

Petrological Characteristics and Supply Suggestion for Restoration Stones in Hong Nang Sida Temple, LAO PDR

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Abstract: With significant historical and academic value, Hong Nang Sida Temple in Lao PDR was designated as a UNESCO world cultural heritage along with nearby Vat Phou Temple. In this study, we discuss the provenance of stones constructing the Hong Nang Sida temple and way to secure it. The main temple in Hong Nang Sida is made with sandstone and siltstone, and they are divided into gray sandstone, grayish-green siltstone, grayish-green sandstone, dark gray sandstone, etc. according to their color. By assuming that they were extracted from nearby Mt. Phu Nak, Douangdy quarry and Vat Chompet quarry, specimens were collected to review the homogeneity with the stones in Hong Nang Sida site. Considering the possibility that they were imported from a long distance, stones from Thailand were also compared. The study on the homogeneity of stones revealed that it would be the most desirable to use rocks from Mt. Phunak as alternative stones for restoration of the main temple. However, it is hard to get sufficient amount of alternative stones for restoration, because Mt. Phu Nak was designated as world heritage protection area. Thus, it is proper to secure alternative stones from Douangdy and Vat Chompet quarry, considering the geochemical homogeneity including color and deposition structure as well as procurement possibility.

1 INTRODUCTION

Along with Cambodia, Vietnam, Myanmar, Thailand and Lao PDR was a country that the ancient Khmer Empire ruled historically and culturally. There are a number of remains related to Khmer including Angkor in Cambodia, My Son sites in Vietnam, Phimai temples in Thailand and Vat Phou sites in Laos. 'Vat Phou Temple and ancient dwelling site in Champasak cultural landscape' including Vat Phou Temple and Hong Nang Sida in Laos is a popular tourist destination in southern Laos designated as the UNESCO World Cultural Heritage in 2001.

Major remains of the Champasak cultural landscape are Phou Kao, Vat Phou Temple Complex, Hong Nang Sida area including Ancient Road as well as Thao Tao Temple, Temples and Inscriptions, Ancient City, Tomo Temple, Other sites on the Champasak Plain.

The study point, Hong Nang Sida, is located on the about 1.5km southside from Vat Phou main

temple. Hong Nang Sida temple consists of platform-mandapa-antarala-cella; cella and antarala lost its original shape because of destroyed upper part. Moreover, stones in the upper part are being piled up around the temple, making it impossible to enter inside.

Therefore, it is expected that the result of this study provides basic scientific data to restore the Khmer remains. In this study, we performed material analysis on rocks consisting of Hong Nang Sida, study on securing alternative stones and procuring stones through analysis on place of origin of main temple rocks. This is essential for supply and demand of alternative stones for maintenance and restoration of Hong Nang Sida in the future and preservation of reused stones.

2 METHODOLOGY

Sandstone at the Hong Nang Sida temple was observed with naked eyes and portable microscope. The petrographical characteristics were recorded to analyze by sampling proper amount of specimens collected for scientific analysis. To assume place of origin of the sandstone consisting of the main temple, geological distribution near the Hong Nang Sida was explored in detail, and areas expected to have the same rocks were studied. During the research process, several samples were secured from Mt. Phu Nak and Douangdy and Vat Chom Phet quarry, and even rock samples confirmed to be imported from Thailand were analyzed for homogeneity test.

