the impact of quarry activities towards the Pinagrealan Cave. Pinagrealan Cave is located at Bulacan, Philipines and can be accessed by Curvada road. The existing limestone quarry owned by Spar Development Co., Inc. is located approximate 250m from the cave entrance. Figure 1.1 shows the location of Pinagrealan Cave and the existing quarry in the study area.

Figure 1.1: Location of Pinagrealan Cave and the existing quarry site (Google Earth Image).

2.0 OBJECTIVE

The main objective for this review is to identify the impact of quarry activities towards the cavern structure.

3.0 SITE BACKGROUND

The Pinagrealan Cave is a limestone cave with height varies from 3m to 7m approximately and width varies from 0.3m to 1.5m. The length of the cave is approximate 1km from the cave entrance to the end of the cave. the existing quarry site is located approximate 250m from the cave entrance with elevation difference of 75m approximately. Figure 3.1 shows the schematic profile of the study area.

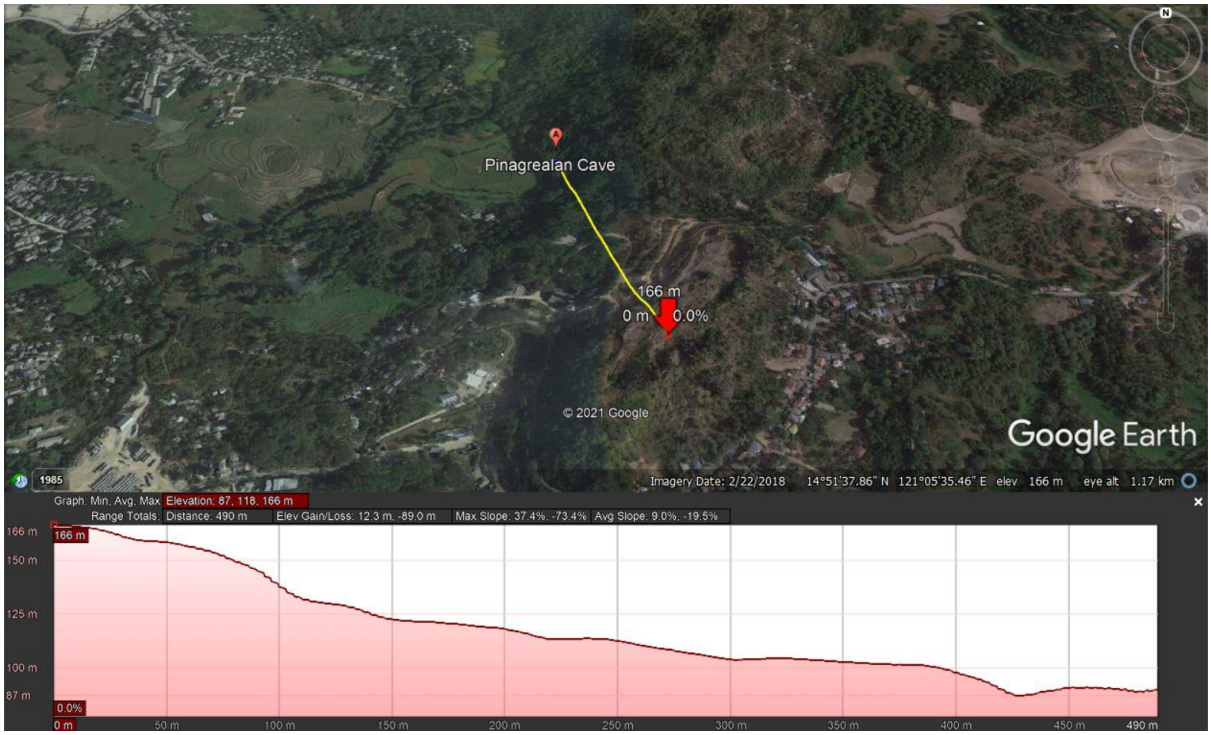

Figure 3.1: Schematic profile of study area (Google Earth); Elevation of Pinagrealan Cave is 91m, and the existing quarry site is 191m above mean sea level.

4.0 FINDINGS

Based on the photograph provided on 6th June 2021, there are several findings that can be observed in the study area.

4.1 Discontinuity

Discontinuity is defined as any break in the continuity of a rock mass that has the potential to have zero or very low tensile strength (ISRM, 1978). Discontinuity is due to deformation of rock mass by natural activities and not by manmade. There are several types of discontinuity such as bedding, joint, foliation, and etc. Based on the photography provided, the type of discontinuity observed is identified as joint.

There are several joints that are observed in the entrance and the interior structure of the cave. The frequency of the joint occurrence and its aperture indicates the severity of the geohazard that may occur. Photo 4.1 and Photo 4.2 show the joint occurrence at the cavern structure.

