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Analysis of minerals in the lavender gemstone by using XRF to determine whether it is a type of Jade

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Abstract. Lavender gemstone is called for one kind of gemstone from Aceh province in Indonesia. This gemstone is well known in Aceh province in Indonesia. Its color is purple and it is so attractive. Nonetheless, minerals contained in this gemstone are still unknown. It is also unknown whether this gemstone can be classified as a jade or not until this study is presented. For this consideration, X-Ray Fluorescent (XRF) has been utilized to study the lavender gemstone from Aceh province in Indonesia. Our results showed that the lavender gemstone from Aceh Indonesia contains 90.80% of SiO₂, 4.69% of NiO, 3.54% of Fe₂O₃, and 0.78% of CaO. It was found that the percentage of oxide compounds contained in the lavender gemstone is significantly different than that in jadeite, nephrite-actinolite, nephrite-tremolite, serpentine-clinochrysotile, serpentine-antigorite, and vesuvianite. Based on these facts, the lavender gemstone from Aceh Indonesia cannot be categorized as jade.

1. Introduction
Natural jade is a highly valued precious stone which is mostly used as jewelry for high-class people [1]. This type of gemstone is rare and found only in several places in the world, such as in Myanmar, United States, Russia, British, Canada, Turkey, and Indonesia. Jadeite and nephrite are considered as jade [2-4]. Jadeite is composed by Na (Al, Fe) Si₂O₆, while nephrite is categorized into group tremolite or antigorite composed by Ca₂ (Mg, Fe)₅ Si₈ O₂₂ (OH)₂ Si₂O₆. Serpentine and vesuvianite are also categorized as jade. Because of its high value, jade has been studied intensively. Recent study found that the gemstone from Turkey contains 63.54% of SiO₂, 20.17% of Al₂O₃, 6.71% of Na₂O, 1.78% of Fe₂O₃, and 2.7% of CaO [5]. This gemstone can be categorized as jadeite-jade. Bio-solar gemstone from Aceh Indonesia was studied recently and it was found that this gemstone contains minerals of CaO (59.8%), SiO₂ (19.7%), Fe₂O₃ (11.1%), Al₂O₃ (7.5%), and NiO (1.3%) [6]. It was concluded that the bio-solar gemstone is a type of vesuvianite-jade [6]. Ismail et al. also found that gemstone black-jade from Aceh Tengah Indonesia contains 39.6% of SiO₂, 35% of Fe₂O₃, 17% of MgO, 3% of CaO, and 2% of NiO. It was suggested that the black-jade gemstone from Aceh Indonesia is a type of serpentine-antigorite-jade [7].

Lavender gemstone is one of well-known gemstones in Aceh province in Indonesia. This gemstone is also called cempaka-lavender which is found in Nagan Raya district in Aceh province. Its color is purple which is so beautiful, as shown in figure 1. This lavender gemstone was ranked into the first
rank in the Indonesian Gemstone Stone Contest in Jakarta in 2014. Nevertheless, what kind of minerals contained in this gemstone is still unknown. More importantly, we should know whether this gemstone can be categorized as a type of jade or not. Accordingly, X-Ray Fluorescent (XRF) has been utilized to study lavender gemstone from Aceh Indonesia. The detailed results are reported in this paper.

Figure 1. Lavender gemstone from Aceh Indonesia

2. Methods
The sample of lavender gemstone used in this study was obtained from Nagan Raya district, Aceh province, Indonesia. The sample was crushed manually into powder by using a commercial gold crusher. X-Ray Fluorescent (XRF), Brand of PANalytical MiniPal Type 4 was used to obtain the mineral contents from this lavender gemstone. The measurement was conducted at room temperature. The data of lavender gemstone obtained from XRF was compared to the jade data that were already previously published to determine whether this lavender gemstone can be categorized as jade or not.

3. Results and Discussion
By using X-Ray Fluorescent (XRF), it was found that the lavender gemstone from Nagan Raya district, Aceh province in Indonesia mainly contains SiO$_2$ that is 90.80%. Other minerals contained in the lavender gemstone are NiO (4.69%), Fe$_2$O$_3$ (3.54%), and of CaO (0.78%). In order to determine whether this gemstone can be categorized as jade or not, we need to compare the minerals contained in the lavender gemstone with the jade-type of gemstones. First, we compared the lavender gemstone with jadeite [8] as shown in table 1. Both the lavender and jadeite contains SiO$_2$. The lavender gemstone contains 90.8% of SiO$_2$ but jadeite contains only 58.07% of SiO$_2$. Its difference is 32.73% which is very significant. Both the lavender and jadeite contain Fe$_2$O$_3$ which is about the same percentage. Jadeite contains 24.89% of Al$_2$O$_3$ and 16.62% of Na$_2$O while the lavender gemstone does not contain these minerals at all. The lavender gemstone contains 4.69% of NiO and 0.78% of CaO, while these minerals do not exist in jadeite. The total difference between oxide compositions contained in the lavender and jadeite is 82.82% with its average of 13.80%.