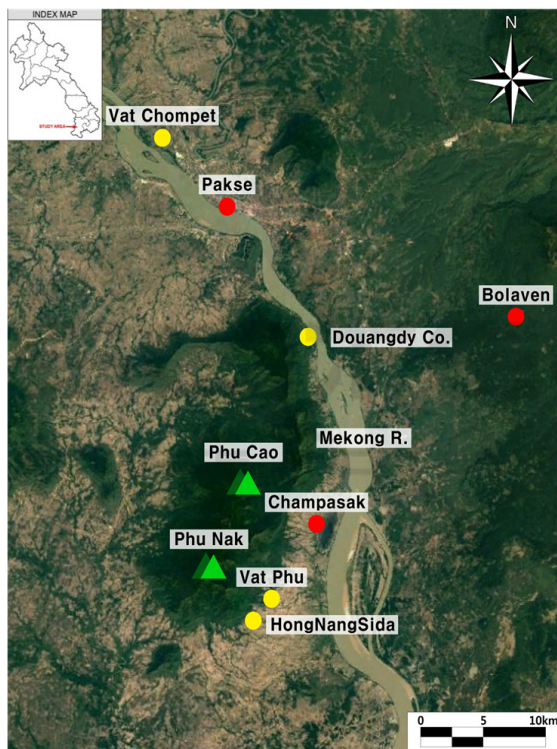


Figure 1: Terrain and sampling points around the Hoang Nang Sida in LAO P.D.R.

In this study, various analysis were conducted for the homogeneity test, and these method were an internationally proven research method that has been applied to various cultural heritages (Lee *et al.*, 2007; 2010; Lee *et al.*, 2006; Lee and Yi 2007; Uchida *et al.*, 2007). The magnetic susceptibility and chromaticity measuring were performed to discuss the homo-geneity for samples. For quantitative analysis of major constituents and trace and rare earth elements, geochemical analysis was performed through using INAA, ICP-MS, and ICP-AES, etc.

3 RESULT AND DISCUSSION

3.1 Petrological Characteristics

Sandstone, consisting of the Hong Nang Sida temple, can be divided into gray sandstone, grayish-green siltstone, grayish-green sandstone and dark gray sandstone in detail. Northside in the temple is mostly covered with grayish-green sandstone and siltstone, but the platform, eastside in the temple, has concentrated with dark gray sandstone; Thus, at least two stone types were used to construct the temple. However, these sandstones have a similar particle size of 5mm regardless of their color. Also, the mineral composition is similar. Quartz is the major mineral, and a small amount of feldspar and mica are observed. Siltstone consists of fine particles with the particle size of around 0.1mm, and quartz accounts for the most. As a minor mineral, biotite is observed in a linear structure.

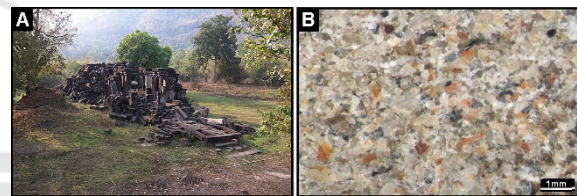


Figure 2: Status of the Hong Nang Sida temple and sandstone. (A) The whole view of the temple. (B) Stereoscope photograph of gray sandstone.

Located in the northwest of Hong Nang Sida, Mt. Phu Nak has exposed bedrocks lying scattered and a lot of traces of quarrying. These traces are observed with a rectangle of dozens cm $\times$ hundreds cm at various spots of outcrops. In the Mt. Phu Nak, grayish-green siltstone, dark gray siltstone and dark gray sandstone are mostly observed. Although most of them have similar petrographic features to rocks used in the main temple of Hong Nang Sida, there is partially a slight difference in stone color, refined structure and particle size.

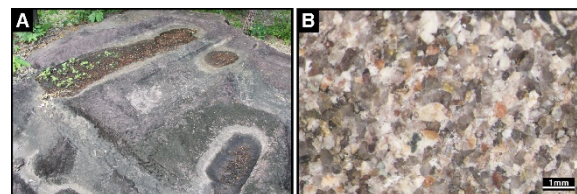


Figure 3: Photographs of the sandstone in the Phu Nak mountain. (A) outcrop and quarry trace. (B) Stereoscope photograph of greenish gray sandstone.

It is essential to secure places to supply almost the same rocks to stones constituting the main temple of Hong Nang Sida in mass. This study investigated rocks from Douangdy quarry, which is about 20 km north from the Hong Nang Sida, and quarry near Vat Chompet Temple that is approximately 20 km northwest. These areas enable mass quarrying, and quarrying has been conducted until recently. Moreover, the rocks belong to the same index horizon of the same period to the sandstone constituting Mt. Phu Nak and Mt. Phou Kao, which are known for the place of origin stone in Hong Nang Sida. The quarried rocks were very heterogeneous, but in the part of the massive structure, they showed high homogeneity with the rocks of the temple.