Photo 4.1: Joints that are observed at the cave entrance.

Photo 4.2: Joint that is observed at the interior of cave.

4.2 Cavern Structure

Based on the photograph observation, there are several cavern structures or known as speleothems that exist in the interior of the cave. Photo 4.3 to Photo 4.5 show the speleothems

that are observed in the photograph of cave interior. Figure 4.1 shows the schematic diagram of the cave interior.

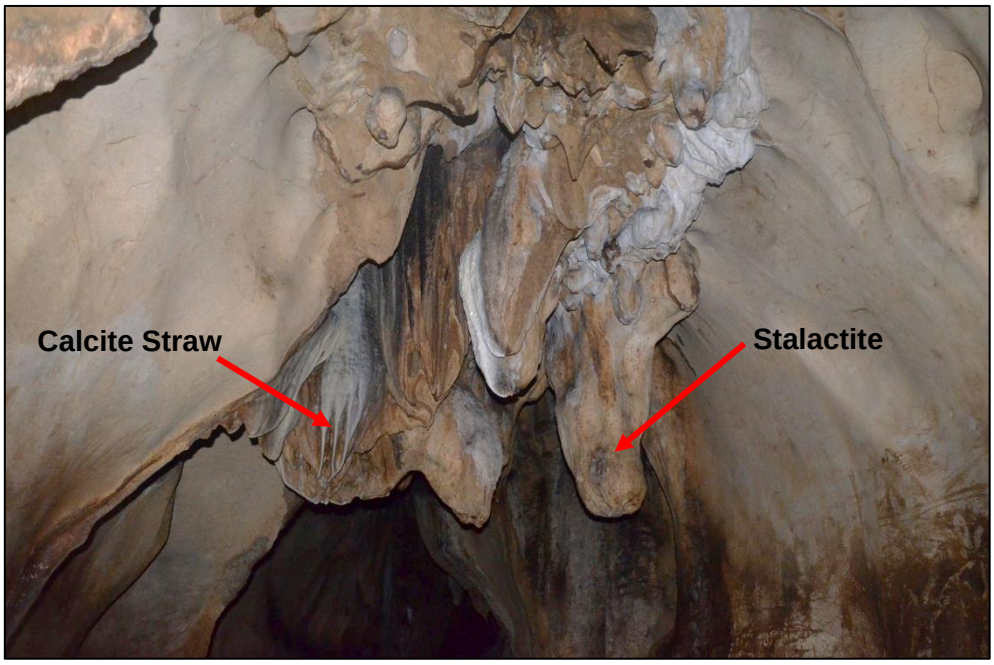

Photo 4.3: Existence of Calcite Straw and Stalactite in the cave interior.

Photo 4.4: Existence of Rimstone Dam in the cave interior.

Photo 4.5: Existence of Curtain flowstone inside the cave.

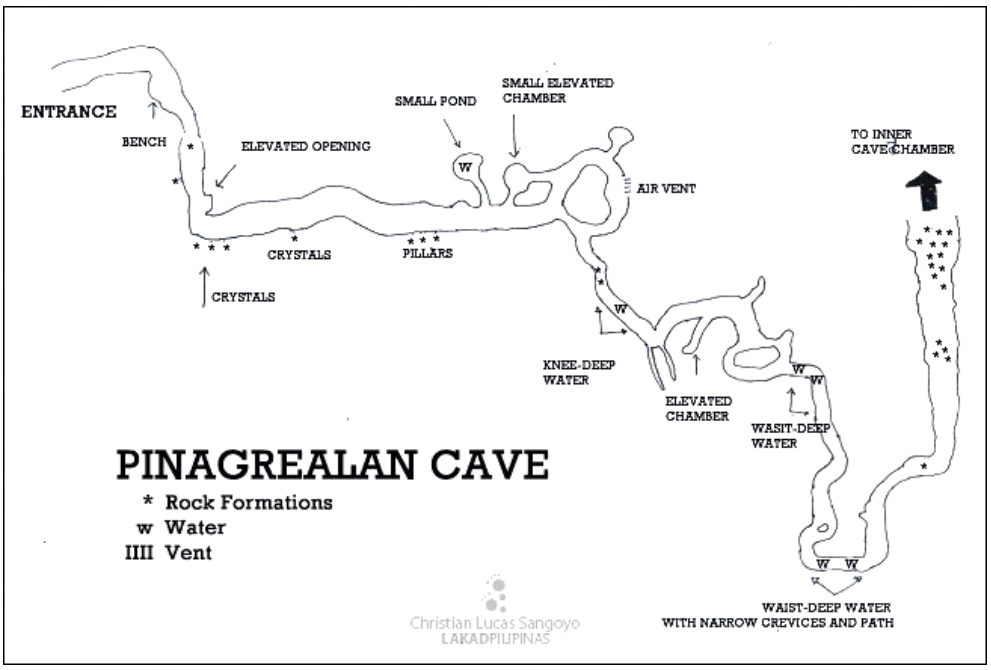

Figure 4.1: Schematic diagram of Pinagrealan Cave interior.