Second, the lavender gemstone was compared with nephrite-actinolite [9] as shown in table 2. The lavender contains 90.8% of SiO$_2$ but it is only 45.40% in nephrite-actinolite. Its difference is 45.40%, which is quite large. Nephrite-actinolite contains 9.96% of MgO and 18.03% of FeO, but these minerals are not contained in the lavender gemstone. Both nephrite-actinolite and the lavender contain CaO, but their percentages are quite different. Nephrite-actinolite contains 12.03% of CaO, but the lavender contains only 0.78% of CaO. Thus, the oxide composition in the lavender is substantially different than that in the nephrite actinolite, the total difference is 92.87% with its average of 15.48%.
| Table 1. Comparison oxide compound compositions in the lavender with jadeite |
|-------------------|------------------|------------------|
| Type of oxides     | Lavender (%)     | Jadeite (%)      | Difference (%) |
| SiO₂              | 90.8             | 58.07            | 32.73           |
| NiO               | 4.69             | 0                | 4.69            |
| Al₂O₃             | 0                | 24.89            | 24.89           |
| Na₂O              | 0                | 16.62            | 16.62           |
| Fe₂O₃             | 3.54             | 0.43             | 3.11            |
| CaO               | 0.78             | 0                | 0.78            |
| Total             |                   | 82.82            |                 |
| Average           |                   | 13.80            |                 |

| Table 2. Comparison oxide compound compositions in the lavender with nephrite-actinolite |
|-------------------|------------------|------------------|
| Type of oxides     | Lavender (%)     | Nephrite-Actinolite (%) | Difference (%) |
| SiO₂              | 90.80            | 45.40            | 45.40          |
| NiO               | 4.69             | 0                | 4.69           |
| Fe₂O₃             | 3.54             | 0                | 3.54           |
| MgO               | 0                | 9.96             | 9.96           |
| CaO               | 0.78             | 12.03            | 11.25          |
| FeO               | 0                | 18.03            | 18.03          |
| Total             |                   | 92.87            |                 |
| Average           |                   | 15.48            |                 |

Third, we compared the lavender gemstone with nephrite-tremolite [10] (see table 3). The lavender contains a lot of SiO₂ (90.8%), while it is only 58.10% of SiO₂ in nephrite-tremolite. Its difference is significantly large, 32.70%. The lavender gemstone contains NiO and Fe₂O₃, but these minerals are not contained in nephrite-tremolite. Nephrite-tremolite contains 23.74% of MgO but the lavender gemstone does not contain this mineral at all. The lavender contains only 0.78% of CaO, but nephrite-tremolite contains 13.29% of CaO. Therefore, it is quite different between the compound composition in the lavender and nephrite-tremolite where its total difference is 77.18% with the average of 15.44%.

| Table 3. Comparison oxide compound compositions in the lavender with nephrite-tremolite |
|-------------------|------------------|------------------|
| Type of oxides     | Lavender (%)     | Nephrite-Tremolite (%) | Difference (%) |
| SiO₂              | 90.80            | 58.10            | 32.70          |
| NiO               | 4.69             | 0                | 4.69           |
| Fe₂O₃             | 3.54             | 23.74            | 23.74          |
| MgO               | 0                | 23.74            | 23.74          |
| CaO               | 0.78             | 13.29            | 12.51          |
| Total             |                   | 77.18            |                 |
| Average           |                   | 15.44            |                 |
Subsequently, the lavender gemstone was compared with serpentine-clinochrysotile [11], (see table 4). Both the lavender and serpentine-clinochrysotile contain SiO$_2$, but its percentage is quite different (48.30%). The lavender gemstone contains 90.8% of SiO$_2$, but serpentine-clinochrysotile contains only 42.50% of SiO$_2$. Serpentine-clinochrysotile contains 41.90% of MgO and 13% of H$_2$O, but the lavender does not. There are 4.69% of NiO, 3.54% of Fe$_2$O$_3$, and 0.78% of CaO in the lavender gemstone. However, these minerals are not contained in the serpentine-clinochrysotile. Thus, the oxide compound in the lavender is quite different than those in the serpentine clinochrysotile with the total different of 112.21%. The average difference is 18.70%.