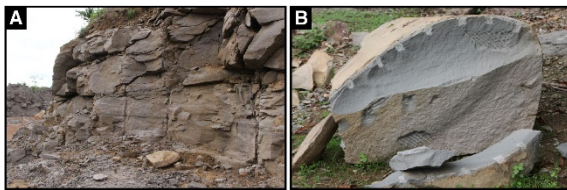


Figure 4: Photographs of current quarry. (A) DouAngdy quarry. (B) Vat Chompet quarry.

The north palace of Vat Phu temple was restored using the stones from Thailand. They had various colors: pinkish gray siltstone, gray siltstone, purple siltstone, and pale yellow sandstone. The color, texture, and structure of the rock are all different, and the matrix contains calcite.

3.2 Chromaticity

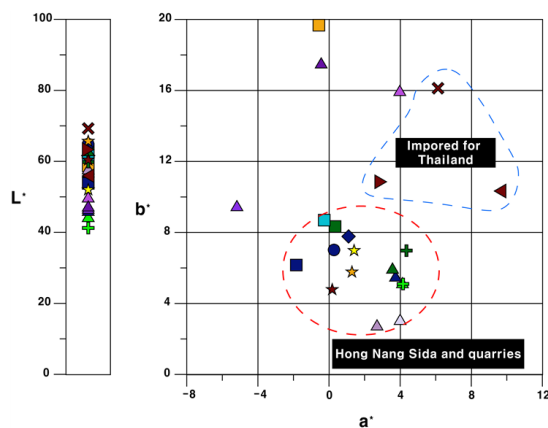


Figure 5: Diagram showing chromaticity of sandstones.

In the study, quantitative chromaticity of samples was measured using MINOLTA CR-300 colorimeter. L^* values of sandstones from Hong Nang Sida site were 46.26 to 64.89 (average 57.68), a^* -1.84 to 3.74

(average 0.60), and b^* 5.55 to 8.70 (average 7.04). Each sandstone samples from Mt. Phu Nak, Douangdy and Vat Chompet quarry, have the similar chromaticity to Hong Nang Sida samples.

On the other hand, some stones from Thailand showed L^* of 55.99 to 69.28 (average 62.30), a^* of 0.18 to 9.62 (average 4.71), and b^* of 4.82 to 16.13 (average 10.54), a wide range of chromaticity. They had relatively high redness and yellowness compared to other samples, and the deviation among samples also was significant.

3.3 Magnetic Susceptibility

The magnetic susceptibility of Hong Nang Sida sandstone showed distribution of 0.017 to 0.228 ($\times 10^{-3}$ SI unit), and the average was 0.115 ($\times 10^{-3}$ SI unit). Although some samples of Mt. Phu Nak, Douangdy and Vat Chompet quarry exceeded the magnetic susceptibility measurement results of Hong Nang Sida, most of them showed similar distribution. All Thailand sandstone has less than 0.100 ($\times 10^{-3}$ SI unit), showing the inhomogeneity.

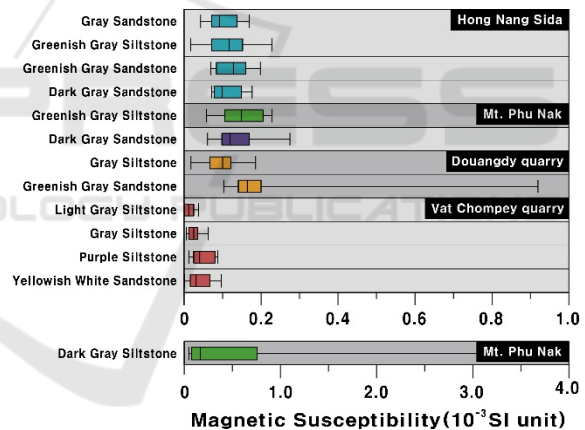


Figure 6: Diagram showing magnetic susceptibility of sandstones.