4.3 Rock Weathering

Soil and rock are prone the weathering due to expose to the surrounding. Weathering agents such as water, wind, and other chemical composition causing the material to become loose and indirectly reduce the rock or stability. According to the photograph observed, exfoliation (Photo 4.6) is observed above the cave entrance approximate 15m from the entrance.

Exfoliation is a type of physical weathering that occurred on the rock surface due to pressure inside the rock is released by exposing it to the surface.

Photo 4.6: Exfoliation that occurred on the rock surface above the Pinagrealan Cave.

5.0 DISCUSSION AND CONCLUSION

The existence of a quarry approximate 100m height above Pinagrealan Cave may cause several environmental impacts on the cave. The quarry activities such as rock blasting may cause seismic impact on the cavern structure. The vibration generated by construction or quarry blasting may have an adverse impact on the environment (Mesec *et.al,* 2018). The vibration effects vary from annoying human disturbances to structural damage. The seismic impact by uncontrolled blasting may trigger the joint aperture to be widened. This phenomenon may lead to instability of the rock structure and thus causing rock failure in the cave.

Uncontrolled blasting may also cause rock fall near the Pinagrealan Cave. The exfoliated weathered rock above and nearby the cave entrance may fall down due to the vibration that triggered the rock fall. This will cause risk to the tourists and nearby residents.

The removal of overburden for extraction by quarry activities may expose the joint to the surface and allowing surface water to infiltrate into the joint aperture. This will increase the pore water pressure in the subsurface and reduce the strength of the cave structure. Hence, it may lead to rock failure inside the cave.

The existence of speleothems in the Pinagrealan Cave can promote the cave to be a geoheritage site or known as geosite. A geosite is a location that has scientific, aesthetic, cultural and recreational values. The speleothems need thousands of years to be formed and should be preserved and maintained to ensure its structure will not be damaged. Thus, promoting the cave as geosite can helps in preserving the speleothems and the cave itself.

As conclusion, the quarry activity needs to be taken into consideration to reduce the probability of rock failure occurred inside the cave and preserved the speleothems as well as reduce the risk impact towards tourists and nearby residents. Last bu not least, the cave can also be promoted into geosite as an alternative way to preserved the speleothems and the cave itself.

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To Investor: Elron Garcia

Impact of the Spar quarry on the Pinagrealan cave

Introduction

The province of Bulacan is well known for its historic caves. Pinagrealan Cave in Minuyan, Norzagaray is one of the famous caves in Bulacan next to Biak na Bato.

Pinagrealan cave is rich in history. It is known for its significant contribution during the Spanish revolution. Its geographical location, surrounded by hills, fulfilled a major consideration for the Katipuneros to use it as one of the camps and hideouts of General Emilio Aguinaldo during the Filipino-Spanish War in 1898. It was also a sanctuary of the Japanese Imperial Army when the Philippines were liberated by American Forces.

Tourists of all ages can appreciate the natural wonders of these underground chambers. Many **impressive formations are created by nature through the centuries including stalactites, stalagmites, columns, draperies, curtains and flowstone**. It also has a lot of beautiful subterranean views which cavers may enjoy and appreciate.

It is a subterranean network of caverns extending more than a kilometer deep. The cave measures about 4 meters by 2.5 meters. Inside the cave runs a refreshing crystal-clear stream and a **few sinkholes** that form natural swimming pools. Several organisms such as **shrimps, biya and bivalves can be seen in the stream**. There are also a few nocturnal bats and unidentified birds flying over the loose canopies of thickets.

Only limited types of species thrive on the hills surrounding the cave. Shrubs, vines, cogon and other plants that can grow on limestone with very thin soil substrate live on them because 85 percent of the whole cave is made up of **limestone.**

It is a different adventure for many cavers to wiggle, waggle, waddle, squirm, push and pull amidst the numerous stalactites and stalagmites just to see the innermost beauty of the cave. One even has to climb up the uneven vertical fractures and rock formations that are embedded in the slippery sand-stones. It is also a good spot for photography because of the dark, dramatic, and mysterious surroundings.