Table 4. Comparison oxide compound compositions in the lavender with serpentine-clinochrysotile

| Type of oxides | Lavender (%) | Serpentine-Clinochrysotile (%) | Difference (%) |
|---------------|--------------|--------------------------------|----------------|
| SiO$_2$       | 90.8         | 42.50                          | 48.30          |
| NiO           | 4.69         | 0                              | 4.69           |
| Fe$_2$O$_3$   | 3.54         | 0                              | 3.54           |
| MgO           | 0            | 41.90                          | 41.90          |
| CaO           | 0.78         | 0                              | 0.78           |
| H$_2$O        | 0            | 13.00                          | 13.00          |
| **Total**     |              |                                | **112.21**     |
| **Average**   |              |                                | **18.70**      |

Next, we compared the lavender with serpentine-antigorite [12] (see table 5). The serpentine-antigorite has 41.65% of SiO$_2$ which is significantly different than that in the lavender gemstone. Its difference is 49.15%. The serpentine-antigorite contains 41.06% of MgO and 14% of H$_2$O. However, these minerals do not exist in the lavender gemstone. Both the serpentine-antigorite and lavender contains Fe$_2$O$_3$ where their amount is about the same. The lavender contains 4.69% of NiO and 0.78% of CaO, yet these minerals are not available in serpentine-antigorite. From the total and average difference shown in table 5, clearly, the oxide compositions contained in the lavender and serpentine-antigorite are considerably different.

Table 5. Comparison oxide compound compositions in the lavender with serpentine-antigorite

| Type of oxides | Lavender (%) | Serpentine-Antigorite (%) | Difference (%) |
|---------------|--------------|----------------------------|----------------|
| SiO$_2$       | 90.8         | 41.65                      | 49.15          |
| NiO           | 4.69         | 0                          | 4.69           |
| Fe$_2$O$_3$   | 3.54         | 2.88                       | 0.66           |
| MgO           | 0            | 41.06                      | 41.06          |
| CaO           | 0.78         | 0                          | 0.78           |
| H$_2$O        | 0            | 14                         | 14             |
| **Total**     |              |                            | **110.34**     |
| **Average**   |              |                            | **18.39**      |

The lavender gemstone was also compared with vesuvianite [13] as shown in table 6. Vesuvianite contains 37% of SiO$_2$, however, its percentage is significantly lower than that in the lavender gemstone. Its difference is 53.78%. There is 16.21% of Al$_2$O$_3$ in the vesuvianite, but this mineral is
not contained in the lavender gemstone. The vesuvianite also contains 36.17% of CaO, while this mineral is only 0.78% in the lavender gemstone. The lavender contains a small amount of NiO and Fe₂O₃, but these minerals are not contained in vesuvianite. The total difference between oxide compound compositions in the lavender and vesuvianite is 116% with its average of 19.34%. Obviously, the compositions of oxide compound in the lavender gemstone are significantly different than those in the vesuvianite.

Table 6. Comparison oxide compound compositions in the lavender with vesuvianite

| Type of oxides | Lavender (%) | Vesuvianite (%) | Difference (%) |
|---------------|--------------|-----------------|---------------|
| SiO₂          | 90.8         | 37.02           | 53.78         |
| NiO           | 4.69         | 0               | 4.69          |
| Al₂O₃         | 0            | 16.21           | 16.21         |
| Fe₂O₃         | 3.54         | 1.47            | 2.07          |
| MgO           | 0            | 3.9             | 3.9           |
| CaO           | 0.78         | 36.17           | 35.39         |
| Total         |              |                 | 116.04        |
| Average       |              |                 | 19.34         |

The summary of total and average differences oxide compositions in the lavender and jade type of gemstones discussed above is listed in table 7. Clearly, nephrite-tremolite has the lowest total difference among the other gemstones (jadeite, nephrite-actinolite, serpentine-clinochrysotile, serpentine-antigorite, and vesuvianite). Nonetheless, some minerals contained in nephrite-tremolite are not available in lavender (MgO and CaO). Moreover, its total and average differences are greater than 20% and 10%, respectively. Therefore, the lavender gemstone cannot be categorized as a nephrite-tremolite type of gemstone.

Table 7. Total and average differences oxide compositions in lavender and other gemstones

| Kind of Gemstone      | Total Difference (%) | Average Difference (%) |
|-----------------------|----------------------|------------------------|
| Jadeite               | 82.82                | 13.80                  |
| Nephrite-Actinolite   | 92.87                | 15.48                  |
| Nephrite-Tremolite    | 77.18                | 15.44                  |
| Serpentine-Clinohrysotile | 112.21          | 18.70                  |
| Serpentine-Antigorite | 110.34               | 18.39                  |
| Vesuvianite           | 116.04               | 19.34                  |

4. Conclusions

Our XRF measurement showed that the lavender gemstone from Aceh province in Indonesia contains 90.80% of SiO₂, 4.69% of NiO, 3.54% of Fe₂O₃, and 0.78% of CaO. Our analysis revealed that the percentage of oxide compounds contained in the lavender gemstone is significantly different than that in jadeite, nephrite-actinolite, nephrite-tremolite, serpentine-clinochrysotile, serpentine-antigorite, and vesuvianite. Therefore, we conclude that the lavender gemstone from Aceh Indonesia cannot be categorized as jade.
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