3.4 Geochemical Characteristics

This study conducted analysis on major elements, rare earth elements, compatible and incompatible elements to discuss the place of origin of rocks in Hong Nang Sida and homogeneity to secure alternative rocks. As a result of the analysis of major elements, most sandstone used in the Hong Nang Sida showed the similar geochemical data, despite the difference of rock floor, and Mt. Phu Nak, Douangdy quarry and Vat Chompet quarry also showed the similar behaviour characteristics on all elements. Stones from Thailand, show different behavior

characteristics: Al_2O_3 lacks, CaO is enriched, and the contents of overall elements lack.

Differences in geochemical characteristics are also observed in Rare Earth Elements, Large Ion Lithophile Elements, and High Strength Filed Elements, but it is difficult to distinguish compared to the analysis of major elements. It was classified into three types based on geochemical characteristics, and the same characteristics as those of the Hong Nang Sida temple were set as type-A. As a result, sandstone in Mt. Phu Nak, Douangdy and Vat Chompet quarry is included in type-A, and has similar geochemical characteristics.

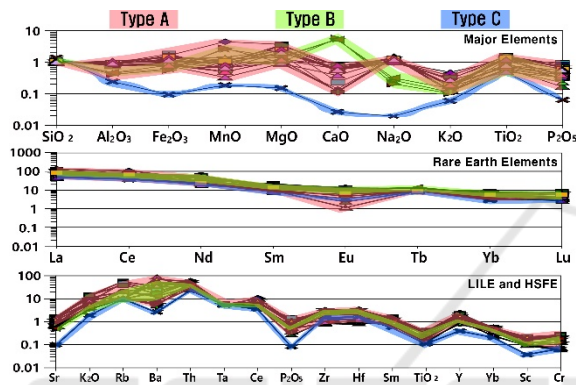


Figure 7: Classification in geochemical characteristics as three types.

4 CONCLUSION

The principle of repairs and maintenance of world heritage has to be pursuit the original shape for restoration without damaging completeness and authenticity. It will be ideal restoration of the main temple using the Mt. Phu Nak sandstone, which has evidence of quarry and the most homogeneous with the Hong Nang Sida rocks. However, since this area is designated as world heritage protection region, It is difficult to obtain enough alternative rocks to restore the temple.

Accordingly, it is required to decide whether the stones are proper for restoration by comparing the type and color, sedimentation structure, mineral compositions, geochemical behavior and etc. This study analyzed stones from Douangdy quarry, Vat Chompet quarry and Thailand except for Hong Nang Sida Temple and Mt. Phu Nak, and evaluated the appropriateness of as alternative rocks for restoration. As a result, it is proper to secure alternative stones from Douangdy and Vat Chompet quarry, considering the geochemical homogeneity, color and

deposition structure as well as procurement possibility.

Stones imported from Thailand were all different in chromaticity, mineral compositions and geochemical behavior. Using the stones will not only be heterogeneous with existing members but also cause different erosion due to difference in weathering strength caused by mineral compositions. As such, using the stones as an alternative should be avoided.

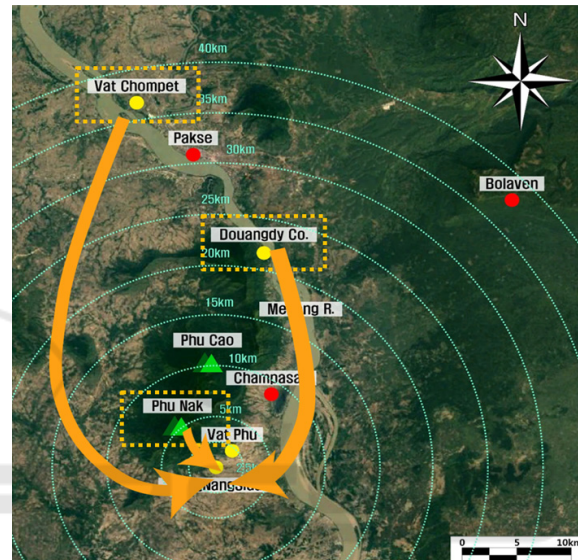


Figure 8: Presumed source and transportation route of the sandstone properties in the Hong Nang Sida.

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