The Pinagrealan Cave is located at Brgy. Minuyan, Norzagaray, Bulacan. From Norzagaray town proper, just ride a “Brgy. Bigte” bound jeep. Then tell the driver to drop you off at the Bigte circle (rotunda or roundabout). From the circle, there are motorcycles for hire that go to the entrance of Pinagrealan Cave.

According to **DENR Memorandurn Circular no. 2012-03 by Department and enivivoirment and natural resources of Philipines Pinagrealan cave is categorized as class III cave described as: „**Caves generally safe to inexperienced visiturs with no known threatened species and archeological. geological, natural histoy, cultural and historical values. The caves may also be utilized for economic purposes such as guano extraction and edible birds nest collection".

Informations provided by an Investor

Investor 06.06.2021. provided me 23 photos of the cave, 15 photos of the quarry located above the cave, documents from Republic cement and map of the cave.

To notice: Investor also send me some pictures and articles till the 8th of June.

Environmental Impacts of Quarrying Stone in Kars

Since the quarry is located 100 feet above the cave (according to Investor), a **very negative environmental impact** on the cave itself is expected.

Blast-induced vibrations and shock waves can cause stalagmites and stalactites to break off and cause cave roofs to crack or collapse. Blasting may cause fracturing of quarry walls, increasing permeability and increasing drainage towards quarry face (Gagen and Gunn, 1987, Gunn and Bailey, 1993). The blast zone beneath the quarry floor in subwater table quarries may be considered as a separate aquifer with high fracture density, low primary porosity, and negligible conduit development (Smart and others, 1991). Blasting-induced fracturing or aperture widening may play a role in initiating flooding events. Lolcama and others (1999) describe a situation where blasting opened a conduit under the floor of a quarry. The conduit was connected to a nearby river and to a local water storage basin. Extensive grouting was required to stop the infl ow of water from those sources. Blasting can negatively impact karst biota and may cause problems with ground-water availability and quality (discussed below). (William H. Langer, 2001).

Since the quarry is located just above the cave, the impact of blasting is extremely large. It is especially necessary to mention that the tremors of the ground caused in this way have a **very negative effect on the living world of the cave and especially on the bats.** The investor informed me that there is an endemic species of bat in this cave that must be protected.

Caves develop one of the most peculiar terrestrial ecosystems. One determining factor for life in karst solution features is the lack of light. The karst environment can be divided into four zones based on the degree of darkness: the twilight zone, the transition zone of complete darkness, the deep zone of complete darkness, the stagnant zone of complete darkness.

Certain species live in each of these zones. Although the living world from the first two zones is adaptable to changes in light, the living world from the zones of complete darkness is extremely sensitive.

As rock is removed by quarrying, any cave passage is destroyed, along with any sediments it may have contained. The habitat provided by the caves and passages will cease to exist.

Animals that inhabit the twilight or transition zone, and are mobile and able to fi nd new homes, might survive; the rest will die. Creatures that have adapted to the deep and stagnant zones will perish.

Blasting can negatively affect karst habitat and biota. Blast-induced vibrations and shock waves can cause cave roofs to crack or collapse, and karst environmental conditions can be altered by just one new crack. Light may enter an otherwise dark cave or passage, or streams and ponds may suddenly drain into a new crack in the fl oor. Either situation can result in the death or displacement of cave communities (Vermeulen and Whitten, 1999).

The limestones that make up this area are characterized by cavernous-crack porosity which makes them very water permeable. Considering that the cave is located just below the surface of the terrain, it can be concluded with certainty that there is a very intensive connection between atmospheric precipitation and groundwater levels in the cave. Accordingly, we can conclude that water polluted by human activities seeps into the cave and pollutes the environment.

Quarrying may intersect active ground-water conduits, or cause their blockage, with adverse consequences for aquatic communities. Ground-water withdrawal and diversion of surface water may cause aboveground and underground hydrologic systems to dry up. Water bodies, which may be inhabited by small, site-endemic fish and snail species, will disappear and with them, the species. Alterations of flow volumes and patterns and the availability of nutrients can profoundly change the limestone environment and may lead to the extinction of whole communities (Vermeulen and Whitten, 1999).

If the work on the quarry causes disturbance of the groundwater level, there is a real possibility of creating a sinkhole. Since I have no information about this, I can't even claim exactly, but I give myself the right to warn of the possibility of this event.

Intensive blasting and quarry work can cause instability of the cave and collapse of the cave roof as well as the possibility of breaking stalactites and stalagmites which, in addition to being a natural resource, in this case can cause accidents to wildlife and tourists and visitors to the cave.

Given that the cave is a natural resource and that it is active in tourism, it is necessary to stop all work above the cave to avoid the possibility of negative impact on the environment and the risk of accidents to visitors.

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Sarajevo, Bosnia and Herzegovina, 08.06.2021.